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Stephen B. DeLoach

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STOCHASTIC TRENDS AND ECONOMIC FLUCTUATIONS IN A LARGE OPEN ECONOMY: EVIDENCE FROM THE UNITED STATES

by

Stephen B. DeLoach

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ABSTRACT

STOCHASTIC TRENDS AND ECONOMIC FLUCTUATIONS IN A LARGE OPEN ECONOMY: EVIDENCE FROM THE UNITED STATES

By

Stephen B. DeLoach

This dissertation examines the importance of stochastic trends in explaining business cycles in the United States. In particular, it investigates the role of open-economy variables in accounting for economic fluctuations.

The focus of Chapter II is on the closed-economy common trends models examined by King, Plosser, Stock, and Watson (KPSW 1991). First, their common trends model is examined in light of the fact that it is implicitly an open-economy model. Then, the issue of identification of the common trends is explored. The evidence shows that their common trends are not uniquely identified. This casts doubt on their interpretation that permanent innovations in real interest rates appear to account for the majority of the short-run forecast-error variance of U.S. output.

In Chapter III, the KPSW model in Chapter II is extended to explicitly incorporate imports, exports, and exchange rates into the model. There is evidence of a long-run import-demand equation for the U.S. which contains a significant deterministic trend. However, the long-run import-demand restriction does not appear to depend significantly upon the real exchange rate. Innovations in the real exchange rate, independent of output and inflation, account for a relatively

large percentage of the forecast-error variance of U.S. output.

In Chapter IV permanent innovations in foreign output are introduced. There is evidence of a stable long-run U.S. export-demand equation which contains foreign output, the real exchange rate, and a significant deterministic trend. The stochastic trend in the real exchange rate explains the majority of both the short-run and long-run forecast-error variance of exports. Though innovations in the real exchange rate have no effect on imports in the long run, it has significant effects in the short run. The majority of the short-run variance in U.S. output seems to be accounted for by the combination of domestic and foreign productivity shocks.

This dissertation is dedicated to my mother, Bobbie, and my father, Bill.

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The completion of this dissertation would have been impossible without the contribution of a number of individuals along the way. This expression of my appreciation to all of the individuals who, in one way or another, have impacted my life and my work, does not account for the true debt of gratitude which I will forever owe.

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CHAPTER I

INTRODUCTION

Traditionally, business cycles have been thought to be the result of temporary stochastic shocks to the economy, while the long-run paths of real flow variables, such as consumption, investment, and output, are restricted to a steady-state growth rate. This steady-state growth rate is presumably determined by the rate of technological progress in the economy, Solow (1970). Economic fluctuations in this case should be studied as deviations around a mean, or around a mean plus trend growth rate.

This interpretation has strict implications for the time series of the relevant economic variables. For example, assume there exists a time series of the form

$$y_t = \mu_t + \epsilon_t \tag{1}$$

where ϵ_t is white noise, and

$$\mu_t = \mu_{t-1} + \beta + \eta_t \tag{2}$$

Harvey (1990) defines β as the deterministic trend of y_t, and μ_t as the stochastic trend of y_t. In equation (2) the stochastic trend, μ_t, is characterized as a random walk plus drift. Therefore, the permanent disturbance in the stochastic trend is η_t. If the variance of η_t is zero, then the series reduces to

$$y_t = \mu_0 + \beta t + \epsilon_t \tag{3}$$

If fluctuations are due to transitory shocks, as is the traditional view, then the series should be written as containing a deterministic trend plus white noise, equation (3). Since ϵ_t has a mean of zero, and a constant variance, then shocks to ϵ_t will have only temporary effects on y_t. ϵ_t would be the source of the observed business cycle behavior, since it is the only source of deviations from the long-run trend.

Nelson and Plosser (1982) found that the trend component of most economic time series can be characterized as a random walk plus drift, equation (2). More specifically,

$$\Delta\mu_t = \beta + \eta_t \tag{4}$$

That is, most economic time series contain a stochastic trend. This stochastic trend should be interpreted as the permanent component of the series. This presents an entirely different explanation of business cycles. If economic time series contain both a permanent and a transitory component, then the traditional way of thinking about business cycles may not be correct. Business cycles may be the result of permanent shocks, such as productivity or permanent inflation shocks.

Recently, several studies have attempted to address the question of whether business cycles are primarily the result of temporary or permanent shocks, (Blanchard and Quah (1989), King, Plosser, Stock, and Watson (1991), Gali (1992)). In addition, Mellander, Vredin, and Warne (1992) examined stochastic trends in a small open economy. To date, however, no study has examined the issue in a large open economy. The focus of this dissertation is to fill this void.

Chapter II examines King, Plosser, Stock, and Watson's (KPSW) (1991) closed-economy common trends model of the U.S., and its implications with regards to net exports. The assumptions and long-run restrictions they use to identify the reduced-form are critically examined. In addition, the issue of proper identification of the permanent shocks is explored. An alternative specification of the model is then proposed and estimated.

Since the models tested in Chapter II do not appear to capture all of the open-economy effects that theoretically exist, they should be extended. The models in Chapter III extend the revised KPSW model of Chapter II to incorporate U.S. demand for imports. In addition, another common trend is introduced to the economy, a permanent shock to real exchange rates. Though the U.S. demand for imports is not dependent upon the real exchange rate in the long run, the real exchange rate does have an effect on the domestic variables through its effect on U.S. exports.

Finally, Chapter IV completes the open-economy model specified in Chapter III by adding another long-run restriction. This restriction is the long-run demand for U.S. exports. This demand is dependent upon the real exchange rate and foreign income (output). The complete model contains four common trends: (1) domestic productivity; (2) foreign productivity; (3) domestic inflation; (4) the real exchange rate. The results suggest that the two productivity shocks account for the majority of U.S. economic fluctuations. Furthermore, the two external shocks, real exchange rate and foreign productivity, play a significant role in explaining domestic business cycles. This is a surprising result for such a large open economy as the U.S..

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II: STOCHASTIC TRENDS AND ECONOMIC FLUCTUATIONS: SOME FURTHER ANALYSIS

CHAPTER II

STOCHASTIC TRENDS AND ECONOMIC FLUCTUATIONS: SOME FURTHER ANALYSIS

1. INTRODUCTION

King, Plosser, Stock and Watson (1991) have investigated the implication of a single permanent stochastic shock found in one-sector Real Business Cycle models. To test this implication empirically, they construct a closed economy common trends model for the U.S. in the postwar period. However, in doing so, they fail to account for net exports[1] in their market clearing condition

$$Y = C + I \tag{1}$$

where, output is defined as private GNP (Y-G). Clearly, equation (1) is not a market-clearing condition since net exports are not accounted for (either by inclusion on the right-hand side, or subtraction from the left-hand side).

The purpose of this chapter is two-fold. Primarily, it examines the King, Plosser, Stock and Watson (KPSW) common trends model in light of the "adding-up" problem. Specifically, this involves investigating the implications that the model has for the current account. Secondly, in the

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[1]Actually, the omitted variable from the closed-economy market-clearing condition is net exports plus changes in inventories (see footnote 2). However, in this study I will simply make reference to "net exports" when impulse response functions are constructed. There is no reason to believe that the interpretation of the results are sensitive to the omission of the changes in inventories in "investment."

process of replicating their model the issue of identification of the permanent components is encountered.

The organization of this chapter is as follows: (1) the theoretical justifications for the restrictions used by KPSW (1991) are reviewed; (2) the econometric methodology of KPSW (1991) is reviewed; (3) their model is replicated and the issue of identification is explored; (4) impulse-response functions for net exports are calculated as a residual of private GNP less consumption and investment, and the implications are examined; (5) an alternative ordering of the permanent shocks in the KPSW model is produced and the results are contrasted with their specification; (6) specification of the permanent shocks is further examined in light of evidence that a common trend associated with the real interest rate is not identified in this model, and an alternative model is estimated.

2. KPSW (1991) REVISITED

2.1 THEORETICAL REVIEW OF KPSW (1991)

This section reviews the theoretical justifications underlying the long-run restrictions imposed by KPSW (1991). The long-run restrictions they impose will be maintained to begin with in this study.

Solow (1970) suggests that there exists a long-run relationship between consumption and output and investment and output. In Solow growth models, per capita output, consumption, and investment all grow at the same rate along a balanced-growth path. This implies that the ratios of real per capita consumption to real per capita output and real per capita investment to real per capita output are stationary stochastic processes. That is,

$$c_t - y_t = \epsilon_{1,t} \; ; \; \epsilon_{1,t} \sim I(0) \qquad (2)$$

$$i_t - y_t = \epsilon_{2,t} \; ; \; \epsilon_{2,t} \sim I(0) \qquad (3)$$

This implies that real per capita consumption, real per capita investment, and real per capita output each possess a common stochastic trend. This common trend is assumed to represent innovations in total factor productivity. The one-sector Solow growth model has recently been extended by Kydland and Prescott (1982) and King, Plosser, and Rebelo (1988). These Real Business Cycle models predict that innovations in total factor productivity are potentially capable of accounting for short-run economic fluctuations as well as long-run growth. KPSW (1991) augment the "great ratios" which are implied by Solow models by including a real interest rate in the theoretical long-run relationship. Theoretically, a permanently higher real interest rate implies that a smaller share of output goes to investment and a larger share goes to consumption.

KPSW (1991) introduce nominal shocks into the model through the money-demand function. Though the demand for money is a demand for real balances, it is possible that because of frictions, or incomplete information, in the short-run changes in inflation can have real effects. In addition, they assume that the Fisher equation holds in the long run. That is,

$$R_t = r_t + \Delta p_t \tag{4}$$

where r_t is the real interest rate. Therefore, the real interest rate is equal to the difference between the nominal interest rate and inflation. Furthermore, they explicitly assume the real interest rate to be non-stationary. Therefore, there is a permanent stochastic trend associated with the real interest rate.

2.2 THE COMMON TRENDS MODEL

The methodology described in KPSW (1991) consists of: (1) a reduced-form represented by a Wold representation of the series in first differences

$$\Delta X_t = \mu + C(L)\epsilon_t \tag{5}$$

where $X_t = (c, i, m-p, y, \Delta p, R)'$ and ϵ_t is the vector of one-step-ahead forecast errors in X_t, given information on lagged values of X_t; (2) a structural model given by

$$\Delta X_t = \mu + \Gamma(L)\eta_t \tag{6}$$

where η_t is a 6x1 vector of serially uncorrelated structural disturbances, consisting of permanent innovations, η^1_t, and transitory innovations, η^2_t. Therefore, if $\epsilon_t = \Gamma_0\eta_t$, where Γ_0

is the structural impact multiplier, $C(L) = \Gamma_0^{-1}\Gamma(L)$.[2]

Their model consists of three permanent stochastic shocks to the system: a real balanced-growth shock, an inflation shock, and a real-interest-rate shock. The reduced-form, equation (5), is estimated as a Vector-Error Correction model with 8 lags and three error correction terms. After estimating equation (13) Γ_0 and η_t^1 can be deduced since $C(L)$ and $\Gamma(1)$ are known.

Identification of the model is accomplished by imposing two restrictions. First, three cointegrating vectors are specified in order to restrict the matrix of long-run multipliers. Secondly, innovations in the permanent components are assumed to be mutually uncorrelated, as well as uncorrelated with innovations in the transitory components.

The matrix of long-run multipliers consists of the three cointegrating vectors and three "common trends", or permanent shocks. KPSW (1991) order the shocks as: (1) a balanced-growth shock; (2) an inflation shock; and (3) a real-interest-rate shock. Their cointegrating vectors are

$$m\text{-}p_t = 1.197y_t - 0.013R_t \qquad (7)$$

$$c_t\text{-}y_t = 0.0033(R_t\text{-}\Delta p_t) \qquad (8)$$

$$i_t\text{-}y_t = -0.0028(R_t\text{-}\Delta p_t) \qquad (9)$$

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[2]see KPSW (1991) Appendix.

In matrix notation,

$$\beta' = \begin{bmatrix} 0 & 0 & 1.0 & -1.197 & 0 & .013 \\ 1.0 & 0 & 0 & -1.0 & .0033 & -.0033 \\ 0 & 1.0 & 0 & -1.0 & -.0028 & .0028 \end{bmatrix} \tag{10}$$

Therefore, the first restriction, the matrix of long-run multipliers is written as

$$\Gamma(1) = [\tilde{A}_0 \Pi : 0] \tag{11}$$

$\tilde{A}_0$ is orthogonal to β' and is a 6x3 matrix partitioned into three cointegrating vectors and three common trends. Π is a 3x3 lower triangular matrix where the first column represents the impact of the first shock, and so forth. Specifically, Π is the Cholesky decomposition of the variance-covariance matrix of the permanent components, where the values on the diagonal are normalized to 1.00. 0 is a 6x3 matrix of 0's, which represent the long-run effects of the three transitory shocks on the six variables in the system.

2.3 IDENTIFICATION OF THE COMMON TRENDS

In order to identify the permanent components of the trends, innovations in the permanent components (η^1_t) are assumed to be mutually uncorrelated, as well as being uncorrelated with innovations in the transitory components (η^2_t). Π (3x3) is the lower triangular decomposition of the variance-covariance matrix of the permanent components, where the values on the diagonal are normalized to 1.00. $\hat{\Pi}$ is given in Table 6 for the original KPSW model. The estimated long-run multipliers for the permanent innovations in their model are reported in Table 4.

In order to construct the common trends it is necessary to assume that the three permanent shocks are uncorrelated. This assumption has an implication for the Π matrix. Specifically, if the permanent shocks are uncorrelated, the Π matrix should be the identity matrix. If Π is the identity matrix, the ordering of the shocks would be of no consequence. However, since the Π matrix resulting from the original KPSW model, reported here in Table 6, is not close to identity, this has implications for the effect of the balanced-growth shock on subsequent shocks.

As Table 4 shows, the long-run response of inflation to a one-percent balanced-growth shock is an increase of 6.31 percent. In addition, a one-percent balanced-growth shock will lead to a decrease in the nominal interest rate of 35.32 percent. Since the one-percent balanced-growth shock leads to both an increase in inflation and a decrease in the nominal interest rate, it can be concluded that the same shock leads to a decrease in the real interest rate. As they are ordered, the permanent shocks do not correspond to the shocks which they claim that they represent. In addition, though the long-run multiplier of the balanced-growth shock on income is 1.00, the long-run multipliers of the balanced-growth shock on consumption and investment are 0.86 and 1.12, respectively. This is inconsistent with the notion of a steady-state balanced-growth shock.

2.4 IMPLICATIONS FOR THE CURRENT ACCOUNT

Having satisfactorily duplicated the KPSW model, I turn to the question of implications for the current account. To do this, impulse-response functions are estimated for the real flow variables (y,c,i,x-m). Mean impulse responses with respect to a one-standard-deviation shock in each of the common trends, along with their respective 95% confidence intervals are calculated and shown in Figures 1-12.[3] Impulse responses for net exports are calculated by subtracting consumption and investment responses from that of output. It is not appropriate to estimate confidence intervals in the same way, since these are non-linear.

The implications for net exports can be seen in Figures 4, 8 and 12. The KPSW model as constructed implies that a permanent balanced-growth shock leads to a short run improvement in the current account. In the long run, however, it leads to a permanent worsening of the current account (a decrease in net exports). In addition, the model implies that permanent shocks to inflation and the real interest rate lead to temporary worsening of the current account. It is plausible that an increase in the real interest rate would have this effect if it leads to an equal improvement in the capital account (vis-a-vis a depreciation of the real exchange rate). However, even if prices are "sticky" in the short run,

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[3]Following Kloek and Van Kijk (1978), confidence intervals were constructed by taking 1000 random draws from the posterior distribution of the orthogonalized impulse responses in the VECM and computing means and variances.

Dornbusch (1976), an increase in domestic prices would lead to a depreciation of the real exchange rate in the short run. In that case, one would expect that the current account would improve in the short run. On the other hand, if net exports in response to changes in real exchange rates follow a J-curve, then this observed response would be plausible.

3. THE KPSW MODEL REVISED

3.1 IDENTIFICATION OF THE COMMON TRENDS

Since the Π matrix in the KPSW model is not close to identity, the permanent components of the three variables do not correspond to the common trends as specified. To rectify this problem alternative orderings were used in order to find an ordering which produces a Π matrix which is as close to an identity matrix as possible. This is reported in Table 9. The ordering which yields the most desirable properties is one in which the real-interest shock is first, the inflation shock is second, and the balanced-growth shock is third.[4] The long-run multipliers are provided in Table 5.

It is interesting to compare the long-run multipliers in Table 5 with those from the KPSW model in Table 4. First, with the alternative ordering, the balanced-growth shock has

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[4]It should be pointed out that this alternative ordering is considered in KPSW (1991). However, they conclude that this alternative does not "change the main qualitative feature of the results." The argument here is that KPSW's preferred ordering of the common trends simply does not correspond to the permanent components of the variables. That is, the actual common trends in the KPSW model simply are not the common trends which they are attempting to identify.

no long-run effect on either inflation or the real interest rate since it is ordered last. Neither the inflation nor the real-interest shock have an effect on real output, since π_{31} and π_{32} are zero for all practical purposes. Further, the inflation shock leads to proportional increases in both inflation and the nominal interest rate. The inflation shock has no effect on the real interest rate, since the real-interest shock is ordered first.

There are several important things worth noting about the variance decompositions reported in Tables 18-20, and the ones ordered in KPSW (1991), Tables 1-3. First, the Real Business Cycle theory's implication that the balanced-growth shock should explain a majority of both the short-run and long-run variability of real macroeconomic variables is not supported in the KPSW model. The alternative ordering does not change this result, the primary result of their paper. Though after 4 quarters, the balanced-growth shock explains 30% (versus 3%) of the variance in output, it has even **less** explanatory power in the long run. Even up to 24 quarters the balanced-growth shock explains less than half of the variance in output. Further, KPSW (1991) were surprised that the inflation shock had a negligible effect on the real variables in the short run. However, with the alternative ordering, the inflation shock's effect is significantly increased. Though it still has a negligible effect of consumption, it does have important effects on output and investment. In fact, over the first 8 quarters, the inflation shock is the single most important determinant of the variance in investment.

The impulse-response function of net exports in Figure 16 is consistent with that in Figure 4. The balanced-growth shock leads to a permanent worsening of the current account. The initial effect of an increase in the balanced-growth shock is to improve the current account (surplus). Furthermore, Figure 18 shows that the response of investment to an increase in the real interest rate is now consistent with the theory outlined in Section 2.1. The hypothesized immediate decrease in investment cannot be rejected.

3.2 FURTHER MODEL SPECIFICATIONS

In this section two further specifications are considered. First, the KPSW model, with alternative ordering, is re-estimated to consider the possibility that the velocity of M2 (money supply) is stationary. Second, the stationarity of the real interest rate is explored.

Hallman, Porter, and Small (1991) model the long-run money-demand equation as

$$m-p_t - y_t = e_{3,t} \; ; \; e_{3,t} \sim I(0) \qquad (12)$$

This differs from the standard money-demand function in equation (9) in that it does not contain the nominal interest rate as an explanatory variable. They reject the null of a unit root for the residual in equation (12). That is, the velocity of M2 is stationary. Since the long-run restriction implied by equation (12) cannot be rejected, I estimate the

VECM with money demand specified as equation (12) instead of (9). Tables 21-23 summarize the forecast-error variance decompositions for this model. The main difference between these estimates and those of the alternative model is that without the nominal interest rate in the money-demand equation, the influence of the inflation shock is minimal, even for investment. These are very similar quantitatively with KPSW's (1991) original results.

In both orderings of KPSW's model considered, there was a negative correlation between the real interest shock and the inflation shock, as seen in Tables 6 and 9. In the model with the shocks most closely identified as a balanced-growth, an inflation, and a real-interest shock, the real-interest shock is ordered first. While it is possible that a change in the real interest rate could lead to a change in inflation, the negative correlation is inconsistent with this ordering. For example, suppose the monetary authorities are targeting nominal interest rates. Now, suppose there is a positive shock to the real interest rate. The nominal interest rate will increase proportionally, according to the assumption of the long-run Fisher equation. If monetary authorities stick to the rule, then they must increase the money supply in order to keep nominal interest rates within the target range. Therefore, in the long run inflation should increase. Thus, under such a rule, a positive shock to the real interest rate will lead to a positive increase in inflation. But, this is opposite of what the model predicts when the real-interest shock is ordered first.

In light of this inconsistency, the inflation shock should be ordered first. The resulting Π matrix is

$$\hat{\Pi} = \begin{bmatrix} 1 & 0 & 0 \\ -0.97 & 1 & 0 \\ 0.003 & -0.007 & 1 \end{bmatrix} \tag{13}$$

When the inflation shock is ordered first, a real interest rate shock is not uniquely identified. Rather, the real-interest shock is a linear combination of the first and second shock. Specifically, $r_t = R - 0.97\Delta p_t$. This leads me to question whether or not the real interest rate is stationary. If it is, then innovations in the real interest rate are only transitory, and, therefore, cannot be identified as a common trend. In addition, if the real interest rate is stationary, then it does not belong on the right-hand side of equations (7) and (8).

KPSW (1991) test the existence of a stable (cointegrating) relationship between the nominal interest rate and inflation. They find no evidence of a stable long-run relationship. Therefore, assuming the long-run Fisher equation (4), they argue that the real interest rate is non-stationary. Recently, Mishkin (1992) and Crowder and Hoffman (1993) have both found evidence of a single common trend between inflation and nominal interest rates. While Mishkin tested the standard Fisher equation (4), Crowder and Hoffman tested the tax-adjusted Fisher equation. Darby (1975) argued that the Fisher equation should take into account tax effects.

Following this logic, the appropriate the long-run Fisher equation should be

$$R_t = r_t^* + 1.30*\Delta p_t \tag{14}$$

where r_t^* is defined as the after-tax real interest rate. Crowder and Hoffman (1992) find that when the Fisher equation is generalized in this way, the hypothesis that the after-tax real interest rate is stationary cannot be rejected, since

$$R_t - 1.30*\Delta p_t = e_{4,t} \; ; \; e_{4,t} \sim I(0) \tag{15}$$

Tables 24 and 25 summarize variance decompositions in the model with the common trends: inflation and balanced growth. I have assumed the long-run relationship between inflation and nominal interest rates given by the Fisher-Darby (after-tax Fisher equation) equation (15). In addition, the cointegrating vectors described in equations (8) and (9) are no longer used. Instead, the cointegrating vectors implied by the standard Solow growth model, equations (2) and (3), are used. Compared with the alternative ordering of the original KPSW model specification, the balanced-growth shock actually accounts for more of the variance in output in both the short-run and the long-run. Again, the inflation shock does not account for much of the variance in either consumption, investment, or output. While it does not account for the majority of the short-run changes in the nominal interest rate, it does explain the long-run nominal interest rate, which is consistent with the cointegrating vector in equation

(15). The short-run changes in the nominal interest rate must be dominated by **transitory** changes in the real interest rate.

Table 26 summarizes the variances due to the transitory shocks in all four of the models examined here at both 12 and 120 quarters. Interestingly, the majority of variance in the real flow variables is not due to either inflation or the balanced-growth shocks. The majority of changes in these variables is due to transitory shocks, likely transitory real interest rate changes. This is in sharp contrast with the results in the VECMs with the real interest rate included as a permanent trend. This conclusion differs form KPSW's (1991) claims that permanent stochastic shocks explain the majority of short-run economic fluctuations.

4. CONCLUSION

This chapter questions the conclusions of KPSW (1991) on two basic grounds. The common trends model as they develop it, is implicitly an open-economy model. Their model implies that the current account is a residual of output minus absorption. Their model predicts that an increase in the balanced-growth shock leads to a permanent worsening of the current account. If imports are dependent on income, then one would expect that a permanent increase in income would lead to permanent worsening of the current account. However, it says nothing about the role of the real exchange rate, and in fact implies that there is no role for the real exchange rate in the long run. This is only true if permanent changes in the real exchange rate have only transitory effects on the real variables. Most notably, imports and exports are not dependent upon exchange rates in the long run.

Secondly, the KPSW model fails to identify the three common trends which they propose to model: the balanced-growth, inflation, and real-interest shocks. That is, since the Π matrix they estimate is not close to an identity matrix, the three permanent shocks are not independent. Thus, a true balanced-growth shock fails to be identified in their model. When the shocks are reordered to take this issue into account, the balanced-growth shock fails to explain the majority of the short-run or long-run variance of the real variables, the main result of KPSW (1991). In addition, in the alternative specification of their model in which there is no common trend associated with the real interest rate, the permanent shocks are not able to account for the majority of short-run fluctuations. With these short-comings in mind, subsequent chapters will focus on extending the revised KPSW model in order to construct an open-economy common trends model for the United States.

TABLE 1

Percentage of Forecast-Error Variance Attributed to the Balanced-Growth Shock in KPSW Model

Period

	1	4	8	12	16	20	24	120
c	2	15	31	48	59	63	65	87
i	14	6	15	27	32	33	33	65
$m-p$	79	77	70	72	74	75	77	79
y	1	3	21	43	53	58	61	90
Δp	31	23	21	17	16	15	14	6
R	13	12	11	11	11	12	14	22

TABLE 2

Percentage of Forecast-Error Variance Attributed to the Inflation Shock in KPSW Model

Period

	1	4	8	12	16	20	24	120
c	1	1	0	1	1	2	2	2
i	8	23	20	12	10	10	8	5
$m-p$	1	4	1	1	1	1	1	0
y	0	3	3	2	2	2	2	0
Δp	45	39	45	50	54	56	57	82
R	3	4	2	2	3	3	2	1

TABLE 3

Percentage of Forecast-Error Variance Attributed to the Real-Interest Shock in KPSW Model

	Period							
	1	4	8	12	16	20	24	120
c	43	30	15	13	10	10	11	7
i	39	47	34	34	35	32	32	17
$m-p$	3	6	9	22	20	18	16	19
y	61	73	56	37	32	28	25	6
Δp	0	10	16	14	14	13	12	5
R	61	70	77	78	78	77	76	75

TABLE 4

Long-Run Multipliers in KPSW Model

variable	y-shock	Δp -shock	$(R-\Delta p)$-shock
c	0.86	-0.0028	0.0033
i	1.12	0.0024	-0.0028
y	1.00	0.00	0.00
m-p	1.66	-0.002	-0.013
Δp	6.31	1.00	0.00
R	-35.32	0.14	1.00

TABLE 5

Long-Run Multipliers in Alternative Ordering

variable	y-shock	Δp -shock	$(R-\Delta p)$ -shock
c	1.00	-0.0036	-0.0025
i	1.00	-0.0036	-0.0086
y	1.00	-0.0036	-0.0058
m-p	1.197	-0.017	-0.016
Δp	0.00	1.00	-0.2796
R	0.00	1.00	0.72

TABLE 6

Variance-Covariance Matrix in KPSW Model

	y	Δp	$(R-\Delta p)$
y	0.00005	-	-
Δp	0.00031	0.10073	-
$(R-\Delta p)$	-0.00205	-0.09792	0.35017

TABLE 7

Correlations between Shocks in KPSW Model

	y	Δp
Δp	0.13954	-
$(R-\Delta p)$	-0.49393	-0.52138

TABLE 8

Π Matrix in KPSW Model

	y	Δp	$(R-\Delta p)$
y	1.00	-	-
Δp	6.30	1.00	-
$(R-\Delta p)$	-41.63	-0.86	1.00

TABLE 9

Variance-Covariance Matrix in Alternative Ordering

	$(R-\Delta p)$	Δp	y
$(R-\Delta p)$	0.35017	-	-
Δp	-0.09792	0.10073	-
y	-0.00205	0.00031	0.00005

TABLE 10

Correlations between Shocks in Alternative Ordering

	$(R-\Delta p)$	Δp
Δp	-0.52138	-
y	-0.49393	0.13954

TABLE 11

Π Matrix in Alternative Ordering

	$(R-\Delta p)$	Δp	y
$(R-\Delta p)$	1.00	-	-
Δp	-0.28	1.00	-
y	-0.01	0.0	1.00

TABLE 12

Variance-Covariance Matrix with Stationary M2-Velocity

	$(R-\Delta p)$	Δp	y
$(R-\Delta p)$	0.46434	-	-
Δp	-0.16221	0.13700	-
y	-0.00489	0.00165	0.00100

TABLE 13

Correlations Between Shocks with Stationary M2-Velocity

	$(R-\Delta p)$	Δp
Δp	-0.64313	-
y	-0.72480	0.44922

TABLE 14

Π Matrix with Stationary M2-Velocity

	$(R-\Delta p)$	Δp	y
$(R-\Delta p)$	1.00	-	-
Δp	-0.33	1.00	-
y	-0.01	0.0	1.00

TABLE 15

Variance-Covariance Matrix in Two Trend Model

	Δp	y
Δp	0.18204	-
y	-0.00101	0.00005

TABLE 16

Correlations Between Shocks in Two Trend Model

	Δp
y	-.35288

TABLE 17

Π Matrix in Two Trend Model

	Δp	y
Δp	1.00	-
y	-0.01	1.00

TABLE 18

Percentage of Forecast-Error Variance Attributed to the Balanced-Growth Shock in Alternative Model

	Period							
	1	4	8	12	16	20	24	120
c	19	27	26	29	38	52	58	85
i	0	12	14	11	11	14	17	38
$m-p$	70	40	26	25	27	30	33	31
y	10	30	36	33	36	41	47	67
Δp	33	19	18	15	13	11	11	4
R	1	1	2	3	3	2	2	1

TABLE 19

Percentage of Forecast-Error Variance Attributed to the Inflation Shock in the Alternative Model

Period

	1	4	8	12	16	20	24	120
c	3	5	4	7	7	7	5	3
i	34	52	39	25	22	21	20	10
$m-p$	0	1	8	10	11	12	12	13
y	11	26	21	16	13	12	11	4
Δp	43	44	48	55	52	52	52	65
R	6	26	25	25	28	28	28	28

TABLE 20

Percentage of Forecast-Error Variance Attributed to the Real-Interest Shock in the Alternative Model

Period

	1	4	8	12	16	20	24	120
c	23	9	13	24	23	19	15	7
i	27	12	16	37	43	40	38	39
$m-p$	13	46	56	59	56	52	49	55
y	40	28	22	34	38	34	30	26
Δp	0	5	8	8	14	18	19	24
R	70	59	62	63	61	62	63	69

TABLE 21

Percentage of Forecast-Error Variance Attributed to the Balanced-Growth Shock with Stationary M2-Velocity Assumption

Period

	1	4	8	12	16	20	24	120
c	12	22	25	29	38	48	56	71
i	6	4	8	10	11	14	17	32
$m-p$	66	43	36	35	39	42	45	54
y	4	13	27	30	33	39	44	52
Δp	54	38	31	25	21	18	17	7
R	0	0	0	1	1	1	1	0

TABLE 22

Percentage of Forecast-Error Variance Attributed to the Inflation Shock with Stationary M2-velocity Assumption

Period

	1	4	8	12	16	20	24	120
c	1	1	4	5	5	5	4	1
i	5	24	18	11	9	9	9	3
$m-p$	13	6	2	1	1	1	1	0
y	0	6	6	4	3	3	3	0
Δp	17	22	28	39	39	39	39	53
R	6	17	19	20	24	24	25	28

TABLE 23

Percentage of Forecast-Error Variance Attributed to the Real-Interest Shock with Stationary M2-Velocity Assumption

Period

	1	4	8	12	16	20	24	120
c	14	5	23	38	37	31	26	25
i	21	10	20	48	53	50	47	54
m-p	5	38	54	58	55	51	48	44
y	24	21	22	42	46	42	39	44
Δp	0	6	11	11	18	23	26	35
R	92	75	76	75	72	71	71	71

TABLE 24

Percentage of Forecast-Error Variance Attributed to the Balanced-Growth Shock in Two-Trend Model

Period

	1	4	8	12	16	20	24	120
c	16	23	23	31	40	47	55	82
i	0	5	17	15	16	16	18	51
m-p	72	43	36	41	40	39	41	37
y	19	35	39	37	42	46	51	79
Δp	38	26	22	13	10	8	8	3
R	3	4	6	8	7	7	6	1

TABLE 25

Percentage of Forecast-Error Variance Attributed to the Inflation Shock in Two-Trend Model

	Period							
	1	4	8	12	16	20	24	120
c	6	2	3	2	7	13	15	12
i	0	15	22	23	23	29	30	21
$m-p$	11	23	13	10	17	25	29	58
y	3	3	7	13	12	14	13	12
Δp	23	26	31	56	66	71	73	91
R	21	11	8	21	35	41	48	91

TABLE 26

Percentage of the Forecast-Error Variance Attributed to Transitory Shocks in Each Model

	12 Quarters				120 Quarters			
	I	II	III	IV	I	II	III	IV
c	38	40	28	44	4	5	3	6
i	27	27	31	37	13	13	11	28
y	18	17	24	50	4	3	4	9

Model I = Original KPSW Model
Model II = KPSW Model Under Alternative Ordering
Model III = Model II With Stationary M2-Velocity Assumption
Model IV = Model With Two Common Trends

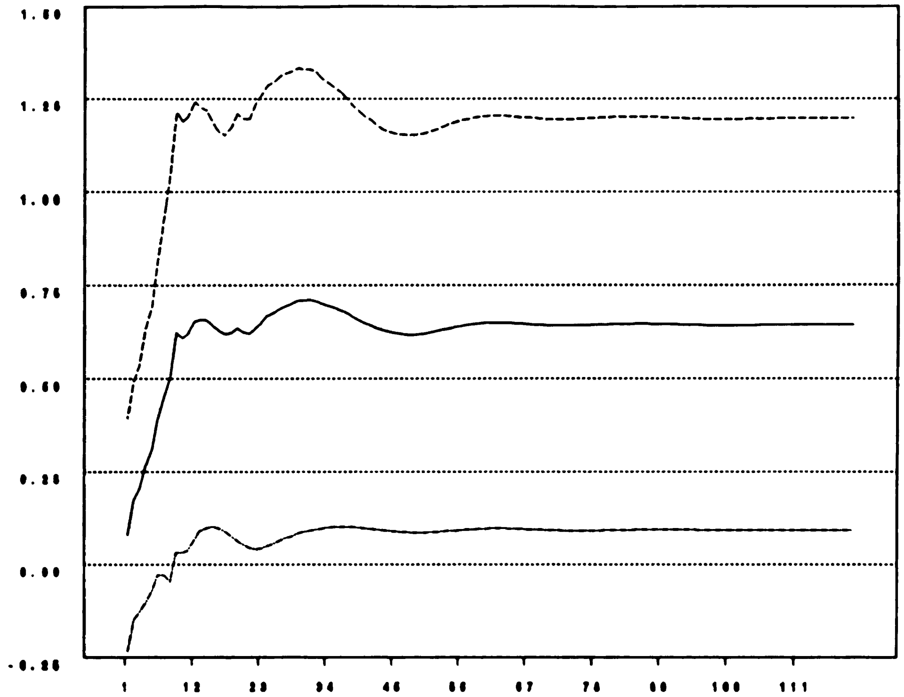

FIGURE 1: Consumption in Response to a One-Standard Deviation Balanced-Growth Shock in KPSW

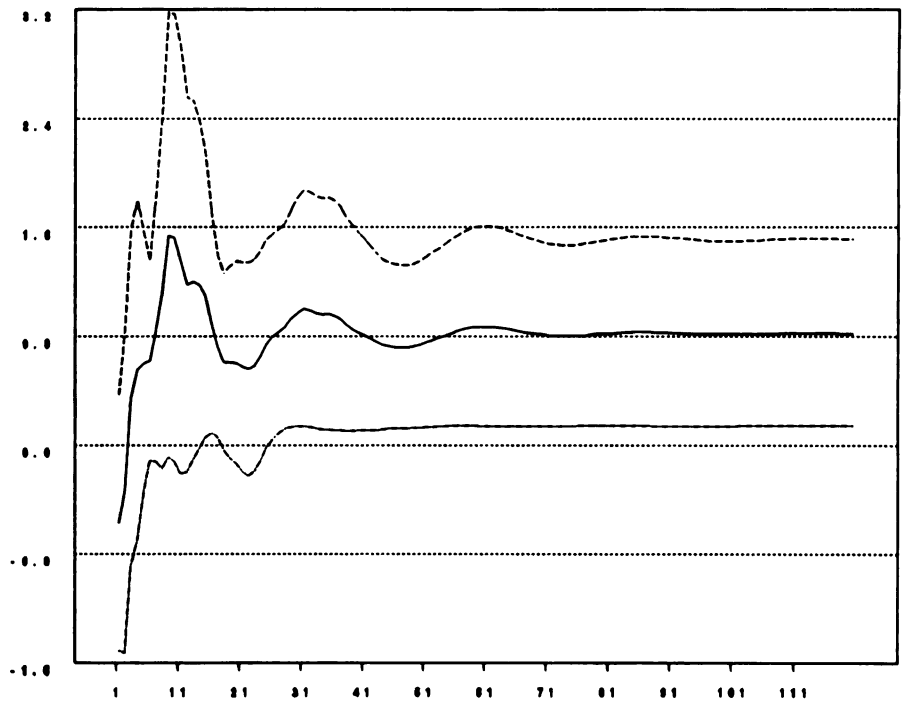

FIGURE 2: Investment in Response to a One-Standard Deviation Balanced-Growth Shock in KPSW

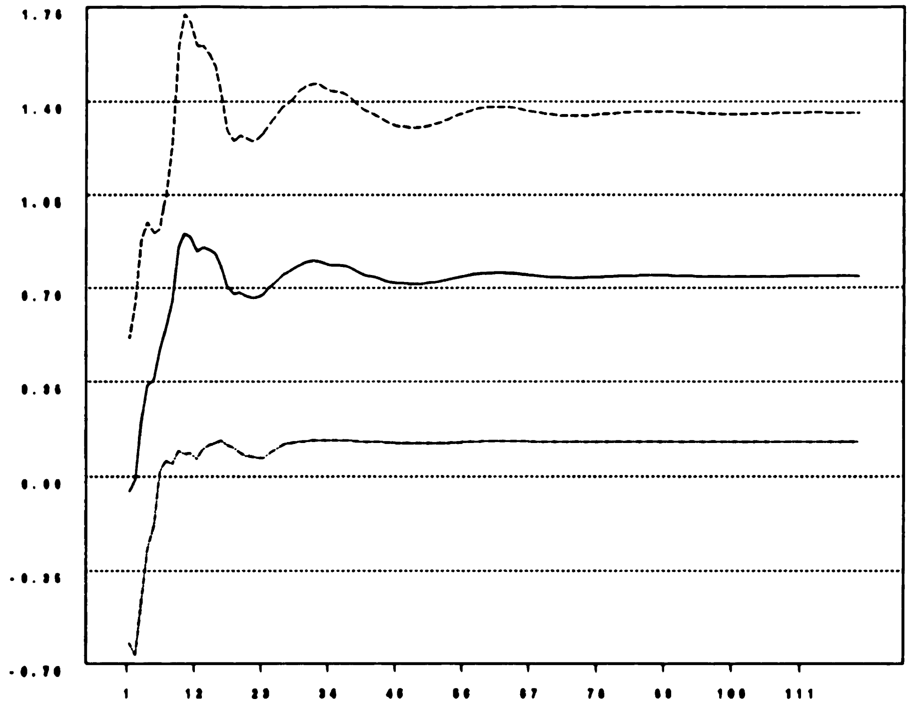

FIGURE 3: Output in Response to a One-Standard Deviation Balanced-Growth Shock in KPSW

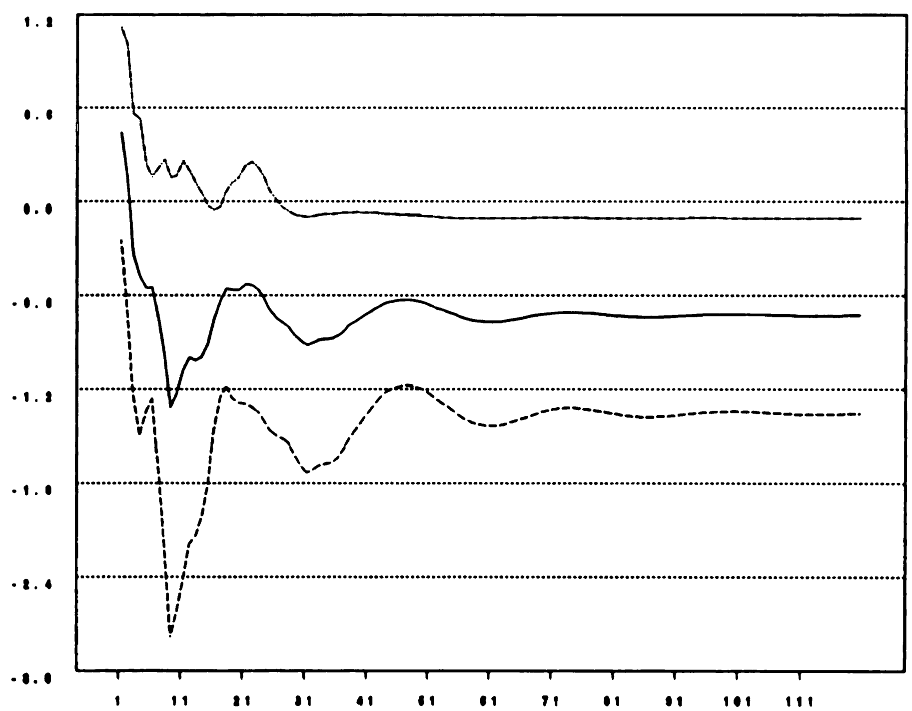

FIGURE 4: Net Exports in Response to a One-Standard Deviation Balanced-Growth Shock in KPSW

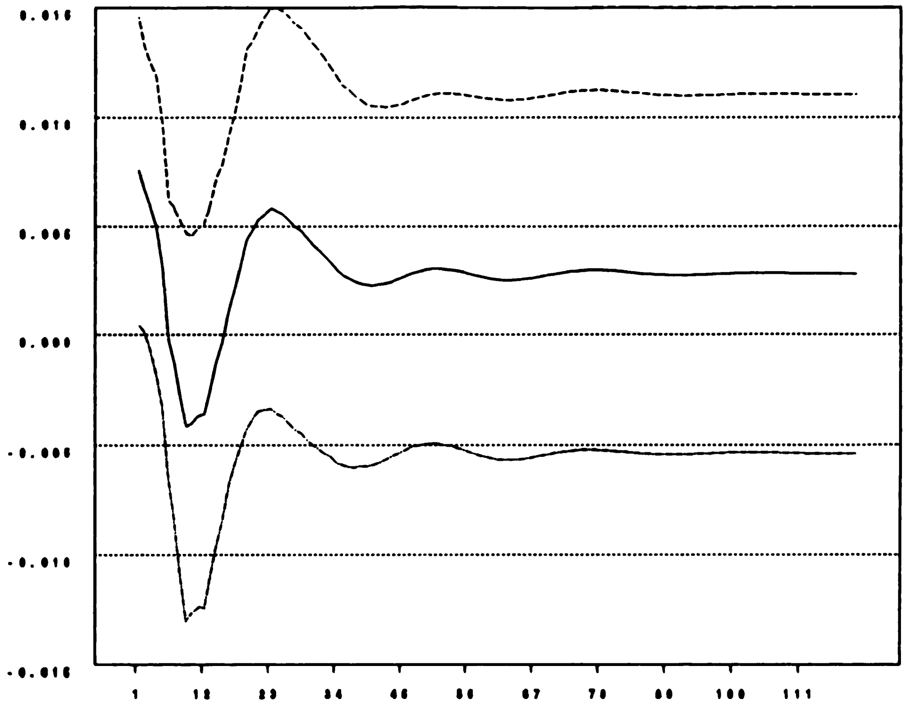

FIGURE 5: Consumption in Response to a One-Standard Deviation Real-Interest-Rate Shock in KPSW

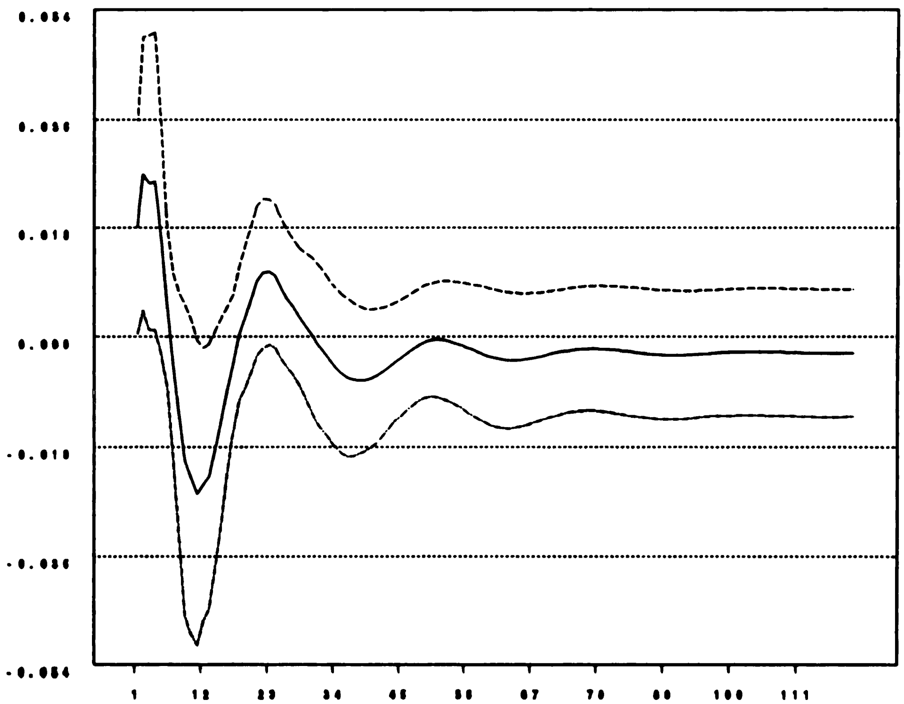

FIGURE 6: Investment in Response to a One-Standard Deviation Real-Interest-Rate Shock in KPSW

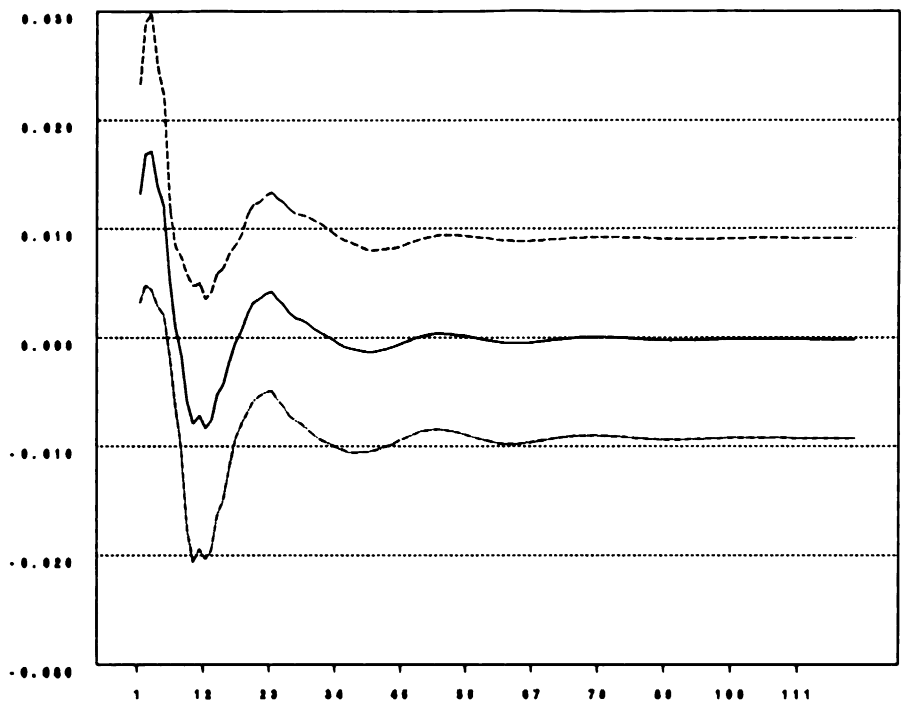

FIGURE 7: Output in Response to a One-Standard Deviation Real-Interest-Rate Shock in KPSW

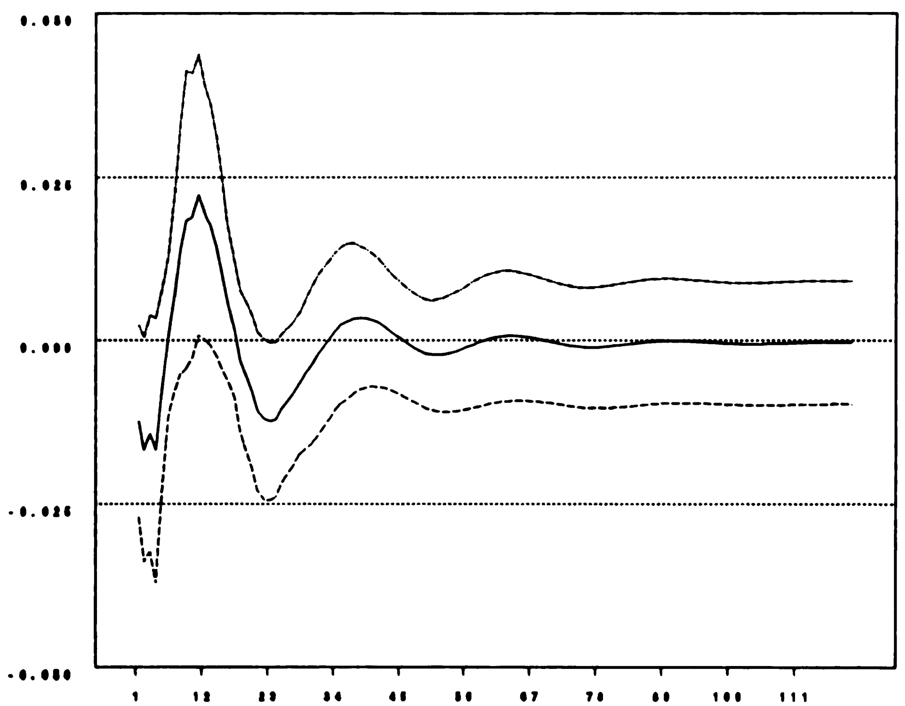

FIGURE 8: Net Exports in Response to a One-Standard Deviation Real-Interest-Rate Shock in KPSW

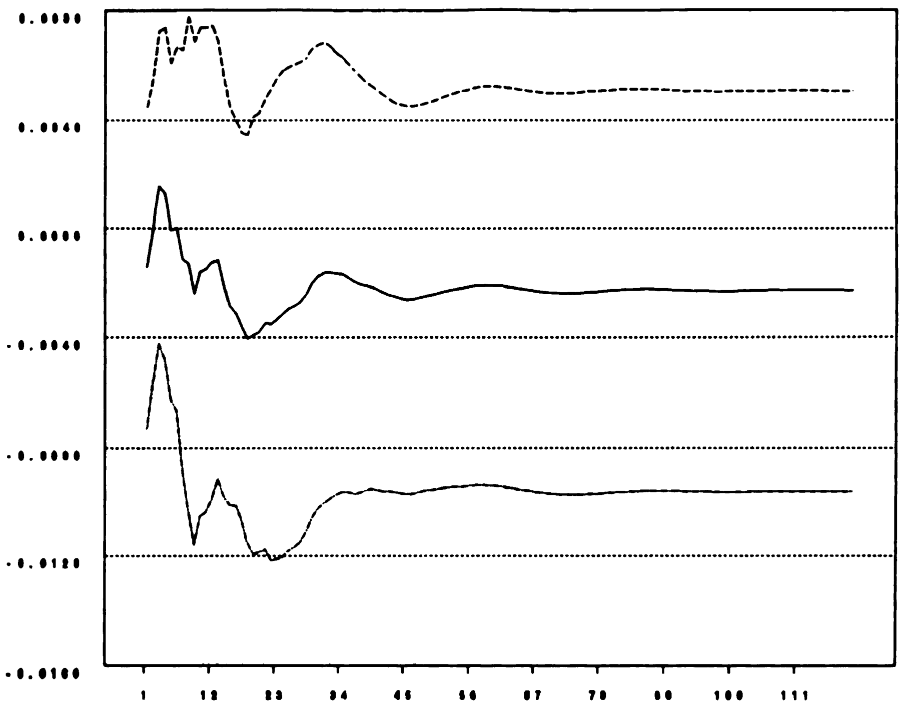

FIGURE 9: Consumption in Response to a One-Standard Deviation Inflation Shock in KPSW

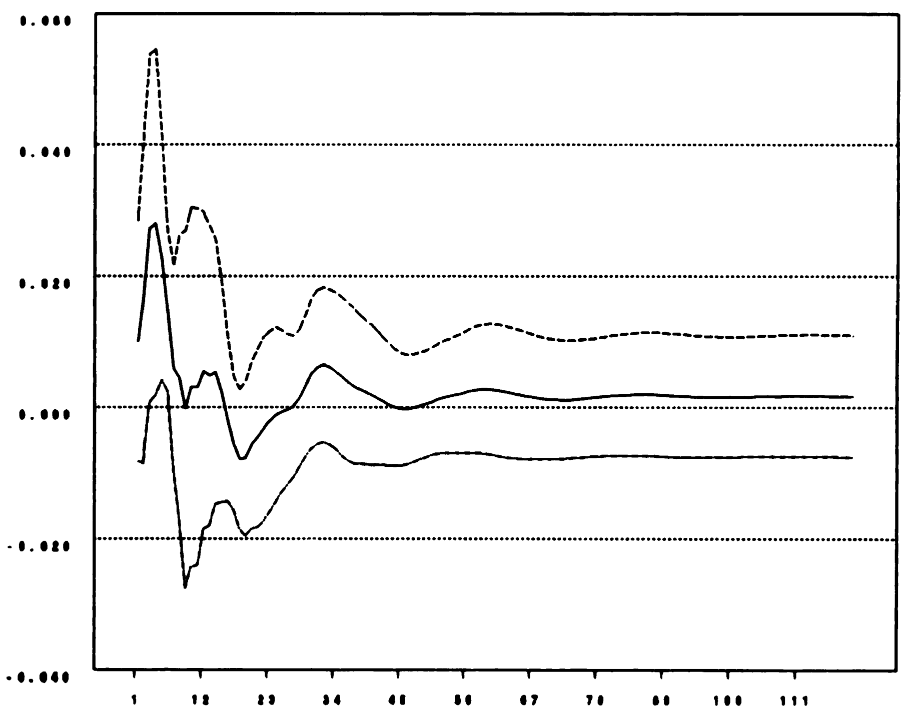

FIGURE 10: Investment in Response to a One-Standard Deviation Inflation Shock in KPSW

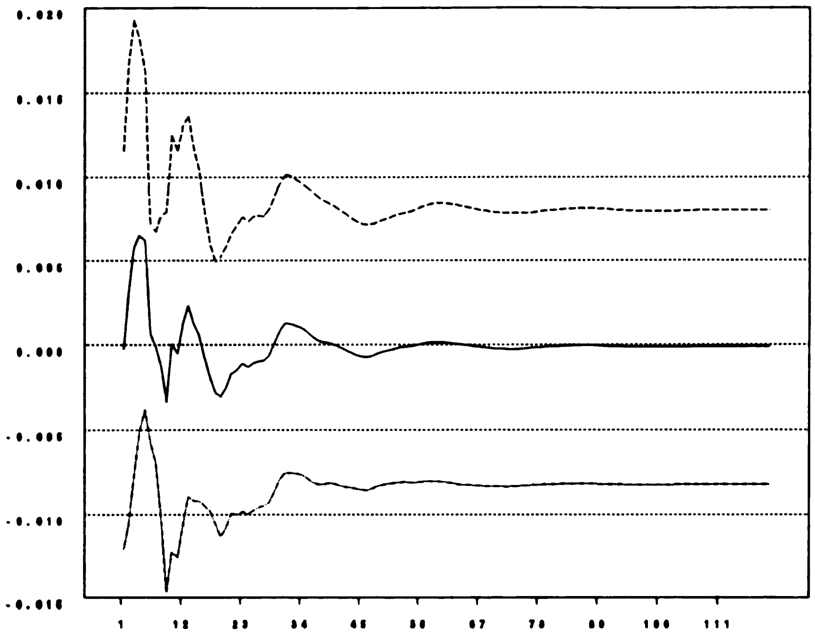

FIGURE 11: Output in Response to a One-Standard Deviation Inflation Shock in KPSW

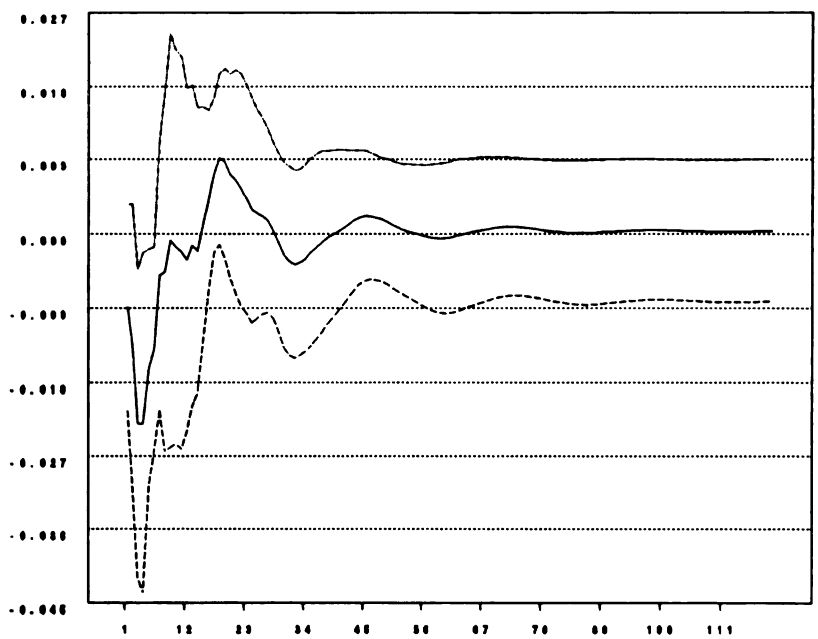

FIGURE 12: Net Exports in Response to a One-Standard Deviation Inflation Shock in KPSW

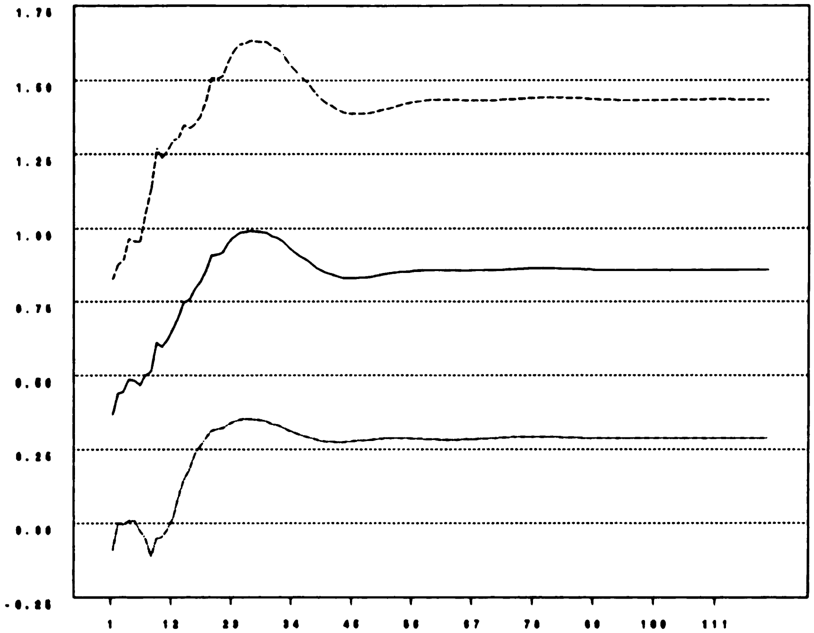

FIGURE 13: Consumption in Response to a One-Standard Deviation Balanced-Growth Shock with Alternative Ordering

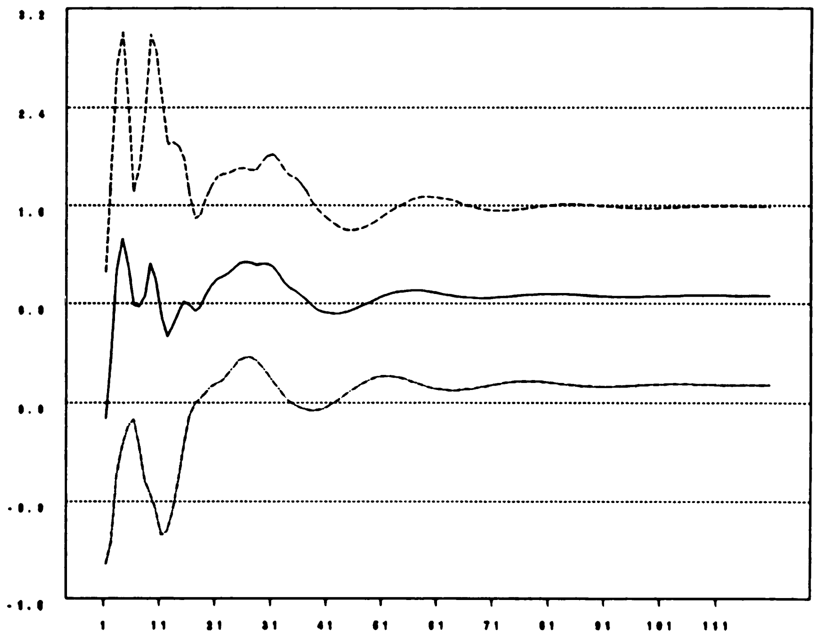

FIGURE 14: Investment in Response to a One-Standard Deviation Balanced-Growth Shock with Alternative Ordering

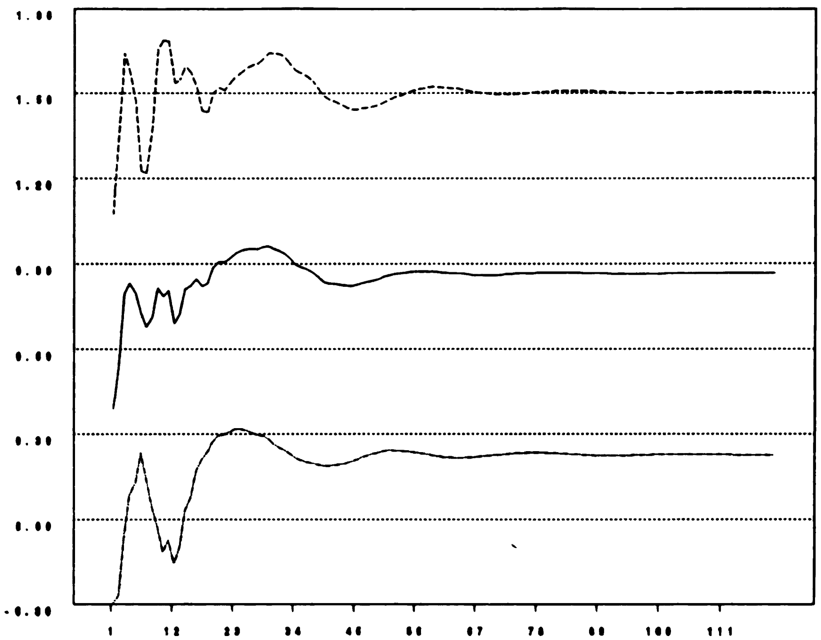

FIGURE 15: Output in Response to a One-Standard Deviation Balanced-Growth Shock with Alternative Ordering

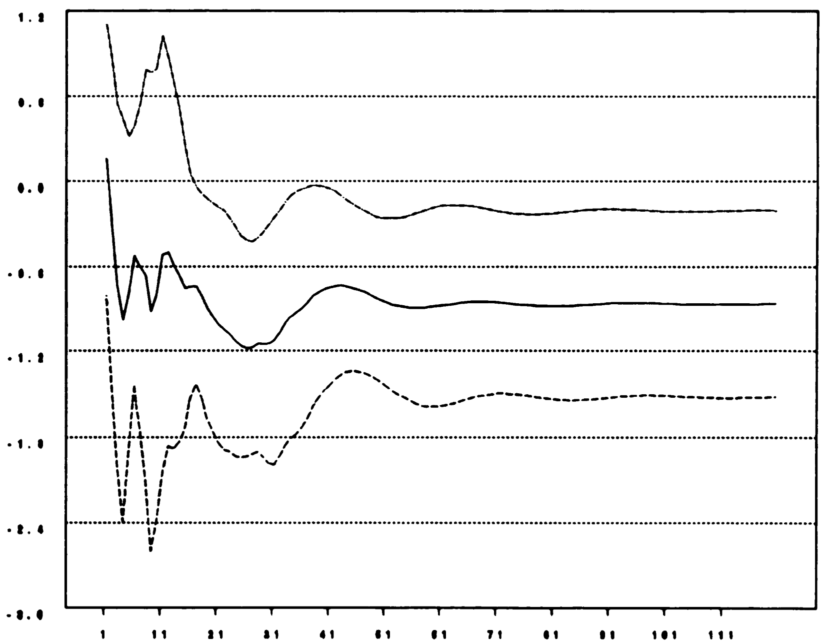

FIGURE 16: Net Exports in Response to a One-Standard Deviation Balanced-Growth Shock with Alternative Ordering

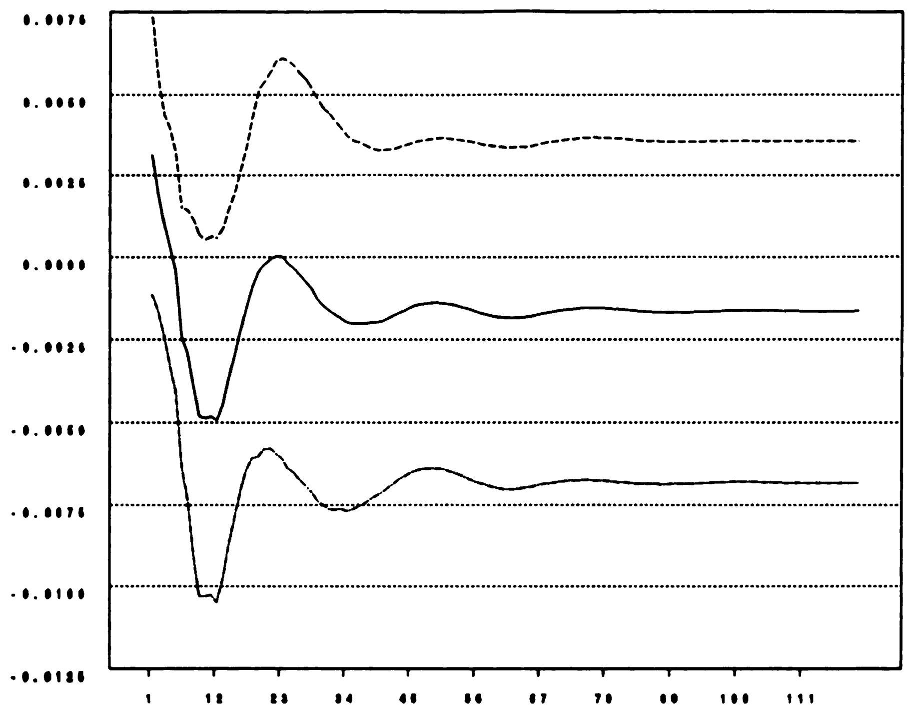

FIGURE 17: Consumption in Response to a One-Standard Deviation Real-Interest-Rate Shock with Alternative Ordering

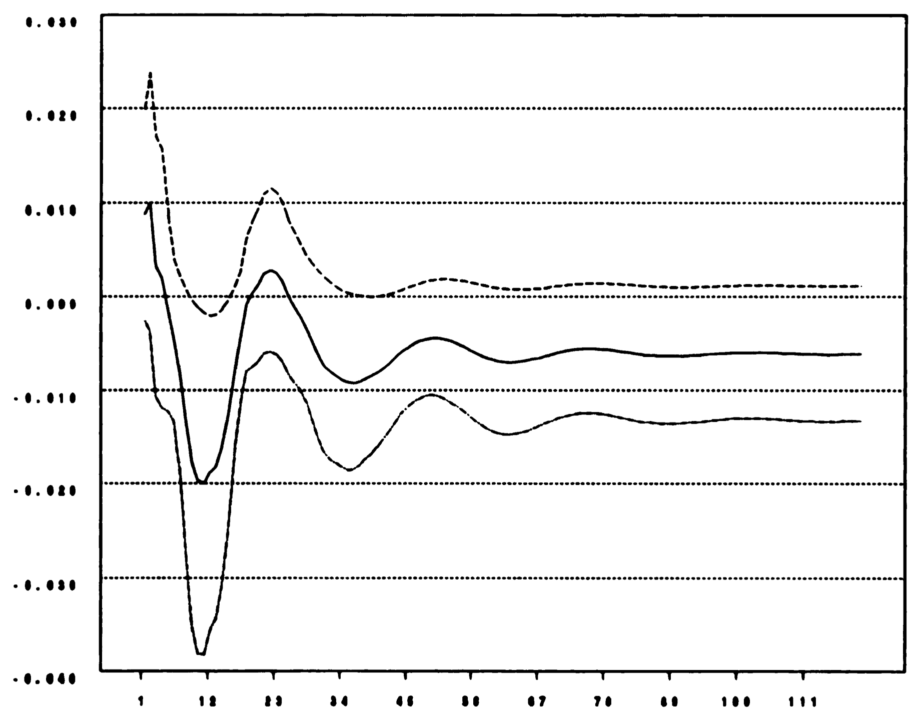

FIGURE 18: Investment in Response to a One-Standard Deviation Real-Interest-Rate Shock with Alternative Ordering

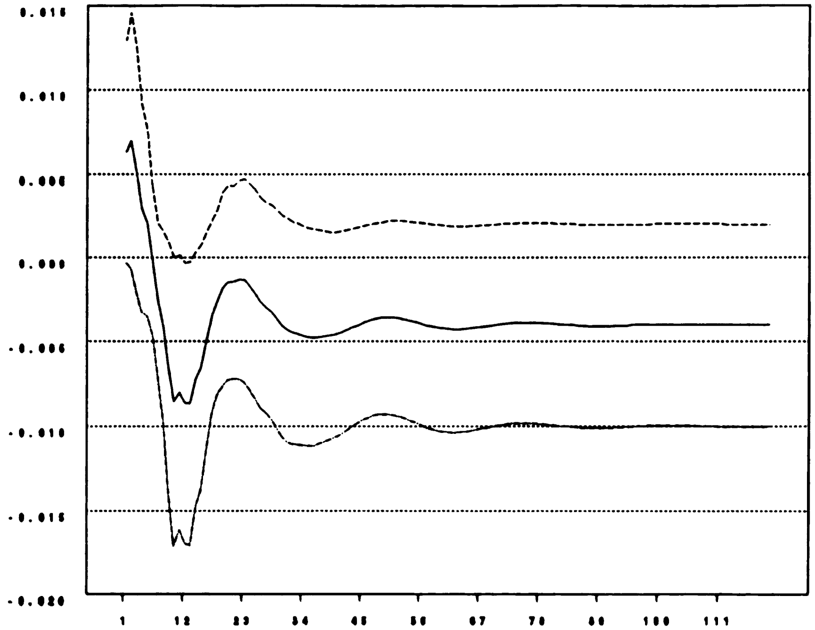

FIGURE 19: Output in Response to a One-Standard Deviation Real-Interest-Rate Shock with Alternative Ordering

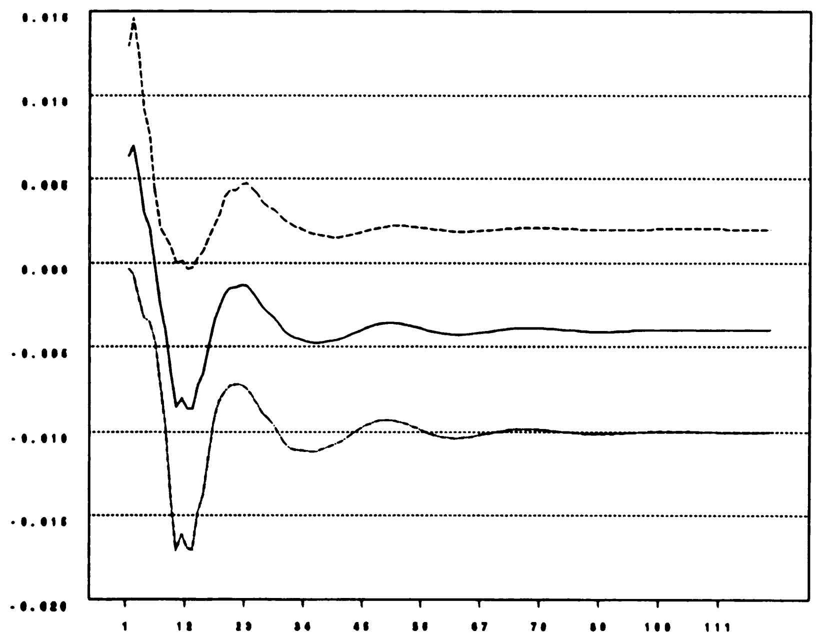

FIGURE 20: Net Exports in Response to a One-Standard Deviation Real-Interest-Rate Shock with Alternative Ordering

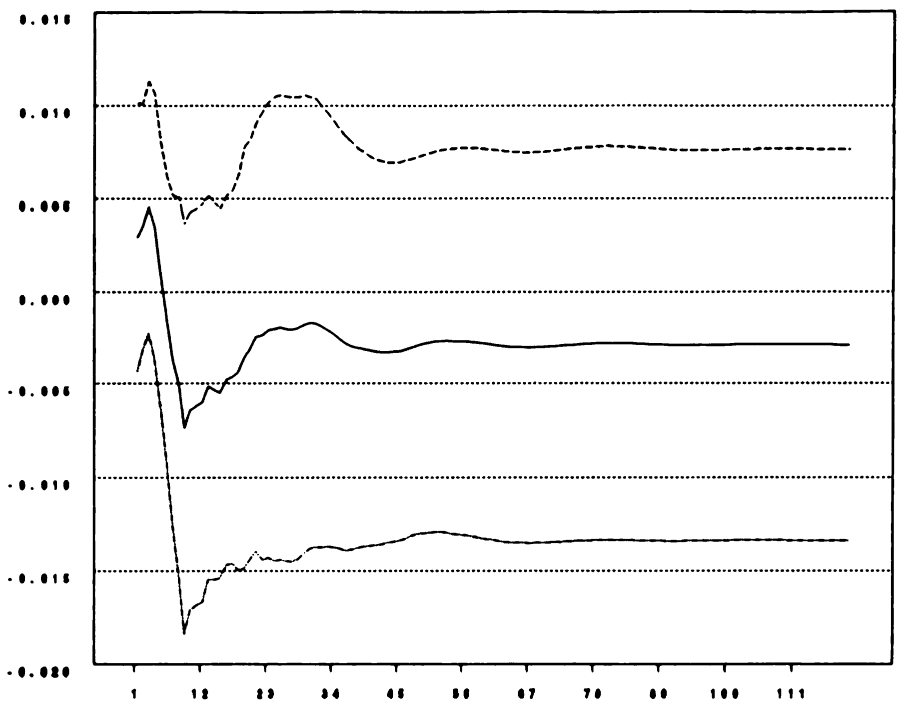

FIGURE 21: Consumption in Response to a One-Standard Deviation Inflation Shock with Alternative Ordering

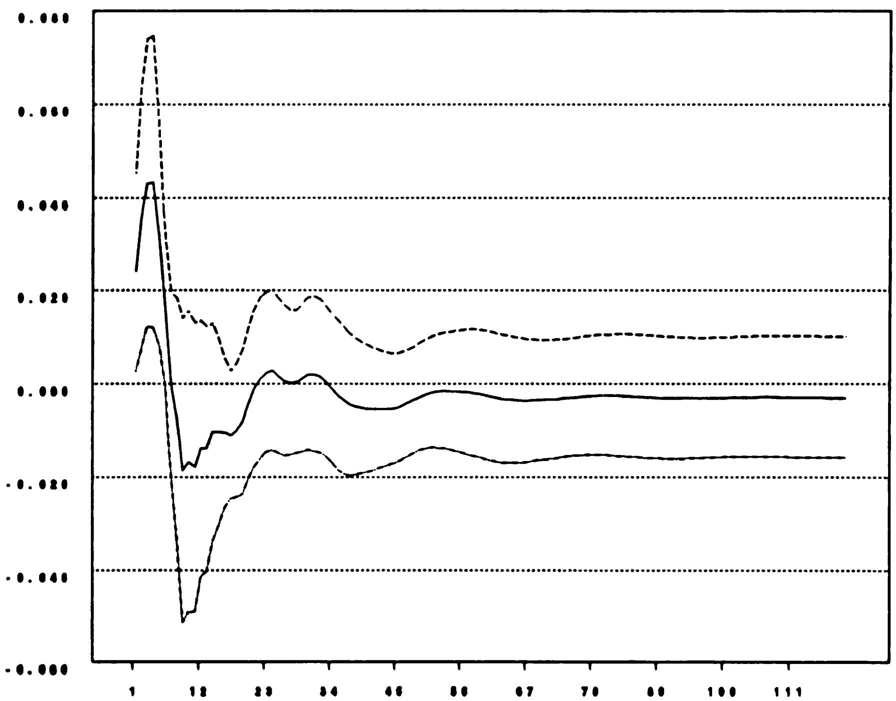

FIGURE 22: Investment in Response to a One-Standard Deviation Inflation Shock with Alternative Ordering

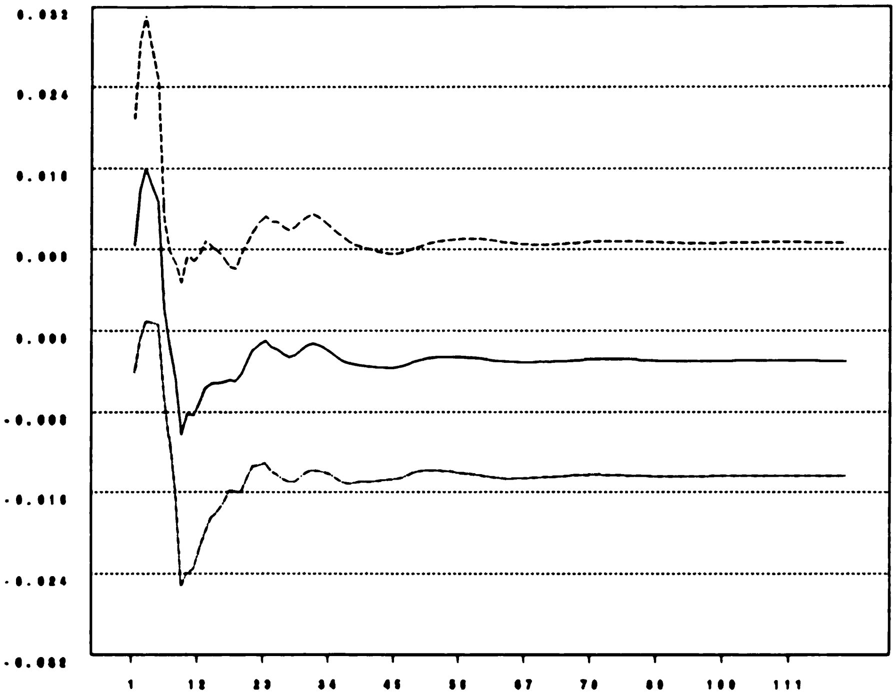

FIGURE 23: Output in Response to a One-Standard Deviation Inflation Shock with Alternative Ordering

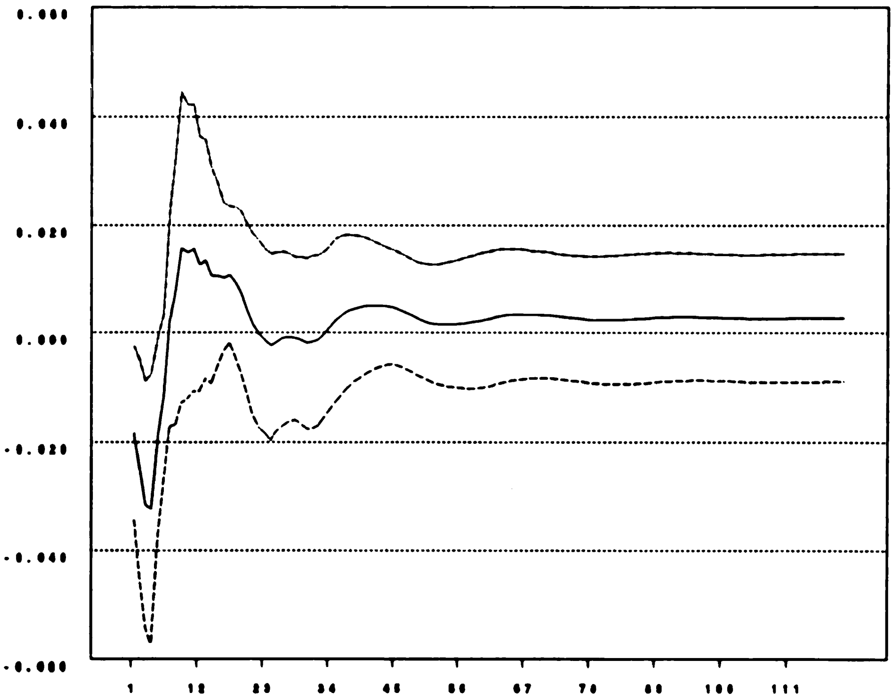

FIGURE 24: Net Exports in Response to a One-Standard Deviation Inflation Shock with Alternative Ordering

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III: STOCHASTIC TRENDS IN A LARGE OPEN ECONOMY

CHAPTER III

STOCHASTIC TRENDS IN A LARGE OPEN ECONOMY

1. INTRODUCTION

With the exception of Mellander, Vredin, and Warne (1992), who examine a small open economy, The importance of open-economy variables is largely ignored in the empirical literature regarding the causes of economic fluctuations. Though such factors are likely to play a significant role in explaining the economic fluctuations in smaller countries, it is commonly assumed that these effects are minimal in larger countries. This chapter extends the closed-economy model of King, Plosser, Stock and Watson (1991) in order to examine economic fluctuations in an open-economy, Vector Error-Correction model (VECM) of the United States.

The organization of the chapter is as follows: (1) a theoretical basis for the long-run restrictions is outlined; (2) long-run properties of the data are examined for both univariate series and linear combinations of certain series (cointegrating vectors); (3) results are presented for estimated impulse response functions and forecast-error variance decompositions; (4) exports are included in the model and the results are contrasted with the model excluding exports; (5) conclusions are drawn, and further extensions are outlined.

2. THEORETICAL BACKGROUND

Since the structural model is identified by imposing restrictions of the reduced-form (i.e., the VECM), it is necessary to justify theoretically the use of the certain restrictions and the omission of other potential restrictions. This section outlines the theoretical justifications of the underlying restrictions which will be used throughout this study.

The models estimated in this chapter will maintain the restrictions implied by the Solow growth model, which were presented in Chapter II.[1] In addition, KPSW's long-run money demand function used in Chapter II will also be employed in this analysis. For the reasons outlined in section 3.2 in Chapter II, the long-run relationship between the nominal

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[1]Stock and Watson's (1993) Dynamic OLS technique to estimate to coefficient on per capita real private output yields,

$$c_t - y_t = \underset{(-.39)}{-.065} + \underset{(1.00)}{0.04 y_t}$$

$$i_t - y_t = \underset{(-5.20)}{-1.42} + \underset{(0.53)}{0.03 y_t}$$

Investment here is defined as "gross private investment (gpi82). The estimates in the investment equation are not sensitive to the definition of investment. When investment is defined as "gross fixed investment" (gif82), the results are quantitatively similar,

$$i_t - y_t = \underset{(-6.68)}{-1.45} + \underset{(0.66)}{0.03 y_t}$$

These estimates are consistent with the theory of balanced-growth, since the coefficient on output is not significantly different from 1.00.

interest rate and inflation specified by Darby (1975) will be assumed. That is,

$$R_t = r_t^* + 1.30\Delta p_t \qquad (1)$$

Using Johansen's estimator,[2] Crowder and Hoffman (1992) have found that a long-run (cointegrating) relationship exists between the rate of inflation and the nominal interest rate,

$$R_t - 1.30\Delta p_t = \epsilon_t \; ; \; \epsilon_t \sim I(0) \qquad (2)$$

Therefore, in the long run all movements in the nominal interest rate are due to movements in inflation. That is, the after-tax real interest rate, equation (1), is stationary.

In particular, the analysis in this chapter examines the long-run properties of the external sector. Theoretically, the demand for real imports is a positive function of real income and a negative function of the relative price of imports. The derived-demand for U.S. real exports is a positive function of "rest-of-the-world" income, and a negative function of the relative price of U.S. exports. However, by including a foreign variable representing "rest-of-the-world" income, the issue of the international transmission of economic fluctuations is introduced, Backus, Kehoe, and Kydland (1992). The issue of the international transmission of business cycles will be explored in a later

---

[2]Crowder and Hoffman (1992) estimated the inflation coefficient using both Stock and Watson's (1993) DOLS technique, and Johansen's (1988) method. Consistent with their findings, I found the DOLS estimate to be 0.77.

chapter.

3. LONG-RUN TIME SERIES PROPERTIES

3.1 THE DATA

Vector autoregressions are performed over the period 1954:1 to 1988:4, with 6 lags of autoregression. The data used are all quarterly, seasonally adjusted, observations covering 1951:4 to 1988:4. The data are as follows: log of per capita real consumption (c), log of per capita private gross real investment (i)[3], log of per capita private real GNP (y), log of per capita real imports (im), log of per capita real exports (ex), the three-month U.S. Treasury bill (R), log of per capita real M2 money supply ($m-p$), and the log of the (multilateral) U.S real effective exchange rate (q). The price deflator was obtained by dividing nominal private GNP by real GNP. The inflation rate (Δp) is the first difference in the log of the deflator. With the exception of M2 from 1951:4 to 1958:4, which was constructed from Banking and Monetary Statistics 1941-1970, all of the variables are from Citibase. The U.S. real exchange rate, vis a vis the G-7[4], is constructed by using the Federal Reserve

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[3]The baseline model estimated in this chapter will use this definition. However, the alternative 9-variable model also estimated in this chapter will use real "gross private fixed" investment per capita. The difference is that the "gross private investment" includes changes in inventories.

[4]Since Citibase does not include Yen/$ nominal exchange rate prior to 1957, the real exchange rate prior to this date excludes Japan.

Board's trade-weighted index (1972-76), and is defined as foreign currency per dollar.[5] Therefore, an increase in the real exchange rate is a real appreciation of the dollar.

3.2 UNIVARIATE CHARACTERISTICS

Nelson and Plosser (1982) show that most macroeconomic time series are characterized by non-stationarity (I(1)). Tables 1 and 2 summarize the univariate characteristics of each of the variables in the model. Using the test proposed by Phillips and Perron (1988) under the null hypothesis of non-stationarity, or I(1), the null cannot be rejected for any of the variables except real per capita consumption in the presence of an intercept and a time trend. The Kwiatkowski-Phillips-Schmidt-Shin test (1991) under the null hypothesis of stationarity, I(0), supports the finding of non-stationarity for all of the variables. The null of stationarity is rejected at the 5% in the presence of a trend for all of the variables, except for real per capita exports and the real exchange rate, where the null is rejected at the 10% level in the presence of a trend, and nominal interest rates, where the null of stationarity cannot be rejected at standard levels.

3.3 MULTIVARIATE CHARACTERISTICS

Though the univariate series are characterized by non-stationarity, economic theory suggests that the paths of two or more of these I(1) variables be related in the long-run.

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[5]Federal Reserve Bulletin, August 1978, pq 700.

Following Engle and Granger (1987), a vector of variables is said to be cointegrated if each variable is individually non-stationary, but a linear combination of the variables is stationary. If two variables are cointegrated, then their long-run paths are not independent.

In addition to the Solow balanced-growth restrictions and the Darby-Fisher restriction, the remaining theoretical relationships discussed in section 2 need to be estimated. Point estimates of the cointegrating vectors are found using Stock and Watson's (1993) Dynamic OLS technique over 1954:1 to 1987:3 with five leads and lags. The estimated cointegrating vectors and their t-statistics are,[6]

$$\underset{}{m\text{-}p_t} = \underset{(2.00)}{0.65} + \underset{(17.08)}{1.199y_t} - \underset{(-3.11)}{0.013R_t} \tag{3}$$

$$im_t = \underset{(4.57)}{4.69} + \underset{(8.34)}{2.726y_t} + \underset{(0.305)}{0.117q_t} \tag{4}$$

$$im_t = \underset{(-1.44)}{-2.67} + \underset{(4.10)}{0.007t} + \underset{(2.73)}{1.13y_t} + \underset{(0.609)}{0.103q_t} \tag{5}$$

Equation (3) represents the money-demand equation. Since the nominal interest rate is significant in the equation, I conclude that it should be included in the long-run money-

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[6]As Stock and Watson (1993) show, the "distributions of the t-ratios tend to be spread out relative to the normal distribution, suggesting that the usual confidence intervals will overestimate precision." Therefore, the t-statistics reported in parentheses below have been adjusted to be "standard normal", so that the standard critical values are appropriate.

demand function, as opposed to the specification suggested by Hallman, Porter and Small (1991). Equations (4) and (5) both represent the derived-demand for real imports.[7] Equation (4) is the estimate of cointegration in the absence of a time trend. Equation (5) is the estimate of cointegration in the presence of a time trend.

Since the theoretical restrictions implied by Solow growth models were not rejected,[8] it is sufficient to test whether the variables *c-y* and *i-y* are stationary. This is reported in Tables 1 and 2. For *c-y* and *i-y* the null of non-stationarity using the Phillips-Perron test is rejected at the 5% level. Using the Kwiatkowski-Phillips-Schmidt-Shin test, the null of stationarity cannot be rejected at the 10% level for *i-y*. However, stationarity of *c-y* is rejected at the 5% level.

Crowder and Hoffman's (1992) finding that the Darby-Fisher equation (2) is stationary is also tested. The Phillips-Perron test confirmed the finding of stationarity, since the null was rejected at the 1% level.[9] Using the Kwiatkowski-Phillips-Schmidt-Shin test, the null cannot be

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[7]The import-demand equations were also estimated with a dummy included to represent the exchange-rate regime shift in 1973. In neither of the equations (11) or (12) was the dummy significant at standard levels.

[8]See footnote 1.

[9]KPSW (1991) found that there was no evidence of cointegration between the nominal interest rate and the inflation rate, and concluded that the real interest rate was non-stationary. However, they did not consider the possibility that the Fisher equation is correctly depicted by equation (4), the Darby equation.

rejected at the 10% level.

In order to test the estimated vectors (3), (4) and (5) for the presence of cointegration, the residuals from each of the estimated vectors are tested for stationarity. If the residuals are I(0), then the variables in the vector are cointegrated. Table 3 summarizes the tests for stationarity of the residuals from each of the three vectors. Shin (1992) has provided a set of critical values for a residual-based test of cointegration which is based upon the Kwiatkowski-Phillips-Schmidt-Shin test under the null hypothesis of cointegration. If the residuals of the estimated vector are stationary, or I(0), then the variables are cointegrated. For the long-run money-demand equation (3), the null of cointegration cannot be rejected at the 10% level. The null is rejected at the 5% level for import demand equation (4). However, in the presence of a time trend, equation (5), the null cannot be rejected at the 10% level. This suggests that a stable long-run relationship exists between real per capita imports, private income, and the real exchange rate in the presence of a deterministic trend. This finding is supported by Rose and Yellen (1989), though Rose (1989) failed to find such a relationship. However, both of these studies use only post-Bretton Woods data, and examine bilateral relationships, where the present study uses multilateral data.

4. EMPIRICAL RESULTS

4.1 AN OPEN-ECONOMY COMMON TRENDS MODEL

The open-economy Vector-Error Correction Model[10] is estimated from 1954:1 to 1988:4 with 6 lags and five error correction terms.[11] It consists of three permanent stochastic shocks to the system: an inflation shock, a real-exchange-rate shock, and a real balanced-growth shock. The cointegrating vectors described in equations (1), (2), (5), (6), and (12) are used to restrict the matrix of long-run multipliers.[12] $\hat{\Pi}$ is given in Table 6 for the 8-variable model, and the estimated long-run multipliers for the permanent innovations in the model are reported in Table 10.

4.2 IMPULSE RESPONSE FUNCTIONS

Impulse response functions with respect to a one-standard-deviation shock in the three common trends are estimated for consumption, investment, output, imports and net exports. The one-standard deviation of the balanced-growth shock is .79%, the real-exchange-rate shock is .73%, and the inflation shock is .66%. Selected mean impulse responses (solid line), along with their respective 95% confidence

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[10]See Chapter II, section 2 for an overview of the methodology.

[11]Following Sims (1980), Likelihood Ratio tests were performed in order to determine the appropriate number of lags of autoregression. When AR(8) is unrestricted, the restriction of AR(6) is not rejected at the 5% level. When AR(6) is unrestricted, the restriction of AR(4) is rejected at the 1% level.

[12]For a more complete exposition, see Appendix.

intervals (dashed lines), are show in Figures 1-15.

A positive balanced-growth shock leads to the proportional permanent increases in output, consumption, and investment as predicted by Solow growth theory. The negative initial effect of the balanced-growth shock on investment in Figure 2 is contrary to theoretical predictions. However, this is not significant at the 95% level. Figure 3 shows that the initial response of imports to the positive balanced-growth shock is to decrease. In the long run, however, the response of imports is significantly positive. Figure 5 shows that the short-run response of net exports to the balanced-growth shock is consistent with intertemporal theories of current account behavior. Intertemporal theories of the current account such as Sachs (1981) predict that positive net exports are procyclical. However, they also predict that net exports will not be affected by a balanced-growth shock in the long run. After about 20 quarters, the response of net exports to the balanced-growth shock is significantly negative.

Though changes in real exchange rates can, theoretically, have significant effects on consumption and investment, there is no evidence that this is the case for the United States. In Figures 6 and 7 the responses of consumption and investment are never significantly different from zero. Given the fact that the United States is a large open economy, this result is not surprising. Furthermore, Figure 8 shows that imports are not significantly affected by the real-exchange-rate shock, either. Rather, the only permanent shock which affects imports is the balanced-growth shock. Figure 10 shows the response of net exports to the real-exchange-rate shock. Though the mean response appears to follow the so-called J-curve, the response to insignificantly different from zero.[13] This is consistent with recent work by Rose and Yellen (1989), who find no reliable evidence of either a short-run or a long-run J-curve.

4.3 VARIANCE DECOMPOSITIONS

Forecast-error variances given in Tables 12-14 show the relative importance of the common trends in accounting for unpredicted variability in the eight variables up to 120 quarters.

One-sector Real Business Cycle models predict that the balanced-growth shock is capable of explaining both short-run and long-run variation. However, examining the forecast-error variance decompositions in Table 12, the balanced-growth shock is relatively unimportant over the short-run. Although it accounts for 68% of the error-variance in imports after only 1 quarter, it accounts for only 11% of the error-variance in consumption, 9% of investment error-variance, and 0% of output error-variance. At 12 quarters, it accounts for 30% of the error-variance in output. At 120 quarters, while the

[13]Most commonly, the J-curve refers to a short-run worsening of the current account in response to an exchange rate **depreciation**, while in the long run, there is a permanent improvement in the current account. However, the exchange-rate shock here is an appreciation.

balanced-growth shock explains only 33% of the error-variance in investment, it explains 87% of the error-variance in consumption, 78% in output and 53% in imports. These estimates are broadly consistent with closed-economy estimates in King, Plosser, Stock, and Watson (1991).

Permanent innovations in inflation do not account for the majority of unpredicted variation in the real flow variables in the short run, either. After 1 quarter, the inflation shocks explain 12% of the error-variance in output, 1% of the error-variance in consumption, 13% of the error-variance in investment, and only 1% of the error-variance in imports. At 4 quarters, it accounts for 47% of investment variance and 35% of output variance. After 12 quarters, however, it only explains 25% of investment variance and 15% of output variance. Clearly, investment is the most sensitive to changes in inflation of any of the variables.

It is not surprising that the real-exchange-rate shock does not explain a large proportion of the variation in the real flow variables. It explains 10% of the error-variance in consumption, 6% of the error-variance in investment, 7% of the error-variance in output, and 11% of the error-variance in imports at 12 quarters. The fact that the real-exchange-rate shock does not account for much of the variation in imports is consistent with the fact that it is an insignificant determinant of the long-run demand for imports, equation (11) and (12).

Table 19 summarizes the percentage of the variance which is accounted for by the transitory shocks. Since the transitory shocks are not uniquely identified, it is not possible to assign the relative importance to any specific factors. Generally speaking, these can be thought of as temporary aggregate demand shifts. Over the course of the three-year horizon, these transitory shocks account for the majority of the variance in the real flow variable (though permanent shocks account for 52% of output variance at 12 quarters). This is different from the conclusions of KPSW (1991), Blanchard and Quah (1989), Gali (1992), and Mellander, Vredin, and Warne (1992). The main reason for the discrepancy between these estimates and those of KPSW (1991) is that they modelled the real interest rate as non-stationary, as one of their permanent innovations.

4.4 AN OPEN-ECONOMY MODEL WITH EXPORTS

The baseline model does not explicitly account for real per capita exports. Rather, it is left as the residual term. As argued in the theoretical section, it is not possible to model the long-run properties of exports without introducing "rest-of-the-world" income. Exports can, however, be added to the model by assuming that they are a fourth common trend, which is not present in any of the cointegrating vectors, and therefore have no long-run effects on anything except for exports itself. If this is done, the results in the previous sections will be tested for their sensitivity to another permanent innovation.[14]

Forecast-error variance decompositions for the 9-Variable model (the baseline model + exports as a fourth trend) are summarized in Tables 15-18. The real-exchange-rate shock now accounts for 30% of the forecast-error variance in output after 1 quarter (versus 5% in the baseline model) and 29% after 12 quarters (versus 7% in the baseline model). In addition after 12 quarters, the real-exchange-rate shock accounts for 34% of the error-variance in consumption, 31% of the error-variance in investment, and 41% of the error-variance in imports. It is also noteworthy that after 120 quarters, 30% of the error-variance in imports is still explained by the real-exchange-rate shock. Moreover, this increase in the importance of the real-exchange-rate shock does not depend upon a large correlation between the real-exchange-rate and balanced-growth shocks.[15] However, it may be the result of the large correlation between the real-exchange-rate and real export shocks.

It is also important to note the effect of the inclusion of exports in the VECM on the relative importance of the other permanent innovations. The balanced-growth shock actually explains more of the 4 and 8 quarter variance in output in the

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[14]In order to include exports in the VECM, the residual in the national income identity becomes "changes in inventories". That is, investment is now defined as "gross fixed investment".

[15]The $\hat{\Pi}$ for the 9-variable model is reported in Table 9.

alternative model, 32% and 35% (versus 13% and 20% in the baseline model). The inflation shock explains less of the 4 and 8 quarter variance in output in the alternative model, 18% and 18% (versus 35% and 25% in the baseline model). Table 19 shows that the majority of short-run forecast-error variance for each of the variables discussed is explained by permanent innovations, not the transitory innovations. This is in contrast with results from the model without exports. Furthermore, the increased relative importance of the permanent innovations in accounting for the forecast-error variances is almost entirely accounted for by the output and real-exchange-rate shocks.

5. CONCLUSION

This study has found that there is evidence that a stable long-run relationship exists between per capita real imports, the multilateral real effective exchange rate, and per capita real private output. However, the real exchange rate is not significant at standard levels in this vector. The evidence suggests that there is a significant deterministic trend in the long-run import-demand function, perhaps the result of the liberalization of trade policies since the Kennedy round of GATT negotiations in the 1960's. When exports are introduced into the model, shocks to the real-exchange-rate have surprisingly large short-run effects on the variance in output, especially for a large open-economy. Furthermore, the permanent stochastic trends account for the majority of both the short-run and long-run forecast-error variance in output. This conclusion does not depend upon the interpretation of the real interest rate as possessing a non-stationary component.

Though the central result of this study is surprising, the models estimated in this chapter should be considered to be reasonable open-economy models of the United States. Impulse responses show that none of the domestic real variables examined are significantly affected by shocks to the real exchange rate. Therefore, the relative importance of real-exchange-rate shocks in accounting for forecast-error variances does not seem to be the result of any unreasonable restrictions. Furthermore, with the exception of the real export shock, which is affected by the real-exchange-rate shock, the permanent innovations are uniquely identified. As in closed-economy models, the balanced-growth shock, as well as the inflation shock, fails to account for the majority of the short-run variance in output.

The inclusion of the export shock in the model presented here suggests that, in order to explain the behavior of an open-economy, the long-run demand for exports should be explicitly modelled. In doing so, the importance of the real exchange rate may be better defined, since it is not a significant determinant of long-run import demand. In modelling the long-run demand for exports, it is necessary to introduce yet another permanent shock to the model. Theoretically a long-run relationship should exist between real exports, the real exchange rate and "rest-of-the-world" income. By adding an additional shock representing the impact of other countries' income on the domestic variables, the issue of the international transmission of real business cycles, along the lines of Backus, Kehoe, and Kydland (1992), is introduced.

TABLE 1

Phillips-Perron Test for Non-Stationarity of Univariate Time Series: 1951:4 - 1988:4

Series	$Zt_{\tilde{\alpha}}$	Zt_{α^*}
c	-4.35	-0.97
i	-0.92	-1.69
$m-p$	-2.54	-0.36
y	-2.78	-0.72
Δp	-1.25	-3.25
R	-0.44	-1.86
im	-3.34	-0.65
ex	-2.34	-0.20
q	-1.01	-1.19
$c-y$[3]	-	-3.30
$i-y$[1,3]	-	-3.33
$i-y$[2,3]	-	-3.56
$R-1.3\Delta p$[3]	-	-4.05

Lags of truncation is 6

Critical Values :

Phillips-Perron (H_0: I(1)):

$Zt_{\tilde{\alpha}}$: 1% = -3.96, 5% = -3.41
Zt_{α^*}: 1% = -3.43, 5% = -2.86

$Zt_{\tilde{\alpha}}$: tests the null of I(1) with intercept and time trend
Zt_{α^*}: tests the null of I(1) with intercept only

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[1]gross fixed investment

[2]gross private investment

[3]1954:1 - 1988:4

TABLE 2

Kwiatkowski-Phillips-Schmidt-Shin Test for Stationarity of Univariate Time Series: 1951:4 - 1988:4

Series	Trend	No Trend
c	.367	2.173
i	.166	1.794
$m-p$	.223	2.041
y	.341	2.152
Δp	.262	1.002
R	.099	1.537
im	.166	2.192
ex	.134	1.176
q	.131	1.476
$c-y$[3]	-	.513
$i-y$[1,3]	-	.047
$i-y$[2,3]	-	.089
$R-1.3\Delta p$[3]	-	.285

Lags of Truncation is 6

Critical Values:

KPSS (H_0: I(0)):

No Trend: 1% = .739, 5% = .463, 10% = .347
Trend: 1% = .216, 5% = .146, 10% = .119

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[1]gross fixed investment

[2]gross private investment

[3]1954:1 - 1988:4

TABLE 3

Shin (1992) Residual-Based Cointegration Tests of Vectors: 1954:1-1987:3

Estimated Vectors	KPSS: No Trend	KPSS: Trend
$m\text{-}p_t = 0.65 + 1.199y_t - 0.013R_t$	.091	-
$im_t = 4.69 + 2.726y_t + 0.117q_t$	.342	-
$im_t = -2.67 + 0.007t + 1.13y_t + 0.103q_t$	-	.079

Lags of truncation for both KPSS tests is 6

Critical Values (Shin 1992):

KPSS (H_0: I(0)):

No Time Trend:

1 Regressor: 5% = .314, 10% = .231
2 Regressors: 5% = .221, 10% = .163

Time Trend:

2 Regressors: 5% = .101, 10% = .081

TABLE 4

Variance-Covariance Matrix of Permanent Shocks in Baseline Model

	Δp	q	y
Δp	0.09266	-	-
q	0.00238	0.00030	-
y	-0.00015	0.00001	0.00003

TABLE 5

Correlations between the Permanent Shocks in the Baseline Model

	Δp	q
q	0.4514	-
y	-0.0899	0.0018

TABLE 6

Π in Baseline Model

	Δp	q	y
Δp	1.00	-	-
q	0.0257	1.00	-
y	-0.0016	0.0634	1.00

TABLE 7

Variance-Covariance Matrix of Permanent Shocks in the 9-Variable Model

	Δp	q	ex	y
Δp	0.10565	-	-	-
q	0.00099	0.00064	-	-
ex	-0.00020	-0.00020	0.00025	-
y	-0.00063	0.00001	0.00002	0.00003

TABLE 8

Correlations Between the Permanent Shocks in the 9-Variable Model

	Δp	q	ex
q	0.1204	-	-
ex	-0.0389	0.5000	-
y	0.3539	0.0722	0.2309

TABLE 9

Π Matrix in the 9-Variable Model

	Δp	q	ex	y
Δp	1.00	-	-	-
q	0.0095	1.00	-	-
ex	-0.0019	-0.3127	1.00	-
y	-0.0059	0.0302	0.1019	1.00

TABLE 10

Long-Run Multipliers in Response to Changes in the Three Common Trends (order: Δp, q, y, with AR(6))

variable	Δp	q	y
c	0.00	0.06	1.00
i	0.00	0.06	1.00
$m-p$	-0.02	0.08	1.20
im	0.00	0.17	1.13
R	1.30	0.00	0.00
y	0.00	0.06	1.00
Δp	1.00	0.00	0.00
q	0.03	1.00	0.00

TABLE 11

Long-Run Multipliers in Response to Changes in the Four Common Trends (order: Δp, q, ex, y, with AR(6))

variable	Δp	q	ex	y
c	0.00	0.03	0.10	1.00
i	0.00	0.03	0.10	1.00
$m-p$	-0.02	0.04	0.12	1.20
im	0.00	0.14	0.12	1.13
R	1.30	0.00	0.00	0.00
y	-0.01	0.03	0.10	1.00
Δp	1.00	0.00	0.00	0.00
q	0.01	1.00	0.00	0.00
ex	0.00	-0.31	1.00	0.00

TABLE 12

Percentage of Forecast-Error Variance Attributed to the Balanced-Growth Shock in the Baseline Model

Period

	1	4	8	12	16	20	24	120
c	11	27	39	37	42	52	61	87
i	9	5	11	11	10	11	14	33
y	0	13	20	30	30	34	41	78
im	68	36	24	15	13	15	21	53

TABLE 13

Percentage of Forecast-Error Variance Attributed
to the Real-Exchange-Rate Shock in the Baseline Model

	Period							
	1	4	8	12	16	20	24	120
c	0	1	8	10	8	9	9	5
i	0	0	1	6	7	8	10	9
y	5	5	4	7	6	7	8	5
im	0	1	4	11	12	14	16	16

TABLE 14

Percentage of Forecast-Error Variance Attributed
to the Inflation Shock in the Baseline Model

	Period							
	1	4	8	12	16	20	24	120
c	1	8	4	2	2	2	2	1
i	13	47	40	25	23	22	20	15
y	12	35	25	15	13	12	11	4
im	1	10	11	8	7	7	6	3

TABLE 15

Percentage of Forecast-Error Variance Attributed to the
Balanced-Growth Shock in the 9-Variable Model

	Period							
	1	4	8	12	16	20	24	120
c	30	45	37	34	36	39	45	71
i	1	19	19	13	12	12	14	37
y	9	32	35	27	27	29	33	64
im	51	23	12	9	8	8	10	37
ex	19	6	6	4	3	3	4	1

TABLE 16

Percentage of Forecast-Error Variance Attributed to the Real-Exchange-Rate Shock in the 9-Variable Model

Period

	1	4	8	12	16	20	24	120
c	0	0	28	34	28	23	20	5
i	1	7	20	31	30	29	30	19
y	30	22	24	29	27	24	23	8
im	3	9	29	41	40	39	38	30
ex	7	19	18	24	31	34	34	28

TABLE 17

Percentage of Forecast-Error Variance Attributed to the Inflation Shock in the 9-Variable Model

Period

	1	4	8	12	16	20	24	120
c	1	7	5	3	8	11	12	12
i	7	33	32	12	14	26	25	20
y	3	18	18	14	13	14	14	12
im	3	10	13	10	11	14	14	10
ex	3	3	6	12	13	11	10	3

TABLE 18

Percentage of Forecast-Error Variance Attributed to the Export Shock in the 9-Variable Model

Period

	1	4	8	12	16	20	24	120
c	2	3	3	5	8	9	9	8
i	1	1	2	4	5	5	4	5
y	1	1	3	4	7	8	8	8
im	0	8	5	3	3	3	4	6
ex	51	51	51	43	38	38	40	63

TABLE 19

Percentage of the Forecast-Error Variance Attributed to Transitory Shocks in Each Model

	8 Variables 12 Periods	9 Variables 12 Periods	8 Variables 120 Periods	9 Variables 120 Period
c	51	24	7	4
i	58	29	43	19
y	48	26	13	8
ir	66	37	28	17

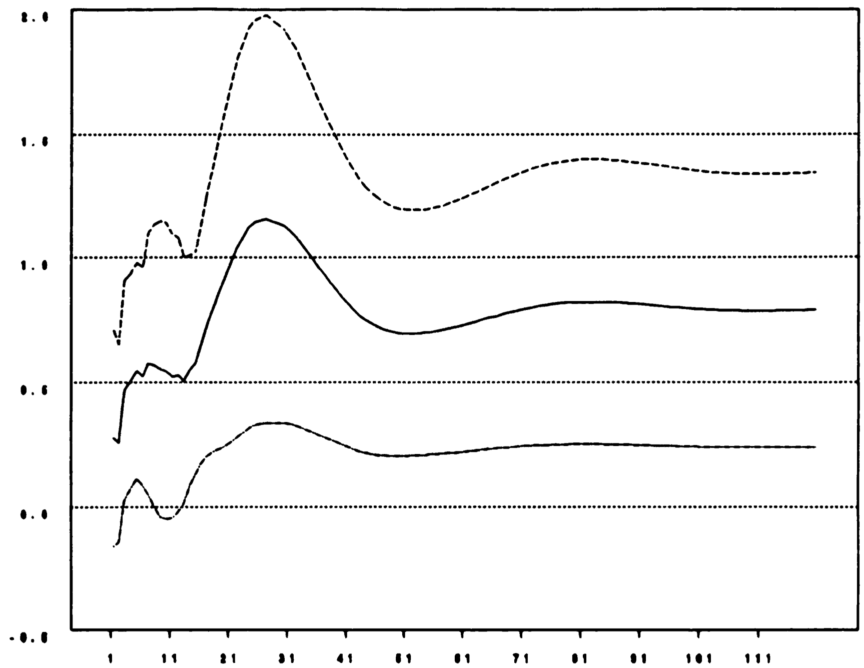

FIGURE 1: Consumption in Response to a One-Standard Deviation Balanced-Growth Shock

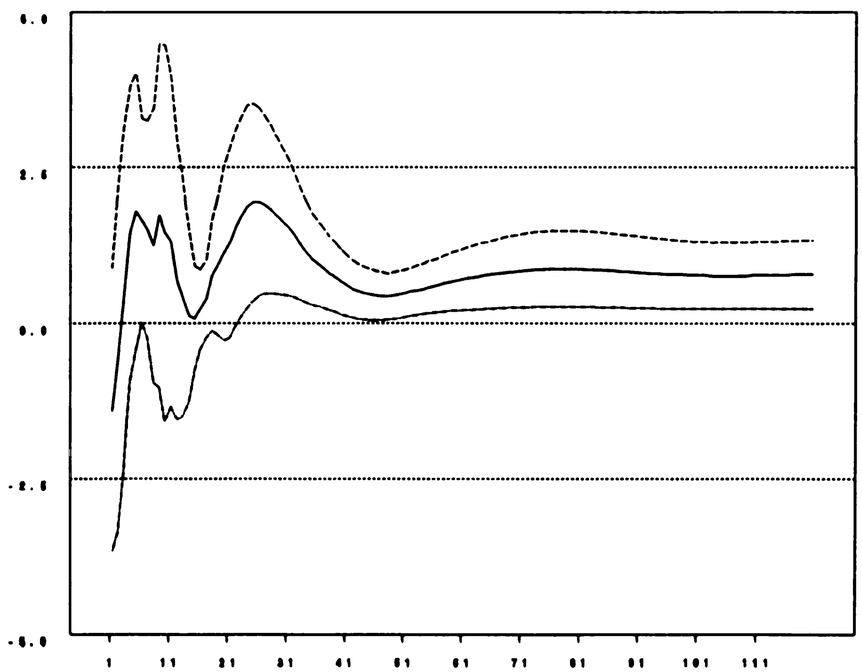

FIGURE 2: Investment in Response to a One-Standard Deviation Balanced-Growth Shock

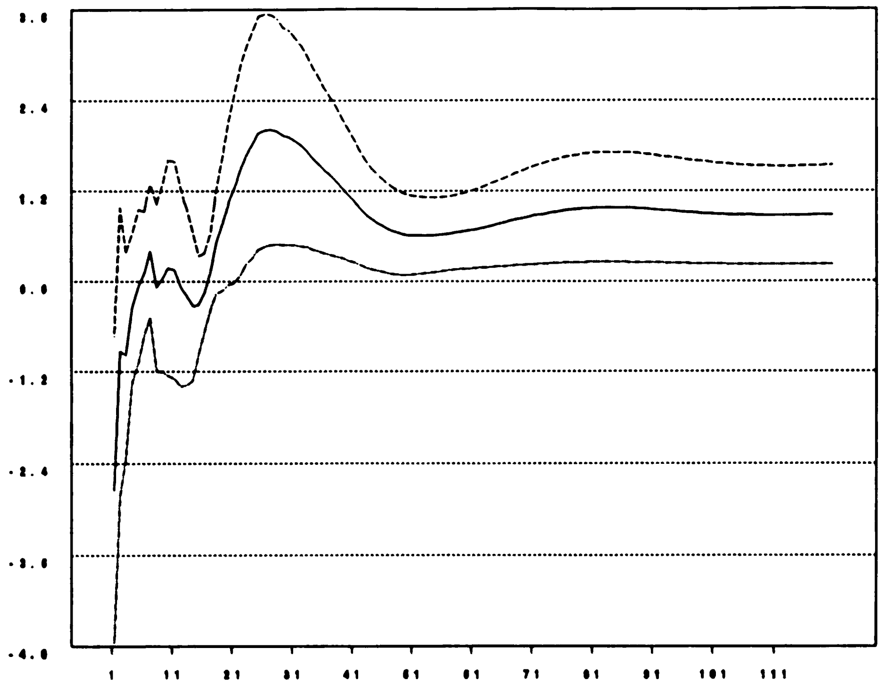

FIGURE 3: Imports in Response to a One-Standard Deviation Balanced-Growth Shock

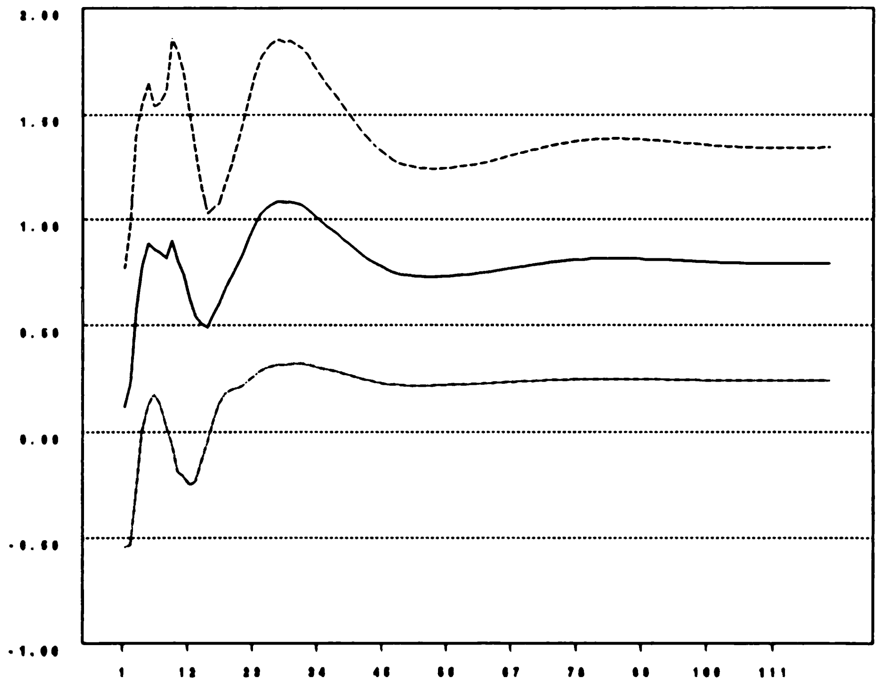

FIGURE 4: Output in Response to a One-Standard Deviation Balanced-Growth Shock

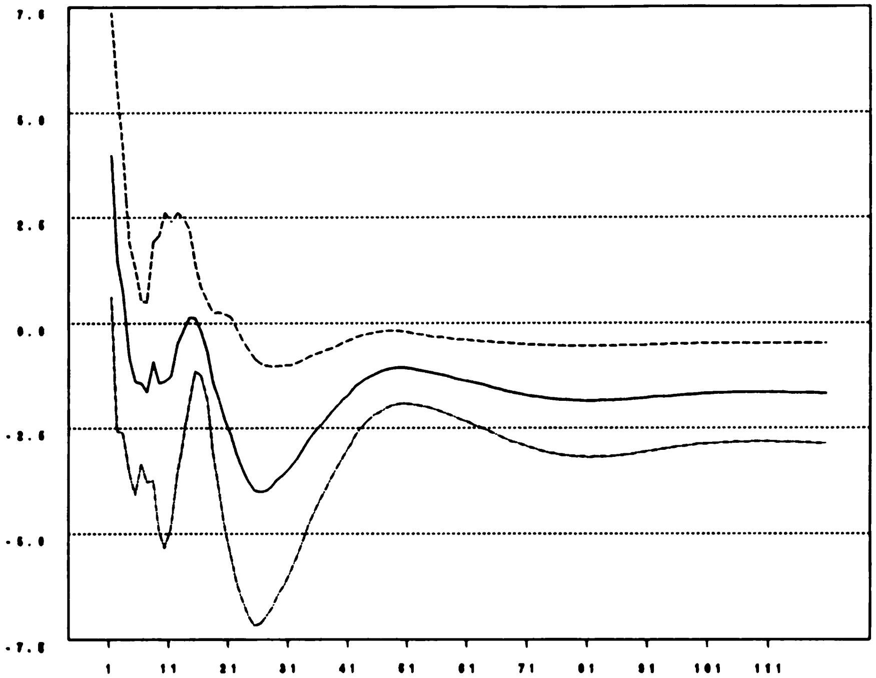

FIGURE 5: Net Exports in Response to a One-Standard Deviation Balanced-Growth Shock

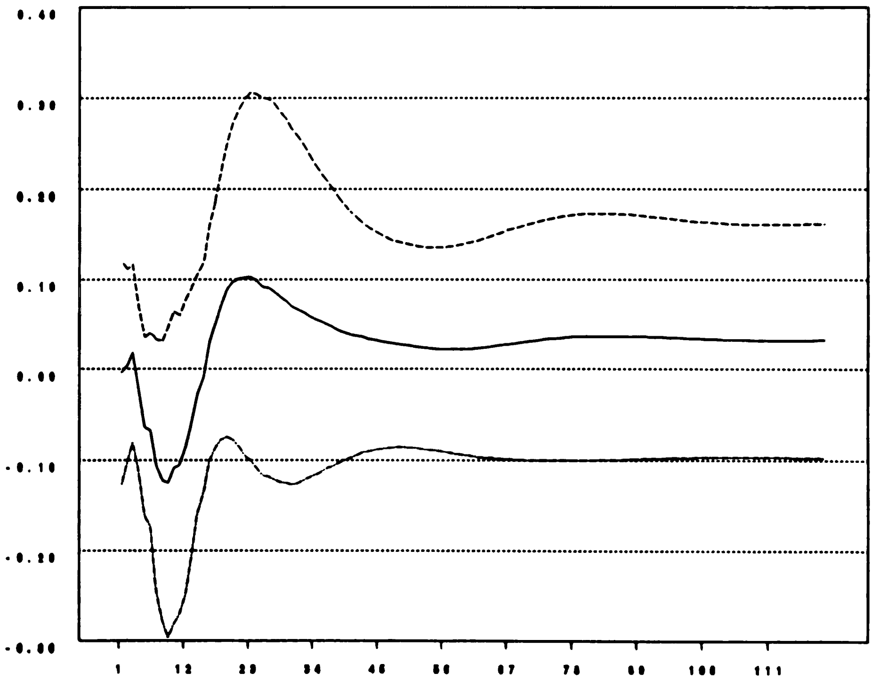

FIGURE 6: Consumption in Response to a One-Standard Deviation Real-Exchange-Rate Shock

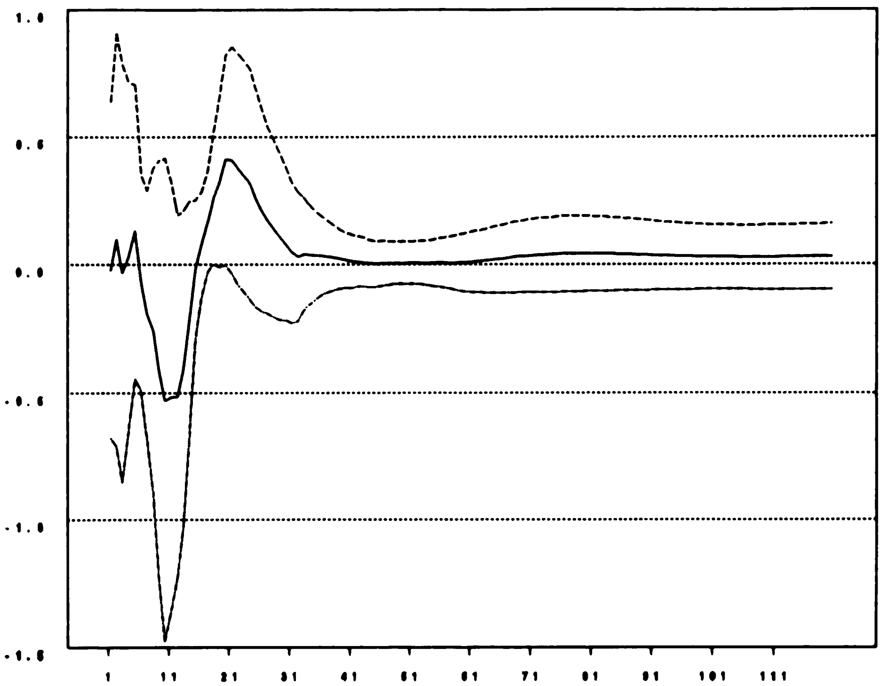

FIGURE 7: Investment in Response to a One-Standard Deviation Real-Exchange-Rate Shock

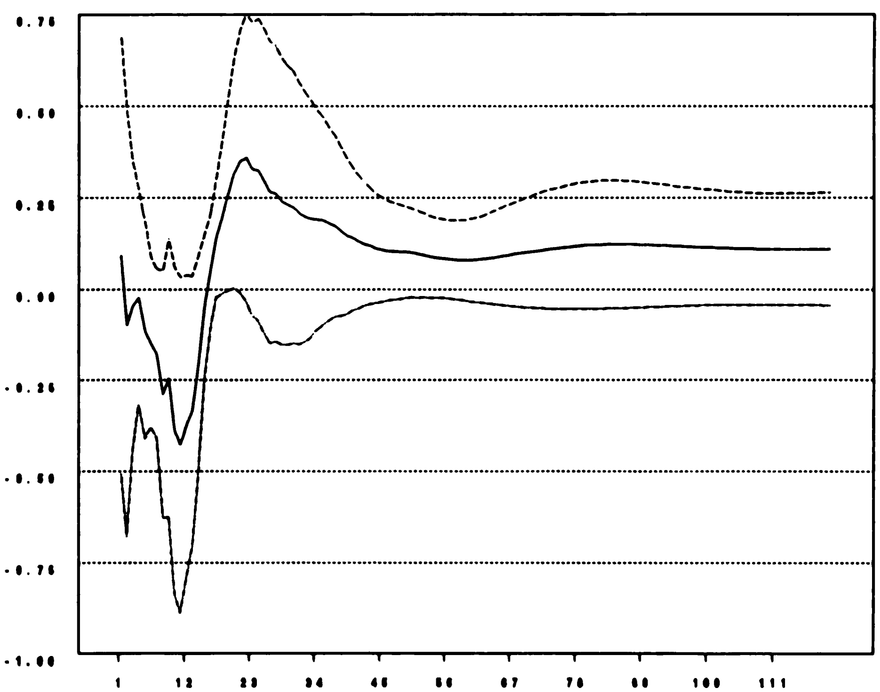

FIGURE 8: Imports in Response to a One-Standard Deviation Real-Exchange-Rate Shock

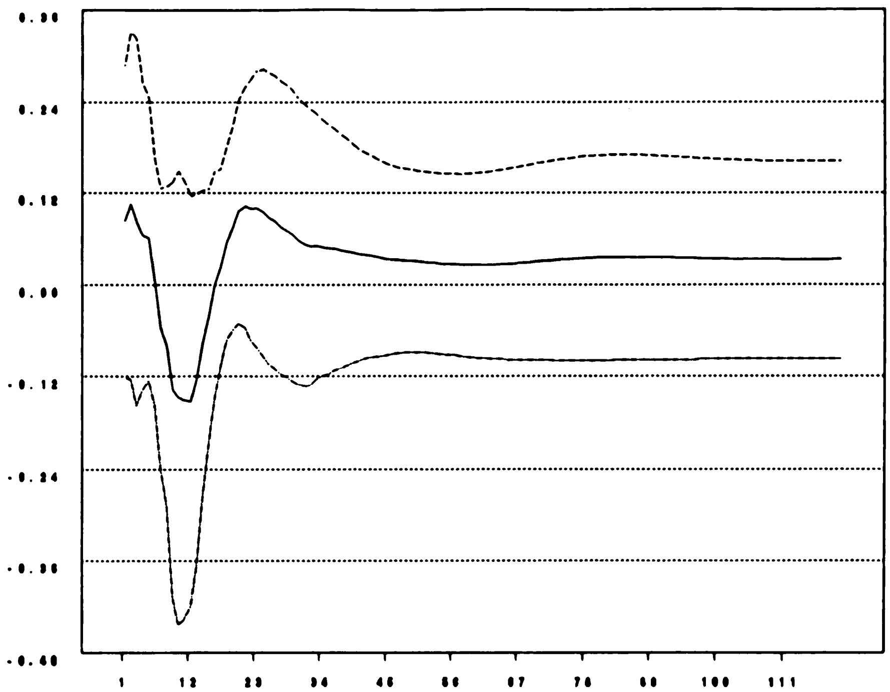

FIGURE 9: Output in Response to a One-Standard Deviation Real-Exchange-Rate Shock

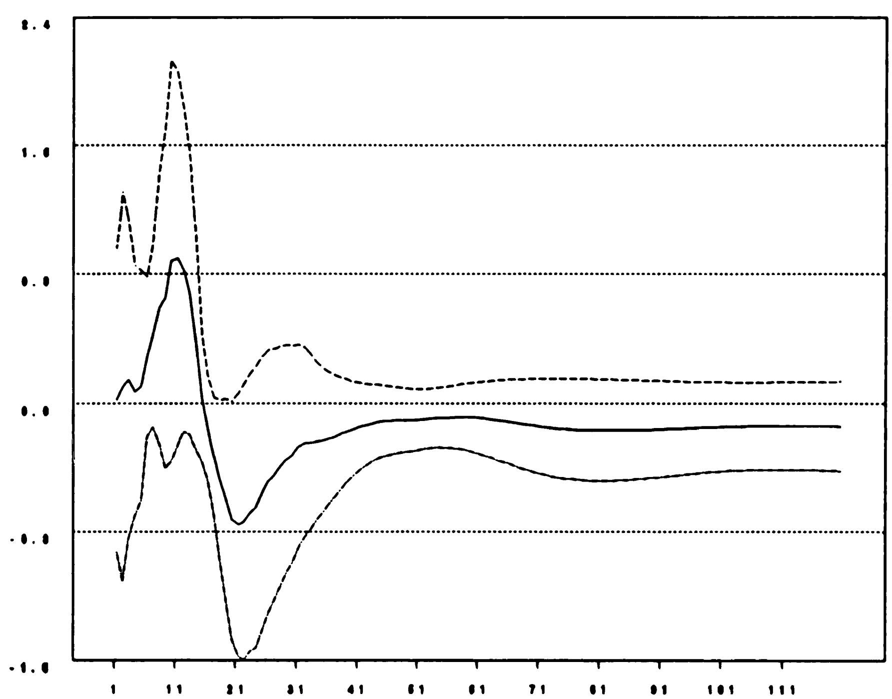

FIGURE 10: Net Exports in Response to a One-Standard Deviation Real-Exchange-Rate Shock

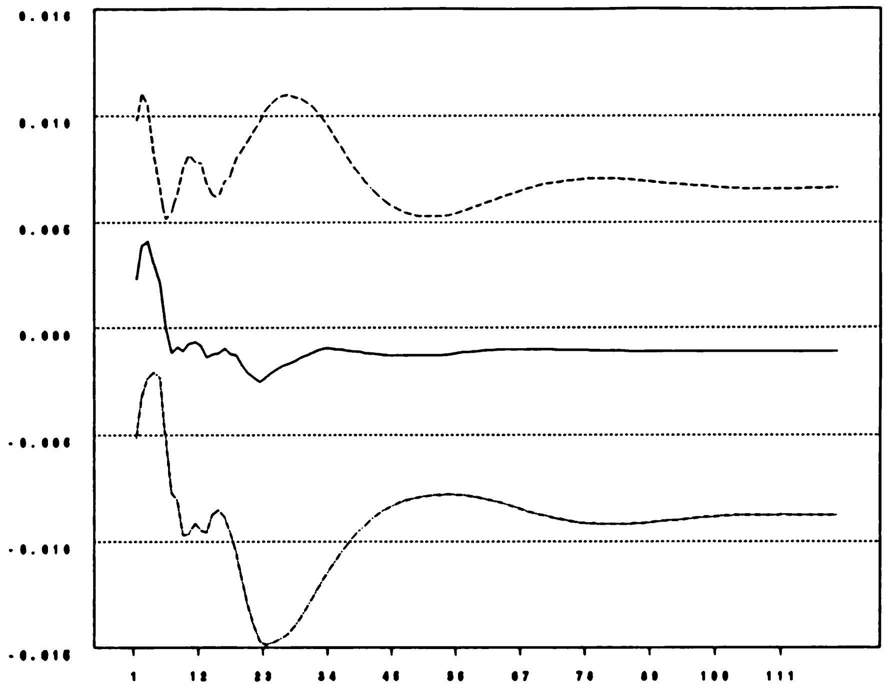

FIGURE 11: Consumption in Response to a One-Standard Deviation Inflation Shock

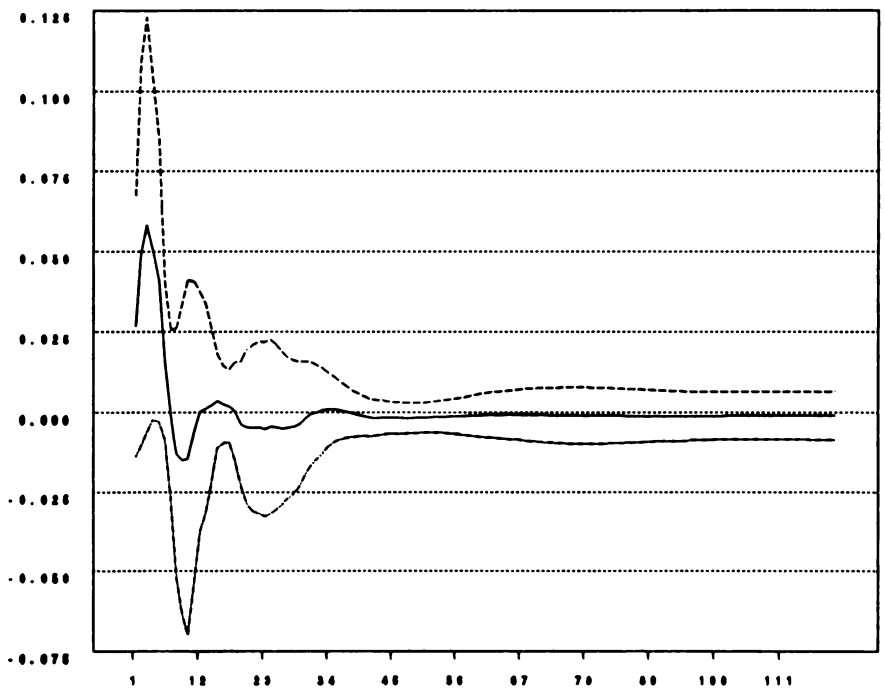

FIGURE 12: Investment in Response to a One-Standard Deviation Inflation Shock

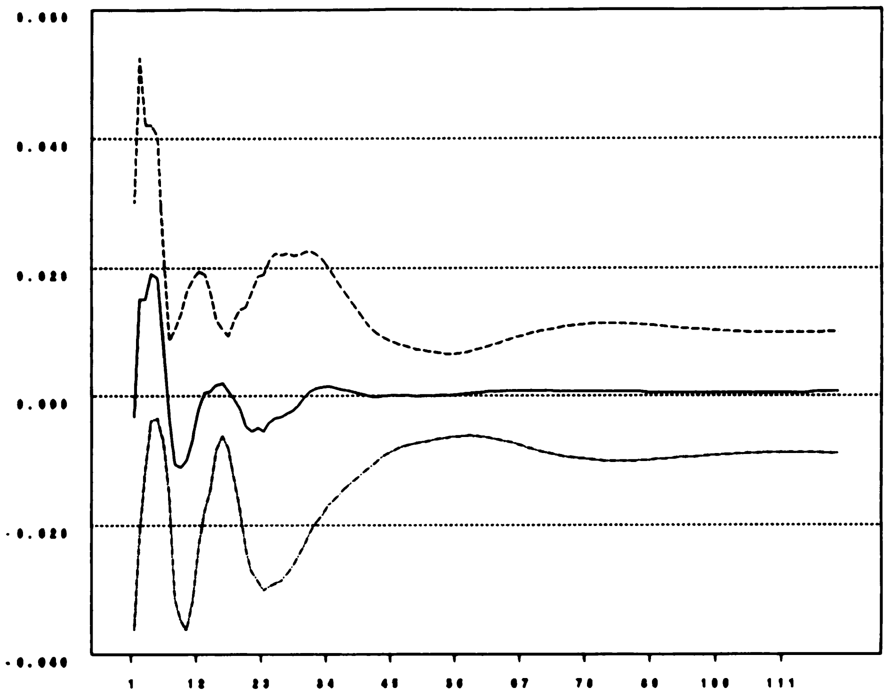

FIGURE 13: Imports in Response to a One-Standard Deviation Inflation Shock

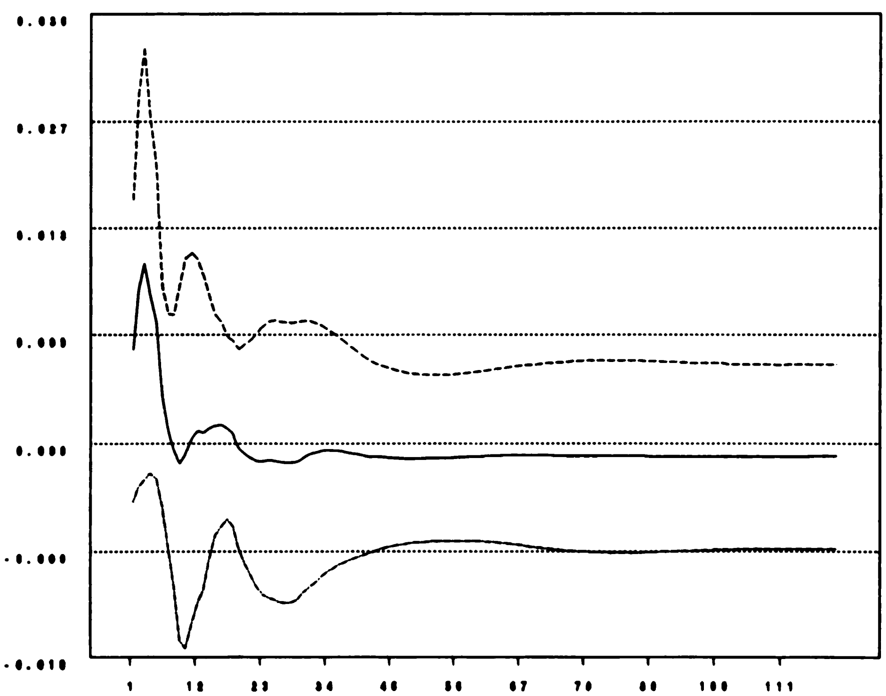

FIGURE 14: Output in Response to a One-Standard Deviation Inflation Shock

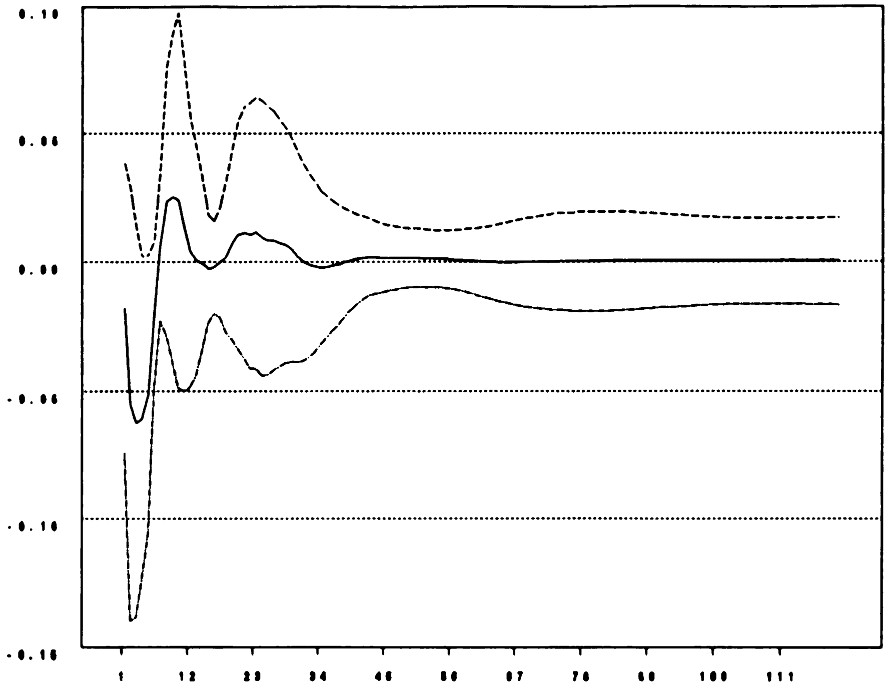

FIGURE 15: Net Exports in Response to a One-Standard Deviation Inflation Shock

APPENDIX

APPENDIX

AN OPEN-ECONOMY (8 VARIABLE) COMMON TRENDS MODEL

A.1. REDUCED-FORM ANALYSIS

The reduced-form is represented by a Wold decomposition of the series in first differences

$$\Delta X_t = \mu + C(L)\epsilon_t \qquad \textbf{(A.1)}$$

where $X_t = (c, i, m\text{-}p, im, y, \Delta p, R, q)'$ and ϵ_t is the vector of one-step-ahead forecast errors in X_t, given information on lagged values of X_t. X_t is I(1), and is cointegrated with the 4 cointegrating vectors, given by the 8x4 matrix β. Then, $\beta' C(1) = 0$, where $C(1) = \sum_{j=0}^{\infty} C_j$, and

$$\beta' = \begin{bmatrix} 0 & 0 & 1.0 & 0 & -1.199 & 0 & .013 & 0 \\ 1.0 & 0 & 0 & 0 & -1.0 & .0033 & -.0033 & 0 \\ 0 & 1.0 & 0 & 0 & -1.0 & -.007 & .007 & 0 \\ 0 & 0 & 0 & 1.0 & -1.13 & 0 & 0 & -.103 \end{bmatrix}.$$

A.2. COMMON TRENDS TRENDS REPRESENTATION

If 2 series are cointegrated, then they must share a common stochastic trend, since they have a common integrated component. KPSW's model can be viewed as a multivariate extension of Beveridge and Nelson (1981). They show that X_t can be written as a linear function of a permanent component and a transitory component

$$X_t = X_0 + A\tau_t + D(L)\epsilon_t \qquad \textbf{(A.2)}$$

where $\tau_t = \gamma + \tau_{t-1} + \eta_t$. A must be orthogonal to β' ($\beta' A=0$) in order to preserve the cointegrating properties of X_t. Since $A\tau_t$ is I(1), and $D(L)\epsilon_t$ is I(0), then $A\tau_t$ is the "common trends" in X_t.

A.3. IDENTIFICATION OF THE COMMON TRENDS

Since τ_t follows a random walk, then $A\tau_t$ follows a random walk. So, the problem of identification becomes a problem of identifying τ_t and η_t when k>1. Since A and τ_t are only identified up to an arbitrary transformation by a nonsingular kxk matrix, define $A = \tilde{A}_0\Pi$. A_0 reflects a priori restrictions about which permanent shock affects which variables.

$$A_0 = \begin{bmatrix} 1 & -.0033 & .0033 & 0 \\ 1 & .007 & -.007 & 0 \\ 1.199 & 0 & -.013 & 0 \\ 1.13 & 0 & 0 & .103 \\ 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

In order to "name" the shocks, $\tilde{A}_0 = A_0\Phi$, where

$$\Phi_1 = \begin{bmatrix} 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 \\ 1 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \end{bmatrix}$$

says that the inflation shock is ordered first, the interest-rate shock is second, the real-exchange-rate shock is third, and the balanced-growth shock is forth. The model is also estimated using an alternative ordering, where the interest-rate shock is first, the inflation shock is second, the real-exchange-rate shock is third, and the balanced-growth shock is forth.

So, $\tilde{A}_0 = A_0\Phi_1$ is given by

$$\tilde{A}_0 = \begin{bmatrix} 0 & .0033 & 0 & 1 \\ 0 & -.007 & 0 & 1 \\ -.013 & -.013 & 0 & 1.199 \\ 0 & 0 & .103 & 1.13 \\ 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 \\ 1 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \end{bmatrix}$$

where the first column represents the long-run impact of the first shock on each of the variables, c, i, m-p, im, y, Δp, R, q.

A.4. ESTIMATION

The reduced-form (A.1) is estimated to get $C(\hat{L})$, $C(\hat{1})$, and $\sum_{j=0}^{\infty} \mathbf{e}_j$. From equation (A.2),

$$\Delta X_t = \tilde{A}_0 \Pi \Delta \eta_t + D(L) \Delta \mathbf{e}_t \ . \qquad \textbf{(A.3)}$$

In the long-run, (A.1) implies that

$$\Delta X_t = C(\hat{1})\sum_{j=o}^{\infty} \epsilon_j \tag{A.4}$$

and equation (A.3) implies that

$$\Delta X_t = \tilde{A}_0 \Pi I_k \tag{A.5}$$

since $E_t \eta_t = I_k$, and $E_t \epsilon_t = \epsilon_{t-1}$. Therefore,

$$C(\hat{1})\sum_{j=0}^{\infty} \epsilon_j = \tilde{A}_0 \Pi I_k = \hat{A} \tag{A.6}$$

where,

$$\hat{A} = \begin{bmatrix} .003 & -.004 & .065 & 1 \\ .013 & -.014 & .065 & 1 \\ .007 & -.021 & .078 & 1.197 \\ .004 & -.003 & .018 & 1.130 \\ .006 & -.007 & .065 & 1 \\ 1 & 0 & 0 & 0 \\ -.002 & 1 & 0 & 0 \\ -.028 & .045 & 1 & 0 \end{bmatrix}$$

and $\Pi = \sum_{\eta}^{1/2}$, where the covariance matrix of the permanent innovations $\sum_{\eta^1} = E(\eta^{1\prime}\eta^1)$.

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IV: THE EFFECT OF STOCHASTIC TRENDS IN FOREIGN OUTPUT ON ECONOMIC FLUCTUATIONS IN THE UNITED STATES

CHAPTER IV

THE EFFECT OF STOCHASTIC TRENDS IN FOREIGN OUTPUT ON ECONOMIC FLUCTUATIONS IN THE UNITED STATES

1. INTRODUCTION

This chapter extends the open-economy Vector Error-Correction Model (VECM) in Chapter III to introduce a permanent shock to foreign productivity in a model explaining business cycles in the United States. By affecting domestic net exports, changes in foreign income may have effects on domestic output. Backus, Kehoe, and Kydland (1992) have recently extended standard one-sector Real Business Cycle models to introduce a foreign productivity shock as an additional real permanent shock which is capable of accounting for domestic economic fluctuations. They suggest that foreign productivity may affect domestic economic fluctuations in two additional important ways. First, through international financial markets, increases in foreign productivity attract capital to the foreign country, and may lead to short-run decreases in domestic investment. This effect could also lead to increases in net exports in the domestic country if capital account deficits are matched be current account surpluses. Second, positive technological spillovers between countries imply that increases in foreign productivity may lead to increases in domestic productivity in the long run, and consequently increases in domestic output, consumption, and investment.

The organization of this chapter is as follows: (1) a theoretical basis for the long-run restriction on export-demand is outlined; (2) long-run properties of the data are examined; (3) results are presented for estimated impulse response functions and forecast-error variance decompositions of the open-economy model; (4) sensitivity tests are performed with regard to the model specification; (5) conclusions are drawn.

2. THEORETICAL BACKGROUND

The open-economy model presented in this chapter will maintain the assumptions regarding the Solow balanced-growth hypothesis, the money-demand specification, the Fisher-Darby equation, and the import-demand equation which were outlined in Chapter III.[1] The analysis in Chapter III abstracted from the effects of foreign output on U.S. exports. The purpose of this chapter is to examine this issue. By including foreign output in the VECM, another permanent shock is introduced. Furthermore, it may be possible to identify a long-run relationship representing the demand for exports. Theoretically, the derived-demand for U.S. real exports is a positive function of "rest-of-the-world" income, and a negative function of the real exchange rate, defined as

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[1]Since the sample period is different from that used in Chapter III, the theoretical long-run restrictions are estimated and tested for the relevant time period. Estimates for the long-run money-demand and import-demand are reported in Tables 3 and 4, along with the tests of cointegration. The tests for stationarity of the balanced-growth relationships, and the Fisher-Darby effect are reported in Tables 1 and 2.

foreign currency per dollar.

By including a foreign variable representing "rest-of-the-world" income, the possibility of international real business cycles is introduced. Backus, Kehoe, and Kydland (1992) model international real business cycles as resulting from "technological spillovers". They argue that foreign productivity shocks actually leads to permanent innovations in domestic productivity. If this is true, the permanent innovation in domestic output is a linear combination of a foreign productivity shock plus a domestic productivity shock. This has implications for the econometric model which will be discussed in Section 4.1.

3. LONG-RUN TIME SERIES PROPERTIES

3.1 THE DATA

Vector autoregressions are performed over the period 1959:2 to 1988:4, with 6 lags of autoregression. The data used are all quarterly, seasonally adjusted, observations covering 1957:2 to 1988:4. All of the definitions for the variables used in Chapter III are the same, except that investment is now defined as the log of per capita gross private fixed investment. Univariate characteristics are reported in Tables 1 and 2.

Foreign output is defined as the log of per capita real private foreign output (y^*). The proxy was constructed by constructing a trade-weighted per capita real private GNP (or GDP) for the G-7 countries, using the Federal Reserve Board's trade-weighted index (1972-76). The foreign data was taken from the International Financial Statistics. Each country's private per capita GNP (GDP) was then converted to U.S. equivalent dollars. At this point the trade-weighted index of G-7 countries was constructed. In order to express foreign output in foreign currency, the index was multiplied by the trade-weighted real exchange rate (foreign currency per dollar). Univariate tests of foreign output, reported in Tables 1 and 2, suggest that foreign output is non-stationary.

3.2 MULTIVARIATE CHARACTERISTICS

The assumptions with regards to the Solow balanced-growth restrictions and the Fisher-Darby effect outlined in Chapter III, section 2 can be tested using standard univariate techniques, since the right-hand-side theoretically consists of only a constant and a random error. These are reported in Tables 1 and 2. Non-stationarity, Table 1, is rejected at the 5% level for both the investment-output ratio and the Fisher-Darby equation. However, at the 5% level non-stationarity of the consumption-output ratio cannot be rejected. However, in Table 2, the null of stationarity (cointegration) cannot be rejected at the 5% level for each of the relationships.

Point estimates of the cointegrating vectors are found using Stock and Watson's (1993) Dynamic OLS technique over 1959:2 to 1987:3 with five leads and lags. The cointegrating vectors used throughout Chapter III, the money-demand and import-demand vectors, were estimated for the new sample period. There estimates are reported in Tables 3 and 4.[2] The estimated cointegrating vectors for the export-demand equation are[3]

$$ex_t = -11.02 + 0.946y_t^* - 0.259q_t \quad (1)$$
$$(-8.31) \quad (11.45) \quad (-1.27)$$

$$ex_t = -6.71 + 0.006t + 0.337y_t^* - 0.496q_t \quad (2)$$
$$(-5.74) \quad (4.25) \quad (2.28) \quad (-4.72)$$

Table 3 summarizes the tests for stationarity of the residuals from each of the vectors in the absence of a deterministic (time) trend. The null of cointegration cannot be rejected at the 5% level for the long-run money-demand function. However, the null is rejected at the 5% level for the long-run import-demand equation with the real exchange rate as an explanatory variable, and at the 10% level for the import-demand equation without the real exchange rate as an explanatory variable. The null is also rejected at the 5% level for the export-demand equation (1). In Table 4 the presence of a time trend, the null cannot be rejected at the 5% level for the export-demand equation (2), or either of the import-demand equations. These results strongly suggest that both long-run import and export-demand functions contain a

[2]The difference in the point estimates in Tables 3 and 4 from those in Chapter III are the result of the different time periods covered. The differences are not statistically significant.

[3]The t-statistics reported in parentheses below are the adjusted statistics. See Footnote 6, Chapter III.

significant deterministic trend.[4]

4. EMPIRICAL RESULTS

4.1 AN OPEN-ECONOMY COMMON TRENDS MODEL

The open-economy Vector-Error Correction Model[5] is estimated from 1959:2 to 1988:4 with 6 lags of autoregression.[6] The cointegrating vector representing export-demand, equation (2), and the theoretical restrictions specified in section 2, are used to identify the matrix of long-run multipliers. These include the "great ratios", the long-run money demand equation, the long-run import and export demand equations, and the Fisher-Darby assumption. The permanent shocks in the model are ordered as (1) an inflation shock, (2) a real-exchange-rate shock, (3) a foreign productivity shock, and (4) a domestic productivity shock. The ordering allows for the possibility that technological progress from foreign countries may "spillover" onto domestic productivity. The Π matrix for the baseline model is reported in Table 7, and the matrix of long-run multipliers is reported in Table 11. Table 7 shows that the spillover effect

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[4]Furthermore, the import and export-demand equations were estimated with a dummy variable representing the exchange-rate regime shift in 1973. In the presence of a deterministic trend the structural dummy was insignificant in both demand equations.

[5]See Chapter II, section 2 for an overview of the methodology.

[6]The Appendix gives a complete exposition of the identification of the baseline common trends model estimated in this paper. For further details, see King, Plosser, Stock, and Watson (1987).

from foreign productivity to domestic productivity is estimated to be 0.02, since π_{43} = 0.02. However, it will become obvious when the impulse response functions are estimated that this is not significantly different from zero. Therefore, the model estimated here finds no statistically reliable evidence for the existence of significant positive foreign technological spillovers on the U.S. productivity. That is, foreign productivity has no significant long-run effects on productivity in the United States.

4.2 IMPULSE RESPONSE FUNCTIONS

Impulse response functions with respect to a one-standard-deviation shock in the four common trends are estimated for consumption, investment, imports, exports, output and net exports. The one-standard deviation domestic productivity shock is .86%, the foreign productivity shock is .78%, the real-exchange-rate shock is .72%, and the inflation shock is .66%. Mean impulse responses (solid line), along with their respective 95% confidence intervals (dashed lines), are shown in Figures 1-24.

Figures 7-12 show how the domestic variables respond to innovations in foreign productivity. None of the domestic impulse responses estimated are significantly affected by the foreign productivity shock in the long run, not even exports (Figure 10). However, exports, investment and output are significantly affected in the short run. Between 10 and 12 quarters, the responses of both investment (Figure 8) and output (Figure 11) are significantly negative. Exports

(Figure 10) show a positive response between 4 and 6 quarters. Since an increase in foreign productivity increases the marginal product of capital in the foreign country, an outflow of capital from the U.S. to the foreign country is likely to occur. The resulting negative capital flow may in turn lead to decreases in investment and output with some lag.

As shown in Figures 6 and 12, the size of the response of net exports to the domestic and foreign productivity shocks are quite different. The foreign productivity shock does not significantly affect net exports either in the short run or the long run. On the other hand, the domestic productivity shock has significant negative effects on net exports in the short run. This is different from the results in Chapter III, where there were significant positive short-run responses. In the long run, the response of net exports with respect to the domestic productivity shock seems to by significantly negative. However, since the response of net exports has not stabilized after 120 periods, it is not definite that the long-run response is negative.[7]

Theoretically, there are several ways in which the real exchange rate can affect domestic variables. Most obviously, it may affect net exports. Figure 18 shows that an increase in the real exchange rate (a real appreciation of the dollar) leads to a significant decrease in net exports in the short

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[7]However, in the open-economy model estimated in Chapter III, the response of net exports with respect to the domestic productivity shock was significantly negative in the long run.

run. There is no evidence of positive responses of net exports in the short run. That is, there is no evidence of a J-curve effect. In the long-run, since exports are more sensitive to changes in the real exchange rate than imports, the real appreciation of the dollar leads to a permanent, significant worsening of the current account.

Shocks to real exchange rates can have direct effects of consumption and investment as well. If imports and domestically-produced consumption goods are imperfect substitutes, then changes in the relative prices of these goods may increase the total level of consumption in the economy. That is, the appreciation of the real exchange rate would lead to positive wealth effects. Since investment depends on international capital flows, innovations in the real exchange rate can have a significant effect on investment as well. In these cases, one would expect the responses of consumption and investment to be positive at some point. However, the responses of consumption (Figure 13) and investment (Figure 14) are never significantly positive. In fact both have significant negative responses between 6 to 12 quarters. Also, output (Figure 17) is not significantly affected by the real-exchange-rate shock.

Responses of consumption, investment, imports and output with respect to shocks in domestic productivity (Figures 1-6) and inflation (Figures 19-24) are consistent the theories discussed in Chapter II, as well as the responses from models estimated in Chapters II and III. A positive inflation shock has no significant effects on the real flow variables in either the short run or the long run. The productivity shock significantly increases all of the variables over the short run and the long run.

4.3 VARIANCE DECOMPOSITIONS

Forecast-error variances given in Tables 13-20 show the relative importance of the common trends in accounting for unpredicted variability in the five real flow variables up to 120 quarters.

Table 14 shows the extent to which changes in foreign productivity account for forecast-error variances of the real domestic flow variables. As explained in Section 4.2, investment may be affected by innovations in foreign productivity in the short run through changes in international capital flows. After 12 quarters 9% of the forecast-error variance is explained by the foreign productivity shock. Though the foreign productivity shock accounts for an estimated 27% of the 1 quarter variance in investment, this result is suspicious. Even if capital flows are affected instantaneously by the increase in foreign productivity, investment would only respond to capital flows with a significant lag. As would be suggested by the impulse responses, the foreign productivity shock does not play a large role in explaining exports. It only accounts for 12% of the variance after 12 quarters, and only 4% after 120 periods. After 12 quarters, it accounts for 9% of the variance in consumption, 9% of the variance in investment, 7% of the variance in imports, and a surprisingly large 13% of the variance in output after 12 quarters.

The effect of permanent real-exchange-rate shocks on consumption, investment and output is surprisingly large. After 12 quarters it accounts for 22% of consumption variance, 15% of investment variance, and 17% of output variance. Furthermore, the real exchange rate is the dominant shock driving changes in U.S. exports, not the foreign balanced-growth shock. After 120 quarters, the real-exchange-rate shock accounts for 63% of the variance in exports. Only 4% of the variance in U.S. exports is due to permanent shocks to foreign income. However, imports are due mostly to changes in income in the long run, while real-exchange-rate shocks only account for 7% of import variance after 120 periods.

Results of the variance decomposition of output are generally favorable to explanations of business cycles like those argued by Real Business Cycles theorists. The real productivity shocks (the combination of the domestic and foreign shocks) account for the majority of the variance in domestic consumption and output after 4 quarters. In fact at the 4 and 8 quarter intervals, the domestic productivity shock explains the majority of output variance by itself. After 12 quarters, the two real productivity shocks account for a combined 57% of output variance. On the other hand, investment is explained more by permanent inflation and real-exchange-rate shocks. As in the model with exports in Chapter

III, the permanent shocks account for the majority of economic fluctuations in both the short and long run.

4.4 SENSITIVITY ANALYSIS

Since the real exchange rate is insignificant at standard levels in the long-run import-demand equation, the model is also estimated without the real exchange rate as an explanatory variable in the long-run import demand equation. This may decrease the degree to which innovations in the real exchange rate explain forecast-error variances of the real flow variables. It may have an effect on the relative importance of other permanent shocks.

The estimates of the cointegrating vectors in this case are

$$\underset{}{im_t} = \underset{(5.07)}{5.68} + \underset{(10.75)}{2.83y_t} \qquad (3)$$

$$im_t = \underset{(-0.16)}{-0.57} + \underset{(1.82)}{0.0054t} + \underset{(1.94)}{1.49y_t} \qquad (4)$$

Tables 3 shows that the residual of equation (3) is not stationary, and therefore equation (3) is not a cointegrating vector. However, Table 4 shows that the residual in equation (4), with the time trend included as an explanatory variable, is stationary. Equation (4) will be substituted for the import-demand equation with the real exchange rate as an additional explanatory variable. Consequently, in the alternative model, per capita real imports have only one permanent component, domestic productivity.

Results for the alternative model are summarized in Tables 17-20. The results are quantitatively similar to those of the baseline model, except for the degree to which shocks to the real exchange rate account for unpredicted variance of the real flow variables. The real-exchange-rate shock now only accounts for 18% of the 1 quarter variance in output, not 25%. Its importance at longer intervals is not significantly affected. In fact, it now accounts for 34% of the 12 quarter variance in imports, versus 26% in the baseline model.

5. CONCLUSION

This chapter focussed on the role of a permanent shock to foreign productivity in accounting for economic fluctuations in the United States. When this shock is added to an open-economy model of the U.S., the combined effects of the domestic and foreign productivity shocks explain the majority of both the short-run and long-run variance in output and consumption. The long-run variation in exports is primarily the result of permanent shocks to real exchange rates, not foreign income. However, as is the case in models without a foreign productivity shock (Chapter III), investment is dominated in the short-run by permanent inflation shocks and other transitory factors, such as temporary changes in real interest rates. In addition, permanent shocks account for the majority of the short and long-run forecast-error variances of the real flow variables.

There are a number of findings here which are not consistent with predictions of the open-economy one-sector Real Business Cycle model of Backus, Kehoe, and Kydland (1992). The existence of a significant positive spillover effect of foreign productivity on domestic productivity is not found. Therefore, the foreign productivity shock appears to impact the domestic economy only through changes in the current and capital accounts. Furthermore, net exports do not respond significantly to the foreign productivity shocks. However, some of the results are consistent with their model. The domestic productivity shock has negative effects on net exports in the short run. This is consistent with their model in that current account surpluses (deficits) may be counter-cyclical (procyclical). This is contrary to the results obtained in the less explicit models of Chapter III. In addition, after a lag, the response of investment to the foreign productivity shock is significantly negative for a short period, which is consistent with the idea that international capital flows affect investment.

TABLE 1

Phillips-Perron Test Non-Stationarity Test of
Univariate Time Series 1957:2 - 1988:4

Series	$Zt_{\tilde{\alpha}}$	Zt_{α^*}
c	-1.74	-0.60
i	-2.75	-1.29
$m-p$	-1.90	-1.22
y	-2.20	-0.77
Δp	-2.68	-2.46
R	-2.49	-1.89
im	-2.29	-0.06
ex	-3.04	0.14
y^*	-1.13	-2.10
q	-2.04	-1.31
$c-y$[1]	-	-2.76
$i-y$[1]	-	-3.05
$R-1.3\Delta p$[1]	-	-3.07

Lags of truncation is 6

Critical Values :

Phillips-Perron (H_0: I(1)):

$Zt_{\tilde{\alpha}}$: 1% = -3.96, 5% = -3.41
Zt_{α^*}: 1% = -3.43, 5% = -2.86

$Zt_{\tilde{\alpha}}$: tests the null of I(1) with intercept and time trend
Zt_{α^*}: tests the null of I(1) with intercept only

---

[1]1959:2 - 1988:4

TABLE 2

Kwiatkowski-Phillips-Schmidt-Shin Stationarity Test of Univariate Time Series 1957:2 - 1988:4

Series	Trend	No Trend
c	.299	1.872
i	.167	1.552
$m-p$	.268	1.631
y	.306	1.780
Δp	.314	0.722
R	.117	1.180
im	.161	1.844
ex	.186	1.866
y^*	.450	1.873
q	.160	1.097
$c-y$[1]	-	0.341
$i-y$[1]	-	0.085
$R-1.3\Delta p$[1]	-	0.359

Lags of Truncation is 6

Critical Values:

KPSS (H_0: I(0)):

No Trend: 1% = .739, 5% = .463, 10% = .347
Trend: 1% = .216, 5% = .146, 10% = .119

[1]1959:2 - 1988:4

TABLE 3

Residual-Based Cointegration Tests of Vectors
Without a Time Trend: 1959:2-1987:3

Estimated Vectors	KPSS: No Trend
$m\text{-}p_t = .72 + 1.211y_t - 0.014R_t$	.150
$im_t = 5.30 + 2.89y_t + 0.131q_t$	.308
$im_t = 5.68 + 2.83y_t$	.238
$ex_t = -11.02 + 0.946y^*_t - 0.259q_t$	.257

TABLE 4

Residual-Based Cointegration Tests of Vectors
With a Time Trend: 1959:2-1987:3

Estimated Vectors	KPSS: Trend
$im_t = -1.94 + 0.006t + 1.29y_t + 0.101q_t$	.101
$im_t = -.57 + 0.0054t + 1.49y_t$	.103
$ex_t = -6.71 + 0.006t + 0.337y^*_t - 0.497q_t$	.031

Lags of truncation for KPSS tests is 6

Critical Values (Shin 1992) KPSS (H_0: I(0)):

Without Trend:
1 Regressor : 5% = .314, 10% = .231
2 Regressors: 5% = .221, 10% = .163

With Trend:
1 Regressor : 5% = .121, 10% = .097
2 Regressors: 5% = .101, 10% = .081

TABLE 5

Variance-Covariance Matrix of Permanent Shocks in the Baseline Model

	Δp	q	y^*	y
Δp	0.18453	-	-	-
q	0.00073	0.00030	-	-
y^*	-0.00123	-0.00002	0.00004	-
y	-0.00200	-0.00001	0.00001	0.00005

TABLE 6

Correlations between the Four Permanent Shocks in the Baseline Model

	Δp	q	y^*
q	0.09811	-	-
y^*	-0.45273	-0.18257	-
y	-0.65843	-0.08165	0.22361

TABLE 7

Π Matrix in the Baseline Model

	Δp	q	y^*	y
Δp	1.000	0.000	0.000	0.000
q	0.004	1.000	0.000	0.000
y^*	-0.007	-0.062	1.000	0.000
y	-0.011	-0.001	0.021	1.000

TABLE 8

Variance-Covariance Matrix of Permanent Shocks in the Alternative Model

	Δp	q	y^*	y
Δp	0.18595	-	-	-
q	0.00110	0.00032	-	-
y^*	-0.00129	-0.00003	0.00005	-
y	-0.00214	-0.00002	0.00002	0.00006

TABLE 9

Correlations between the Four Permanent Shocks in the Alternative Model

	Δp	q	y^*
q	0.14260	-	-
y^*	-0.42306	-0.23717	-
y	-0.64068	-0.14434	0.36515

TABLE 10

Π Matrix in the Alternative Model

	Δp	q	y^*	y
Δp	1.000	0.000	0.000	0.000
q	0.006	1.000	0.000	0.000
y^*	-0.007	-0.075	1.000	0.000
y	-0.012	-0.020	0.074	1.000

TABLE 11

Long-Run Multipliers in the Baseline Model in Response to Changes in the Four Common Trends

variable	Δp	q	y^*	y
c	-0.01	0.00	0.02	1.00
i	-0.01	0.00	0.02	1.00
$m-p$	-0.03	0.00	0.03	1.21
im	-0.01	0.10	0.03	1.29
ex	0.00	-0.52	0.34	0.00
R	1.30	0.00	0.00	0.00
y^*	-0.07	-0.06	1.00	0.00
Δp	1.00	0.00	0.00	0.00
q	0.00	1.00	0.00	0.00
y	-0.01	0.00	0.02	1.00

TABLE 12

Long-Run Multipliers in the Alternative Model in Response to Changes in the Four Common Trends

variable	Δp	q	y^*	y
c	-0.01	-0.02	0.07	1.00
i	-0.01	-0.02	0.07	1.00
$m-p$	-0.03	-0.03	0.09	1.21
im	-0.01	-0.03	0.11	1.49
ex	-0.01	-0.52	0.34	0.00
R	1.30	0.00	0.00	0.00
y^*	-0.01	-0.07	1.00	0.00
Δp	1.00	0.00	0.00	0.00
q	0.01	1.00	0.00	0.00
y	-0.01	-0.02	0.07	1.00

TABLE 13

Percentage of Forecast-Error Variance Attributed to the Domestic Balanced-Growth Shock in the Baseline Model

	Period							
	1	4	8	12	16	20	24	120
c	32	65	57	48	44	40	44	60
i	1	31	29	21	20	18	16	43
y	11	60	58	44	44	42	41	59
ex	22	15	14	6	4	6	15	10
im	39	21	17	14	14	11	11	48

TABLE 14

Percentage of Forecast-Error Variance Attributed to the Foreign Productivity Shock in the Baseline Model

	Period							
	1	4	8	12	16	20	24	120
c	6	5	4	9	8	6	4	1
i	27	9	5	9	9	9	9	5
y	0	4	4	13	13	12	10	2
ex	4	11	10	12	9	7	6	4
im	2	6	4	7	7	7	6	2

TABLE 15

Percentage of Forecast-Error Variance Attributed to the Real-Exchange-Rate Shock in the Baseline Model

Period

	1	4	8	12	16	20	24	120
c	3	2	19	22	19	14	10	1
i	0	2	9	15	15	15	14	6
y	25	9	13	17	16	14	12	2
ex	10	6	20	37	38	42	41	63
im	6	14	18	26	24	20	17	7

TABLE 16

Percentage of Forecast-Error Variance Attributed to the Inflation Shock in the Baseline Model

Period

	1	4	8	12	16	20	24	120
c	3	2	3	3	9	19	24	35
i	3	37	39	33	32	34	35	32
y	5	10	13	11	10	14	18	33
ex	5	12	10	20	27	26	22	11
im	0	10	17	14	14	17	21	27

TABLE 17

Percentage of Forecast-Error Variance Attributed to the Domestic Balanced-Growth Shock in the Alternative Model

Period

	1	4	8	12	16	20	24	120
c	33	63	57	48	44	40	44	60
i	1	29	30	22	21	18	18	44
y	11	60	59	46	46	44	43	59
ex	19	13	13	6	4	6	15	10
im	35	21	20	14	13	10	11	51

TABLE 18

Percentage of Forecast-Error Variance Attributed to the Foreign Productivity Shock in the Alternative Model

Period

	1	4	8	12	16	20	24	120
c	5	5	4	7	6	4	3	1
i	25	9	5	8	8	8	8	4
y	0	5	4	11	11	10	9	2
ex	6	13	14	14	10	8	6	4
im	4	5	3	6	6	6	5	2

TABLE 19

Percentage of Forecast-Error Variance Attributed to the Real-Exchange-Rate Shock in the Alternative Model

	Period							
	1	4	8	12	16	20	24	120
c	5	4	22	26	23	16	12	2
i	1	1	9	17	17	16	14	6
y	18	7	12	18	17	15	13	3
ex	12	7	18	35	37	41	40	65
im	11	10	22	34	32	25	21	5

TABLE 20

Percentage of Forecast-Error Variance Attributed to the Inflation Shock in the Alternative Model

	Period							
	1	4	8	12	16	20	24	120
c	4	2	2	2	9	20	24	36
i	3	37	36	30	30	32	33	32
y	6	10	11	9	9	13	17	33
ex	6	12	11	22	28	27	22	11
im	0	9	13	9	11	16	21	31

TABLE 21

Percentage of the Forecast-Error Variance Attributed to the Transitory Shocks in Each Model

	Baseline 12 Periods	Alternate 12 Periods	Baseline 120 Periods	Alternate 120 Period
c	18	17	3	1
i	22	23	14	14
y	15	16	4	3
ex	25	13	12	10
im	39	37	16	11

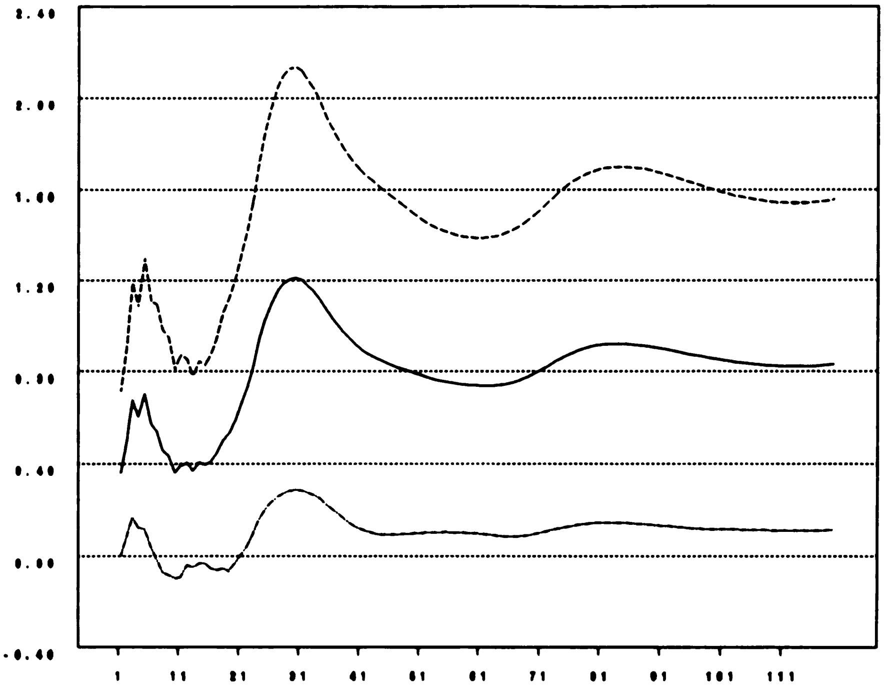

FIGURE 1: Consumption in Response to a One-Standard Deviation Domestic Productivity Shock

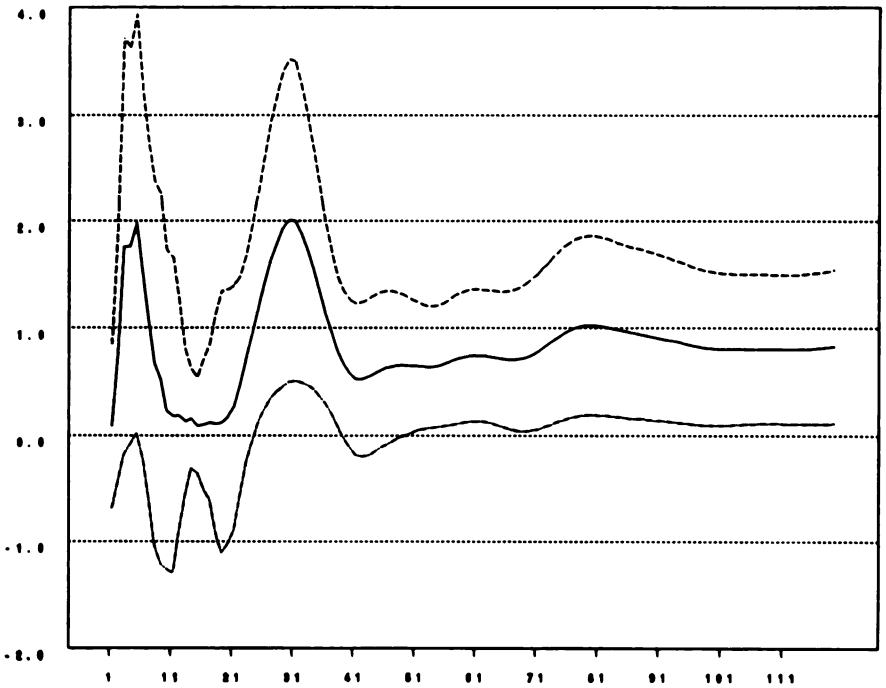

FIGURE 2: Investment in Response to a One-Standard Deviation Domestic Productivity Shock

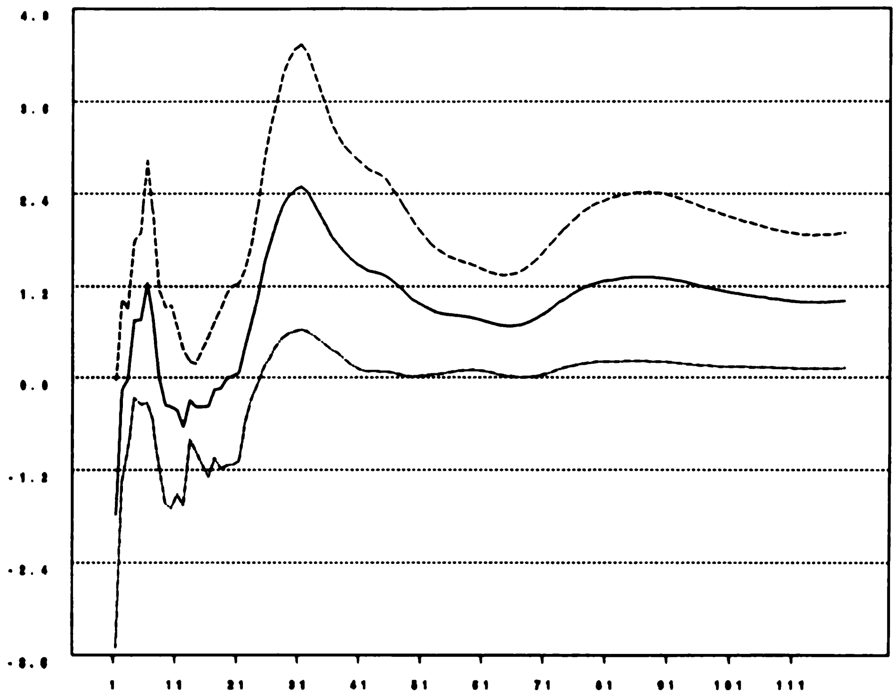

FIGURE 3: Imports in Response to a One-Standard Deviation Domestic Productivity Shock

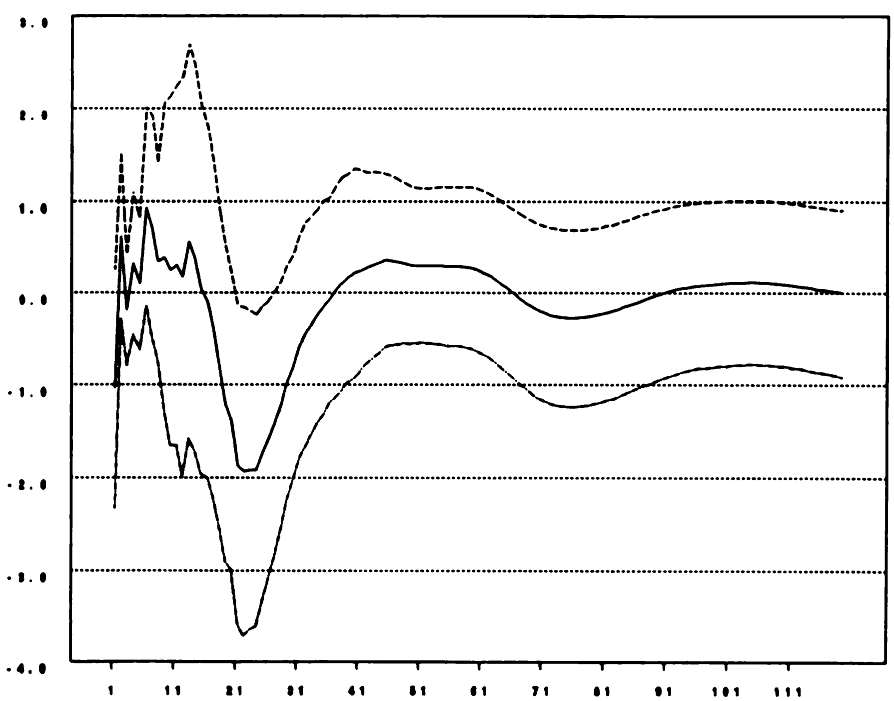

FIGURE 4: Exports in Response to a One-Standard Deviation Domestic Productivity Shock

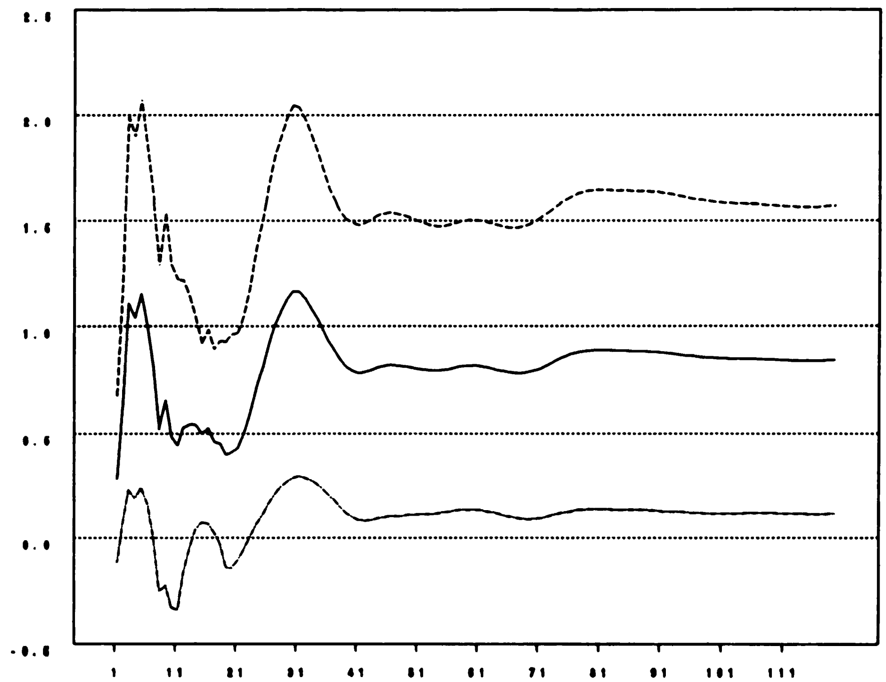

FIGURE 5: Output in Response to a One-Standard Deviation Domestic Productivity Shock

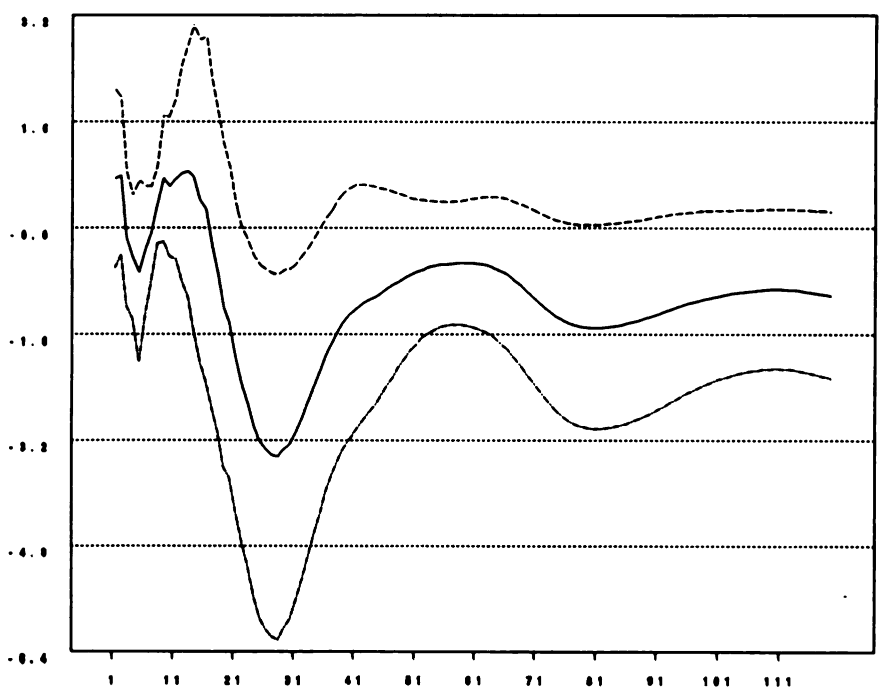

FIGURE 6: Net Exports in Response to a One-Standard Deviation Domestic Productivity Shock

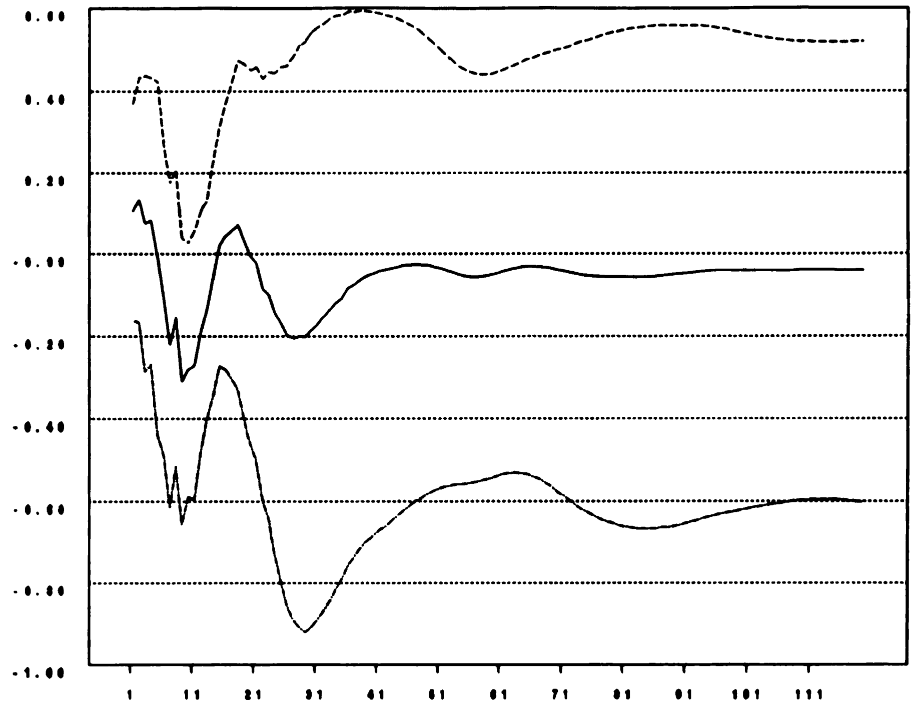

FIGURE 7: Consumption in Response to a One-Standard Deviation Foreign Productivity Shock

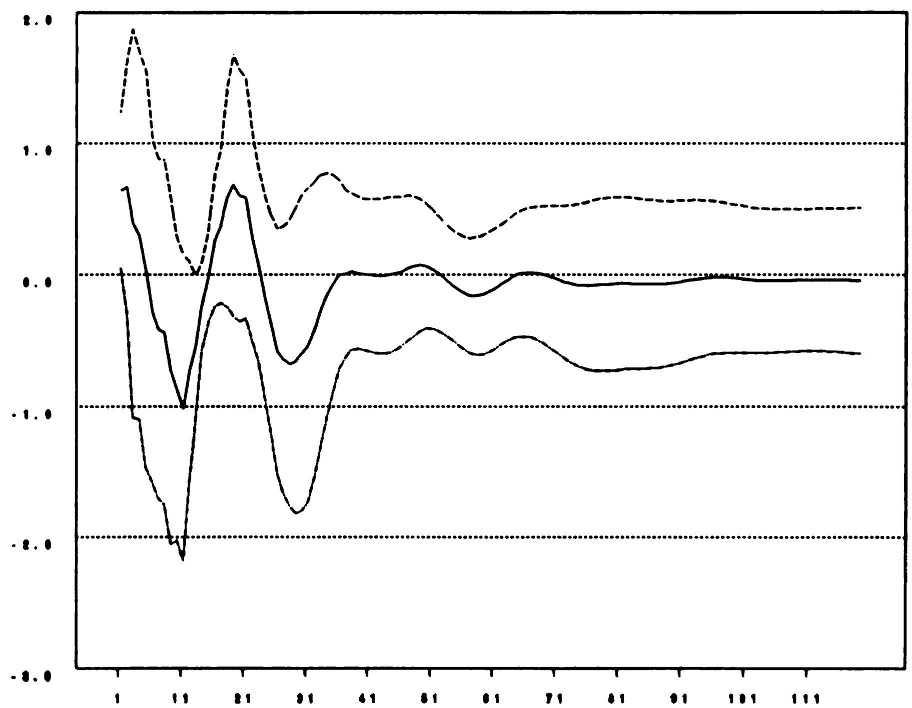

FIGURE 8: Investment in Response to a One-Standard Deviation Foreign Productivity Shock

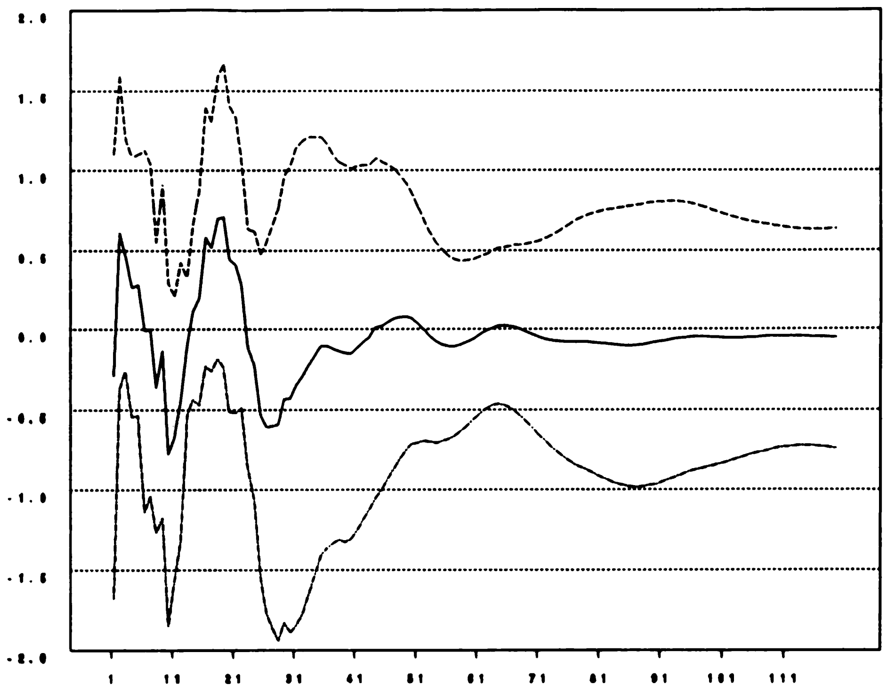

FIGURE 9: Imports in Response to a One-Standard Deviation Foreign Productivity Shock

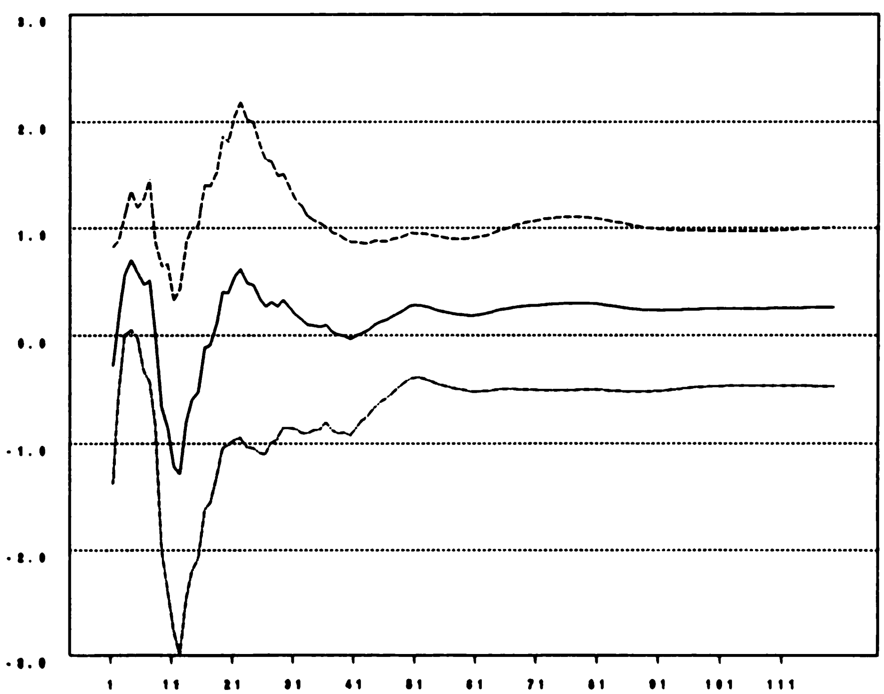

FIGURE 10: Exports in Response to a One-Standard Deviation Foreign Productivity Shock

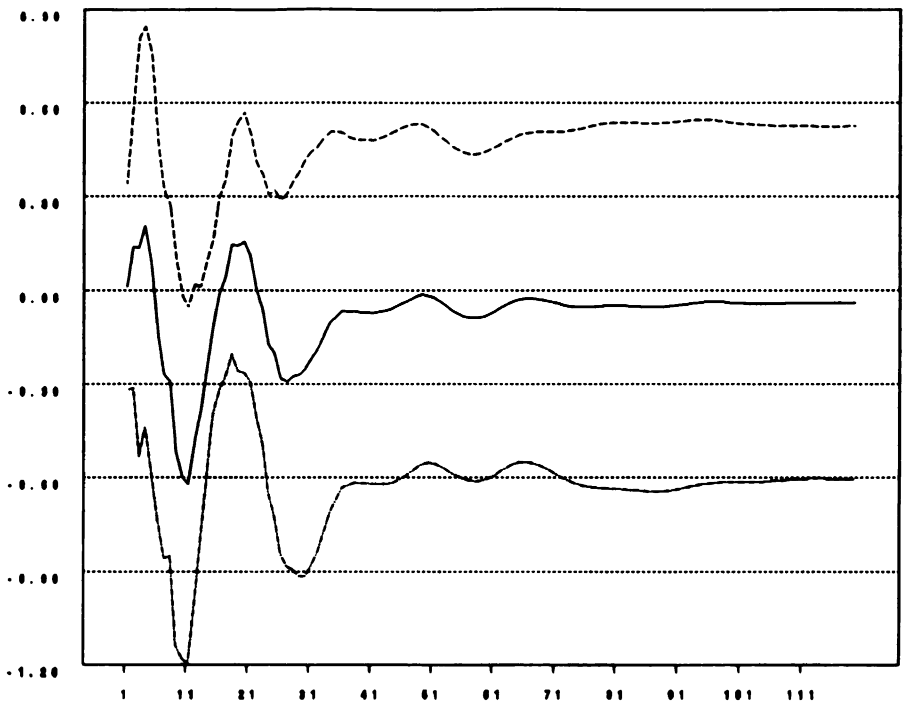

FIGURE 11: Output in Response to a One-Standard Deviation Foreign Productivity Shock

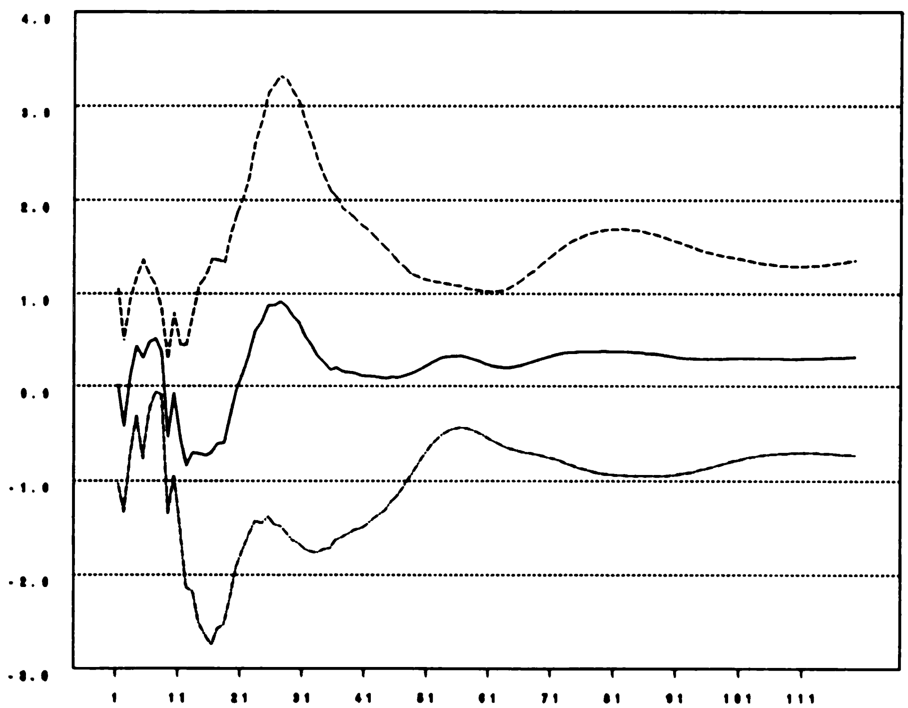

FIGURE 12: Net Exports in Response to a One-Standard Deviation Foreign Productivity Shock

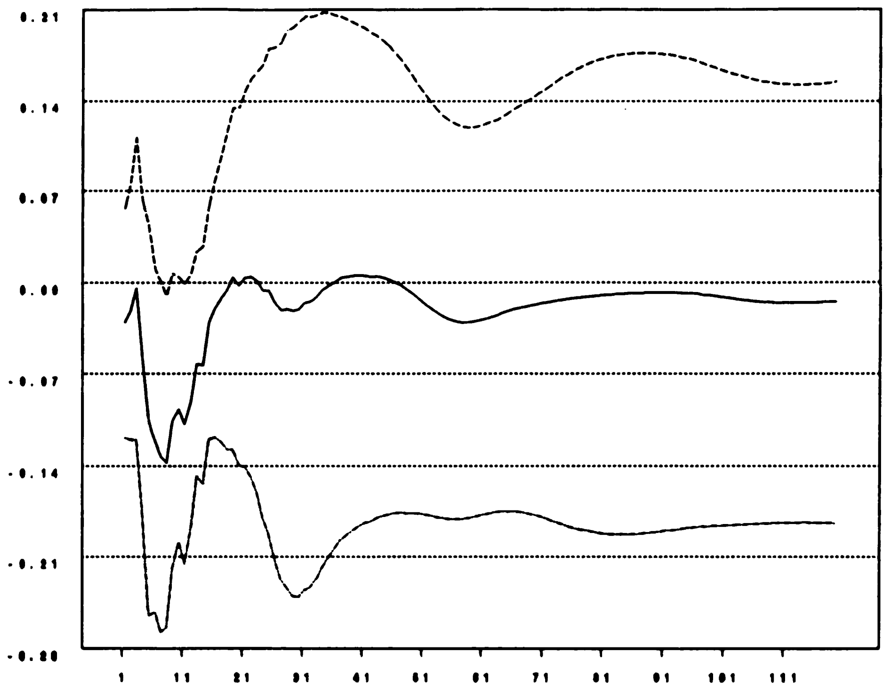

FIGURE 13: Consumption in Response to a One-Standard Deviation Real-Exchange-Rate Shock

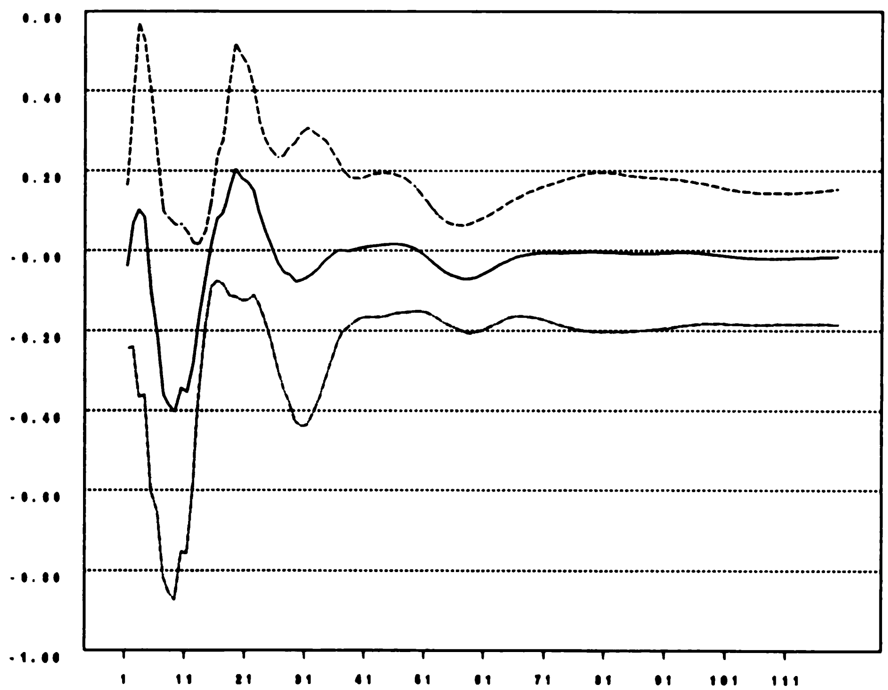

FIGURE 14: Investment in Response to a One-Standard Deviation Real-Exchange-Rate Shock

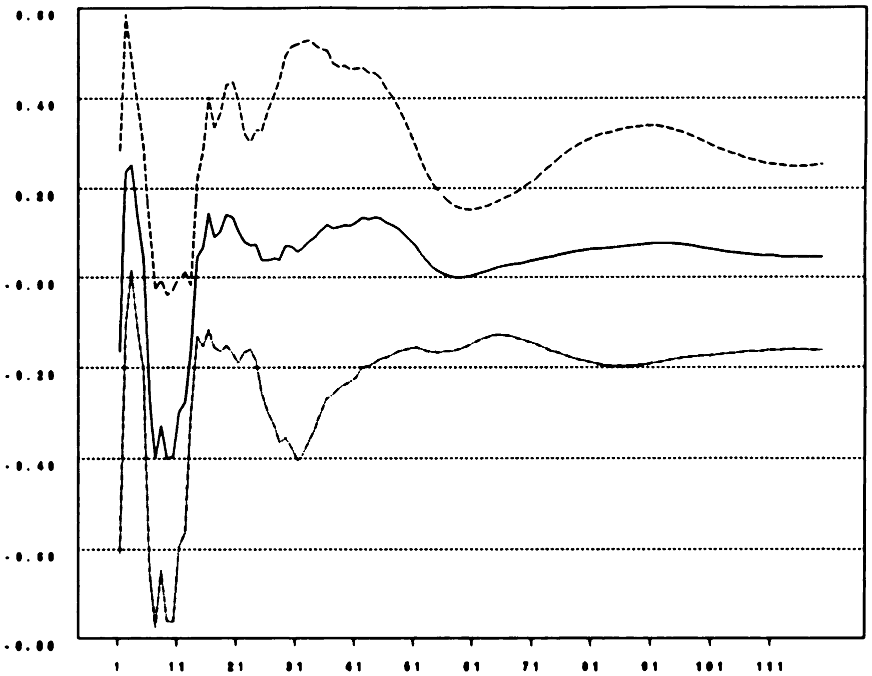

FIGURE 15: Imports in Response to a One-Standard Deviation Real-Exchange-Rate Shock

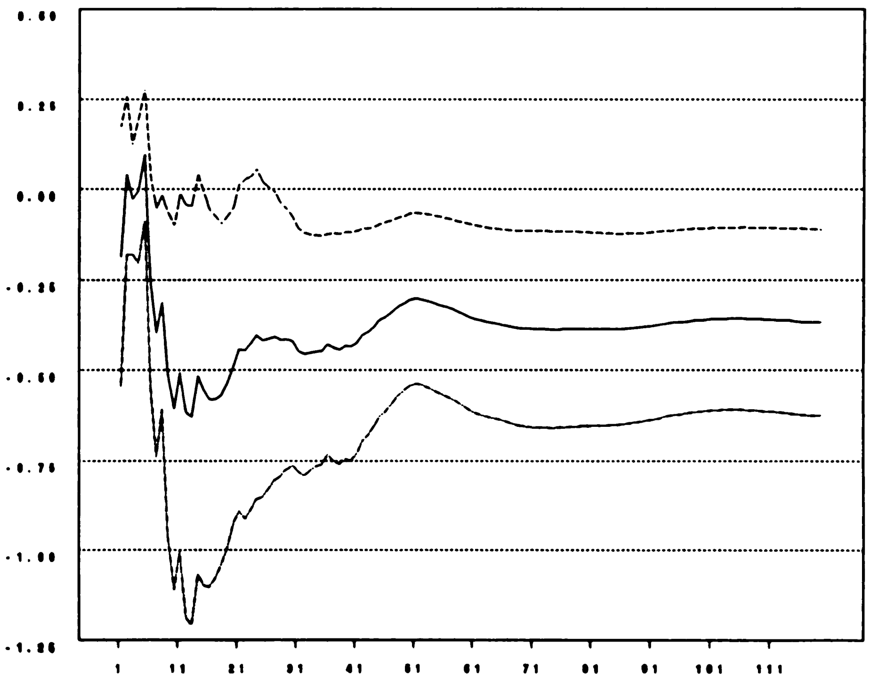

FIGURE 16: Exports in Response to a One-Standard Deviation Real-Exchange-Rate Shock

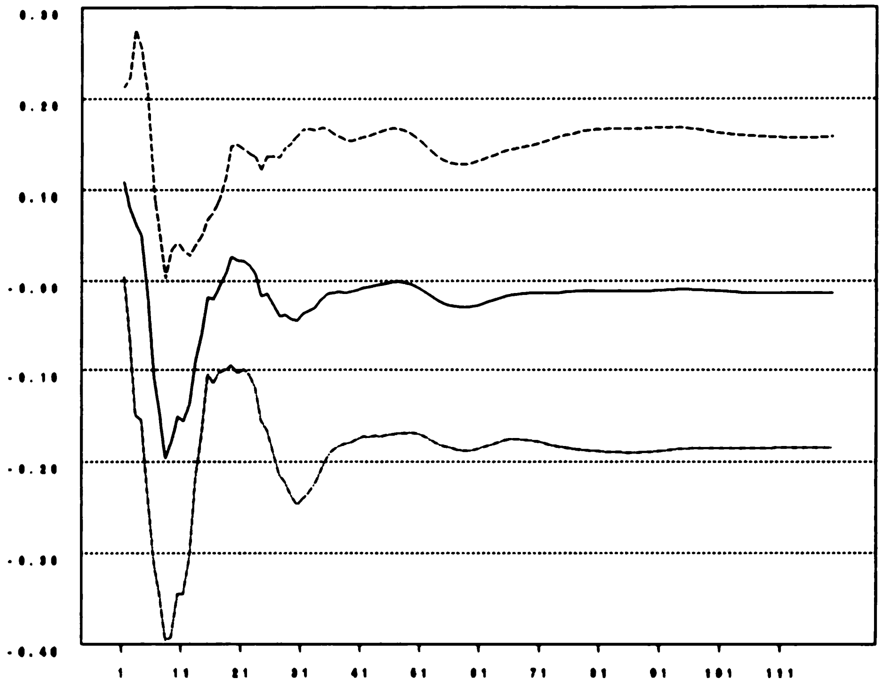

FIGURE 17: Output in Response to a One-Standard Deviation Real-Exchange-Rate Shock

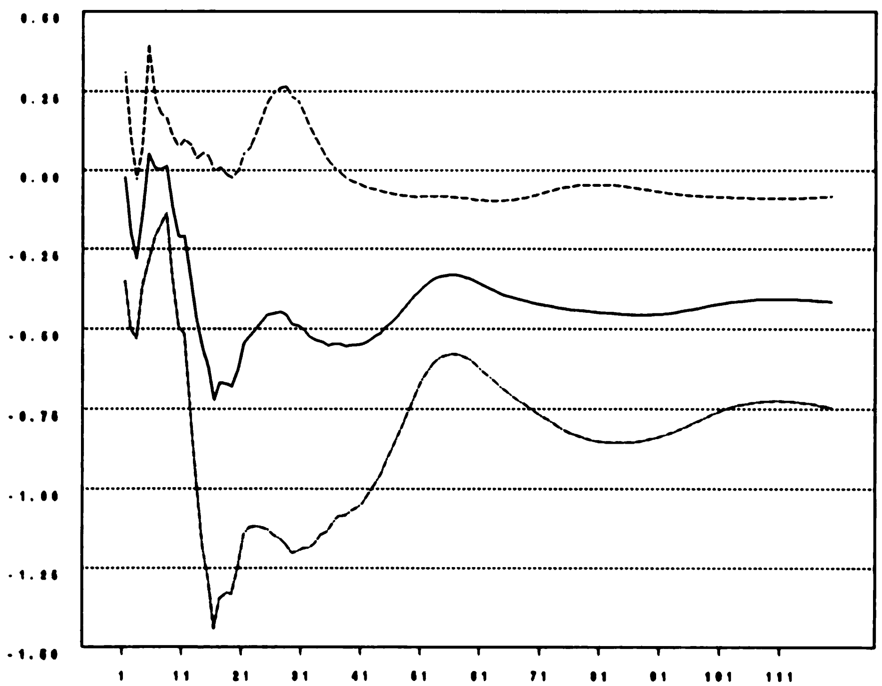

FIGURE 18: Net Exports in Response to a One-Standard Deviation Real-Exchange-Rate Shock

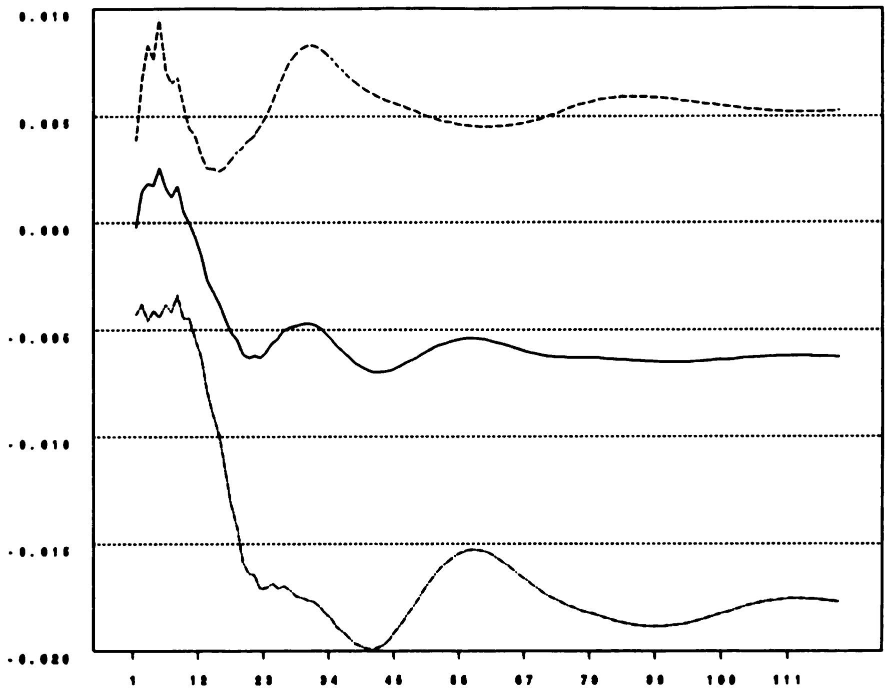

FIGURE 19: Consumption in Response to a One-Standard Deviation Inflation Shock

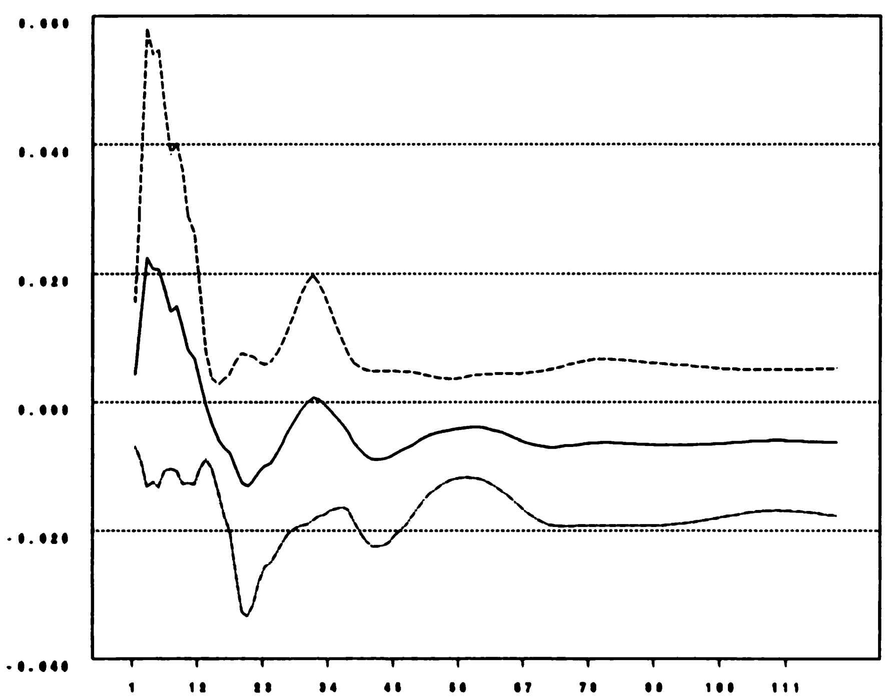

FIGURE 20: Investment in Response to a One-Standard Deviation Inflation Shock

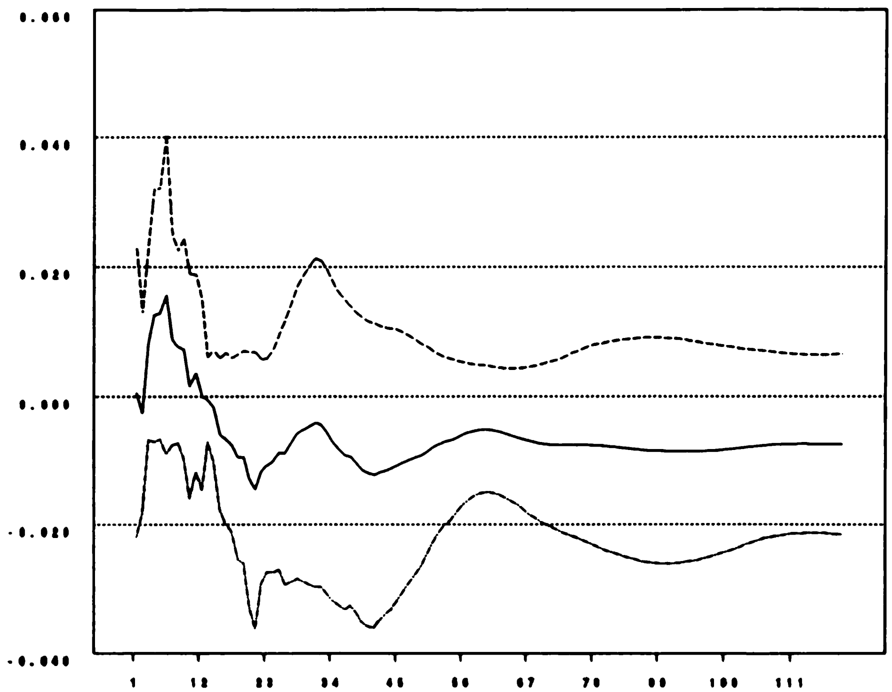

FIGURE 21: Imports in Response to a One-Standard Deviation Inflation Shock

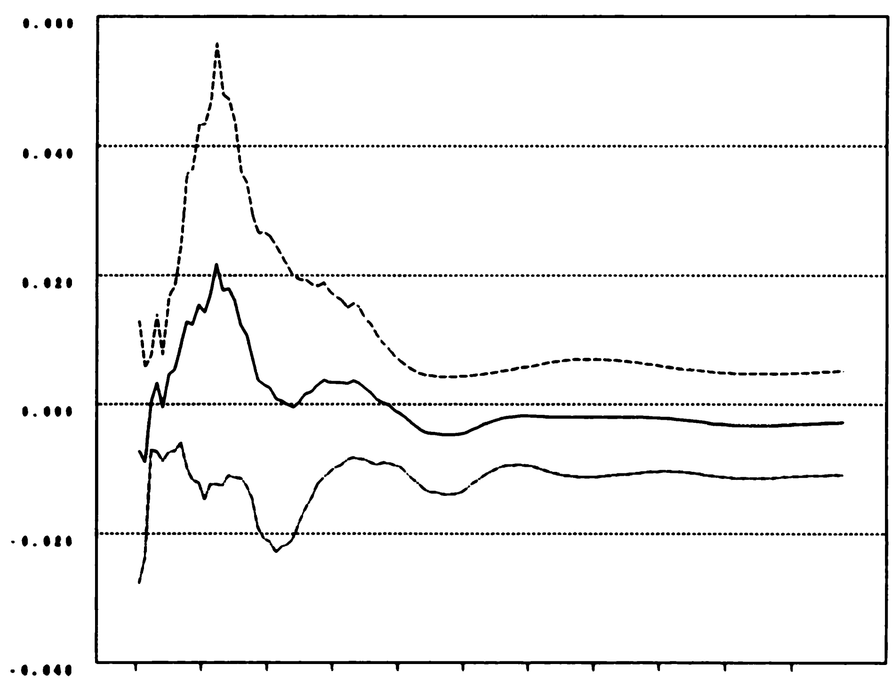

FIGURE 22: Exports in Response to a One-Standard Deviation Inflation Shock

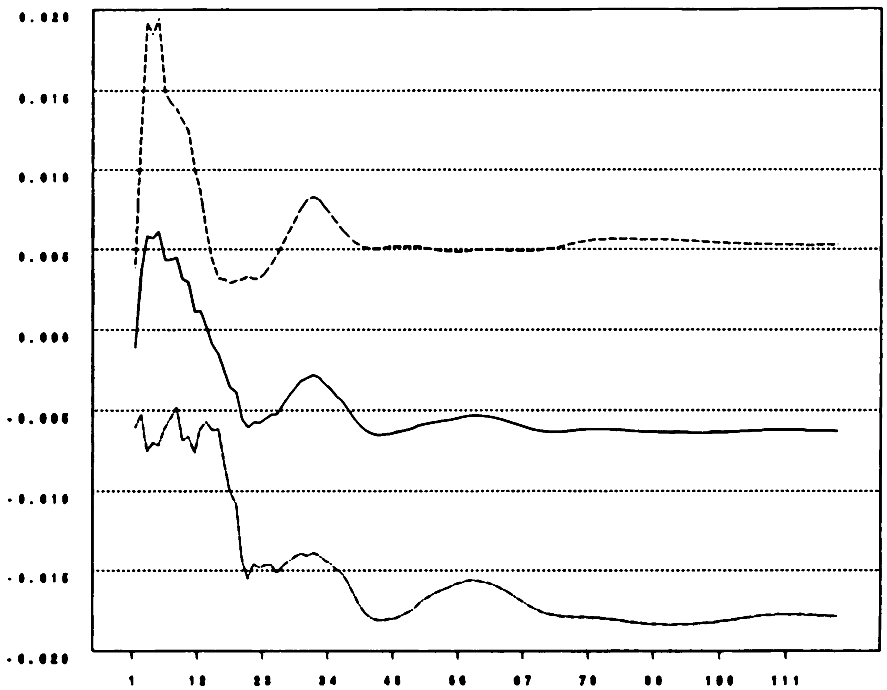

FIGURE 23: Output in Response to a One-Standard Deviation Inflation Shock

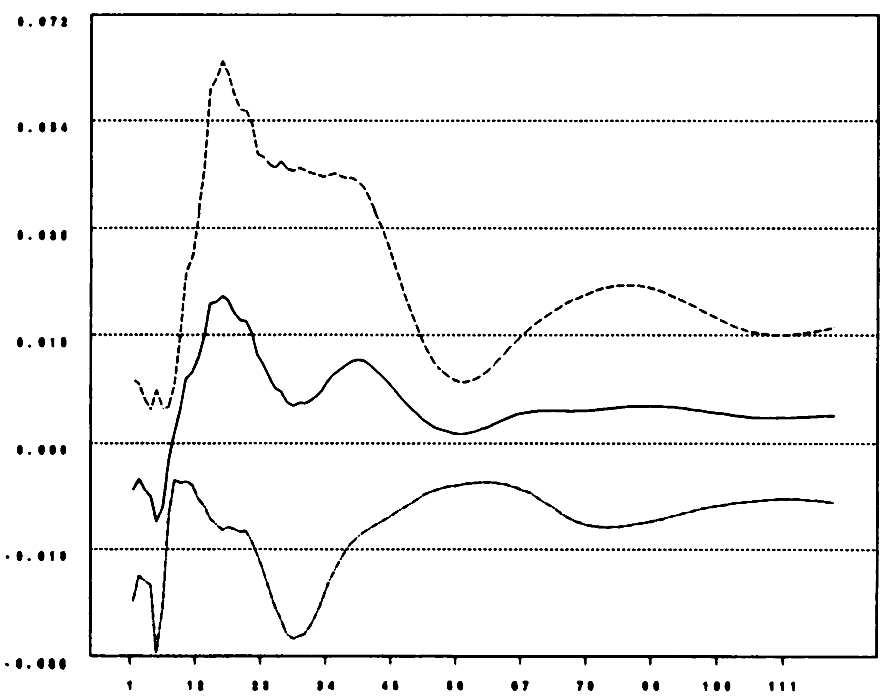

FIGURE 24: Net Exports in Response to a One-Standard Deviation Inflation Shock

APPENDIX

APPENDIX

AN OPEN-ECONOMY COMMON TRENDS MODEL

A.1. REDUCED-FORM ANALYSIS

The reduced-form is represented by a Wold decomposition of the series in first differences

$$\Delta X_t = \mu + C(L)\epsilon_t \tag{A1}$$

where $X_t = (c, i, m-p, im, ex, R, y^*, \Delta p, q, y)'$ and ϵ_t is the vector of one-step-ahead forecast errors in X_t, given information on lagged values of X_t. X_t is I(1), and is cointegrated with the 4 cointegrating vectors, given by the 8x4 matrix β. Then, $\beta' C(1) = 0$, where $C(1) = \sum_{j=0}^{\infty} C_j$, and

$$\beta' = \begin{bmatrix} 0 & 0 & 1.0 & 0 & 0 & .014 & 0 & 0 & 0 & -1.21 \\ 1.0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1.0 \\ 0 & 1.0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1.0 \\ 0 & 0 & 0 & 1.0 & 0 & 0 & 0 & 0 & -.101 & -1.29 \\ 0 & 0 & 0 & 0 & 1.0 & 0 & -.337 & 0 & .497 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1.0 & 0 & -1.3 & 0 & 0 \end{bmatrix}.$$

A.2. COMMON TRENDS REPRESENTATION

If 2 series are cointegrated, then they must share a common stochastic trend, since they have a common integrated component. KPSW's model can be viewed as a multivariate extension of Beveridge and Nelson (1981). They show that X_t

can be written as a linear function of a permanent component and a transitory component

$$X_t = X_0 + A\tau_t + D(L)\epsilon_t \tag{A2}$$

where $\tau_t = \gamma + \tau_{t-1} + \eta_t$. A must be orthogonal to β' ($\beta' A=0$) in order to preserve the cointegrating properties of X_t. Since $A\tau_t$ is I(1), and $D(L)\epsilon_t$ is I(0), then $A\tau_t$ is the "common trends" in X_t.

A.3. IDENTIFICATION OF THE COMMON TRENDS

Since τ_t follows a random walk, then $A\tau_t$ follows a random walk. So, the problem of identification becomes a problem of identifying τ_t and η_t when k>1. Since A and τ_t are only identified up to an arbitrary transformation by a nonsingular kxk matrix, define $A = \tilde{A}_0\Pi$. A_0 reflects a priori restrictions about which permanent shock affects which variables.

$$A_0 = \begin{bmatrix} 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 1.21 \\ 0 & 0 & .101 & 1.29 \\ .337 & 0 & -.497 & 0 \\ 0 & 1.3 & 0 & 0 \\ 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

In order to "name" the shocks, $\tilde{A}_0 = A_0\Phi$, where

$$\Phi_1 = \begin{bmatrix} 0 & 0 & 1 & 0 \\ 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

says that the inflation shock is ordered first, the real-exchange-rate shock is second, the foreign productivity shock is third, and the domestic productivity shock is forth.

So, $\tilde{A}_0 = A_0\Phi_1$ is given by

$$\tilde{A}_0 = \begin{bmatrix} 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 1.21 \\ 0 & .101 & 0 & 1.29 \\ 0 & -.497 & .337 & 0 \\ 1.30 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

where the first column represents the long-run impact of the first shock on each of the variables, c, i, $m-p$, im, ex, R, y^*, Δp, q, y.

A.4. ESTIMATION

The reduced-form (A.1) is estimated to get $C(\hat{L})$, $C(\hat{1})$, and $\sum_{j=0}^{\infty} e_j$. From equation (A.2),

$$\Delta X_t = \tilde{A}_0 \Pi \Delta \eta_t + D(L)\Delta e_t \ . \qquad \textbf{(A3)}$$

In the long-run, (A.1) implies that

$$\Delta X_t = C(\hat{1})\sum_{j=o}^{\infty} \epsilon_j \qquad \textbf{(A4)}$$

and equation (A.3) implies that

$$\Delta X_t = \tilde{A}_0 \Pi I_k \qquad \textbf{(A5)}$$

since $E_t \eta_t = I_k$, and $E_t \epsilon_t = \epsilon_{t-1}$. Therefore,

$$C(\hat{1})\sum_{j=0}^{\infty} \epsilon_j = \tilde{A}_0 \Pi I_k = \hat{A} \qquad \textbf{(A6)}$$

where,

$$\hat{A} = \begin{bmatrix} -.01 & .03 & -.10 & 1 \\ -.01 & .03 & -.10 & 1 \\ -.03 & .04 & -.12 & 1.21 \\ -.01 & .14 & -.12 & 1.29 \\ 0 & -.535 & .337 & 0 \\ 1.30 & 0 & 0 & 0 \\ -.01 & -.113 & 1 & 0 \\ 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ -.01 & .03 & -.10 & 1 \end{bmatrix}$$

and $\Pi = \sum_{\eta}^{1/2}$, where the covariance matrix of the permanent innovations $\sum_{\eta^1} = E(\eta^{1\prime}\eta^1)$. Π for the 10-variable model is reported in Table 10.

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