

## Analyzing Exchange Rate Misalignment in Iran Based on Structural VAR Approach

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### Abstract

A central problem in empirical macroeconomics is to determine when and how much the exchange rate is misaligned. This paper clarifies and calculates the concept of the equilibrium real exchange rate, using a structural vector auto regression (VAR) model. By imposing long-run restrictions on a VAR model for Iran, four structural shocks are identified: nominal demand, real demand, supply and oil price shocks. The identified shocks and their impulse responses are consistent with an open economy model of economic fluctuations and highlight the role of the exchange rate in transmission mechanism of an oil-exporting country. Nominal and fiscal shocks appear to have important impact on output and the real exchange rate, even in the short run.

**Keywords:** Exchange rate misalignment, Iran economy, structural VAR.

### 1- Introduction

To determine whether the real exchange rate is misaligned with respect to its long-run equilibrium is an important issue for policy makers. Decisions to devalue or to implement any exchange rate policy other than a clean float require both measuring the actual real exchange rate (RER) and estimating the equilibrium RER. Economic theory typically predicts that the behavior of the

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real exchange rate should be closely related to the behavior of deviations from purchasing power parity (PPP). According to the purchasing power parity (PPP) hypothesis, nominal exchange rates adjust to offset changes in relative prices and all movements in the real exchange rates are transitory. Hence prices in different countries will eventually move towards equilibrium in a common currency. For many developing countries that are facing large inflation differentials between domestic and foreign inflation rates, the PPP hypothesis has therefore proved particularly useful, since it can be used to predict any over- and undervaluation of their currency. Any policy advice will therefore be dependent on the validity of PPP.

A feature of the PPP approach to equilibrium exchange rates was the choice of a single equilibrium rate for all periods, without reference to movements in the fundamentals. The standard theory-based criticism was that notion of equilibrium delivers a relationship between the real exchange rate and the fundamentals, not a single value for the real exchange rate. Since the fundamentals are themselves time-varying, this criticism has often been summarized in the claim that the equilibrium real exchange rate should move over time. There is now widespread agreement that there have been substantial deviations from PPP since the abandonment of the Bretton Woods fixed exchange rate system (see e.g. Froot and Rogoff 1995). In particular, real exchange rates can deviate from PPP even in the long run, and can in fact be very volatile. Recently, empirical studies have shown that real exchange rates are not only very volatile in the short run; but also the speed of convergence to PPP in the long run is extremely slow (see Rogoff 1995). The persistent deviation from PPP casts doubt on the Dornbusch (1976) open macroeconomic (overshooting) model, which explains short run real exchange rate volatility with sticky prices and monetary disturbances. Instead, long run deviation from PPP suggests the influence of real shocks with large permanent effects. The fact that many different empirical studies do not reject the hypothesis of a unit root in the real exchange rate (see e.g. Serletis and Zimonopoulos 1997) also supports the argument that the variations in real exchange rates are attributed to permanent shocks.

Overall the PPP hypothesis are more likely to be confirmed for studies that has met the following four conditions: when the span of data is long enough to capture a statistical equilibrium relationship, typically 70 or more years; when

the trivariate specification, containing domestic and foreign prices and exchange rate, without any restriction (symmetry and proportionality) is used; when bilateral exchange rate other than against the US dollar is used; and when the countries studied has experienced rapid periods of inflation or deflation (Breuer, 1994). These results refer mainly to developed countries. Studies of PPP in developing countries have been scarcer, but have provided results that show a consensus in favor of the PPP hypothesis for high inflation countries (see for instance McNown and Wallace (1989), Liu (1992) and Mahdavi and Zhou (1994)). However, in a recent study using new panel data techniques, Holmes (2001) rejects PPP for high inflation countries. Despite this, PPP is still often used as a base for predicting future real exchange rates (see OECD 2003). Instead, the failure to find support for PPP should encourage researchers to construct exchange rate models that investigate the role of other economic fundamentals as sources of deviations from PPP.

This paper analyzes the equilibrium real exchange rate based on structural vector auto regression (VAR) approach. The VAR model is particularly useful, as it can be used to decompose the variation in the real exchange rate into components attributable to different economic shocks (impulses). The different shocks will be identified through assumptions about their long-run impact on the variables in the model, and nominal and real shocks are distinguished in particular. The model is applied to Iran. During recent years, following oil boom and exchange rate unification in 1380, Iran has been experiencing an appreciating real exchange rate. Many economic institutions and advisers concerning the non-oil export, therefore, recommended that, based on a measure of PPP, Iran should devalue its exchange rate. However, if PPP does not hold, these policy advices might be very misleading.

The paper is organized as follows. Section two briefly outlines the recent exchange rate experience in Iran and relates it to the hypothesis of PPP. In section three the structural VAR model is set out. Section four traces the impulse response of the variables in the model to the identified shocks, and thereafter calculates the long-run, equilibrium real exchange rate. Section five summaries and concludes.

## 2- PPP and the Long Run Real Exchange Rate in Iran

Iran has experienced double digit inflation since 1350s with inflation being on a declining path since 1379<sup>1</sup>. So a natural starting point for analyzing the relationship between the exchange rate in Iran and its fundamentals is the by now well-known concept of PPP, which is usually understood as a prediction that the real exchange rate must be stationary and fluctuate around the mean in the long run.

Figure 1 plots the (logarithm of) the external real exchange rate in Iran relative to the US dollar, together with its mean, during the sample 1338-1382, the period of analysis. Figure 1 clearly emphasizes that the real exchange rate in Iran does not fluctuate around a fixed value in the short run. Instead the exchange rate wanders widely, and only slowly returns to its mean. In fact, from 1371 and onwards, the exchange rate has appreciated steadily from its mean, being on average 47 % below its mean in 1382.

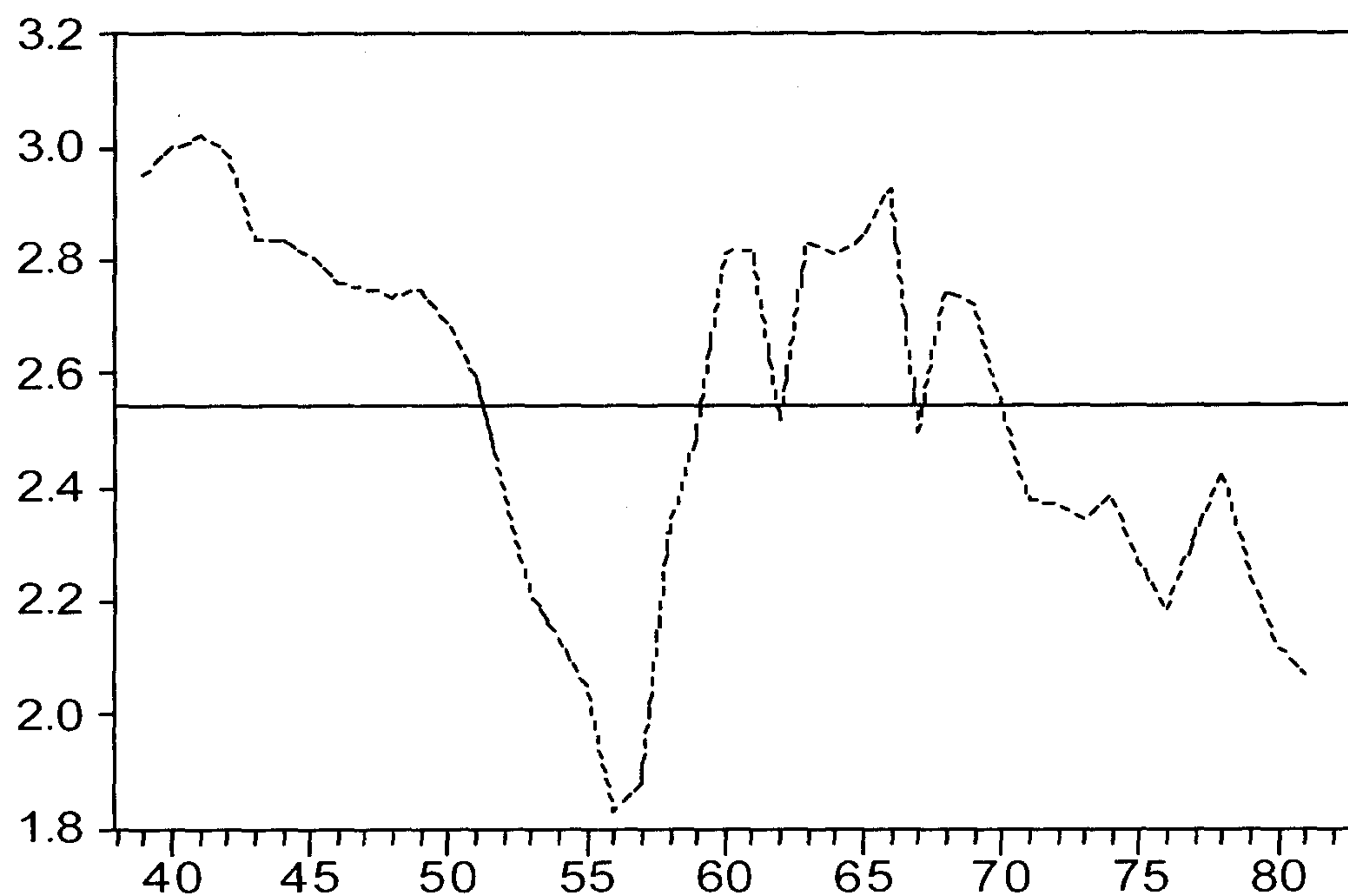


Figure 1: The Real Exchange Rate and its Mean, (Logarithms)

1- Central Bank of the Islamic Republic of Iran, Economic Trends, Different Issues

Augmented Dickey Fuller (ADF) unit-root tests confirm that one cannot reject the hypothesis that the real exchange rate is non-stationary against the stationary hypothesis ( $t_{ADF} = -1.98$  and  $t_{ADF} = -2.08$  using respectively a constant or both a constant and trend in the estimation). Hence, the long run deviation from PPP suggests the influence of real shocks with large permanent effects.

Below we therefore proceed by using instead an econometric VAR model, which decomposes the stochastic variation in the real exchange rate into components attributable to different economic shocks (see for example Clarida and Gali 1994). In particular, we will specify an exchange rate model that allows for both real and nominal shocks. By accumulating the contribution of the permanent (real) shocks to the real exchange rate, one will get a measure of the long run trend in the real exchange rate which can then be interpreted as the long run equilibrium real exchange rate.

There are other related approaches in the literature that also take the departure from PPP as a starting point, but that may be less advantageous than the VAR-approach. For instance, the concept of the Fundamental Equilibrium Exchange rate (FEER), due to Williamson (1985), relies on more normative issues in its definitions, and may not necessarily be well defined in a statistical sense. Another approach is the IMF's Macroeconomic Balance Approach, (see Isard and Faruqee 1998), which involves the calculation of internal and external demands at their potential levels (and, in the case of Iran, the oil price at its 'permanent' level). Hence, the methodology will therefore be very time-sensitive.

### **3- Structural VAR Methodology**

By estimating a VAR model containing the four variables; external Real exchange rate relative to the US dollar( $s_t$ ), real non-oil GDP( $y_t$ ), consumer prices ( $p_t$ ) and real oil export ( $ox_t$ ), four structural shocks can be identified; real demand shocks ( $e_t^{RD}$ ), nominal shocks ( $e_t^{NOM}$ ), aggregate supply shocks ( $e_t^{AS}$ ) and oil export shocks( $e_t^{OX}$ ). The choice of variables and the restrictions imposed

on the VAR model below, builds on a standard open economic model, as in Hoffmaister et al (1996).

Assume all variables are nonstationary integrated,  $I(1)$ , variables, where stationarity is obtained by taking first differences<sup>1</sup>. Ordering the vector of stationary variables are as  $z_t = (\Delta x_t, \Delta y_t, \Delta s_t, \Delta p_t)'$ , its moving average representation can be written as:

$$z_t = C(L)e_t \quad (1)$$

where  $e_t$  is a vector of reduced form serially uncorrelated residuals with covariance matrix  $\Sigma$ . Assume that the orthogonal structural disturbances ( $\varepsilon_t$ ) can be written as linear combinations of the innovations ( $e_t$ ), i.e.  $e_t = D_0 \varepsilon_t$ . A (restricted) form of the moving average containing the vector of original disturbances can then be found as:

$$z_t = D(L)\varepsilon_t \quad (2)$$

where  $C(L)D_0 = D(L)$ . the  $\varepsilon_t$ 's are normalized so they all have unit variance. If  $D_0$  is identified, one can derive the MA representation in (2). However, the  $D_0$  matrix contains sixteen elements, so to orthogonalize the different innovations, sixteen restrictions are needed. First, from the normalization of  $\text{var}(\varepsilon_t)$  it follows that  $\Omega = D_0 D_0'$ . A four variable system imposes ten restrictions on the elements in  $D_0$ . Six more restrictions are then needed to identify  $D_0$ . These will come from restrictions on the long run multipliers of the  $D(L)$  matrix. Ordering the four serially uncorrelated orthogonal structural shocks:  $\varepsilon_t = (\varepsilon_t^{OX}, \varepsilon_t^{AS}, \varepsilon_t^{RD}, \varepsilon_t^{NOM})'$ , the long run expression of (2) can then simply be written as:

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1- The assumptions of stationarity are verified empirically in appendix.

$$\begin{bmatrix} \Delta ox \\ \Delta y \\ \Delta s \\ \Delta p \end{bmatrix} = \begin{bmatrix} D_{11}(1) & D_{12}(1) & D_{13}(1) & D_{14}(1) \\ D_{21}(1) & D_{22}(1) & D_{23}(1) & D_{24}(1) \\ D_{31}(1) & D_{32}(1) & D_{33}(1) & D_{34}(1) \\ D_{41}(1) & D_{42}(1) & D_{43}(1) & D_{44}(1) \end{bmatrix} \begin{bmatrix} \varepsilon^{OX} \\ \varepsilon^{AS} \\ \varepsilon^{RD} \\ \varepsilon^{NOM} \end{bmatrix} \quad (3)$$

where  $D(1) = \sum_{j=0}^{\infty} D_j$  indicate the long run matrix of  $D(L)$ . The restrictions on the long-run multipliers of the system that are used here to identify the structural shocks are based on a standard open economy model.

First, the nominal demand shock is separated from the other shocks, by assuming that the nominal shock can have no long run effects on the real exchange rate (see Clarida and Gali 1994). Hence, the real exchange rate encompasses both short term volatility and long run deviations from PPP. In particular, PPP is preserved in the long run with respect to monetary changes, so that a nominal shock will increase the price and depreciate the exchange rate proportionally. This leaves the real exchange rate unchanged in the long run, as predicted by the Dornbusch overshooting model. Thus:

$$D_{34}(1) = 0 \quad (4)$$

Second, the key (long run) identifying assumption that distinguishes between the demand and supply shocks, asserts that in the long run, the level of production will be determined by supply side factors (aggregate supply and real oil price shocks) only (see Blanchard and Quah 1989). However, in the short run, due to nominal and real rigidities, all four disturbances can influence production. Hence:

$$D_{23}(1) = D_{24}(1) = 0 \quad (5)$$

Finally, the oil price shock itself is identified as the only shock that can have a long run effect on the real oil export. However, in the short run, all shocks are allowed to influence real oil prices:

$$D_{12}(1) = D_{13}(1) = D_{14}(1) = 0 \quad (6)$$

No restrictions are placed on prices, although there are some over identifying restrictions on prices that can be tested informally by examining the impulse response analysis. For instance, the standard aggregate demand/supply diagram suggests that whereas positive real demand and nominal shocks (that increase production only temporarily) shall increase prices permanently, following a positive aggregate supply shock (that increases production permanently), prices shall fall permanently.

With the six long run restrictions, the matrix  $D(1)$  will be lower triangular, and one can use this to recover  $D_0$ . The long run representation of expression (2) implies:

$$C(1)\Omega C(1)' = D(1)D(1)' \quad (7)$$

(7) can be computed from the estimate of  $\Omega$  and  $C(1)$ . As  $D(1)$  is lower triangular, expression (7) implies that  $D(1)$  will be the unique lower triangular Choleski factor of  $C(1)\Omega C(1)'$ .

#### **4- Sources of Real Exchange Rate Fluctuations**

The sample uses annual data, 1338-1381. The start date reflects availability of data. All variables are taken from Central Bank of Iran. Estimating a well specified VAR, figures 2-4 plot the impulse responses of the four shocks on the real exchange rate, prices and real GDP, respectively.<sup>1</sup> The figures presented give the cumulative response in (the level of) each endogenous variable to a unit

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1- For neither of the variables, can one reject the hypothesis of  $I(1)$  in favor of the (trend) stationary alternative but one can reject the hypothesis that all variables are  $I(2)$ . Lag reduction tests suggest a lag order of two. Estimating a VAR-model with two lags and a step dummy variable for Islamic revolution, one can reject the hypothesis of serial correlation, heteroscedasticity and non-normality in each equation at the 1 % level. Testing for co-integration, one can conclude that none of the variables in the VAR models are co-integrated (see Appendix).



(innovation) shock. All the different shocks have the effects as expected by a standard open economy model.

For a large oil producing country like Iran, a positive oil price shock appreciates the real exchange rate, decreases prices and expands Non-oil GDP in the long run. The dynamics of adjustment of the output in a typical oil exporting country have the expected sign and confirm the relative importance of oil shock.

A positive supply shock, like a structural reform that increases efficiency, leads to an expansion of output, while overshooting its long-run level. The technological shock, consistent with the Balassa-Samuelson effect, leads to a large real appreciation of the real exchange rate the extent of which occurs almost on impact, with an overshooting in the second year<sup>1</sup>. Moreover it reduces prices and increases real production permanently, as expected in a flexible price exchange rate model.

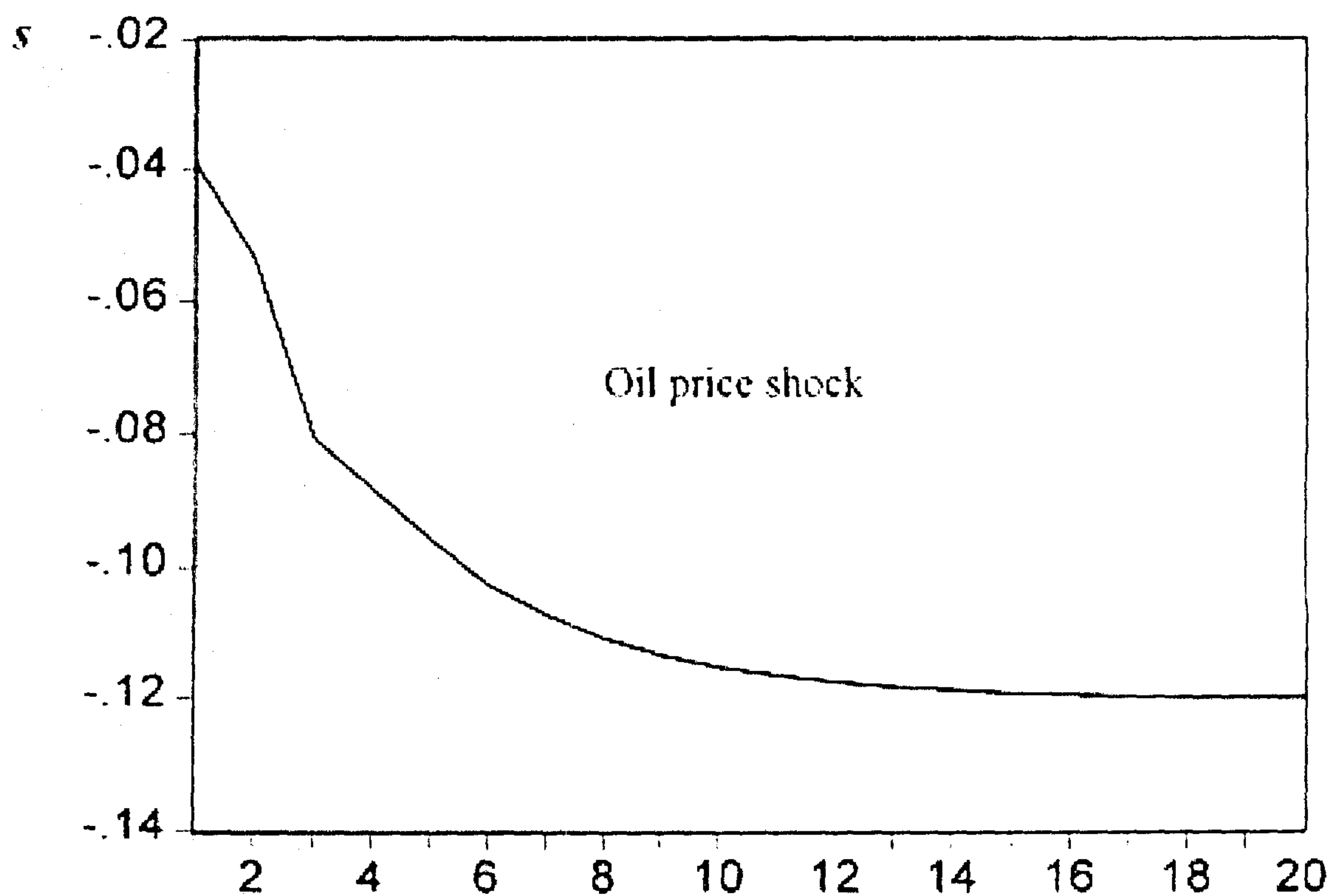
A positive real demand shock like a fiscal expansion appreciates the real exchange rate, with a overshooting in the first year, and increases prices gradually. On impact, Non-oil GDP increases temporarily, thereafter declining and eventually converges gradually to baseline level (as in a dampened cycle).

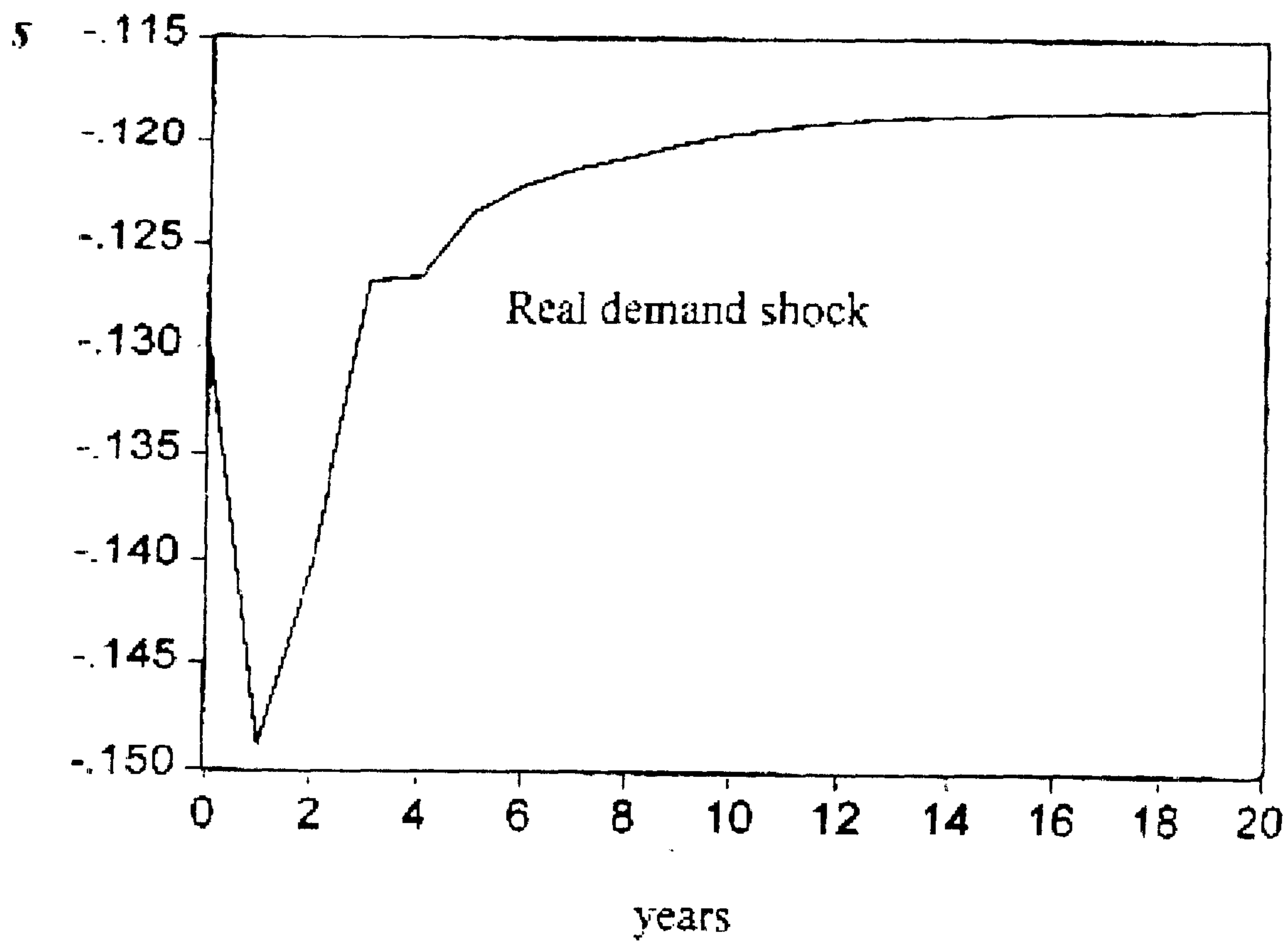
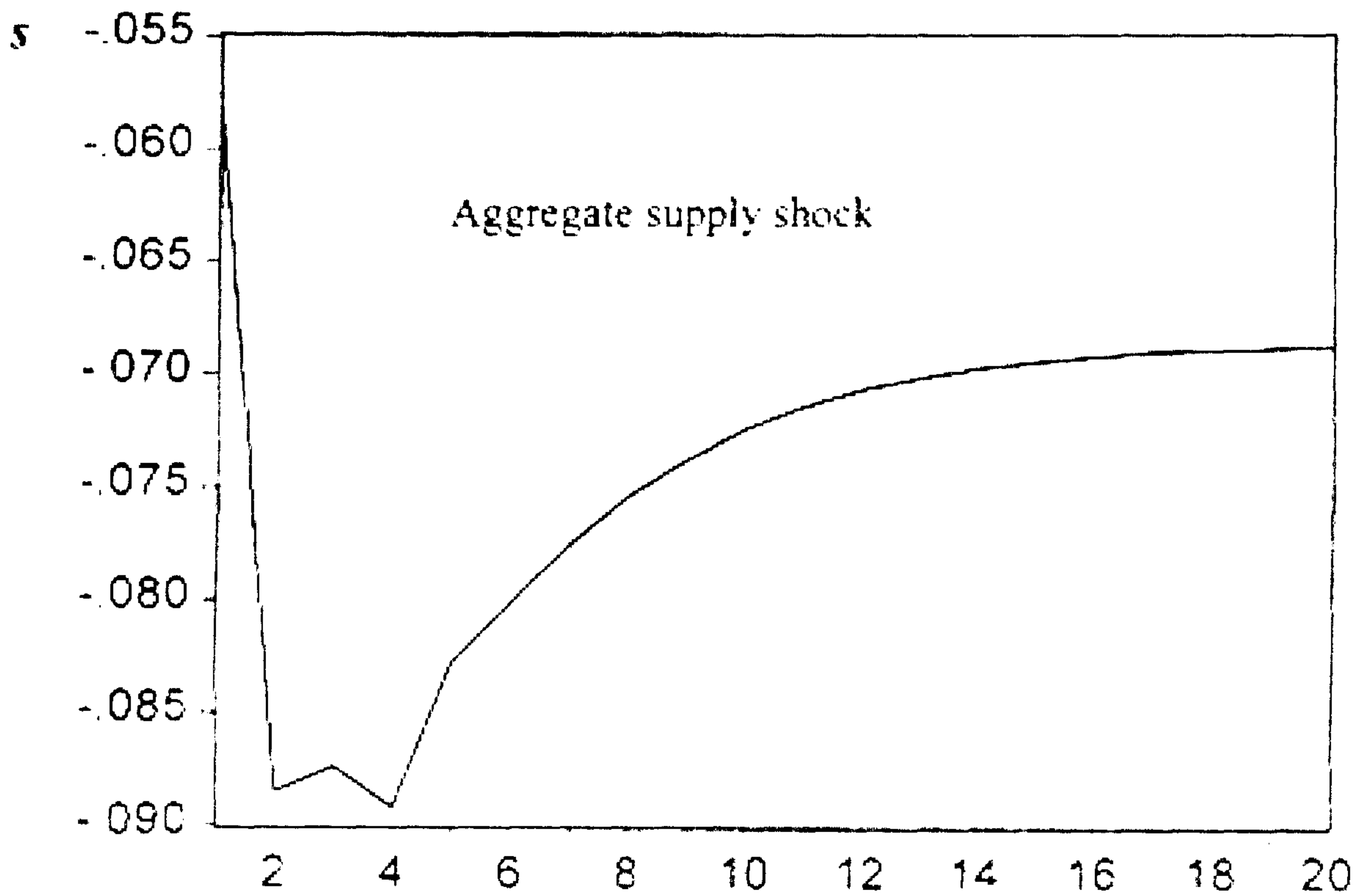
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1- According to Edwards (1989) model, the effect of technological progress on the real exchange rate depends on two things; how technological progress affects different sectors and the type of progress considered, whether product augmenting or factor augmenting. If any productivity shock occurred, it would have a positive income effect, which would in turn generate a positive demand pressure on non-tradable goods. The increased demand would increase the price of non-tradable, and hence lead to an appreciation in the real exchange rate. However, technological progress could also depreciate the real exchange rate. This could happen if technological progress result in supply effects and if these more than offset the demand effects. The implication is that technological progress could appreciate or depreciate the real exchange rate. Edwards (1989) found that an increase in technological progress depreciated the real exchange rate in all his regressions.

This response is consistent with a Keynesian view of fiscal policy, implying that Iran efforts to consolidate its fiscal position were not sustained during our sample period. Giavazzi and Pagano(1990) compare the Keynesian view of fiscal contractions with the so-called German or expectational view(see also Bertola and Drazen(1993)). The latter stresses that the expectation of future fiscal consolidation offsets the initial contraction on output.

In line with Dornbusch's overshooting model, a nominal shock depreciates the real exchange rate temporarily, before it appreciates (overshoots) back to long run equilibrium. Prices increase slowly to a new permanent higher level. It is not surprising that the nominal innovation is the main determinant of the price level and more than 50 percent of the response happens in the first three years. Due to the adjustment in prices, the effect on non-oil GDP is essentially zero.





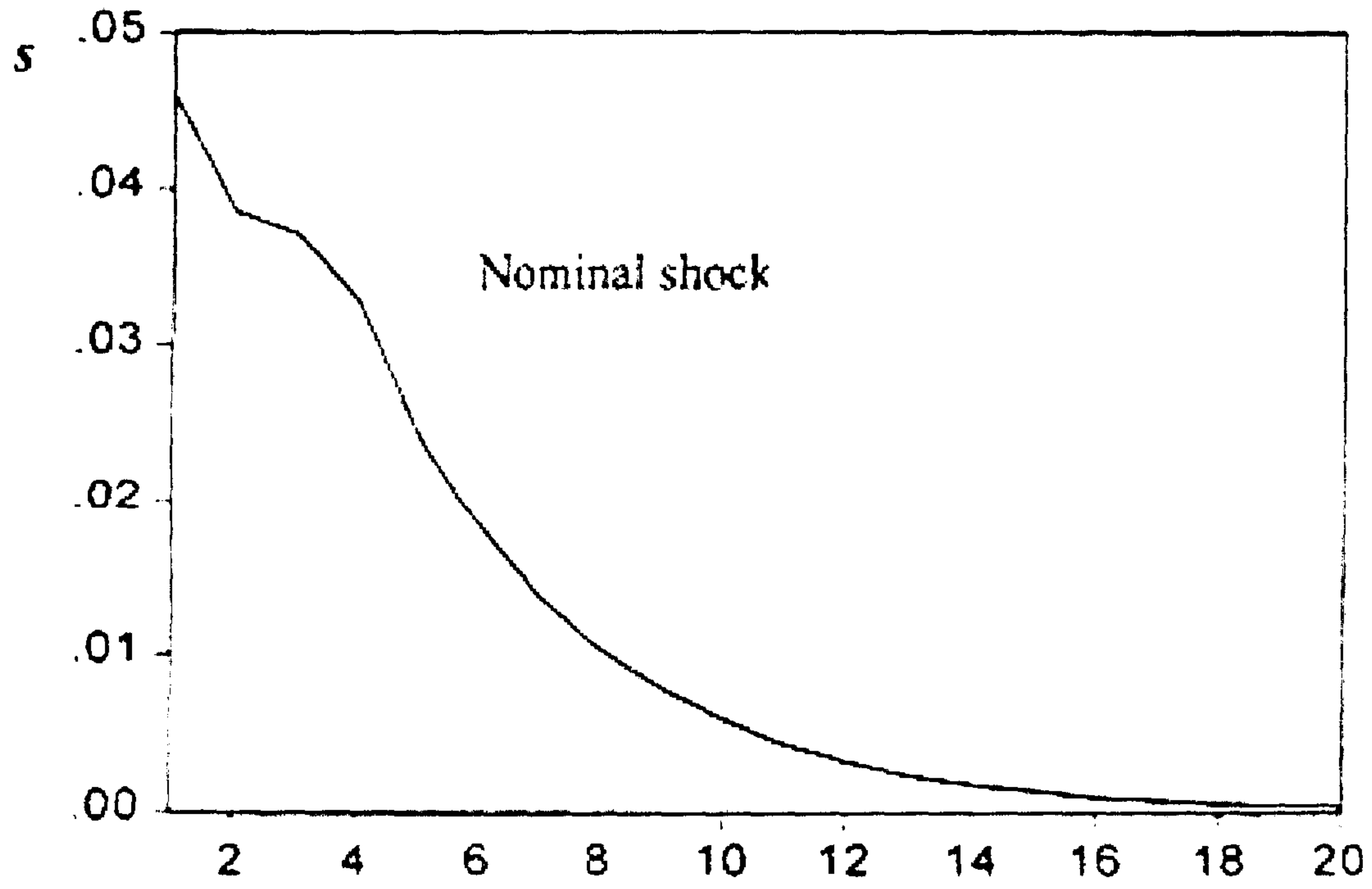
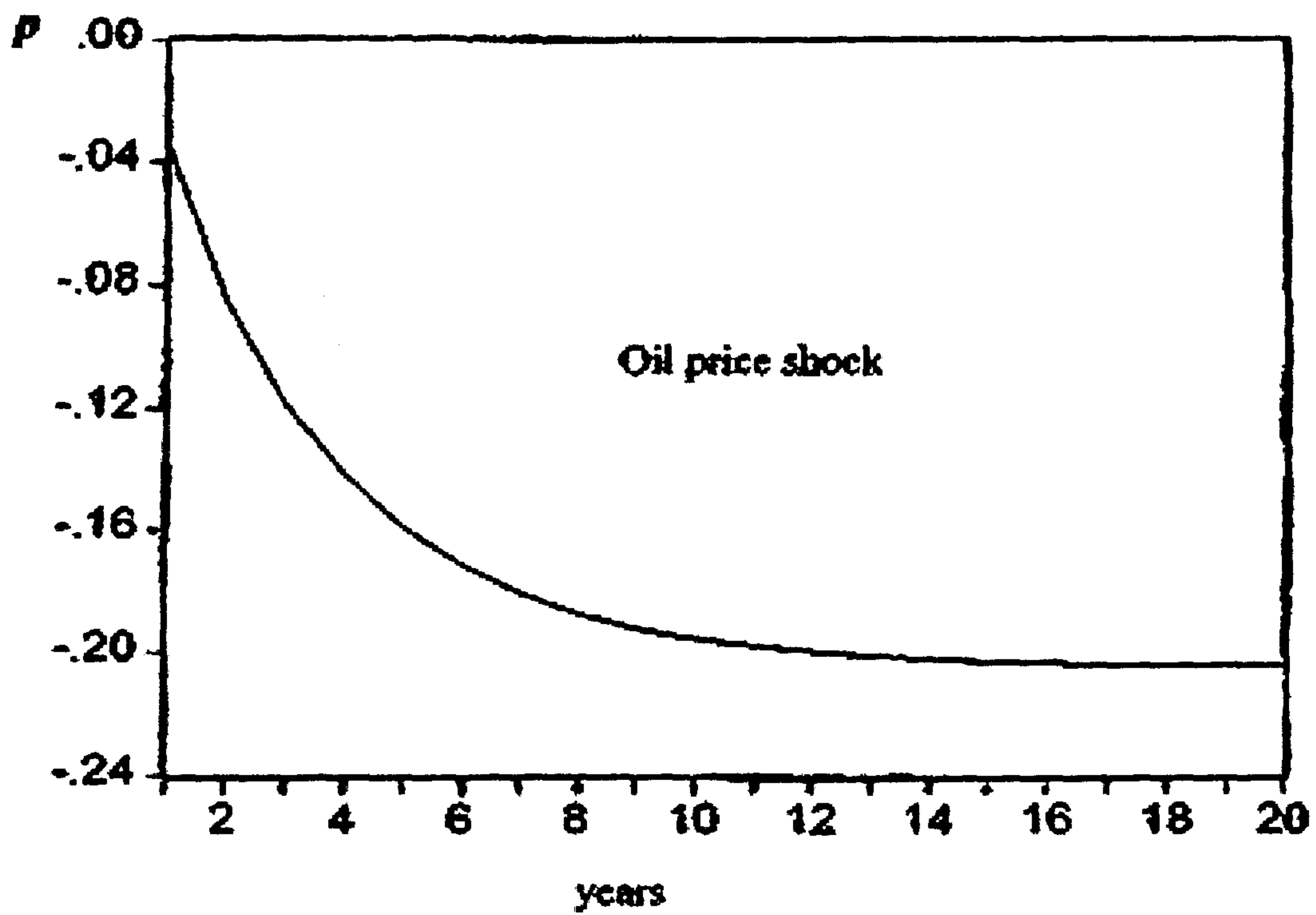
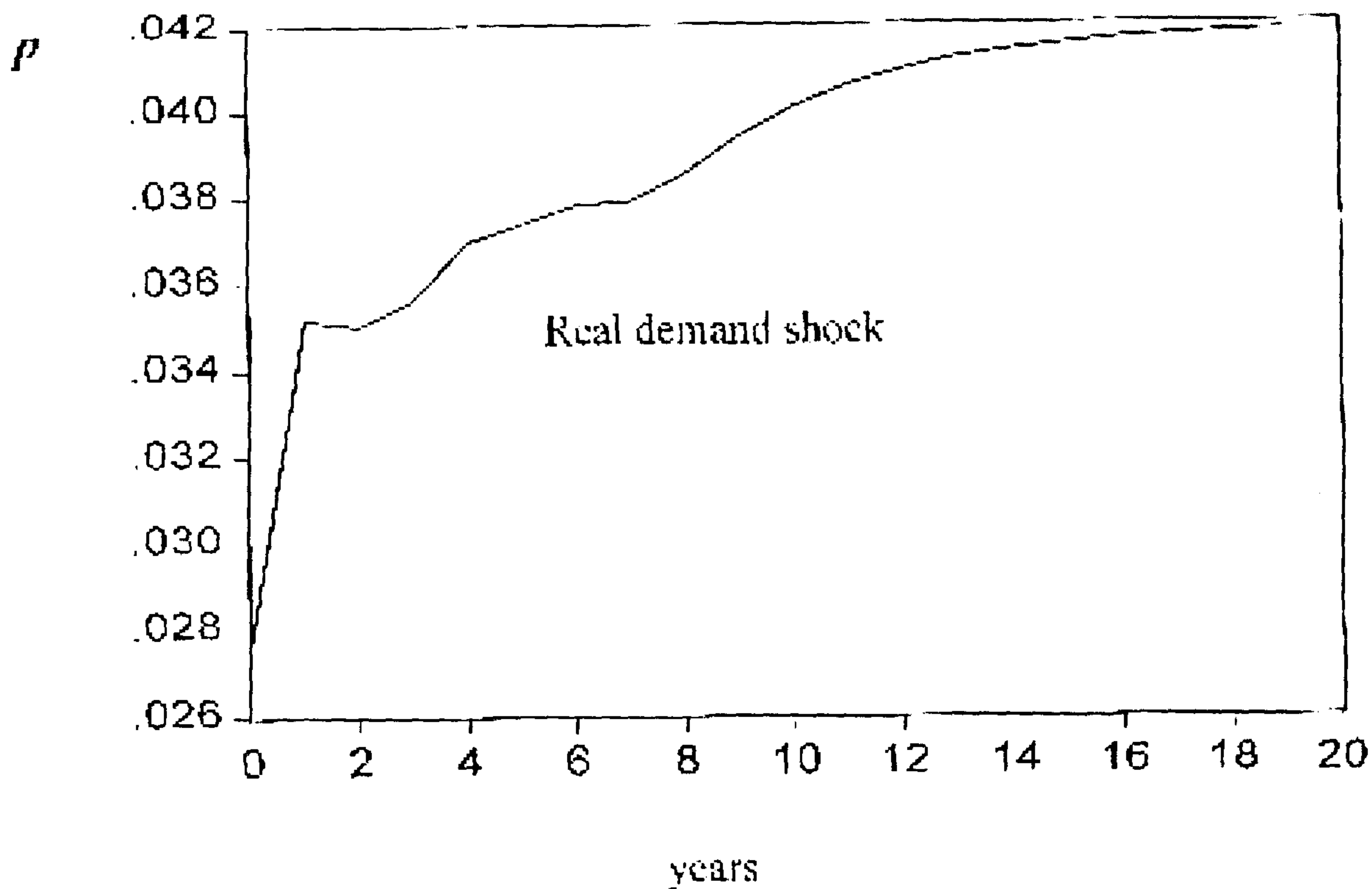
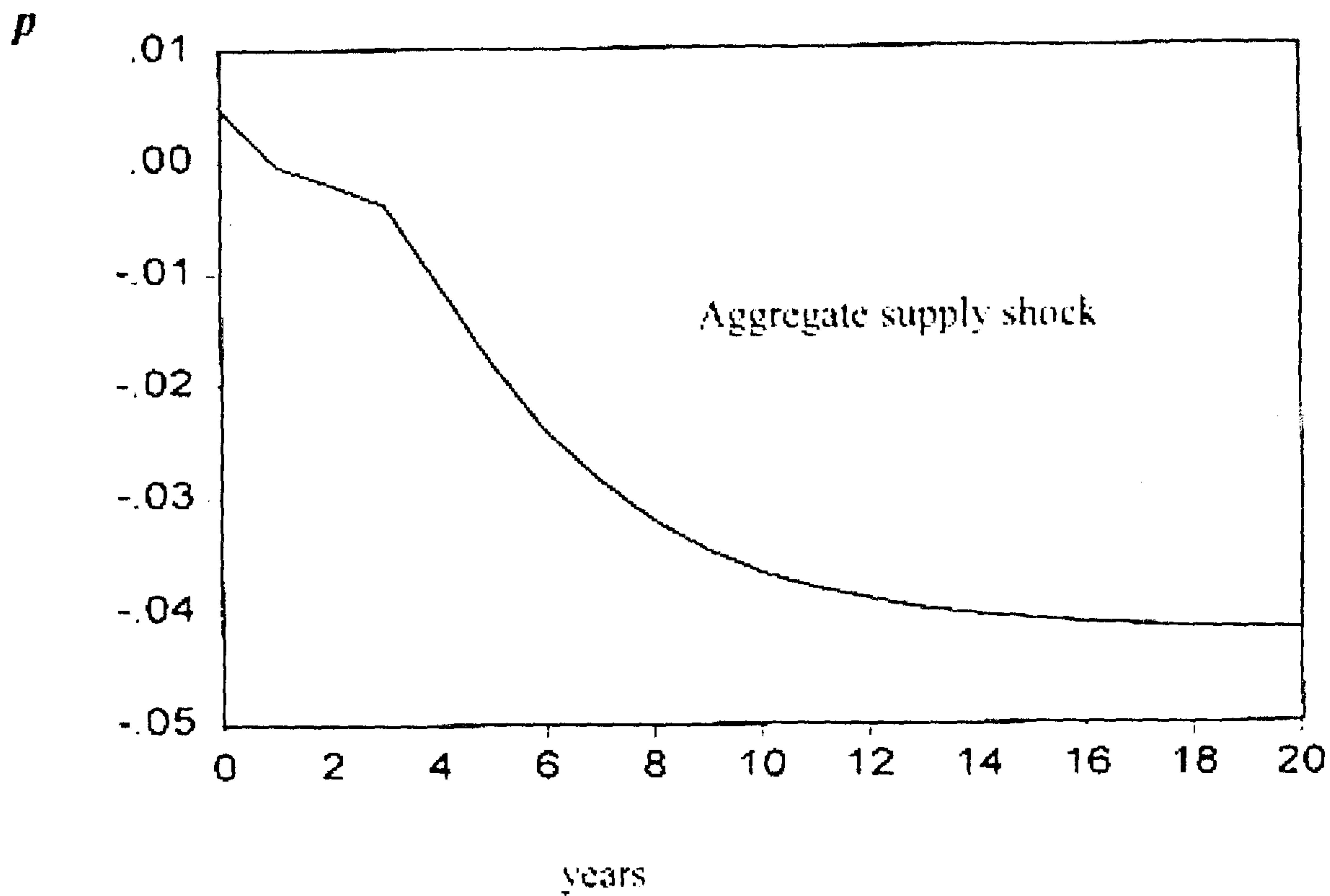


Figure 2: Impulse Responses for the Real Exchange Rate





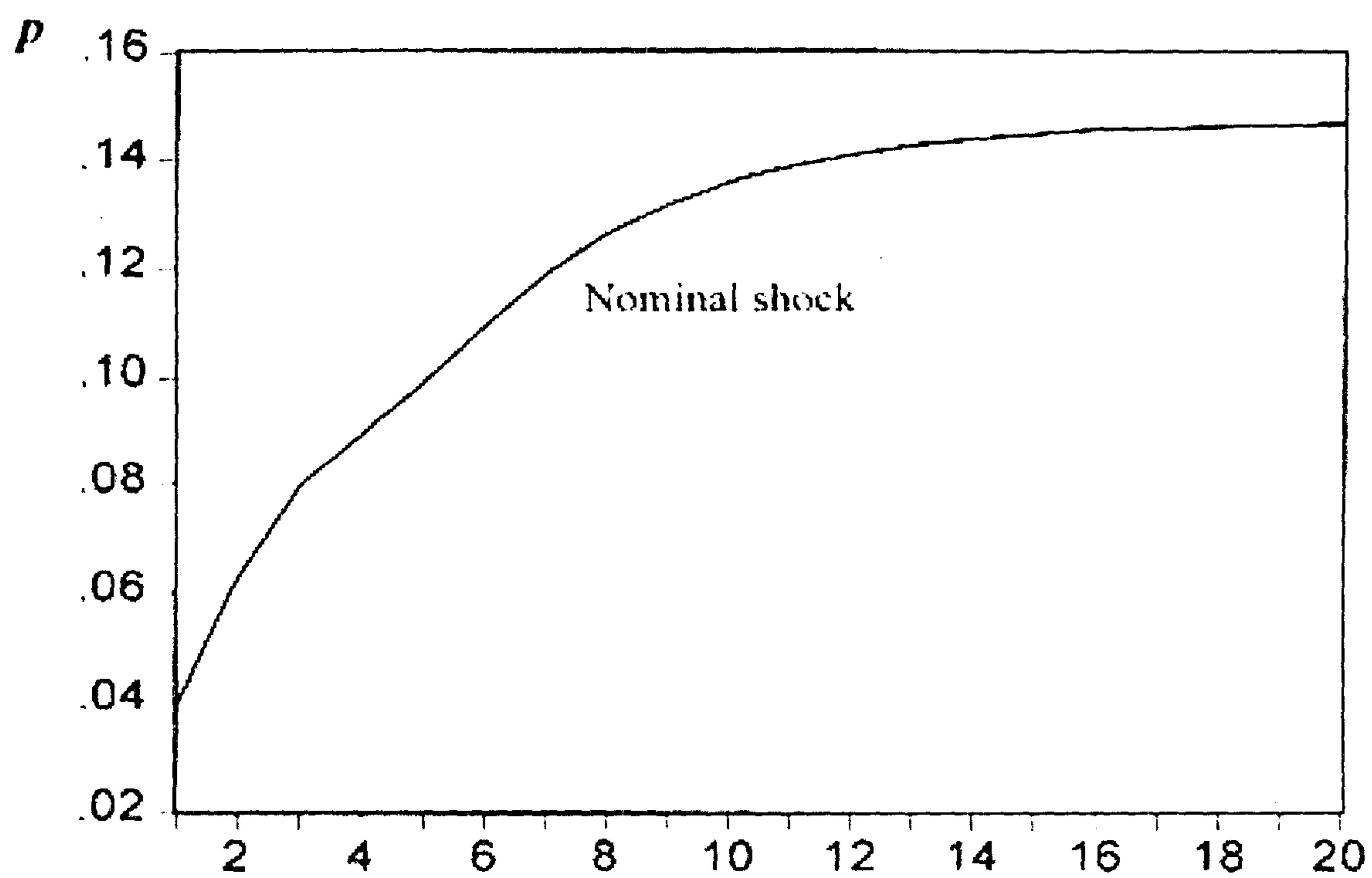
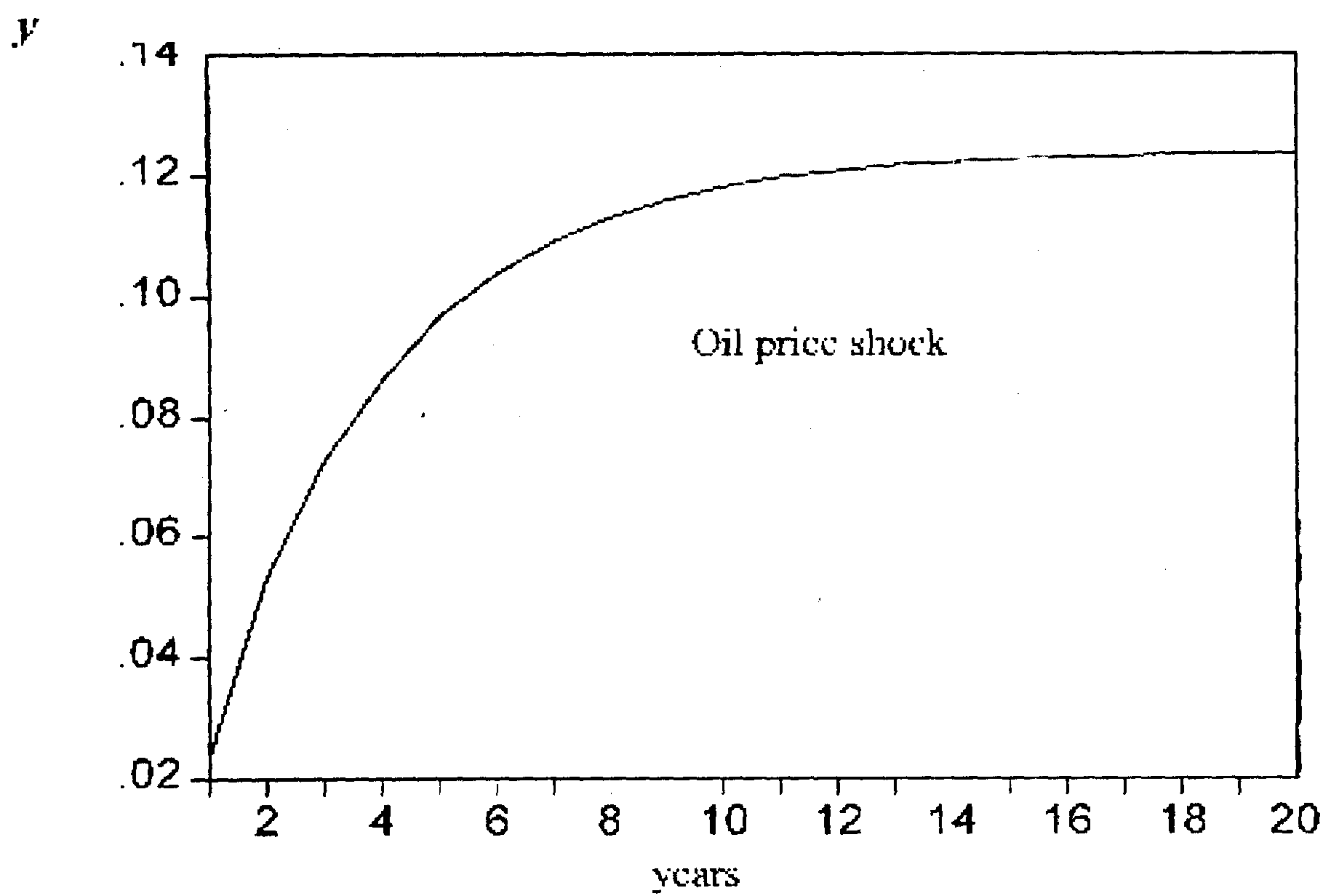
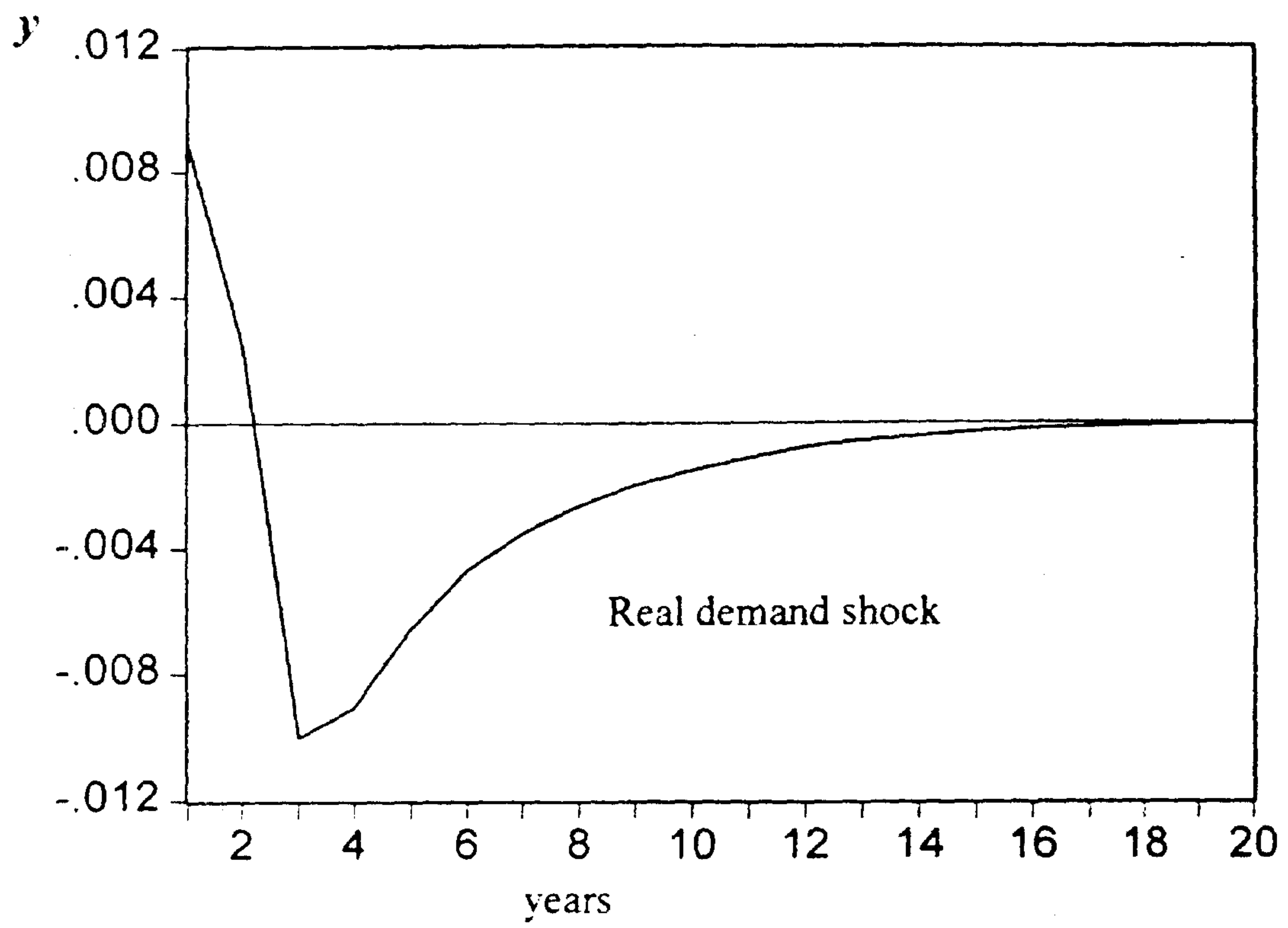
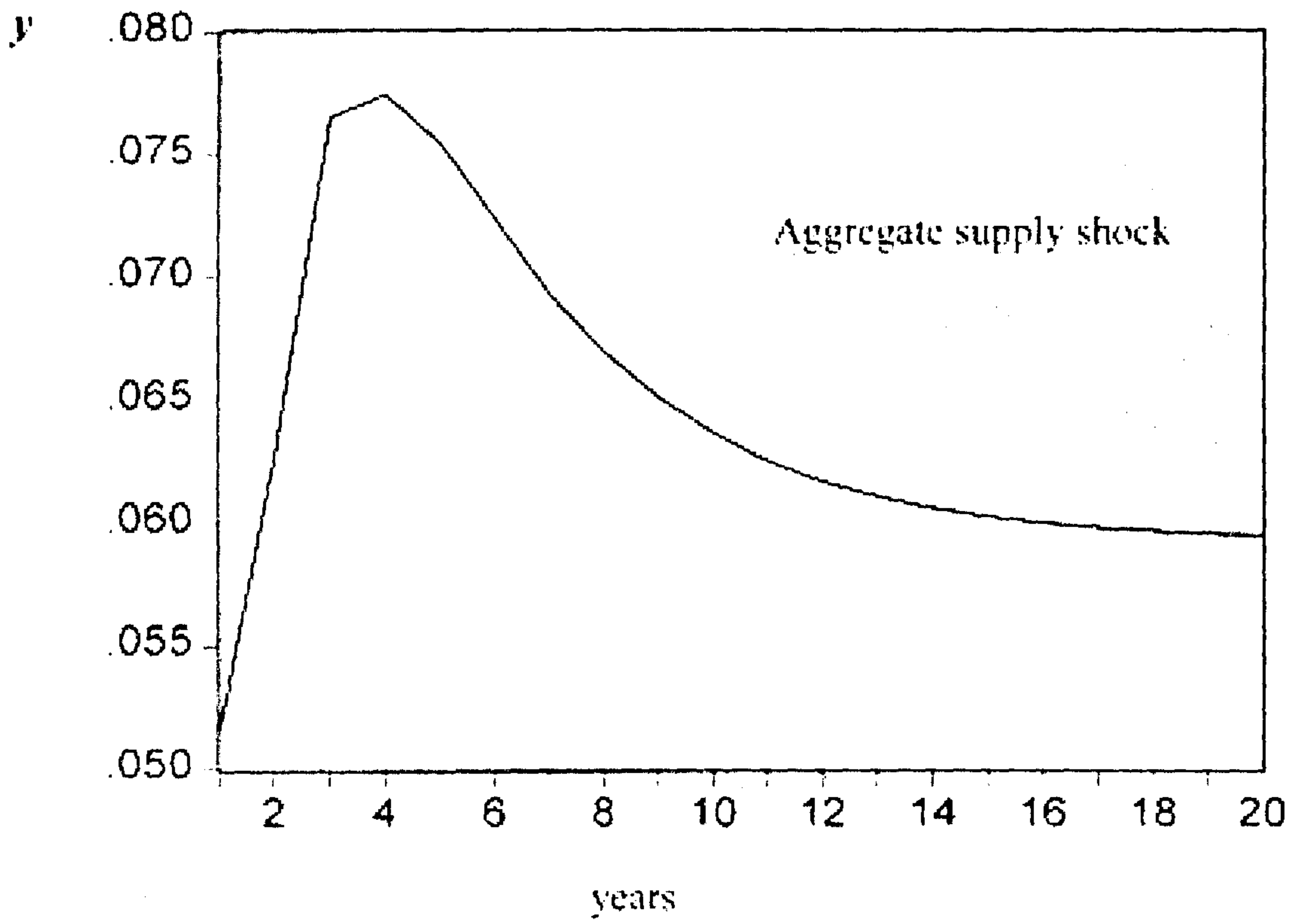
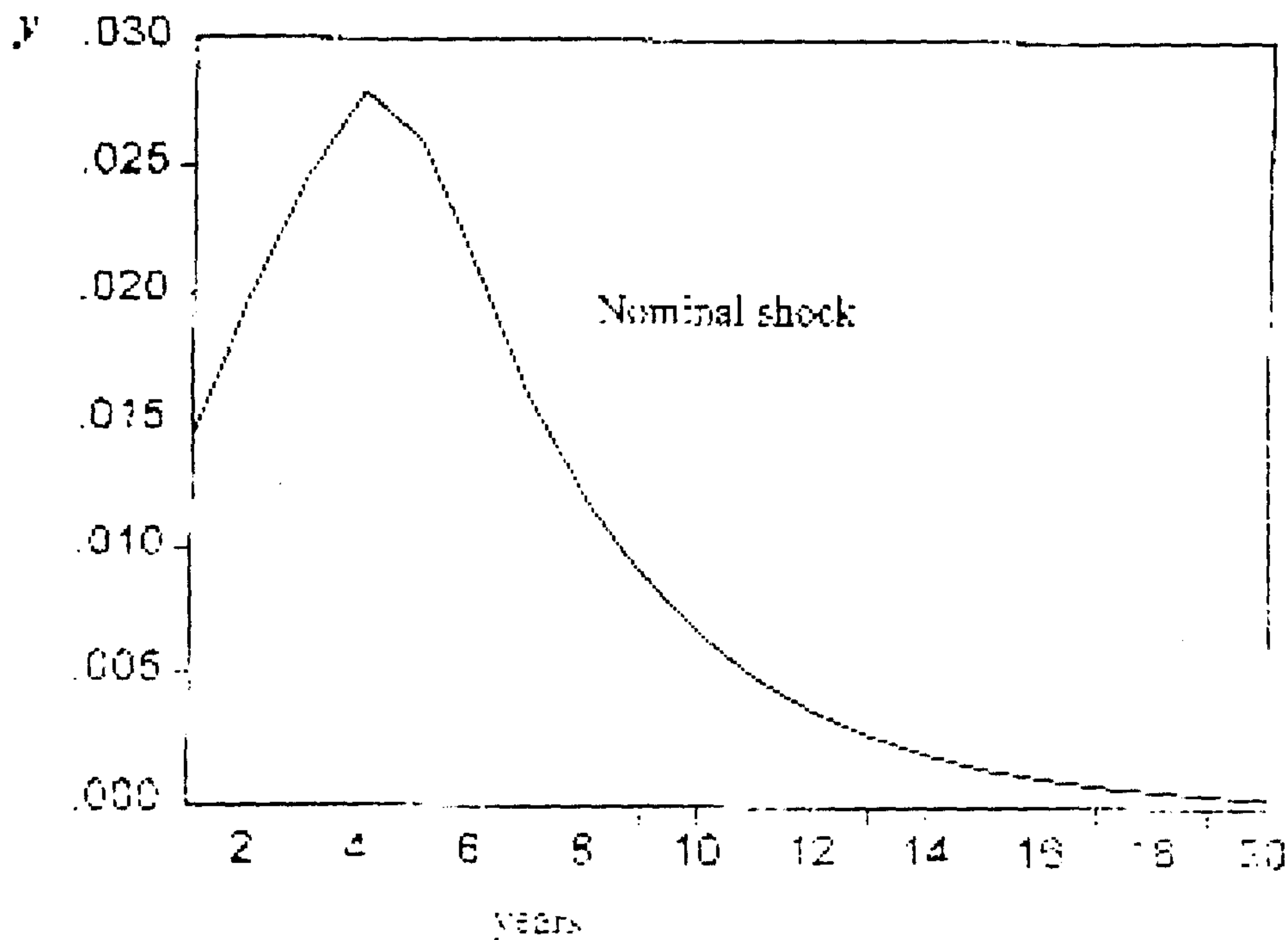


Figure 3: Impulse Responses for the Real







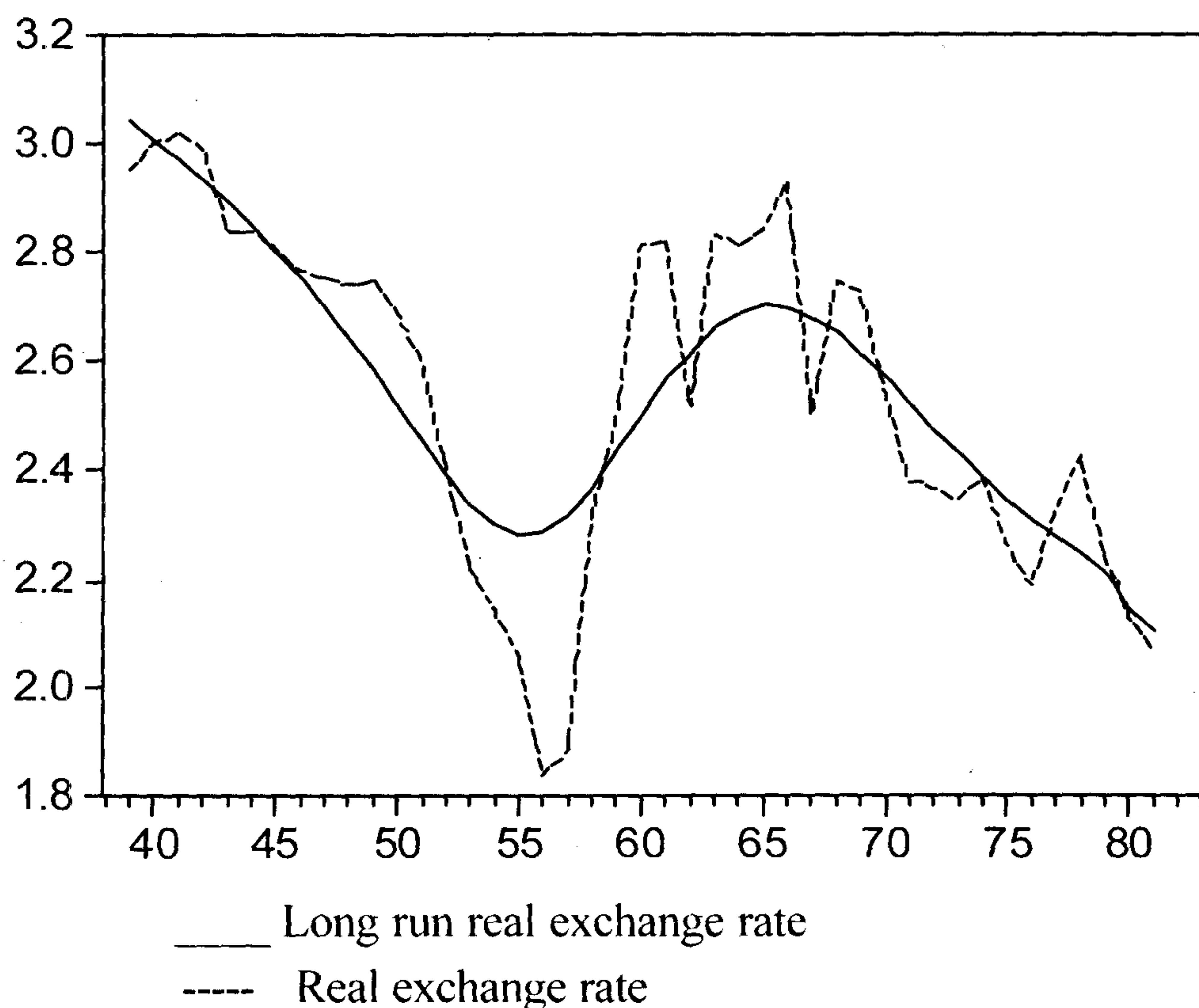
**Figure 4: Impulse Responses for the Non-oil GDP**

Finally, figure 5 plots the time path of the real exchange rate that is due to the permanent effect of aggregate supply, oil price and real demand shocks, adding the drift term, together with the log of the actual real exchange rate. If one takes the contribution of the permanent shocks to the real exchange rate as a measure of the long run trend in the real exchange rate, then this is a measure of the long run equilibrium real exchange rate. Any deviation of the real exchange rate above (below) the trend signifies an undervaluation (overvaluation).

Figure 5 suggests that although the trend (accumulated oil prices, real demand and supply shocks) follows the real exchange rate closely, in many periods, permanent shocks fail to explain the full move in the real exchange rate. In particular, the real exchange has been undervalued before the first oil shock in 1353 and subsequently overvalued in the period 1353-1357. Following the first plan of the Islamic republic (1368-1372) and liberalization attempts, the real



exchange rate was overvalued again from 1369<sup>1</sup>. This may be consistent with the fact that the high oil revenues and increasing foreign borrowing in the beginning of the 1369 allowed Iran to pursue an ambitious fiscal spending program with a unsustainable capital inflow during the first development plan which eventually led to debt and currency crisis in 1373. The overvaluation of the real exchange rate from its trend from 1379 and onwards, has the least severe in this sample, being 2 % below trend in 1380, reaching to 3 % in 1381 thanks to 1380 unification. However, the degree of overvaluation is much smaller in the VAR model compared to the static PPP -measure as we now are able to explain more of the long term movements in the real exchange rate within the model



**Figure 5: Long Run Real Exchange Rate (Accumulated Shocks)**

1- The exchange rate system was significantly liberalized and simplified in 1370 when the number of exchange rates in the official market was reduced from seven to three.

## 6- Conclusions and Summary

This paper clarifies and calculates the concept of the equilibrium real exchange rate in an oil exporting developing country like Iran. In particular, the relative ability of demand and supply shocks in explaining real exchange rate fluctuations is examined. To do so, a structural VAR model is specified in real exchange rates, real non-oil GDP, prices and the real oil export revenues, that are identified through long run restrictions on the dynamic multipliers in the model. The way the model is specified, four structural shocks are identified; nominal demand, real demand, aggregate supply and oil price shocks.

There seems to be overwhelming evidence that the behavior of the real exchange rate in Iran is not related to PPP. The hypothesis of PPP, as recognized in the fourth development plan (1383-1388), can therefore be misleading to predict any over- and undervaluation of the exchange rate. Instead, if one takes the contribution of the permanent oil, demand and supply shocks to the real exchange rate as a measure of the long run trend in the real exchange rate, then this is a measure of the long run equilibrium real exchange rate. The model implies that the real exchange rate is overvalued following positive oil shocks, expansionary fiscal policies and increasing foreign borrowing as early in the first development plan. However, the overvaluation is relatively small compared to that implied by the PPP, hence; any policy advice based on PPP would exaggerate the misalignment of the real exchange rate in Iran.

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**APPENDIX: Model Specification****Table A.1: Augmented Dickey-Fuller unit Roots, 1338-1382**

Series	$t_{ADF}$	Series	$t_{ADF}$
ox	-1.87	?ox	-2.94*
y	-1.93	?y	-2.91*
s	-2.08	?s	-3.56*
p	-1.86	?p	-3.21*

Notes: Critical values were taken from Fuller (1976). A constant and a time trend are included in the regression using levels, whereas only a constant is included in the regression using first differences. The number of lags is determined by selecting the highest lag with a significant t value on the last lag, as suggested by Doornik and Hendry (1997).

\* Rejection of the unit root hypothesis at the 5 percent level

**Table A.2: Misspecification Tests, 1338-1382**

Test statistics	?ox	?y	?s	?p
AR $\chi^2(4)$	1.13(0.88)	0.98(0.91)	0.81(0.93)	1.08(0.89)
RESET $\chi^2(1)$	0.52(0.47)	0.96(0.33)	0.77(0.38)	0.62(0.43)
NORM $\chi^2(2)$	2.56(0.27)	1.07(0.58)	2.89(0.24)	1.90(0.39)
HET $\chi^2(1)$	1.29(0.26)	0.62(0.43)	0.79(0.37)	0.99(0.32)

Notes: The number in brackets is the p-values of the test statistics. See Doornik and Hendry (1997) for references and descriptions.

**Table A.3: Johansen Co-integration Tests; Co-Integrating Vector (ox, y, s, p), 1338-1382**

$H_0$	$H_1$	Critical value5% $\lambda_{max}$	Critical value5% $\lambda_{trace}$	$\lambda_{max}$	df-adj $\lambda_{max}$	$\lambda_{trace}$	df-adj $\lambda_{trace}$
$r = 0$	$r \geq 1$	23.98	45.51	19.78	15.98	42.56	31.90
$r \leq 1$	$r \geq 2$	18.43	26.05	13.31	9.76	19.95	13.62
$r \leq 2$	$r \geq 3$	12.07	14.89	7.63	5.32	6.82	4.23
$r \leq 3$	$r \geq 4$	2.98	3.41	1.99	0.87	1.56	0.78

Notes: df-adj refers to the eigenvalue adjusted for degrees of freedom (see Reimers 1992).