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An Empirical Analysis of Ricardian Equivalence and Macroeconomic Interdependence in Korea.

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AN EMPIRICAL ANALYSIS OF RICARDIAN EQUIVALENCE AND MACROECONOMIC INTERDEPENDENCE IN KOREA

A Dissertation

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by
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To

my parents

who have a strong intergenerational altruism

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ABSTRACT

The dissertation research has two objectives. The first is to investigate the relevance of Ricardian equivalence to the Korean economy. The second objective is to investigate the empirical validity of the proposition of macroeconomic interdependence in Korea. The above two issues are examined by specifying and estimating a vector autoregressive (VAR) model as a compact approximation of macroeconomic reality in Korea.

The nine variables selected for the VAR model are based upon theoretical and institutional considerations. Monthly Korean data for the period 1973:5-1989:11 are used in the analysis. First differencing for eight of the system variables is determined by unit root tests and further supported by cointegration tests. In addition, the Akaike information criterion leads us to select the optimal lag length of 12 months. Furthermore, an appropriate ordering of system variables is chosen based upon theoretical and institutional considerations.

The dynamic effects of government debt and foreign shocks are evaluated by estimating variance decompositions (VDCs), impulse response functions (IRFs), and cumulative impulse responses (CIRFs). To estimate the standard errors of the VDCs, IRFs, and CIRFs, a Monte Carlo integration procedure is

employed. The innovation accounting results appear to be fairly insensitive to alternative model specifications.

Two salient features of the empirical findings are as follows. First, government debt has, at least in the short run, negative effects on macroeconomic activity in Korea. The results are generally consistent with the Ricardian equivalence hypothesis. Second, the proposition of macroeconomic interdependence is supported for the Korean economy. The innovation accounting results indicate that the Korean economy is significantly influenced by foreign output and foreign price shocks during the sample period considered here.

CHAPTER 1

INTRODUCTION

I. Purpose of the Dissertation

This dissertation has two objectives. The first is to investigate the relevance of Ricardian equivalence to the Korean economy. Is a government deficit stimulative in Korea? In the standard view of fiscal policy, deficit-increasing tax cuts are believed to stimulate aggregate demand and thus deficits are expansionary. Alternatively, the Ricardian equivalence hypothesis revived by Barro (1974) predicts that the method by which deficits are financed has no independent effect on economic activity because rational economic agents fully perceive the implied future taxes of deficit financing.

The second objective is to investigate the degree to which foreign disturbances are transmitted to the Korean economy. The conventional view suggests that flexible exchange rates completely insulate the domestic economy from foreign shocks, whereas recent studies indicate that the domestic economy is internationally interdependent because foreign shocks affect the domestic economy in many ways (see, for example, Dornbusch 1983). Because the Korean economy is heavily dependent upon foreign trade, the dissertation

attempts to determine the importance of foreign shocks, relative to domestic shocks, to the Korean economy. The channels through which these foreign shocks are transmitted to Korea will also be analyzed.

For this study, a fairly pragmatic approach will be taken. Rather than developing specific theoretical models for explaining Ricardian equivalence and macroeconomic interdependence, implications that emanate from a number of models are considered in the empirical analysis. In this way a general set of possible effects of fiscal policy and international transmission of foreign disturbances can be investigated. It is for this reason that the above two issues are examined by specifying and estimating a vector autoregressive (VAR) model as a compact approximation of macroeconomic reality in Korea.

The nine variables selected for the VAR model are based upon theoretical and institutional considerations. Because many economic time series are characterized as nonstationary processes, a unit root test will be conducted to evaluate whether the data series used are difference stationary or trend stationary. If each series is characterized by difference stationarity, a cointegration test will be employed to investigate whether a linear combination of nonstationary series is stationary. In addition, the Akaike information criterion will be used to determine an optimal lag length for all equations of the VAR system. Furthermore, an appropriate

ordering of system variables will be chosen based upon theoretical and institutional considerations.

The dynamic effects of government debt and foreign shocks will be evaluated by estimating variance decompositions (VDCs), impulse response functions (IRFs), and cumulative impulse responses (CIRFs), which are based upon the moving average representation of a VAR. Because these innovation accounting results are generally considered to be sensitive to alternative model specifications, the possible sensitivity of the results will be examined with respect to different variable orderings, an alternative choice of VAR order, and a different data transformation method. Furthermore, a Monte Carlo integration procedure will be employed to estimate the standard errors of the VDCs, IRFs, and CIRFs so that the significance of the effects of debt and foreign shocks can be determined.

II. Selection of the Korean Economy

The Korean economy is chosen for the following two reasons. The first is that the Republic of Korea (Korea, hereafter) has achieved remarkable economic growth over the last two decades, and this growth has been accompanied by persistent budget deficits. Thus, the macroeconomic effect of government debt is a matter of concern in Korea.

Most studies of the empirical validity of the Ricardian

equivalence hypothesis have concentrated on industrialized countries. However, examination of the role of deficits in a variety of economies--both developed and developing--is crucial to understanding the macroeconomic effects of government deficits. Only Evans (1988, 1990) has investigated the role of budget deficits in Korea. In a single-equation model of output, Evans used a measure of the budget deficit and found that the deficit does not have a significant effect on output in Korea. In theory, however, Ricardian equivalence has implications for the behavior of other important macro variables, besides output. In this study, the limited scope of Evans' studies is avoided by investigating the effects of debt on interest rates, output, prices, and real exchange rates.

The second reason for selection of the Korean economy is because it is heavily dependent on foreign trade, and the impact of external disturbances cannot be ignored in the process of economic development in Korea. In particular, the external shocks that affect Korea's exports and imports may have significantly influenced economic activity in Korea. This suggests the investigation of the extent to which foreign disturbances are transmitted to the domestic economy in Korea.

Only one study has examined the macroeconomic interdependence of the Korean economy. Kim (1987) estimated a small-size structural model and provided some simulation results that U.S. monetary and fiscal policies significantly

influenced the Korean economy. A worrisome aspect of this procedure is that it may misestimate the impact of policy actions due to the possible misspecification of the structural model. An alternative procedure is the reduced-form VAR technique that does not limit the channels through which variables operate. In particular, potentially incorrect a priori restrictions are not imposed by using the VAR technique. Also in contrast to the previous work--which focused on U.S. monetary and fiscal policy shocks to the Korean economy--this study will employ external output and price shocks that are linear combinations of the corresponding U.S. and Japanese variables. This consideration is attributable mainly to the fact that the Korean economy is heavily dependent on foreign trade and that the U.S. and Japan are the two major trading partners in Korea.

III. Organization of the Dissertation

The dissertation consists of five chapters and is organized as follows. Chapter 2 reviews the literature relevant to the Ricardian equivalence hypothesis and the proposition of macroeconomic interdependence. Both the theoretical and empirical literature are discussed. Chapter 3 discusses the VAR methodology. Motivations for using the VAR approach are first described. Then, the use of VDCs, IRFs, and CIRFs to determine the relative importance of one

variable to another and to examine the dynamic characteristics of the system variables is described. A unit root test and cointegration tests for stationarity are also discussed in this chapter. Chapter 4 specifies a nine-variable VAR model as a compact approximation of macroeconomic reality in Korea. It discusses selection of system variables, choice of a data set, and some model specification issues. Empirical results are also presented and analyzed in this chapter. Finally, chapter 5 concludes with the four most important contributions of the dissertation research to the empirical literature relevant to the Korean macroeconomy. Some limitations of the dissertation research and a future research area will also be discussed.

CHAPTER 2

LITERATURE REVIEW

I. Introduction

This chapter has two objectives. The first is to review the literature on the effects of government debt on macroeconomic activity. In the standard view, it is believed that bond-financed government expenditures are more stimulative than tax-financed expenditures because households do not fully discount the implied future taxes generated by debt finance, and hence spending on consumer goods and services may rise (Modigliani 1961; Blinder and Solow 1973). Many economists have viewed the current U.S. experience of tax cuts as harmful to the macroeconomy since the budget deficits they generated may lead to low saving, high interest rates, and large trade deficits in the short run, and low capital accumulation and therefore low economic growth in the long run. Alternatively, the Ricardian equivalence hypothesis revived by Barro (1974) predicts that the method by which government expenditures are financed has no independent effect on economic activity because rational economic agents fully perceive the implied future taxes of deficit financing. Therefore, much attention has been focused on this

controversial issue about fiscal policy.

The second objective is to review the literature on the international transmission of foreign disturbances to the domestic economy. The conventional view suggests that flexible exchange rates completely insulate the domestic economy from foreign shocks (Friedman 1953; Johnson 1969). Recent studies, however, indicate both theoretically and empirically that the insulation properties of flexible rates are achieved only in special cases because foreign shocks affect the domestic economy in so many ways (see, for example, Dornbusch 1983). A high degree of international transmission of external shocks with current flexible rates has increased economists' interest in theories and evidence about the proposition of macroeconomic interdependence.

To elaborate on these two objectives, the remainder of the chapter is organized as follows. Section II presents a review of the theoretical and empirical literature on the Ricardian equivalence hypothesis. Section III reviews the theoretical and empirical literature on the proposition of macroeconomic interdependence. Each of the two sections further discusses the existing evidence relevant to the Korean economy. Finally, a brief summary and conclusion follow in section IV.

II. Ricardian Equivalence Hypothesis

As noted earlier, the conventional view of the effect of fiscal policy suggests that government bonds are wealth and thus a switch from tax to debt finance of expenditures is expansionary. In sharp contrast to the conventional view, the Ricardian equivalence view predicts that debt is not wealth and a substitution of debt for lump-sum tax financing of a given level of government spending has no independent effect on consumer expenditures. In particular, a current tax cut financed by issuing government bonds is assumed to be "equivalent" to an increase in future taxes. Current households, who fully perceive the implied future taxes required to service and retire government debt, would increase their savings to compensate future generations for their tax burdens.

However, the assumptions underlying the Ricardian equivalence hypothesis have been questioned by a number of authors; if the restrictive assumptions are violated, Ricardian equivalence will not hold. Thus, no clear role for government debt emerges from the theoretical literature. For this reason, it is especially important to understand the Ricardian equivalence hypothesis within the context of a standard IS-LM model.[1]

A. The IS-LM Analysis of Ricardian Equivalence

In a recent issue of *Economic Inquiry*, Fields and Hart (1990) provide an IS-LM analysis of the Ricardian equivalence hypothesis. They incorporate the present value of implied future taxes of government debt into current households' disposable income and present a modified version of the conventional IS curve. This is an important development because it makes the hypothesis understood within the IS-LM framework. Hence, the results provide the effect of debt on aggregate demand. Their discussion is extended here with the inclusion of private sector net wealth in the consumption function because the analysis of Ricardian equivalence eventually boils down to the wealth effect of government debt.

The Ricardian equivalence hypothesis implies that a shift from lump-sum tax finance to bond finance of a given level of government spending has no effect on consumer expenditures and hence aggregate demand. The effects of the two financing decisions cannot be distinguished under the assumption of Ricardian equivalence. To elaborate on the hypothesis in more detail, the basic model used is a variant of the IS function that incorporates not only the present value of the implied future taxes of debt but also allows private sector net wealth to affect consumption. The IS-LM model is specified as:

$$(2.1) \qquad y = c(y_d, w) + i(r) + g,$$

$$(2.2) \qquad M/P = l(y, r, w).$$

Equation (2.1) represents the IS (investment-savings) schedule, where c, i, and g are, respectively, private consumption, investment, and government spending. Assume, for simplicity, that the government obtains no revenue from money creation. If a tax cut is financed by selling bonds to the public, the Ricardian equivalence hypothesis predicts that the government will levy higher taxes in the future to service and retire bonds sold today. Thus, the current-period government budget constraint requires that the sum of government expenditures be equal to the sum of current taxes and the present value of the implied future taxes of debt. This suggests that household disposable income consistent with Ricardian equivalence be defined as $y_d = y - t - \Delta B(1+r)\delta/rP$, where y represents real income and t denotes taxes. The real present value of the implied future taxes of debt is measured as $PV = (\Delta B/P)\ [1 + 1/(1+r)^1 + 1/(1+r)^2 + \ldots] = \Delta B(1+r)/rP$, where ΔB represents the change in government bonds issued to finance budget deficits, and P and r are, respectively, the price level and interest rates.

Private sector net wealth $w = MB/P + B(1-\delta)/rP + K$, where MB, B, and K are, respectively, the monetary base, government bonds, and the capital stock which is assumed to be fixed. The tax discounting parameter (δ) denotes the extent to which

people perceive the implied future taxes associated with debt. If $\delta = 0$, nothing is discounted for future tax liabilities, and hence government bonds are totally private sector net wealth. If $\delta = 1$, people fully perceive the implied future taxes associated with debt, and hence bonds are not private sector net wealth. Also note that if $\delta = 0$, disposable income defined above will be real income less real taxes levied in a current period. If $\delta = 1$, disposable income will be real income less the sum of current taxes and the present value of the implied future taxes of debt.

Equation (2.2) represents the LM (demand for money = supply of money) schedule, where M/P denotes the real money stock. The demand for real money is negatively related to the interest rate, r, and is positively related to real income, y, and net wealth, w. w is included in the money demand to be consistent with the wealth effect on consumption in equation (2.1).

To examine the validity of Ricardian equivalence within the IS-LM framework, we consider two cases of deficits. The first is the case of a deficit-increasing tax cut, given the level of government spending. Suppose rational economic agents fully perceive the implied future taxes of deficit financing, as predicted by Ricardian equivalence. In this case, the initial increase in disposable income due to the tax cut cancels out, since the present value of the implied future taxes of debt will reduce disposable income by the amount

equal to the current tax cut if $\delta = 1$. In addition, government bonds are not perceived as private sector net wealth, and thus bond sales alter neither private consumption nor the demand for money. Therefore, the Ricardian equivalence hypothesis predicts that the tax cut financed by bond sales does not affect private consumption, and thus aggregate demand.

The second case is an increase in deficits due to an increase in government spending which is financed by taxes or bonds. The tax finance of government spending raises current taxes. Thus, disposable income simply represents real income less the value of current taxes. On the other hand, the bond finance of government spending, holding current taxes constant, is assumed to be fully perceived by rational economic agents as a rise in future taxes, i.e., $\delta = 1$. In this case, disposable income represents real income less the present value of the implied future taxes of debt, leaving private sector net wealth unchanged. The increased tax burden in either case lowers disposable income equally, so that private consumption falls by the same amount in each case. This consideration of changes in private consumption fills in the discussion of Fields and Hart (p. 189), leaving their general conclusion unaltered: "a change in g has the same effect regardless of how it is financed." The equivalent effects are obtained from the assumption that the present value of the implied future taxes of debt is *exactly* the same

as current tax increases, and thus consumption falls by an equal amount in both cases. That bond finance and lump-sum tax finance of an increase in government spending cannot be distinguished is referred to as Ricardian equivalence.[2] We now turn to the theoretical debates on the assumptions of the Ricardian equivalence hypothesis.

B. Theoretical Debates on Ricardian Equivalence

The Ricardian equivalence hypothesis that a substitution of debt for tax financing of a given level of government expenditures has no effect on economic activity is based upon some restrictive assumptions: 1) altruistically motivated transfers are given across generations, 2) capital markets are perfect, 3) taxes are lump sum, but not distortionary, and 4) there is no uncertainty about future taxes and income. A substantial amount of literature has examined the appropriateness of these assumptions, and has found that Ricardian equivalence does not hold if these assumptions are relaxed. Bernheim (1987) provides a critical review of the literature, and Aschauer (1988) and Barro (1989) provide a survey that advocates the "Ricardian alternative." The theoretical debates are briefly summarized as follows.

First, a number of studies reject the assumption of intergenerational transfers motivated solely by altruism. Buiter (1979), among others, argues that many parents bequeath

nothing to their children. However, Kotlikoff and Summers (1981) provide evidence that a large portion of aggregate U.S. saving is motivated by the altruistic motive for intergenerational transfers.

Tobin and Buiter (1980) also argue that some people without children are not linked to future generations; these people will tend to be better off with current tax cuts. In this case, the current-period tax cut stimulates aggregate demand and thus Ricardian equivalence does not hold. Barro (1989, p. 41), however, notes that although childless people may be wealthier with current tax cuts, "people with more than the average number of descendants experience a decrease in wealth when taxes are replaced by budget deficits," and hence the aggregate net wealth effect from people with and without children will be negligible.

Second, Buiter and Tobin (1979) argue that government debt will have real effects on private consumption if capital markets are imperfect. For example, young people and minority groups may face difficulty in obtaining loans because they possess poor collateral. Hence, their borrowing rates will be higher than the government's. Suppose that the government cuts current (lump-sum) taxes, holding the path of government spending constant. The liquidity constraints faced by these people may lead to an increase in current consumption because they feel wealthier than before the current tax cut. As shown by Hubbard and Judd (1986), about 20 percent of individuals

are liquidity-constrained in the United States, and hence private consumption may rise. Therefore, government debt may have short-run effects on aggregate demand if the capital markets are not perfect or efficient.

In contrast to the previous studies that treat liquidity constraints as being exogenously determined, Hayashi (1987) and Yotsuzuka (1987) argue that liquidity constraints may adjust in response to government policies. Using a model in which liquidity constraints are treated as endogenous, they find that Ricardian equivalence holds even in the presence of imperfect capital markets. For example, Yotsuzuka argues that high risk takers may borrow at high interest rates whereas other people typically face a relatively low borrowing rate. The adverse selection of the borrowing rate is due to asymmetric information. In this case, the private pooled lending offered by banks is assumed to adjust to government borrowing. As a result, the real effect of government borrowing on private consumption will be negligible, because in this case the government does not have any informational advantage over the private sector. Thus, the existence of this type of capital market imperfection in itself is not a sufficient reason for the failure of Ricardian equivalence.

Third, the Ricardian equivalence hypothesis assumes that taxes are lump sum and the lump-sum tax cut is fully discounted by rational economic agents as an increase in future taxes. However, as Barro (1989) indicates, if taxes

are not lump sum but are distortionary, variations in tax rates will affect the macroeconomy. Suppose that a current tax cut represents a reduction in marginal income tax rates and the current reduction in tax rates is offset by higher tax rates in the future. Because income tax rates apply to personal disposable income, variations in tax rates affect individuals' incentives to work and produce. The current reduction in tax rates, for example, motivates individuals to work and produce more today and causes individuals to save more. Thus, output may rise, and after-tax real interest rates fall. The higher tax rates in the future, on the other hand, will provide a disincentive for individuals to work and produce, so that output may fall and interest rates rise. Therefore, the results are non-neutral.[3] The Ricardian equivalence hypothesis will not be supported if taxes distort an individual's decision to work and produce.

Fourth, Feldstein (1976), among others, argues that, in the presence of uncertainty, people will have a higher discount rate in capitalizing the future tax liabilities of debt. In this case, the present value of the implied future taxes will be *smaller* than current tax cuts; hence, private sector net wealth rises; and hence, people may raise their consumption under uncertainty. This is in a sharp contrast to a prior argument by Barro (1974). Barro suggests that when future tax liabilities and the timing of these taxes are uncertain, people may perceive the present value of the

implied future taxes of debt to be *greater* than the present value of the income streams associated with debt. If such is the case, private sector net wealth falls under uncertainty.

Chan (1983) also supports Barro's (1974) argument when lump-sum taxes are introduced under uncertainty. Because the lump-sum tax cut *raises* the uncertainty about each individual's future disposable income, people with risk aversion will reduce current consumption and will increase saving. However, the results are different when income taxes are introduced under uncertainty. Chan shows that the income tax cut *reduces* the uncertainty about each individual's future disposable income, and hence people may raise current consumption and reduce their saving under uncertainty. The results of the latter case are consistent with those of Feldstein (1976).

C. Empirical Findings of Ricardian Equivalence

As discussed earlier, no clear role for government debt emerges from the theoretical literature. Because the Ricardian equivalence hypothesis is based on some restrictive assumptions, the hypothesis will not hold if the assumptions are violated. For this reason, it is especially important to examine empirical evidence. The following subsections summarize the empirical findings on macroeconomic variables such as consumption, interest rates, prices, output, and real

exchange rates.

C.1. *Consumption*

In the consumption function analysis that includes a measure of either the budget deficit or government debt, the existing evidence on Ricardian equivalence is inconclusive. Kochin (1974), Barro (1978), Tanner (1979), Kormendi (1983), and Seater and Mariano (1985) provide evidence that economic agents fully discount the implied future taxes of government debt, so that debt has no direct impact on private consumption. Opposite results are obtained by Yawitz and Meyer (1976), Feldstein (1982), Reid (1985, 1989), Bernheim (1987), and Modigliani (1987), where government bonds are found to be private sector wealth.

Developing a "consolidated approach" to examining the private sector consumption behavior, Kormendi (1983) finds that a debt-financed tax cut, holding government spending constant, does not increase private consumption. This is consistent with Ricardian equivalence. Kormendi also finds that government spending affects private consumption negatively (the magnitude of substitution effects equals -0.23). This implies that economic agents are not "myopic," and government spending and private consumption are less than perfect substitutes. Thus, government spending matters even if Ricardian equivalence holds. Furthermore, failure to find a positive association of debt with private consumption is

consistent with the Ricardian view. Indeed, government debt is found to have negative effects on private consumption, and the negative effects are explained within the Ricardian equivalence framework. For example, as Kormendi notes, if their share of future taxes and the timing of these taxes were uncertain, individuals may raise their savings more than the present value of the income streams associated with bonds issued to finance a deficit. If such is the case, a fall in private consumption will be expected.

Barth, Iden, and Russek (1986), however, find that Kormendi's results do not appear to be very robust with respect to the extended sample periods (updating through 1983), with respect to the partitions of total government debt (into its federal and state and local components), and with respect to the measurement of debt (par value vs. market value).[4] In addition, based on the life cycle hypothesis of consumption behavior, Modigliani and Sterling (1986) estimate a consumption function alternative to Kormendi's consolidated approach and find that the Ricardian equivalence hypothesis receives little empirical support. That is, private consumption is found to rise as government debt increases and as "net taxes" (i.e., total taxes net of transfer payments and real government interest) fall.

More recently, Feldstein and Elmendorf (1990) persuasively argue that Kormendi's finding in favor of Ricardian equivalence is primarily due to the inclusion of

World War II periods. During the war years, for example, shortages of consumer goods and "patriotic" motives reduced private consumption and raised private saving, whereas a massive increase in defense spending raised government spending more than a tax increase. Modigliani and Sterling (1990) further indicate that failure to account for "temporary taxes" and the specification of variables in differences rather than in levels have biased Kormendi's results in favor of Ricardian equivalence. In response to these comments, Kormendi and Meguire (1990a) provide further evidence that the results in favor of Ricardian equivalence are essentially unaffected even with the exclusion of the war period (1941-1946). In addition, Modigliani and Sterling's measure of temporary taxes has no material effect on the result when the model is estimated in differences rather than in levels. The choice of estimation in differences is also supported by using an extended Engle-Granger cointegration test, where the model variables are found not likely to be cointegrated. Thus, differencing is suggested.

In addition to this debate, a number of studies, including Aschauer (1985), Bernheim (1987), Leiderman and Razin (1988), and Leiderman and Blejer (1988), argue that traditional single-equation consumption models omit expected future variables. Because a strong version of intertemporal utility is a crucial assumption of the Ricardian equivalence hypothesis, current consumption should be influenced by future

variables as well. The omission of future variables in traditional models may lead to biased and inconsistent estimates of the related variables.

Based upon this line of reasoning, Aschauer (1985) estimates a system of two equations within an intertemporal optimization framework. The intertemporal optimization model of consumption assumes that current households maximize the present value of utility from current and future consumption subject to intertemporal budget constraints. Based upon quarterly U.S. data, Aschauer finds that the substitutability of government spending for private consumption is of reasonable magnitude (-0.23) and the joint hypothesis of rational expectations and Ricardian equivalence is not rejected by the data. Leiderman and Razin (1988) further develop an intertemporal stochastic model where consumers maximize expected lifetime utility subject to intertemporal budget constraints. Using monthly Israeli data, they do not reject the Ricardian view even with the imposition of liquidity constraints and finite horizons. In addition, within the context of an open-economy intertemporal model, Johnson (1986) finds evidence contrary to Ricardian equivalence for the Canadian economy. Rock, Craigwell, and Sealy (1989) also estimate the intertemporal optimization model for two Caribbean economies and find the result consistent with Ricardian equivalence for Barbados, but the hypothesis is rejected for Trinidad and Tobago.

C.2. *Interest Rates*

The standard view suggests that a switch from lump-sum tax to deficit finance of a given level of government spending increases interest rates by stimulating aggregate demand. However, the Ricardian view predicts that the deficit has no effect on interest rates. The effect of the deficit on interest rates has been investigated in a number of studies. Plosser (1982), for example, estimates a vector autoregressive model to measure the impact of government debt on interest rates. The methodology used by Plosser is the joint estimation method that Mishkin (1982) used to estimate rational expectations models to avoid any problems that may arise in Barro's (1977) two-step procedure. One of the main results found by Plosser is that, for quarterly U.S. data from 1954 to 1978, unexpected movements in privately held federal debt do not raise the rate of return. This implies that government debt issued to finance deficits is not private sector wealth.

In contrast to the stock measure of government debt, Evans (1985) employs a measure of budget deficits, which is a flow concept, and allows current and past values of the deficit to predict interest rates. The U.S. experience of large deficits, especially during the Civil War, World Wars I and II, and the postwar periods, is found not to produce high interest rates. Indeed, a negative effect on interest rates is found, as in the case of Kormendi (1983) for private

consumption. Feldstein (1986a) points out that expected future deficits rather than current and past deficits may affect interest rates more significantly. In this case, economic agents are assumed to expect future deficits in advance of tax cuts, or future surpluses in advance of tax increases. Including a measure of expected budget deficits in interest rate determination, Feldstein (1986a) finds a significantly positive effect on interest rates. Plosser (1987), however, provides evidence that the effect of future deficits on interest rates is not significantly different from zero, as does Evans (1987a).

Mascaro and Meltzer (1983) use short-term (3-month) and long-term (10-year) interest rates, and provide evidence that budget deficits do not have a significant effect on short- and long-term interest rates. Using the short-term interest rate, Makin (1983) also finds no significant effect of the deficit on the three-month Treasury bill rate. Similar results are obtained by Hoelscher (1983), where federal government borrowing is insignificantly different from zero in determining the short-term rate. Using multivariate Granger-causality tests, McMillin (1986b) and Darrat (1990) investigate the causal impact of deficits on the short-term interest rate. Neither deficit measures nor the market value of debt are found to Granger-cause the short-term interest rate. By contrast, Hoelscher (1986) employs long-term interest rates, arguing that residential construction and

business plant and equipment spending, which are major components of private investment spending, are more sensitive to the long-term interest rate than to the short-term rate. An increase in deficits is found to raise the long-term interest rate. By contrast, Darrat (1989) provides no evidence that deficits have causal influence on the long-term interest rate.

In addition, Barro (1987) provides evidence that two episodes of high deficits in British history have no significant effect on interest rates, which is consistent with the Ricardian equivalence view. Similar results are obtained by Evans (1987b) for Canada, France, Germany, Japan, the United Kingdom, and the United States.

C.3. *Prices*

The standard view that government debt raises the price level is well-summarized in Beard and McMillin (1986). There are two channels through which government debt affects the price level or inflation. The first is the wealth effect channel discussed previously. The second channel is the monetization of debt. If deficits are financed by money creation, then the monetary base increases. The increase in the supply of money, in turn, raises the price level. However, the Ricardian equivalence hypothesis, which assumes neither the wealth effect of debt nor the monetization of debt, predicts that government debt does not affect the price

level or inflation.

The debt-monetization hypothesis has been extensively examined. The studies of Niskanen (1978), McMillin and Beard (1980), Hamburger and Zwick (1981), Levy (1981), McMillin (1981), Dewald (1982), Barth, Sickles, and Weist (1982), Allen and Smith (1983), Blinder (1983), Miller (1983), and McMillin (1986a) suggest that deficits are monetized. However, evidence on no monetization is found by Barro (1978b), Dwyer (1982), McMillin and Beard (1982), Joines (1985), King and Plosser (1985), and Barnhart and Darrat (1988).

In a carefully constructed paper, McMillin and Beard (1980) provide evidence that unborrowed reserves (and thus the money supply) are endogenous and that Federal Reserve responds substantially and positively to the state of fiscal policy (e.g., an increase in government spending and an exogenous tax cut). Hamburger and Zwick (1981) further examine the proposition that the growth rate of the nominal quantity of money increases when budget deficits increase. After appropriate changes (e.g., shortening the sample period), they also find a positive relationship between the growth rate of the money stock and the deficit. However, McMillin and Beard (1982) show that Hamburger and Zwick's results are sensitive to the averaging of the deficits. If the deficits are not averaged, no relationship is found between the money supply and the deficit. This implies that the deficit is not monetized and thus no effect on prices.

By employing a Sims-type VAR that consists of six variables, Dwyer (1982) finds unidirectional causality running from prices to debt, but not the reverse. This finding is thus consistent with the Ricardian equivalence view, in which debt is neither perceived as net wealth (the first channel) nor monetized (the second channel). Garrison (1984), however, finds that debt affects the price level by both channels, while King and Plosser (1985) provide evidence that debt is not monetized and has little effect on inflation. In addition, Barnhart and Darrat (1988) find for seven industrial countries that deficits are not monetized. Shim (1988), however, provides evidence for 13 industrial countries that debt affects the price level even if no evidence is found for debt monetization. Shim's result implies that debt affects the price level or inflation through the wealth effect channel for these countries.

C.4. *Output*

The output effect of the deficit is examined by Eisner and Pieper (1984). In their investigation, reduced-form output equations are estimated to measure the effect of high-employment federal surpluses on GNP. The measure of the high-employment federal surplus explains what the government budget surplus would be if the economy moved along the path of trend output rather than its actual output. Eisner and Pieper provide evidence for the U.S. economy that several different

measures of the high-employment federal surplus have negative effects on GNP. This suggests that output would rise if the high-employment budget were in deficit, which is consistent with the standard view.

Within a rational expectations framework, Koray and McMillin (1987) find that for the Canadian economy the output effect of privately held domestic debt is primarily due to unanticipated changes in debt growth, whereas anticipated changes in debt have no significant effect on output. The results are, in general, consistent with Ricardian equivalence. Similar findings are obtained by Koray and Hill (1988) for the postwar U.S. experience. Aschauer (1990) also fails to find a positive association between the deficit and output in single-equation output equations. He employs the high-employment budget deficit, and finds that the deficit has a negative effect on real output for the United States.

Furthermore, the effects of the deficit on macroeconomic variables (e.g., interest rates, prices, and output) are investigated in the literature by specifying vector autoregressions (VARs) as an approximation of small macro models. For the interwar period (July 1921-June 1938) which was characterized by both deficits and surpluses, McMillin and Beard (1988) use a measure of budget deficits and find that the effects of deficit are not important in affecting interest rates, prices, and output.

For the postwar period (1961:1-1984:4, quarterly) in

which persistent deficits were experienced, Fackler and McMillin (1989) split U.S. government debt into two series: U.S. debt held by domestic residents and U.S. debt held by foreigners. This consideration aimed to detect "separately" the opposite effects on interest rates that result from domestic and foreign holdings of debt. According to the standard view of fiscal policy, domestic holdings of debt raise interest rates due to the wealth effect of debt, while foreign holdings of debt mitigate the rise in interest rates because of capital inflows from abroad. Because of these two opposite effects, a total measure of domestic and foreign holdings of debt may not distinguish between these two effects even with the standard view. For this reason, the total debt was split into domestic and foreign holdings of debt. Fackler and McMillin, however, do not find a significant impact on macro variables of either type of debt. The results are generally consistent with the Ricardian view.

McMillin and Koray (1989) further examine the effect of debt for the Canadian economy within the context of an open economy. Because foreign shock variables are known to be important in constructing a small open economy, the U.S. money supply shock is included in the VAR model that tests for the validity of Ricardian equivalence in Canada. No significantly positive effects of debt are found for interest rates, prices, and output, which is also consistent with Ricardian equivalence.

C.5. *Real Exchange Rates*

The standard view suggests that the wealth effect of government debt induces private consumption to rise, and hence debt raises interest rates by stimulating aggregate demand. Under the assumption of perfect capital mobility, the high interest rate relative to the rest of the world strengthens the relative attractiveness of domestic assets. The capital inflows due to the high interest rate then create a surplus in the balance of payments. An appreciation of the home currency is necessary to create a trade deficit and hence to offset the balance-of-payments surplus. Therefore, the value of the domestic currency appreciates as the deficit rises (Feldstein 1986b). However, the Ricardian view predicts that government debt is not private sector wealth; hence, there is no effect on consumption or interest rates; and hence, the exchange rate is not affected by a substitution of debt for lump-sum taxes given a particular level of government spending (Evans 1986).

In addition, Frenkel and Razin (1987) introduce the change in the relative price of foreign and domestic goods as another possible channel of debt transmission to real exchange rates. For example, the wealth effect of debt stimulates private consumption of domestic goods, and thereby the domestic price level rises relative to the foreign price level. Because the real exchange rate is defined as the nominal exchange rate (the ratio of domestic to foreign currencies) multiplied by the relative prices (the ratio of

foreign to domestic prices), the fall in the relative prices "directly" leads to an appreciation of the real exchange rate. Contrary to this standard view, Ricardian equivalence predicts that the real exchange rate remains unchanged because debt has no effect on domestic prices and thereby the relative prices.

Feldstein (1986b) investigates the effect of deficits on the real exchange rate between the U.S. dollar and the German mark over the flexible exchange rate period (1973 through 1984). In single-equation models of exchange rate determination, Feldstein employs an expected U.S. budget deficit, which is an estimate of the five-year deficit forecast, because the level of real interest rates and the exchange rate are assumed to be influenced by the expected future deficit rather than current and past deficits. The rise in the expected future budget deficit is found to have a significant, positive effect on the real exchange rate. That is, the U.S. dollar appreciates as the government deficit rises.

Evans (1986), however, finds that a budget deficit does not lead to an appreciation of the U.S. dollar. Indeed, bilateral real exchange rates between the U.S. dollar and the currencies in several European countries depreciate as the deficit rises. This finding is further confirmed for the U.S.-Canadian exchange rate in McMillin and Koray (1990). As McMillin and Koray note, the depreciation of the exchange rate as a result of the budget deficit can be explained within the

Ricardian equivalence framework. For example, people may save more than the present value of the income streams associated with bonds issued to finance a deficit because their share of future taxes and the timing of these taxes are "uncertain" when the government deficit rises. If such is the case, interest rates are expected to fall because the supply of loanable funds increases, and thereby the exchange rate is expected to depreciate due to capital outflows in the home country, U.S.A.

D. Evidence on the Korean Economy

It is somewhat surprising that most empirical studies dealing with the Ricardian equivalence hypothesis have concentrated on industrialized economies. Few have been studied for a developing country, Korea. Evans (1988, 1990) formulates a simple neoclassical model of the Korean macroeconomy and investigates the role of fiscal policy in Korea. Both studies use a measure of the budget deficit over the sample period, 1953-1983 (annual). In a single-equation output equation, Evans (1988) finds that the deficit depresses output and, by conjecture, private consumption in Korea. Estimating an alternative specification of the model, Evans (1990) further provides evidence that the output effect of deficit is negative but insignificantly different from zero. Therefore, the results are, in general, consistent with the

Ricardian equivalence hypothesis.

However, whether the results are robust with respect to the following considerations is an open question. First, Ricardian equivalence suggests that macro variables other than output should also be unaffected if government debt is not perceived as household wealth. Thus, as discussed earlier, the effects of debt can be examined not just on output, but on interest rates, prices, and real exchange rates.

Second, as indicated by Eisner and Pieper (1984) and recently by Spiro (1990), using a flow concept of the budget deficit may be inappropriate in examining the link between government fiscal policy and economic activity. For example, Spiro argues that market prices are determined primarily by an interaction of the accumulated stock of a product and the consumers' willingness to hold this stock, not by a flow supply of and flow demand for new production. Analogously, to investigate the effect of budget deficits, an appropriate measure of the fiscal policy variable will be a stock concept of government debt rather than the flow of current deficits.

Third, a single reduced-form output equation may lead to misestimation of the impact of policy actions due to possible misspecification of the model (e.g., the right-hand-side variables may erroneously be treated as exogenous when they are in fact jointly determined). An alternative procedure is the reduced-form Sims (1980) VAR that does not impose the potentially incorrect a priori restrictions on exogeneity and

does not limit the channels through which a policy variable operates.

Finally, the possible role of foreign shock variables should be taken into account for a small open economy like Korea. Genberg, Salemi, and Swoboda (1987) have recognized the importance of foreign variables in constructing a model of the small open economy, and Lutkepohl (1982) has also stressed that misleading results may be obtained from VARs that omit relevant variables.

III. The Proposition of Macroeconomic Interdependence

During the 1950s, before capital mobility was introduced by the Mundell-Fleming model, a small open economy was characterized as an "insular economy." In such an economy, capital was assumed immobile internationally, nominal wages and prices were rigid, and expectations were ignored. In the insular economy, flexible exchange rates completely insulate the domestic economy from foreign shocks, whereas fixed rates allow foreign shocks to influence the domestic economy through the trade balance (see Marston 1985).

Theoretically, the insulation property under the flexible rate will be incomplete if some relevant assumptions are made. Because foreign shocks affect the domestic economy in so many ways, the insulation of the domestic economy from foreign disturbances is achieved only in special cases. Empirical

findings also indicate that foreign disturbances are internationally interdependent and are transmitted via several channels. Most empirical studies investigate the international transmission of foreign disturbances or the proposition of macroeconomic interdependence for developed countries, and few studies have focused on a developing country like Korea.

The purpose of this section is to examine both the theoretical and empirical literature on the proposition of macroeconomic interdependence. The theoretical literature is presented in subsection A, empirical findings are reviewed in subsection B, and finally, the existing evidence for the Korean economy is described and some possible directions for this research are further discussed in subsection C.

A. Theoretical Considerations of Macroeconomic Interdependence

A.1. *The Mundell-Fleming Model of the Small Open Economy*

Mundell (1963) and Fleming (1962) first introduced international capital mobility in open macroeconomic models, but the studies differ in one respect. Mundell assumes perfect capital mobility between domestic and foreign countries, while Fleming assumes imperfect capital mobility. Mundell (1963, p.475) assumes perfect capital mobility by stating that "a country cannot maintain an interest rate different from the general level prevailing abroad." In the

conventional IS-LM-BP analysis, perfect capital mobility represents a horizontal balance of payments (BP) curve at a given interest rate, while imperfect capital mobility implies an upward sloping BP curve. Together with the assumption of perfect or imperfect capital mobility, the Mundell-Fleming model has been widely used for policy analysis in open economy macroeconomics. It is for this reason that the international transmission of foreign monetary disturbances[5] is examined within that model for a small open economy.

For the case of the small open economy, a more general assumption would be imperfect capital mobility, where the BP curve is positively sloped. In this case, the rate of capital flows increases, but it remains finite, as international interest differentials increase. We further assume that the interest sensitivity of capital flows is low relative to the interest sensitivity of money demand. Hence, the positive BP curve is steeper than the LM curve.[6] In addition, the country under consideration is assumed too small to influence foreign output or the world level of interest rates.

Suppose the money supply increases in a foreign country. The increase in the foreign money supply, ceteris paribus, causes the exchange rate defined as the ratio of domestic to foreign currencies to fall, and thus it leads to an appreciation in the home currency relative to the rest of the world. The appreciation of the domestic currency, in turn, lowers exports and raises imports, and thereby shifts the IS

curve downward to the left, from IS_0 to IS_1. This movement is illustrated in Figures 2.1 and 2.2 for flexible and fixed exchange rates, respectively. Domestic output initially falls, and so does the interest rate. The BP curve also shifts upward to the left, from BP_0 to BP_1, because, to achieve a balance of payments equilibrium, a higher interest rate is required to induce capital inflows, and a lower level of income is also required to reduce imports. Because the new internal equilibrium point B is below the new BP schedule, an incipient balance-of-payments deficit occurs.[7]

Under the flexible exchange rate regime, the deficit in the balance of payments will cause the exchange rate to rise. The reason is that the initial decrease in domestic interest rates mitigates the attractiveness of domestic assets relative to the rest of the world, and thus domestic investors will move away from domestic assets and toward foreign assets. The excess demand for foreign exchange will cause the exchange rate to rise. The increase in the exchange rate (i.e., a depreciation of the home currency) will raise exports and lower imports, and thus it will offset the incipient balance-of-payments deficit. In Figure 2.1, the increase in exports due to a depreciation of the home currency shifts both IS_1 and BP_1 curves back to the initial levels, IS_0 and BP_0, respectively. Consequently, the flexible exchange rate completely insulates the domestic economy from foreign shocks.

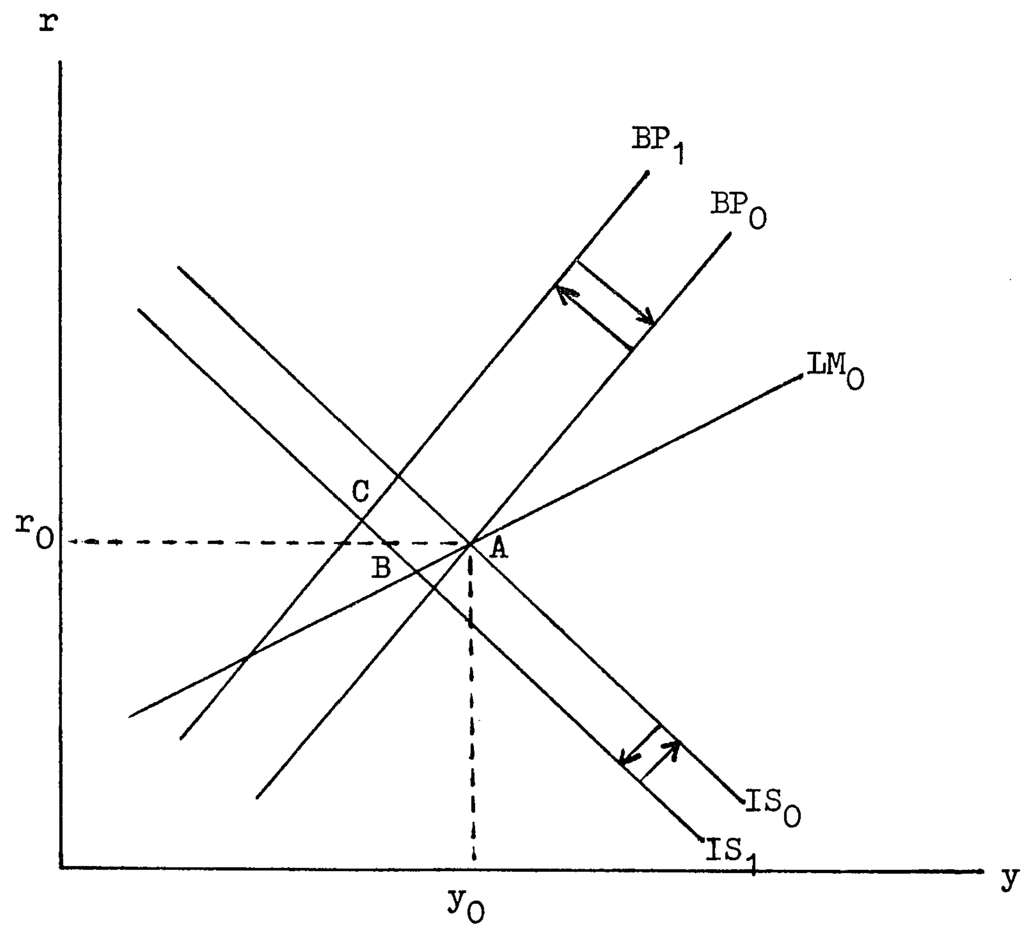


Figure 2.1. The Effect of an Increase in Foreign Money Supply on the Domestic Economy under Flexible Exchange Rates--Small Open Economy

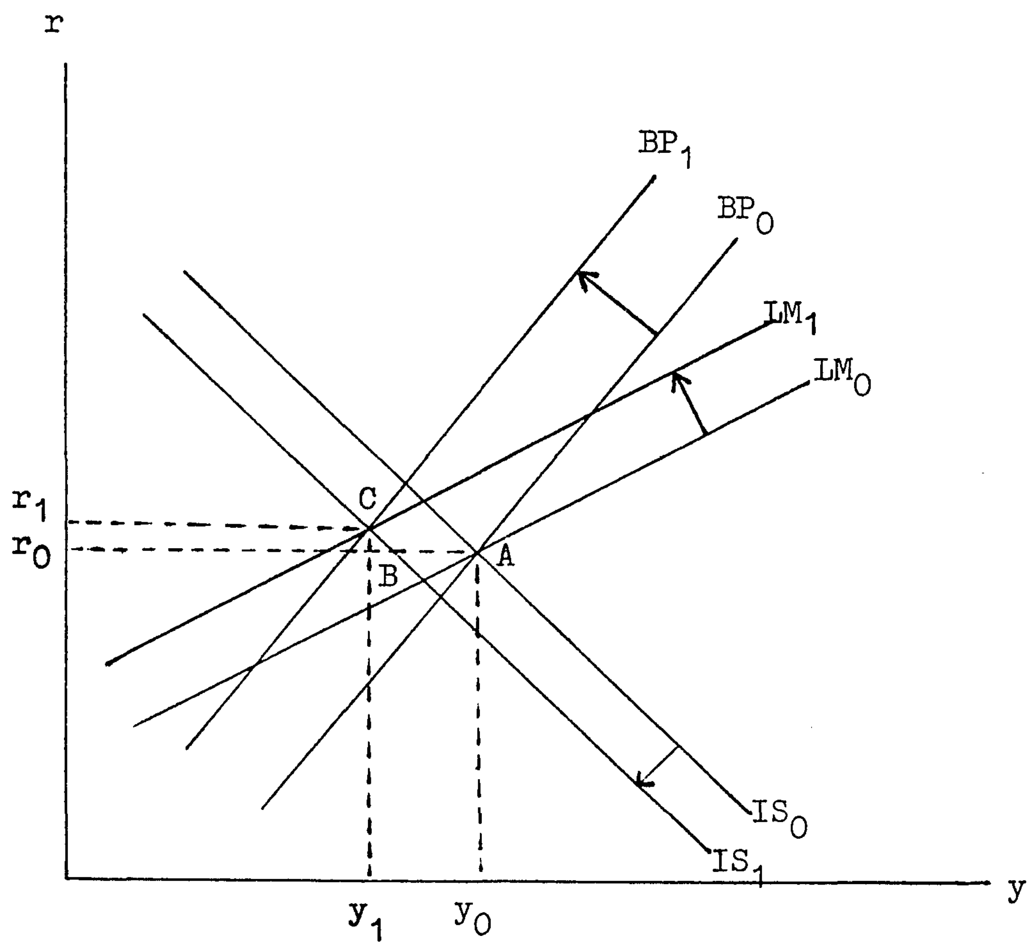


Figure 2.2. The Effect of an Increase in Foreign Money Supply on the Domestic Economy under Fixed Exchange Rates--Small Open Economy

Under the fixed exchange rate regime, the initial shifts of the IS and BP curves are the same as in the case of flexible rates. This is illustrated in Figure 2.2.[8] Under the fixed rate, monetary authorities intervene in the foreign exchange market by buying or selling foreign reserves to prevent the exchange rate from fluctuating. Because the exchange rate rises due to capital outflows (with an initial decrease in interest rates), monetary authorities prevent the exchange rate from rising by selling foreign reserves at the exchange rate parity. Thus, the money supply that includes domestic currency plus foreign reserves falls. The LM curve shifts upward to the left. This process continues until the balance-of-payments equilibrium is restored at point C. Thus, the LM curve shifts to LM_1. Consequently, domestic output falls, but the changes in the interest rate depend on the magnitude of the BP shift. Therefore, it can be concluded that the fixed exchange rate allows the domestic economy to be affected by foreign shocks, while the flexible exchange rate completely insulates the domestic economy from foreign disturbances.

A.2. *Rational Expectations Model*

In the Mundell-Fleming model discussed above, expectations were assumed to be fixed, and thus economic agents were assumed not to expect any exchange rate changes in the future. This assumption would be appropriate with a fixed

exchange rate, but not with a flexible rate. Therefore, recent developments in international policy analysis have introduced rational expectations (RE) into open economy macro models. Saidi (1980), Cox (1980), and Flood and Marion (1982) introduce the assumption of rational expectations in a small open economy, and Kimbrough and Koray (1984), Frenkel and Razin (1986a, 1986b, 1987), and Koray (1987) in a large open economy.

Saidi (1980) develops a small open economy RE model and examines the insulation property of flexible exchange rates. The model with "full current information" assumes that economic agents expect correctly the future level of world prices in a rational manner. The full current information model predicts that the insulation property of the flexible rate holds only if permanent movements in the world price level are fully perceived. However, domestic output is found to fluctuate with temporary movements in the world price level. His "incomplete current information" model, which assumes that economic agents do not have complete current information about future price changes, also predicts that the domestic economy is internationally interdependent with external disturbances. The international interdependence is also investigated by Cox (1980) under alternative exchange rate regimes. He finds that the degree of international transmission is greater with flexible exchange rates than with fixed rates. Managed-floating exchange rates are suggested to

insulate the domestic economy fully from foreign shocks. In a stochastic macroeconomic model for a small open economy, Flood and Marion (1982) also find that fixed exchange rates completely insulate the domestic economy, but conclude that the complete insulation is not necessarily a desirable policy goal because social welfare falls.

Kimbrough and Koray (1984) develop a large open economy RE model (so-called RE equilibrium model). Kimbrough and Koray use a full current information model within a rational expectations framework and examine the effects of foreign monetary disturbances on the domestic economy under flexible exchange rates. The results of the RE equilibrium model suggest that perceived changes in foreign money growth do not influence domestic output; only an unperceived increase in the foreign money growth raises domestic output.

In contrast to the international transmission of monetary disturbances, Frenkel and Razin (1986a, 1986b, 1987) investigate the international transmission of fiscal policies. Developing two-country general equilibrium models of the world economy, Frenkel and Razin analyze the effects of domestic budget deficits and government spending on foreign consumption and real exchange rates, operating through the wealth effect. If domestic deficits do not raise domestic wealth (i.e., Ricardian equivalence holds), foreign wealth will be unaffected. However, if Ricardian equivalence does not hold, domestic deficits are predicted to lower foreign wealth, and

thereby foreign consumption falls and real exchange rates depreciate. Thus, the deficits are transmitted "negatively" to foreign countries. The model also shows that a transitory rise in government spending lowers both domestic and foreign wealth, and hence private consumption falls at home and abroad. Koray (1987) incorporates rational expectations into a two-country equilibrium model, and finds that anticipated changes in foreign government debt do not affect domestic output and trade balance (i.e., Ricardian equivalence holds). Only unanticipated increases in foreign government debt are transmitted "positively" to domestic output and the trade balance of a home country.

B. Empirical Findings on Macroeconomic Interdependence

The preceding discussion suggests that the extent of insulation from foreign disturbances has been inconclusive in the theoretical literature, depending on the assumptions made. When rational expectations were introduced into open economy macro models, for example, the insulation property appeared to be irrelevant. For this reason, it is especially important to examine empirical evidence on the proposition of macroeconomic interdependence. Although other classifications are quite possible, the existing literature is classified here in two categories: structural and reduced-form models and a vector autoregressions (VAR) technique.

B.1. *Structural and Reduced-Form Models*

Darby (1983) estimates a large-scale structural model and provides simulation results that the international transmission of U.S. monetary and fiscal policy shocks is trivial for other industrial countries even under fixed exchange rates. This is a "surprising" result and is not consistent with the Mundell-Fleming model in which the fixed rate allows the domestic economy to be policy-interdependent with foreign shocks.

A number of authors estimate single-equation models to measure the effects of foreign disturbances on the domestic economy. Laskar (1983), for example, examines the degree of the short-run independence of monetary policy under fixed rates (1957-1971). He estimates several different models (e.g., structural, reduced form, and reaction function models) for seven industrial countries and finds that a high degree of monetary policy independence appears to be relevant even under fixed exchange rates. Batten and Ott (1985) estimate a dynamic reduced form model of the money growth rate under flexible exchange rates (1974-1982). The results are mixed. For Switzerland, Italy, and France, flexible exchange rates are found to insulate domestic economies from the influence of U.S. money growth, while the money growth rate for the rest of the industrial countries in their sample appears to be significantly affected by U.S. money growth.

Darby and Lothian (1989) also find that flexible rates

allow the domestic economy to be policy interdependent for most countries in the short run. Using a cross-sectional approach, Darby and Lothian find that both flexible and fixed exchange rates insulate the domestic economy from foreign shocks in the long run, and that the long-run independence of monetary policy is greater under flexible rates than under fixed rates. Burdekin (1989), however, finds that over the sample period 1962-1985 (for both fixed and flexible rates), the impact of the U.S. monetary and fiscal policy shocks as well as the transmission of U.S. inflation appear to be significant across the four European countries, comprising France, Italy, the United Kingdom, and Germany.

Kimbrough and Koray (1984) and Koray (1987) use open-economy rational expectations models to estimate the international transmission of foreign policy shocks. Kimbrough and Koray find that unanticipated changes in U.S. money growth have negative effects on Canadian output (though this is "puzzling" given the predictions in their theoretical model), and have positive effects on the trade balance in Canada. For the U.S. economy, Koray finds that unanticipated changes in Canadian government debt have not only positive effects on the U.S. output but improves the trade balance in the United States. The results in both studies are generally consistent with the proposition of macroeconomic interdependence under fixed and flexible exchange rate regimes.

B.2. *Vector Autoregressions Technique*

Recent studies that include Burbidge and Harrison (1985b), Genberg, Salemi, and Swoboda (1987), Kuszczak and Murray (1987), and Lastrapes and Koray (1990) suggest that the VAR technique is well-suited for the analysis of macroeconomic interdependence between countries. The standard VAR, originally proposed by Sims (1980), is an unconstrained reduced-form model and does not impose either cross-equation restrictions or potentially spurious a priori constraints on the exogeneity of variables. To examine the effects of foreign shocks or the transmission channels of foreign disturbances, variance decompositions (VDCs) and impulse response functions (IRFs) can be estimated. If the VDCs, for example, indicate that the forecast error variance of domestic variables is significantly accounted for by foreign shocks, this can be interpreted as the existence of international transmission between countries. In addition, the IRFs indicate the expected paths of domestic variables in response to foreign disturbances, and thereby transmission channels can also be investigated.[9]

Burbidge and Harrison (1985b) estimate a nine-variable VAR (4 Canadian and 4 U.S. variables in addition to a spot exchange rate) and provide evidence of macroeconomic interdependence between Canada and the United States. Genberg, Salemi, and Swoboda (1987) apply a modified Sims VAR to the Swiss economy. They estimate a seven-variable VAR (4

domestic and 3 foreign variables) and find that foreign disturbances affect Swiss variables dominantly during the entire sample period (for both fixed and flexible rates). Furthermore, the flexible exchange rate is also found not to insulate the Swiss economy from foreign shocks.

More recently, Lastrapes and Koray (1990) distinguish the short-run and long-run properties of international transmission by using, respectively, the VAR technique and the cointegration test. The concept of cointegration first introduced by Granger (1981) is a statistical counterpart to the concept of equilibrium between variables in economic theory. For example, if two variables are in equilibrium, a linear combination of the two series should have a fixed distribution that does not change over time. Using the standard Engle-Granger cointegration test (a time trend is included), Lastrapes and Koray (1990) provide evidence of no long-run relationships between domestic and foreign variables. However, in the short run, the degree of macroeconomic interdependence found by estimating variance decompositions differs over alternative exchange rate regimes and across three European countries. Thus, they conclude that structural modeling for a small open economy cannot be generalized but should be based upon its own institutional characteristics, since the degree of insulation and macroeconomic interdependence is different over the short and long runs, over different exchange rate regimes, and across countries.

C. Evidence on the Korean Economy

Most empirical studies provide strong evidence for industrial countries that one country's shocks are internationally transmitted to another via several channels. In one of the few papers that investigates the macroeconomic interdependence of developing economies, Kim (1987) estimated a small-size structural model for the Korean economy over the sample period 1973:1-1983:4 (quarterly), and provided some simulation results that U.S. monetary and fiscal policies significantly influenced the Korean economy. In particular, U.S. fiscal policy leads to a depreciation of the Korean-U.S. exchange rate and causes Korean output and prices to rise. On the other hand, U.S. monetary policy is found to transmit negatively to the Korean macroeconomy, e.g., Korean output and prices fall with an appreciation of the exchange rate due to the U.S. monetary shocks.

Although the simulation experiment may help us to understand how the world would operate for a given specification of the structural relations, the robustness of the results is an open question with respect to the methodology he used as well as the external shock variables on which he focused.

First, a worrisome aspect of the structural model approach is that it may misestimate the impact of policy actions due to a possible misspecification of the structural

relations. An alternative procedure is the reduced-form VAR that does not limit the channels through which a policy variable operates. In this regard, the VAR technique seems appropriate to evaluate the macroeconomic interdependence of the Korean economy.

Second, contrary to the previous work--which focused on U.S. monetary and fiscal policy shocks to the Korean economy--this study will employ external output and price shocks that are linear combinations of the corresponding U.S. and Japanese variables. This consideration is attributable mainly to the fact that the Korean economy is heavily dependent on foreign trade and that the U.S. and Japan are the two major trading partners in Korea.

IV. Summary and Conclusion

We now summarize the two important issues discussed in this chapter. First, in contrast to the conventional view of fiscal policy, the Ricardian equivalence hypothesis predicts that debt is not wealth and a substitution of debt for lump-sum tax financing of a given level of government spending has no independent effect on consumer expenditures. However, the assumptions underlying the Ricardian equivalence hypothesis have been questioned by a number of authors; if the restrictive assumptions were violated, Ricardian equivalence would not hold. Thus, no clear role for government debt

emerges from the theoretical literature. Furthermore, a substantial amount of empirical literature on Ricardian equivalence has not resolved the macroeconomic role of government debt. The empirical findings are, in general, sensitive to the measurement of a deficit variable, the specification of model variables in levels or in differences, and the sample periods used.

The second important issue is the degree to which the domestic economy is insulated from foreign disturbances. There is no theoretical consensus on this issue. For example, the insulation property appears to be irrelevant when rational expectations are introduced into open economy macro models. Because foreign shocks affect the domestic economy in so many ways, insulation is achieved only in special cases. Empirical findings also indicate that foreign disturbances are, in most cases, internationally interdependent and are transmitted via several channels.

For these two issues, Evans (1988, 1990) and Kim (1987), respectively, provided evidence for the Korean economy which was consistent with the Ricardian equivalence hypothesis and the proposition of macroeconomic interdependence. Over the sample period, 1953-1983, Evans found that a deficit depressed output and, by conjecture, private consumption in Korea. Kim estimated a small-size structural model, and provided evidence that transmission of U.S. monetary and fiscal policy shocks was significant for the Korean economy during the sample

period 1973:1-1983:4. However, whether the results of Evans (1988, 1990) and Kim (1987) are robust with respect to the methodology and sample periods they used and with respect to the measurement of relevant variables on which they focused remains an open question.

Endnotes

1. Barro (1988) discusses the Ricardian equivalence hypothesis within the context of a market-clearing approach, in which intertemporal budget constraints that face households and the government are introduced; Froyen (1990) elaborates on the hypothesis in the framework of a loanable funds market; and Fields and Hart (1990) discuss it within the IS-LM model.

2. If the exact assumption is violated, the two financing decisions will not have identical effects and hence Ricardian equivalence will not be supported. More general cases are provided in the following. Totally differentiating equation (2.1) yields

$$dy = (\partial c/\partial y_d)dy - (\partial c/\partial y_d)dt^* + dg,$$

where $t^* = t + \Delta B(1+r)\delta/rP$. Rearranging the equation, we obtain

$$[1 - (\partial c/\partial y_d)]dy = dg - (\partial c/\partial y_d)dt^*.$$

Thus,

$$dy/dg = [1 - mpc\ (dt^*/dg)] / (1 - mpc),$$

where $mpc = \partial c/\partial y_d$. The size of dy/dg depends on the term, dt^*/dg, where tax burden (t^*) consists of current taxes and implied future taxes. The case of a balanced-budget change in g (i.e., $dt^*/dg = 1$) implies that $dy/dg = 1$.

However, if deficits are financed by bonds, dt^*/dg will depend on degrees of tax discounting. For example, *strict* Ricardians (i.e., $\delta = 1$) are assumed to discount future tax liabilities of debt exactly the same as current tax increases. Then, $dt^*/dg = 1$, and hence $dy/dg = 1$. Therefore, the effects on y due to changes in g are identical in either tax financing or bond financing of g. However, if individuals are *uncertain* of their share of future taxes and the timing of these taxes, as noted by Kormendi (1983), people may discount future tax liabilities of debt extremely high (i.e., $\delta > 1$). In this case, $dt^*/dg > 1$, and hence $dy/dg < 1$. Therefore, the two deficit-financing decisions make the corresponding output effects different. Another possibility arises from the fact that dt^*/dg can be less than one and greater than zero if future tax liabilities are *partially* perceived (i.e., $0<\delta<1$). Then, $dy/dg > 1$. Thus, the effects on y due to changes in g are also different in tax financing and bond financing of g. This makes the IS curve in Fields and Hart (1990) a special case.

3. As noted by Barro (1989), the non-neutral results are also inconsistent with the standard Keynesian view, in which

a reduction of tax rates will induce people to consume more and save less, and hence interest rates rise. This is in contradiction with Barro's (1989) observation that interest rates fall if tax rates are reduced (i.e., a positive correlation between tax cuts and interest rates).

4. There exist several methods of constructing the market value of debt in the literature (see, for example, Seater 1981; Butkiewicz 1983; Cox and Hirschorn 1983; Eisner and Pieper 1984; Cox 1985; and Cox and Haslag 1986).

5. Other foreign disturbances (e.g., foreign output and price shocks) will be discussed in detail in chapter 4.

6. As Branson (1979, p.332) notes, the BP schedule is empirically found to be steeper than the LM schedule for the U.S. economy. Because the interest sensitivity of capital flows is found to be relatively low for the U.S. economy, the assumption of the less responsive capital flows is not unreasonable for a small open economy like Korea. Froyen (1990, p. 640), however, employs a flatter BP curve, assuming a higher interest sensitivity of capital flows than that of money demand. But the results are unaffected.

7. As is well known, the Mundell-Fleming model is a fixed-price version of the Keynesian model. Thus, we do not include changes in the price level, for simplicity.

8. In Figure 2.2, the shift from BP_0 to BP_1 is due to a fall in exogenous export demand resulting from a foreign money supply shock. If there were no external shocks, the BP curve would not shift with the fixed exchange rate because exchange rates remain fixed and hence no balance-of-payments deficits or surpluses occur.

9. More details on the VAR methodology are provided in chapter 3.

CHAPTER 3

VAR METHODOLOGY

I. Introduction

A vector autoregression (VAR) approach, originally proposed by Sims (1980), has been widely used for policy analysis as well as forecasting. The standard Sims VAR is a system of dynamic linear equations in which each variable is regressed on a vector of past values of all the variables in the system and the number of lags are identical for all variables. The dynamic relationships of the variables are frequently characterized by computing variance decompositions, impulse response functions, and cumulative impulse response functions. The following four considerations led to the selection of the VAR approach for this study.

First, the standard Sims VAR, a reduced-form approach, avoids imposing potentially inappropriate a priori restrictions such as the assumption that a policy variable is exogenous, as is often done in a traditional structural model approach. Sims argued that virtually all variables could be jointly determined within a dynamic macroeconomic framework. Hence, the VAR model has been proposed as an alternative dynamic specification in which all variables are treated as

endogenous and no contemporaneous variables enter the right-hand-side of the model. Although the model variables can be selected by using economic theory, no restrictions are imposed on how these variables interact. Therefore, the VAR approach is, in general, less restrictive than the traditional approach.

Second, Sims also contended that the VAR approach could avoid potentially spurious identifying restrictions on the lag structure of a dynamic macro model. As is well known, the traditional approach arbitrarily and hence incorrectly excludes lags of other endogenous variables, and the exclusion of relevant lags may lead parameter estimators to be biased. Since economic theory that is often used for constructing structural econometric models is not very explicit about the lags in time series relationships, atheoretical statistical methods that allow the data themselves to select appropriate lag lengths seem adequate in selecting the VAR order.

Third, as indicated by Sims, the VAR approach is appropriate in testing economically meaningful hypotheses. Although the estimated coefficients are difficult to interpret in terms of a structural model, the relative importance of one variable to another can be determined by estimating variance decompositions (VDCs), impulse response functions (IRFs), and cumulative impulse response functions (CIRFs). The VDCs, IRFs, and CIRFs are based on the moving average representation of the VAR system, which shows how the system variables

respond to shocks to a particular innovation. Furthermore, transmission channels through which one variable influences the other can also be examined by using the VAR techniques.

Fourth, the VAR approach is broadly consistent with a variety of structural models since it is a reduced-form approach. Keynesians and monetarists, for example, use different structural models in accordance with their own views of the true structure of the economy. However, users of VARs typically estimate atheoretical models without imposing theoretical restrictions on the residuals of the VAR, and examine the dynamic characteristics of the model by calculating VDCs, IRFs, and CIRFs. It therefore serves as a general model such that analysts who have different views of the true structure of the economy can use the same VAR model.

The drawback, of course, is that it is difficult to distinguish sharply among different structural models, since the VAR technique is a reduced-form approach. Cooley and LeRoy (1985) and Leamer (1985) have pointed out this limitation of the VAR approach.

In the next section a VAR process with k variables will be specified and some of its properties will be discussed. In section III, stationarity of time series are discussed prior to considering some model specification and estimation issues that are presented in section IV. In section V, the moving average representation of the VAR process will be illustrated within a simple two-variable VAR model, and variance

decompositions, impulse responses, and cumulative impulse responses will then be discussed. Finally, section VI concludes with a brief summary of the VAR methodology discussed in this chapter.

II. Vector Autoregressive Process

A vector autoregressive process of order p, VAR(p), for a system of k variables can be defined as

$$X_t = A + B_1 X_{t-1} + \dots + B_p X_{t-p} + u_t. \tag{3.1}$$

In this system of k equations, X_t is a k x 1 vector of variables, that is, $X_t = (X_{1t}, \dots, X_{kt})'$. Thus, a sample of T observations for each of the variables consists of k time series. A is a k x 1 vector of constants; B_n, n=1, ... ,p, are k x k coefficient matrices; and p is the lag length. Thus, the number of parameters in each equation is kp + 1. The k x 1 vector of residuals, u_t, is a white noise process. That is, the u_t have mean zero, $E(u_t) = 0$, the same nonsingular covariance matrix $E(u_t u_t') = \Sigma_u$ for all t, and u_t and u_s are uncorrelated (or independent) for $t \neq s$.

Alternatively, the VAR process in equation (3.1) can be written in a stacked form as

$$X_t = A + B(L)\ X_t + u_t, \tag{3.2}$$

where B(L) represents a k x k matrix of polynomials in the lag operator L. That is,

$$B(L) = \begin{bmatrix} B_{11}(L) & . & . & . & B_{1k}(L) \\ . & & . & & . \\ . & & & . & . \\ . & & & . & . \\ B_{k1}(L) & . & . & . & B_{kk}(L) \end{bmatrix},$$

where $B_{ij}(L) = \sum_{n=1}^{p} b_{ij,n} L^n$ for i, j = 1, ..., k. The element $b_{ij,n}$ represents the coefficient on n th lag of the j th variable in equation i. As noted earlier, the standard Sims VAR is an unrestricted reduced-form approach and has a common lag length for each variable in each equation. That is, no restrictions are imposed on coefficient matrices to be null, and the same lag length is used for all variables. Choice of the VAR order p will be discussed in detail in section IV.A.

As noted by Judge et al. (1988), we may estimate each equation of the VAR system separately by least squares as long as regressors are identical in all equations of the system. To see the properties of this OLS estimator, we assume additionally that the residuals u_t have a multivariate normal distribution $N(0, \Sigma_u)$. It can be shown that the OLS estimator converges to the true value of the coefficient b. Thus, the OLS estimator is consistent. Furthermore, since the residuals u_t are assumed to be normally distributed, the OLS estimator is asymptotically equivalent to the maximum likelihood

estimator which is asymptotically efficient. Therefore, without loss of estimation efficiency, the system of equations can be estimated on an equation-by-equation basis by least squares.

Before considering the estimation of the VAR model, the following section discusses stationarity of a vector stochastic process. Stationarity is important in specifying and estimating the VAR model, and data transformations are often necessary to ensure stationarity.

III. Stationarity of Time Series

A vector stochastic process is called "stationary" if all random vectors have the same mean vector, constant variances, and the same autocovariance matrices through time. More formally, Judge et al. (1985) state that a vector stochastic process X_t is stationary if

(a) $E[X_t] = u$ for all t,

(b) $E[(X_t - u)(X_t - u)'] = \Sigma_X < \infty$ for all t,

(c) $E[(X_t - u)(X_{t+h} - u)'] = \Gamma_X(h)$ for all t and h.

The first and second conditions imply, respectively, that all random vectors have the same mean vector u and finite variance-covariance matrices Σ_X for all t. The third condition implies that the covariance matrices between vectors

X_t and X_{t+h} (i.e., autocovariance matrices $\Gamma_X(h)$) do not depend on a particular time point t but only on h. That is, if h = 0, the covariance matrices are the same for all t.

For practical purposes, as Judge et al. (1988) note, the time series used for the VAR model will be stationary if they have no time trends, no fixed seasonal patterns, or no time-varying variances. Nelson and Plosser (1982) further indicate that if the series are "trend-stationary," use of levels with inclusion of a time trend will meet stationarity; if the series are "difference-stationary," differencing often converts the process to a stationary one. Because choice of a wrong transformation or failure to account for nonstationarities has far-reaching consequences in interpreting the VAR model, the stationarity of the series used in this dissertation is investigated by employing the unit root test developed by Fuller(1976) and Dickey and Fuller (1979).

A. Augmented Dickey-Fuller Unit Root Test

A number of authors have applied the Dickey-Fuller unit root test to evaluate whether a set of variables are stationary. Nelson and Plosser (1982) found that many macroeconomic time series contain first-order unit roots, so that the series follow difference stationary rather than trend stationary processes. As a result, first differencing is suggested to achieve stationarity. Using varying methods,

Schwert (1987), Wasserfallen (1988), and Kormendi and Meguire (1990b) reached similar conclusions.

For the augmented Dickey-Fuller unit root test, each variable is regressed on a constant, a linear deterministic time trend, a lagged dependent variable, and q lags of first differences:

$$(3.3) \qquad X_{1t} = a + b\ \text{TIME} + \text{rho}\ X_{1,t-1} + d_1\ (X_{1,t-1} - X_{1,t-2}) + \ldots + d_q\ (X_{1,t-q} - X_{1,t-q-1}) + u_t,$$

where X_{1t} is the level of the variable under consideration. Several first-difference terms are included to reduce serial correlation of residuals, and the lag length of q can be determined as suggested by Schwert (1987): for monthly data, q = integer value of $12 * (T/100)^{1/4}$ where T is the number of observations.

The null hypothesis in this test is that the autoregressive process contains one unit root, i.e., H_0: rho=1. The null hypothesis of one unit root is tested against the stationary alternative. Test statistics can be calculated by subtracting one from the estimated coefficient and dividing this by the estimated standard error of the coefficient. Since the distribution of test statistics is skewed to the left relative to the student-t distribution, Fuller (1976) used Monte Carlo experiments to tabulate the sampling distribution of the test statistics. While Fuller's Table

8.5.2 is sufficient for most uses, a recent study by Guilkey and Schmidt (1989) provides a more detailed table with extended sample sizes and critical levels. If the null hypothesis of a unit root cannot be rejected at a significance level, the series considered is more properly characterized as a difference stationary, rather than a trend stationary, process, and this series should be differenced prior to inclusion in the VAR model.

B. Engle-Granger Cointegration Test

Suppose that the augmented Dickey-Fuller tests indicate that all variables in the model contain first-order unit roots and hence should be first-differenced. This will, however, not be appropriate if the variables are cointegrated. The concept of cointegration introduced by Granger (1981) is a statistical counterpart to the concept of equilibrium between variables in economic theory. For example, if two variables are in equilibrium according to economic theory, a linear combination of the two series should be statistically stationary. That is, the amount by which actual observations deviate from this postulated equilibrium has a fixed distribution that does not change over time.

For data transformation of the VAR model, Engle and Granger (1987) state that nonstationary individual series can be cointegrated (or stationary) if the nonstationary individual series are combined together. In such a case, the

VAR formulation in differences may cause model misspecification because a linear combination of nonstationary individual series may itself be stationary in levels.

Following Engle and Yoo (1987), the standard cointegration test is performed by regressing the following two equations separately,

$$(3.4) \qquad \begin{aligned} X_{1t} &= b_1 + b_2 X_{2t} + b_3 X_{3t} + \ldots + b_k X_{kt} + u_t \\ u_t &= rho\ u_{t-1} + d_1(u_{t-1} - u_{t-2}) + \ldots \\ &\qquad + d_q(u_{t-q} - u_{t-q-1}) + v_t, \end{aligned}$$

where X_{it}, i=1, ... ,k, are the levels of the variables in the system, and u_t and v_t are disturbance terms. The same lag length, q, is used as in the unit root test.

The standard cointegration test is a two-step procedure. First, the so-called cointegrating regression uses all variables of the VAR system. As indicated by Engle and Granger (1987), least squares provide a consistent estimator of the b coefficients. At the second stage, an augmented Dickey-Fuller test is performed using the residuals of the cointegrating regression. The second step is similar to the unit root test discussed above, but differs in two respects: (a) the cointegration test uses the residuals from the cointegrating regression to test for the presence of unit roots, and (b) the unit root regression excludes an intercept and a time trend.

The null hypothesis of no cointegration (H_0: rho=1) states that a linear combination of the variables contains unit roots, that is, nonstationary. The null is tested against the stationary alternative that the variables are cointegrated. Test statistics are calculated in a similar fashion to the ones for the unit root test. The critical values for the cointegration test are provided by Engle and Yoo (1987), but their tables are limited with respect to the number of variables. For a large system of variables, Boschen and Mills' (1989) extended tables can be used. If the null hypothesis of no cointegration cannot be rejected at an acceptable significance level, the VAR formulation in differences is appropriate.[1]

C. <u>Hansen-type Cointegration Test</u>

Recently, Hansen (1990) contended that the OLS residual-based approach of Engle and Granger (1987) depends upon the number of variables in the system, and thus it has low power against reasonable alternatives as the size of the system increases. In particular, the b coefficients of the OLS estimation stay random in the limit, but do not converge to constants. The unit root test-statistics constructed from the OLS residuals therefore depend on these random elements, which varies with the number of variables in the system.

An alternative GLS approach, which uses a Cochrane-Orcutt procedure, has been proposed to avoid this problem. The model

for the Hansen-type cointegration test is specified as

$$
\begin{aligned}
(3.5) \qquad X_{1t} &= b_1 + b_2 X_{2t} + b_3 X_{3t} + \ldots + b_k X_{kt} + u_t \\
u^*_t &= \text{rho } u^*_{t-1} + d_1 (u^*_{t-1} - u^*_{t-2}) + \ldots \\
&\qquad + d_q (u^*_{t-q} - u^*_{t-q-1}) + v_t,
\end{aligned}
$$

where X_{it}, $i = 1, \ldots, k$, are detrended and demeaned residuals. Although detrending and demeaning of each series are optional, detrending is allowed because the series may have time trends, and demeaning is allowed because the cointegrating relationship may contain intercepts.

Next, the cointegrating regression, which uses the detrended and demeaned residuals, is estimated by using the Cochrane-Orcutt procedure. That is, the first equation in (3.5) is estimated as

$$(X_{1t}-\rho X_{1,t-1}) = b_1 + b_2(X_{2t}-\rho X_{2,t-1}) + \ldots + b_k(X_{kt}-\rho X_{k,t-1}) + u_t,$$

where ρ = first-order autocorrelation coefficient. Then, the estimated coefficients, b_i, are used to compute u^*_t for the unit root regression (the second equation in (3.5)). That is, $u^*_t = X_{1t}$ - fitted X_{1t}, where the fitted value of X_{1t} is the product of the parameter estimators obtained from the Cochrane-Orcutt procedure times the values of the right-hand-side variables in the cointegrating regression. More formally,

$$u^*_t = X_{1t} - (b_1 + b_2 X_{2t} + \ldots + b_k X_{kt}),$$

where b_i, i=1,...,k, are the parameter estimators obtained from the Cochrane-Orcutt procedure. Note that u^*_t is not equal to the residual u_t of the cointegrating regression, because

$$u_t = X_{1t} - (b_1 + b_2 X_{2t} + \ldots + b_k X_{kt})$$
$$- \rho\ (X_{1,t-1} - b_2 X_{2,t-1} - \ldots - b_k X_{k,t-1})$$

$$= u^*_t - \rho\ (X_{1,t-1} - b_2 X_{2,t-1} - \ldots - b_k X_{k,t-1}).$$

Finally, the computed u^*_t is regressed by OLS to test for the presence of a unit root as in the augmented Dickey-Fuller test. The same lag length, q, is used as in the standard cointegration test.

The null hypothesis of no cointegration (H_0: rho=1) is tested against the alternative that a linear combination of the variables are cointegrated. Test statistics are computed in a similar fashion to the ones for the standard cointegration test. However, the critical values to be used are the same as in the unit root test, because the estimated test statistics are known to be distributed identically to the ones for the univariate Dickey-Fuller test. Hence, as noted earlier, the merit of this approach is that it avoids the problem of the OLS residual-based approach in which the power of the test depends on the number of the variables in the

system. Again, if the null hypothesis of no cointegration cannot be rejected at an acceptable significance level, the VAR formulation in differences is appropriate.

IV. Model Specification and Estimation Issues

In this section, we consider some other important issues on the specification and estimation of the VAR model. Three issues are addressed: (a) determination of order p of the VAR, (b) dealing with contemporaneous correlation of VAR residuals, and (c) robustness of innovation accounting results to the ordering of variables.

A. Selection of VAR Order

The selection of appropriate lag lengths is an important issue for VAR specification. As Thornton and Batten (1985) indicate, if the model excludes relevant lags, the parameter estimators will be biased; if the model includes irrelevant lags, the parameter estimators will be unbiased but inefficient; and if both are the case, the parameter estimators will be biased and may be inefficient. As a result, estimation results may be distorted due to a faulty selection of lags.

Because economic theory is often not very explicit about the lags in time series relationships, atheoretical statistical methods that allow data themselves to select

appropriate lag lengths are often used in the literature. One of the statistical methods is Akaike information criterion (AIC). Following Lutkepohl (1982), the AIC criterion will be used to select the VAR order, and the order p is chosen that minimizes

$$(3.6) \qquad AIC(p) = \ln \det(\Sigma_p) + 2k^2 p / T \qquad \text{for } p=1,\ldots,m,$$

where k is the number of variables in the system; T is the sample size to use; Σ_p is an estimate of the residual covariance matrix for the p th order VAR model; and m is the maximum lag length considered.

It should be noted that the AICs are computed by using a full model rather than estimating each equation separately, and hence a minimum value of AIC determines optimal, common lags for all equations of the VAR system. Furthermore, while the chosen lag length should be sufficiently large to reduce serial correlation of the residuals, a degrees of freedom problem will be particularly relevant for this study since the sample size under consideration is small relative to the large VAR model. To preserve degrees of freedom, the maximum lag length (m) is arbitrarily set at twelve months.

B. Orthogonalization of VAR Residuals

One problem in interpreting innovation accounting results of the VAR is that there is contemporaneous correlation among

the residuals of the VAR model. For example, if the residuals in each equation of the system are contemporaneously correlated, a "pure" innovation in a particular variable cannot be isolated. For this reason, innovation accounting is often performed by orthogonalizing the VAR residuals. The consequences and a possible remedy for this problem can be shown by using a simple model. As illustrated by Hakkio and Morris (1984), a simple two-variable autoregressive process of order one is

$$(3.7) \qquad \begin{bmatrix} X_t \\ Y_t \end{bmatrix} = \begin{bmatrix} b_{11} & b_{12} \\ b_{21} & b_{22} \end{bmatrix} \begin{bmatrix} X_{t-1} \\ Y_{t-1} \end{bmatrix} + \begin{bmatrix} v_{1t} \\ v_{2t} \end{bmatrix},$$

where
$$\Sigma_v = E \begin{bmatrix} v_{1t} \\ v_{2t} \end{bmatrix} [v_{1t} \quad v_{2t}] = \begin{bmatrix} 1 & r \\ r & 1 \end{bmatrix}.$$

We assume, for simplicity, that the variances of v_{1t} and v_{2t} equal one and their covariance equals r. Then, a unit increase in X_t induces an instantaneous increase in Y_t by r. Because v_{1t} and v_{2t} are contemporaneously correlated, it is impossible to determine whether the innovation to Y is the result of exogenous shocks to Y alone or the result of Y's response to another variable X. This observation suggests that a change in v_{2t} cannot be attributed to a pure Y innovation. For this reason, innovation accounting is often performed by using the Choleski decomposition of the residual variance-covariance matrix, Σ_v, to identify orthogonal shocks

to each variable.[2]

Using the Choleski decomposition, the covariance matrix can be written as

$$\Sigma_v = H^{-1} H^{-1'}$$

or

$$H \Sigma_v H' = I,$$

where H^{-1} is lower triangular. Then,

$$H^{-1} = \begin{bmatrix} 1 & 0 \\ r & \surd 1-r^2 \end{bmatrix},$$

$$H = \begin{bmatrix} 1 & 0 \\ -r/\surd 1-r^2 & 1/\surd 1-r^2 \end{bmatrix}.$$

Premultiplying both sides of equation (3.7) by H results in a system of two equations such as:

$$(3.8) \qquad \begin{aligned} X_t &= b_{11} X_{t-1} + b_{12} Y_{t-1} + v_{1t}, \\ Y_t &= r X_t + (b_{21} - b_{11}r)X_{t-1} + (b_{22} - b_{12}r)Y_{t-1} \\ &\quad v_{2t} - r v_{1t}. \end{aligned}$$

The transformed system of equations, (3.8), can be rewritten as

$$(3.9) \qquad X_t = b_{11} X_{t-1} + b_{12} Y_{t-1} + e_{1t},$$
$$Y_t = r X_t + (b_{21} - b_{11}r)X_{t-1} + (b_{22} - b_{12}r)Y_{t-1} + \sqrt{1-r^2}\, e_{2t},$$

where
$$e_{1t} = v_{1t},$$
$$e_{2t} = (v_{2t} - r\, v_{1t}) \,/\, \sqrt{1-r^2}.$$

The residuals (e_{1t}, e_{2t}) have the convenient property that they are uncorrelated, and hence each e is orthogonal to each of the other shocks to e by construction. Therefore, a pure shock to X or Y innovation can be isolated within a transformed VAR model. This is the purpose of the Choleski decomposition of the covariance matrix for the VAR residuals.

C. Ordering of Variables

Although the Choleski decomposition orthogonalizes the VAR residuals, it is generally recognized that innovation accounting results of the VAR are potentially sensitive to the ordering of variables. By inspection of equation (3.9), we find that a current value of X_t affects Y_t by r, but a current value of Y_t does not affect X_t. This implies that a reverse ordering of variables, e.g., Y first and X second in equation (3.7), will result in a two-equation system different from (3.9). Therefore, when there is substantial contemporaneous correlation, variable ordering matters. When a variable higher in order changes, the variable lower in order is changed as well. Consequently, innovation accounting results

may be potentially sensitive to the ordering of variables.[3]

Because of the potential sensitivity of innovation accounting results to ordering, theoretical and institutional considerations should be used to determine appropriate orderings. This is in spirit of Bernanke (1986). For example, it can be assumed that developments of a small economy do not contemporaneously affect a large economy; a financial sector block precedes a goods market block; and implementation of monetary policy is contemporaneously independent of fiscal policy (see, for example, Genberg et al. 1987; Fackler and McMillin 1989). Other reasonable orderings based upon the efficient market hypothesis can be considered.

Alternatively, a structural approach to VARs can avoid the sensitivity of innovation accounting results to variable orderings. This is because, as noted by Bernanke (1986), the structural VARs impose particular identifying restrictions on contemporaneous residuals of the VAR. The identifying restrictions then eliminate the contemporaneous correlation across the VAR residuals. The structural approach is, however, not used for this study, since the contemporaneous exclusion restrictions employed in structural VARs may also be subject to criticism. Bernanke and Blinder (1989), for example, note that the results of structural VARs are, in general, sensitive to the restrictions imposed to identify the model. Thus, the standard Sims VAR, in which few restrictions are placed on how the variables interact, seems to be adequate

for the purpose of this study.

V. Innovation Accounting

The innovation accounting that has been popularized by Sims (1980) is based on the moving average (MA) representation of the VAR in which each variable is expressed as a vector of its own current innovation and lagged innovations of all the variables in the system. If each innovation is orthogonalized, the pure effect of one variable on another can be determined by computing variance decompositions, impulse responses, and cumulative impulse responses at a particular forecast horizon. Hence, the innovation accounting results of the VAR characterize the dynamic relationships among macroeconomic time series.

Following Hakkio and Morris (1984), the MA representation is obtained by using the recursive substitution of the VAR system (3.9). That is, recursive substitution in X_t yields

$$
\begin{aligned}
X_t = {} & b_{11}\ (b_{11}\ X_{t-2} + b_{12}\ Y_{t-2} + e_{1,t-1}) \\
& + b_{12}\ [r(b_{11}\ X_{t-2} + b_{12}\ Y_{t-2} + e_{1,t-1}) + (b_{21} - b_{11}r)X_{t-2} \\
& + (b_{22} - b_{12}r)Y_{t-2} + \sqrt{1-r^2}\ e_{2,t-1}] + e_{1t}
\end{aligned}
$$

$$
\begin{aligned}
= {} & (b^2_{11} + b_{11}b_{12}r + b_{12}b_{21} - b_{11}b_{12}r)X_{t-2} \\
& + (b_{11}b_{12} + b^2_{12}r + b_{12}b_{22} - b^2_{12}r)Y_{t-2} \\
& + (b_{11} + b_{12}r)e_{1,t-1} + b_{12}\sqrt{1-r^2}\ e_{2,t-1} + e_{1t}
\end{aligned}
$$

$$= (b^2_{11} + b_{12}b_{21})\ (b_{11}\ X_{t-3} + b_{12}\ Y_{t-3} + e_{1,t-2})$$
$$+ (b_{11}b_{12} + b_{12}b_{22})\ [r(b_{11}\ X_{t-3} + b_{12}\ Y_{t-3} + e_{1,t-2})$$
$$+ (b_{21} - b_{11}r)X_{t-3} + (b_{22} - b_{12}r)Y_{t-3} + \sqrt{1-r^2}\ e_{2,t-2}]$$
$$+ (b_{11} + b_{12}r)e_{1,t-1} + b_{12}\sqrt{1-r^2}\ e_{2,t-1} + e_{1t}.$$

Thus,

$$X_t = e_{1t} + (b_{11} + b_{12}r)e_{1,t-1} + (b^2_{11} + b_{12}b_{21} + b_{11}b_{12}r$$
$$+ b_{12}b_{22}r)e_{1,t-2} + \ldots + b_{12}\sqrt{1-r^2}\ e_{2,t-1} + (b_{11}b_{12}$$
$$+ b_{12}b_{22})\sqrt{1-r^2}\ e_{2,t-2} + \ldots\quad .$$

Similarly, recursive substitution in Y_t yields

$$Y_t = r\ e_{1t} + (b_{21} + b_{22}r)e_{1,t-1} + [b_{21}(b_{11} + b_{22}) + r(b_{12}b_{21}$$
$$+ b^2_{22})]e_{1,t-2} + \ldots + \sqrt{1-r^2}\ e_{2t} + b_{22}\sqrt{1-r^2}\ e_{2,t-1}$$
$$+ (b_{12}b_{21} + b^2_{22})\sqrt{1-r^2}\ e_{2,t-2} + \ldots\quad .$$

Therefore, the moving average representation is summarized as

$$X_t = e_{1t} + (b_{11} + b_{12}r)e_{1,t-1} + (b^2_{11} + b_{12}b_{21} + b_{12}r(b_{11} + b_{22}))e_{1,t-2} + \ldots + b_{12}\sqrt{1-r^2}\ e_{2,t-1} + b_{12}(b_{11} + b_{22})\sqrt{1-r^2}\ e_{2,t-2} + \ldots\quad , \tag{3.10a}$$

$$Y_t = r\ e_{1t} + (b_{21} + b_{22}r)e_{1,t-1} + [b_{21}(b_{11} + b_{22}) + r(b_{12}b_{21} + b^2_{22})]e_{1,t-2} + \ldots + \sqrt{1-r^2}\ e_{2t} + b_{22}\sqrt{1-r^2}\ e_{2,t-1} + (b_{12}b_{21} + b^2_{22})\sqrt{1-r^2}\ e_{2,t-2} + \ldots\quad . \tag{3.10b}$$

Note that current and lagged innovations, e, are orthogonal disturbances obtained from the Choleski decomposition discussed earlier in the previous section. Based on this MA representation, we now discuss variance decompositions, impulse responses, and cumulative impulse responses in the following subsections.

A. Variance Decompositions

As noted earlier, the Choleski decomposition identifies orthogonal shocks to each variable. The orthogonal shocks then allow one to decompose the variance of each variable according to the contribution from each orthogonal innovation. This allocation of the proportion of forecast error variance that is accounted for by innovations in each variable is referred to as the variance decompositions (VDCs). The VDCs are typically used to examine the dynamic relationships among macroeconomic time series. For example, if one variable is predicted to have a substantial effect on another, the first variable should explain a significant fraction of the variation in the second for a given forecast horizon. The followings illustrate how to compute the VDCs for the 2-period-ahead forecast horizon, for example.

Using the MA representation of a VAR (equation (3.10a)), the 2-period-ahead value of X_t is:

$$X_{t+2} = e_{1,t+2} + (b_{11}+b_{12}r)e_{1,t+1} + (b^2_{11}+b_{12}b_{21}+b_{12}r(b_{11}+b_{22}))e_{1t}+ \ldots$$
$$+ b_{12}\sqrt{1-r^2}\; e_{2,t+1} + b_{12}(b_{11}+b_{22})\sqrt{1-r^2}\; e_{2t} + \ldots \quad .$$

The 2-period-ahead forecast of X_t at time t is:

$$E_t(X_{t+2}) = 0 + 0 + (b^2_{11}+b_{12}b_{21} + b_{12}r(b_{11}+b_{22}))e_{1t} + \ldots$$
$$+ 0 + b_{12}(b_{11}+b_{22})\sqrt{1-r^2}\; e_{2t} + \ldots \quad ,$$

since $E_t(e_{i,t+1}) = E_t(e_{i,t+2}) = 0$ and $E_t(e_{i,t}) = e_{i,t}$. Then, the 2-period-ahead forecast error of X_t is obtained by:

$$X_{t+2} - E_t(X_{t+2}) = e_{1,t+2} + (b_{11}+b_{12}r)e_{1,t+1} + b_{12}\sqrt{1-r^2}\; e_{2,t+1}.$$

Finally, the 2-period-ahead forecast error variance of X_t is obtained by:

$$(3.11) \qquad E_t[X_{t+2} - E_t(X_{t+2})]^2 = 1 + (b_{11}+b_{12}r)^2 + b^2_{12}(1-r^2),$$

since, by assumption, $Var(e_{1t}) = Var(e_{2t}) = 1$. The cross-product terms are ignored because $Cov(e_{1t}, e_{2t}) = Cov(e_{1t}, e_{1s}) = 0$. The equation (3.11) represents the total forecast error variance of X explained by its own innovation, e_1, and the shock to the other variable, e_2. That is, the first and second terms are the proportions of the variance accounted for by e_1, while the third term is the proportion accounted for by e_2. Therefore, the percentage of the variance in X explained

by its own innovation (i.e., shock to e_1) is

$$V(X_x) = \frac{1 + (b_{11}+b_{12}r)^2}{1 + (b_{11}+b_{12}r)^2 + b^2_{12}(1-r^2)} * 100.$$

The percentage of the variance in X explained by the Y innovation (i.e., shock to e_2) is

$$V(X_y) = \frac{b^2_{12}(1-r^2)}{1 + (b_{11}+b_{12}r)^2 + b^2_{12}(1-r^2)} * 100.$$

Analogously, the 2-period-ahead forecast error variance of Y_t can be obtained from (3.10b) by:

$$(3.12) \qquad E_t[Y_{t+2} - E_t(Y_{t+2})]^2 = r^2 + (b_{21}+b_{22}r)^2 + (1-r^2) + b_{22}(1-r^2).$$

The first and second terms are the proportions of the variance explained by e_1 and the third and fourth terms are the proportions by e_2. Then, the percentage of the variance in Y explained by the X innovation (i.e., shock to e_1) is

$$V(Y_x) = \frac{r^2 + (b_{21}+b_{22}r)^2}{r^2 + (b_{21}+b_{22}r)^2 + (1-r^2) + b_{22}(1-r^2)} * 100.$$

The percentage of the variance in Y explained by its own innovation (i.e., shock to e_2) is

$$V(Y_y) = \frac{(1-r^2) + b_{22}(1-r^2)}{r^2 + (b_{21}+b_{22}r)^2 + (1-r^2) + b_{22}(1-r^2)} * 100.$$

As we have seen, the VDCs capture both direct and indirect effects. The forecast error variance for each variable is attributed to its own shock and to shocks to other system variables. Therefore, as indicated by Sims (1982), the VDCs can be used to detect the strength of "Granger-causal" relations. The degree to which one variable Granger-causes another can be determined by computing the proportions of the forecast error variance explained by its own innovation and innovations in other variables. Therefore, the VDCs are used to determine the relative importance of one variable to another in assessing the quantitative relationship between variables, whereas the direction of effect can be evaluated by using the IRFs discussed below.

B. Impulse Response Functions

In general, impulse response functions (IRFs) show the expected paths of the system of variables in response to a shock to a particular variable. To be specific, the orthogonalized innovations, e_{1t} and e_{2t} in equation (3.10), represent the shocks to X_t and Y_t, respectively, and the

corresponding coefficients are the elements of impulse response functions. For example, a one standard error innovation in X_t (i.e., shock to e_{1t}) increases X_t by 1 since the variance of X is previously assumed to be 1. The shock to e_{1t} also increases Y_t by r because the covariance equals r. However, a one standard error innovation in Y_t (i.e., shock to e_{2t}) increases Y_t alone, leaving X_t unaffected in the period in which the shock occurs. As noted earlier, this was the consequence of the standard Choleski decomposition of the VAR residuals. Furthermore, the coefficients of $e_{1,t-1}$ and $e_{1,t-2}$ represent the impact on X_t or Y_t at horizons one and two, respectively, and hence characterize the dynamic relationship of the variables. The impulse response functions are summarized as follows.

The impulse response function for X with respect to the orthogonalized innovation e_1 is:

$$\partial X_t \;/\; \partial e_{1t} = 1,$$

$$\partial X_{t+1} / \; \partial e_{1t} = b_{11} + b_{12} r,$$

$$\partial X_{t+2} / \; \partial e_{1t} = b^2_{11} + b_{12} b_{21} + b_{12} r (b_{11} + b_{22}),$$

$$\vdots$$

The impulse response function for X with respect to the orthogonalized innovation e_2 is:

$$\partial X_t \;/\; \partial e_{2t} = 0,$$

$$\partial X_{t+1}/\; \partial e_{2t} = b_{12}\sqrt{1-r^2},$$

$$\partial X_{t+2}/\; \partial e_{2t} = b_{12}(b_{11} + b_{22})\sqrt{1-r^2},$$

$$\vdots$$

Similarly, the impulse response function for Y with respect to the orthogonalized innovation e_1 is:

$$\partial Y_t \;/\; \partial e_{1t} = r,$$

$$\partial Y_{t+1}/\; \partial e_{1t} = b_{21} + b_{22}r,$$

$$\partial Y_{t+2}/\; \partial e_{1t} = b_{21}(b_{11} + b_{22}) + r(b_{12}b_{21} + b^2_{22}),$$

$$\vdots$$

The impulse response function for Y with respect to the orthogonalized innovation e_2 is:

$$\partial Y_t \;/\; \partial e_{2t} = \sqrt{1-r^2},$$

$$\partial Y_{t+1}/\; \partial e_{2t} = b_{22}\sqrt{1-r^2},$$

$$\partial Y_{t+2}/\; \partial e_{2t} = (b_{12}b_{21} + b^2_{22})\sqrt{1-r^2},$$

$$\vdots$$

As we have seen, the impulse response functions represent the dynamic responses of the system of variables to shocks to

a particular innovation, and indicate the directions of the effect of one variable on another. Therefore, IRFs can be a useful tool to examine transmission channels through which one variable influences the other over time. In particular, assessing the qualitative relationship of the effects (i.e., determining positive or negative effects) will be one advantage of computing the IRFs.

C. Cumulative Impulse Responses

As noted by McMillin and Koray (1990), if a model is fitted to differenced data, a better understanding of how the level of model variables responds to a particular shock can be obtained by computing cumulative impulse response functions (CIRFs). The current-period CIRFs are obtained by adding up prior-period IRFs and represent the response of the levels of the differenced data. The CIRFs are more formally illustrated below with a simple two-variable VAR model.

Suppose the two variables of the VAR system (3.9) are transformed to first differences:

$$(3.9') \quad \begin{aligned} X_t - X_{t-1} &= b_{11}(X_{t-1}-X_{t-2}) + b_{12}(Y_{t-1}-Y_{t-2}) + e_{1t}, \\ Y_t - Y_{t-1} &= r(X_t-X_{t-1}) + (b_{21}-b_{11}r)\ (X_{t-1}-X_{t-2}) \\ &\quad + (b_{22}-b_{12}r)\ (Y_{t-1}-Y_{t-2}) + \sqrt{1-r^2}\ e_{2t}, \end{aligned}$$

where e_{1t} and e_{2t} are orthogonal shocks by construction. The MA representation is obtained by using the recursive substitution

of the system (3.9′). That is, recursive substitution in (X_t - X_{t-1}) yields

$$
\begin{aligned}
X_t - X_{t-1} = b_{11}[&b_{11}(X_{t-2}-X_{t-3}) + b_{12}(Y_{t-2}-Y_{t-3}) + e_{1,t-1}] \\
&+ b_{12}[r(X_{t-1}-X_{t-2}) + (b_{21}-b_{11}r)(X_{t-2}-X_{t-3}) \\
&+ (b_{22}-b_{12}r)(Y_{t-2}-Y_{t-3}) + \sqrt{1-r^2}\ e_{2,t-1}] + e_{1t}.
\end{aligned}
$$

Rearranging the terms, we have

$$
\begin{aligned}
X_t - X_{t-1} &= e_{1t} + b_{11}\ e_{1,t-1} + b_{12}\sqrt{1-r^2}\ e_{2,t-1} \\
&\quad + b_{12}r[b_{11}(X_{t-2}-X_{t-3}) + b_{12}(Y_{t-2}-Y_{t-3}) + e_{1,t-1}] \\
&\quad + [b^2_{11}+b_{12}(b_{21}-b_{11}r)]\ (X_{t-2}-X_{t-3}) \\
&\quad + [b_{11}b_{12}+b_{12}(b_{22}-b_{12}r)]\ (Y_{t-2}-Y_{t-3}) \\
&= e_{1t} + (b_{11}+b_{12}r)\ e_{1,t-1} + b_{12}\sqrt{1-r^2}\ e_{2,t-1} \\
&\quad + (b^2_{11}+b_{12}b_{21})\ (X_{t-2}-X_{t-3}) \\
&\quad + (b_{11}b_{12}+b_{12}b_{22})\ (Y_{t-2}-Y_{t-3}).
\end{aligned}
$$

Substitution of ($X_{t-2}-X_{t-3}$) and ($Y_{t-2}-Y_{t-3}$) yields

$$
\begin{aligned}
X_t - X_{t-1} = e_{1t} &+ (b_{11}+b_{12}r)\ e_{1,t-1} + (b^2_{11}+b_{12}b_{21})\ e_{1,t-2} \\
&+ b_{12}\sqrt{1-r^2}\ e_{2,t-1} + (b_{11}b_{12}+b_{12}b_{22})\sqrt{1-r^2}\ e_{2,t-2} \\
&+ b_{12}r(b_{11}+b_{22})\ (X_{t-2}-X_{t-3}) \\
&+ [b_{11}(b^2_{11}+b_{12}b_{21}) + (b_{11}b_{12}+b_{12}b_{22})(b_{21}-b_{11}r)]\ (X_{t-3}-X_{t-4}) \\
&+ [b_{12}(b^2_{11}+b_{12}b_{21}) + (b_{11}b_{12}+b_{12}b_{22})(b_{22}-b_{12}r)]\ (Y_{t-3}-Y_{t-4}).
\end{aligned}
$$

Again, substitution of $(X_{t-2}-X_{t-3})$ yields

$$X_t - X_{t-1} = e_{1t} + (b_{11}+b_{12}r)\,e_{1,t-1} + (b^2_{11}+b_{12}b_{21}+b_{11}b_{12}r+b_{12}b_{22}r)\,e_{1,t-2}$$
$$+ b_{12}\sqrt{1-r^2}\ e_{2,t-1} + (b_{11}b_{12}+b_{12}b_{22})\sqrt{1-r^2}\ e_{2,t-2}$$
$$+ \alpha\ (X_{t-3}-X_{t-4}) + \beta\ (Y_{t-3}-Y_{t-4}),$$

where $\alpha = b_{11}(b^2_{11}+b_{12}b_{21}) + (b_{11}b_{12}+b_{12}b_{22})(b_{21}-b_{11}r) + b_{11}b_{12}r(b_{11}+b_{12})$,

$\beta = b_{12}(b^2_{11}+b_{12}b_{21}) + (b_{11}b_{12}+b_{12}b_{22})(b_{22}-b_{12}r) + b^2_{12}r.$

Then, the level of X_t can be written as

$$X_t = X_{t-1} + e_{1t} + (b_{11}+b_{12}r)\,e_{1,t-1} + (b^2_{11}+b_{12}b_{21}+b_{11}b_{12}r+b_{12}b_{22}r)\,e_{1,t-2}$$
$$+ b_{12}\sqrt{1-r^2}\ e_{2,t-1} + (b_{11}b_{12}+b_{12}b_{22})\sqrt{1-r^2}\ e_{2,t-2}$$
$$+ \alpha\ (X_{t-3}-X_{t-4}) + \beta\ (Y_{t-3}-Y_{t-4}).$$

Substitution of X_{t-1} and rearranging them yields

$$X_t = X_{t-2} + e_{1t} + (1+b_{11}+b_{12}r)\,e_{1,t-1}$$
$$+ (b_{11}+b_{12}r+b^2_{11}+b_{12}b_{21}+b_{11}b_{12}r+b_{12}b_{22}r)\,e_{1,t-2}$$
$$+ (b^2_{11}+b_{12}b_{21}+b_{11}b_{12}r+b_{12}b_{22}r)\,e_{1,t-3}$$
$$+ b_{12}\sqrt{1-r^2}\ e_{2,t-1}$$
$$+ (b_{12}\sqrt{1-r^2} + b_{11}b_{12}\sqrt{1-r^2} + b_{12}b_{22}\sqrt{1-r^2})\ e_{2,t-2}$$
$$+ \alpha(X_{t-4}-X_{t-5}) + \beta(Y_{t-4}-Y_{t-5}) + \alpha(X_{t-3}-X_{t-4}) + \beta(Y_{t-3}-Y_{t-4}).$$

Again, substitution of X_{t-2} yields

$$
\begin{aligned}
X_t = X_{t-3} &+ e_{1t} + (1+b_{11}+b_{12}r)\ e_{1,t-1} \\
&+ (1+b_{11}+b_{12}r+b^2_{11}+b_{12}b_{21}+b_{11}b_{12}r+b_{12}b_{22}r)\ e_{1,t-2} \\
&+ (b_{11}+b_{12}r+b^2_{11}+b_{12}b_{21}+b_{11}b_{12}r+b_{12}b_{22}r)\ e_{1,t-3} \\
&+ (b^2_{11}+b_{12}b_{21}+b_{11}b_{12}r+b_{12}b_{22}r)\ e_{1,t-4} \\
&+ (b_{12}\sqrt{1-r^2})\ e_{2,t-1} \\
&+ (b_{12}\sqrt{1-r^2} + b_{11}b_{12}\sqrt{1-r^2} + b_{12}b_{22}\sqrt{1-r^2})\ e_{2,t-2} \\
&+ (b_{12}\sqrt{1-r^2})\ e_{2,t-3} \\
&+ (b_{11}b_{12}\sqrt{1-r^2} + b_{12}b_{22}\sqrt{1-r^2})\ e_{2,t-4} \\
&+ \alpha(X_{t-5}-X_{t-6}) + \beta(Y_{t-5}-Y_{t-6}) + \alpha(X_{t-4}-X_{t-5}) + \beta(Y_{t-4}-Y_{t-5}) \\
&+ \alpha(X_{t-3}-X_{t-4}) + \beta(Y_{t-3}-Y_{t-4}).
\end{aligned}
$$

Thus, the MA representation for the level of X is rewritten as

$$
\begin{aligned}
(3.10a') \quad X_t = e_{1t} &+ (1+b_{11}+b_{12}r)\ e_{1,t-1} \\
&+ (1+b_{11}+b_{12}r+b^2_{11}+b_{12}b_{21}+b_{11}b_{12}r+b_{12}b_{22}r)\ e_{1,t-2} \\
&+ \ldots\ldots \\
&+ (b_{12}\sqrt{1-r^2})\ e_{2,t-1} \\
&+ (b_{12}\sqrt{1-r^2} + b_{11}b_{12}\sqrt{1-r^2} + b_{12}b_{22}\sqrt{1-r^2})\ e_{2,t-2} \\
&+ \ldots\ldots\ .
\end{aligned}
$$

Similarly, the MA representation for the level of Y is obtained as

$$(3.10b') \quad Y_t = r\ e_{1t} + (r+b_{21}+b_{22}r)\ e_{1,t-1}$$
$$+ (r+b_{21}+b_{22}r+b_{21}(b_{11}+b_{22})+r(b_{12}b_{21}+b^2_{22})\ e_{1,t-2}$$
$$+ \ldots.$$
$$+ \sqrt{1-r^2}\ e_{2t}$$
$$+ (\sqrt{1-r^2} + b_{22}\sqrt{1-r^2})\ e_{2,t-1}$$
$$+ (\sqrt{1-r^2} + b_{22}\sqrt{1-r^2} + (b_{12}b_{21} + b^2_{22})\sqrt{1-r^2})\ e_{2,t-2}$$
$$+ \ldots. \quad .$$

Each coefficient in equations (3.10a′) and (3.10b′) represents the cumulative impulse responses of the variables, X and Y, with respect to the orthogonal shocks, e_1 and e_2, for given forecasting horizons. That is, the CIRFs for X with respect to the orthogonalized innovation e_1 is:

$$\partial X_t \ / \ \partial e_{1t} = 1,$$
$$\partial X_{t+1} / \ \partial e_{1t} = 1 + b_{11} + b_{12}r,$$
$$\partial X_{t+2} / \ \partial e_{1t} = 1 + b_{11} + b_{12}r + b^2_{11} + b_{12}b_{21} + b_{12}r(b_{11} + b_{22}),$$
$$\vdots$$

The CIRFs for X with respect to the orthogonalized innovation e_2 is:

$$\partial X_t \ / \ \partial e_{2t} = 0,$$
$$\partial X_{t+1} / \ \partial e_{2t} = b_{12}\sqrt{1-r^2},$$
$$\partial X_{t+2} / \ \partial e_{2t} = b_{12}\sqrt{1-r^2} + b_{12}(b_{11} + b_{22})\sqrt{1-r^2},$$

.
.
.
.

Similarly, the CIRFs for Y with respect to the orthogonalized innovation e_1 is:

$$\partial Y_t \;/\; \partial e_{1t} = r,$$

$$\partial Y_{t+1} / \; \partial e_{1t} = r + b_{21} + b_{22}r,$$

$$\partial Y_{t+2} / \; \partial e_{1t} = r + b_{21} + b_{22}r + b_{21}(b_{11} + b_{22}) + r(b_{12}b_{21} + b^2_{22}),$$

.
.
.
.

The CIRFs for Y with respect to the orthogonalized innovation e_2 is:

$$\partial Y_t \;/\; \partial e_{2t} = \sqrt{1-r^2},$$

$$\partial Y_{t+1} / \; \partial e_{2t} = \sqrt{1-r^2} + b_{22}\sqrt{1-r^2},$$

$$\partial Y_{t+2} / \; \partial e_{2t} = \sqrt{1-r^2} + b_{22}\sqrt{1-r^2} + (b_{12}b_{21} + b^2_{22})\sqrt{1-r^2},$$

.
.
.
.

As we have seen, the CIRFs are the sum of prior-period shocks. For example, the 1-period CIRFs are the sum of current-period and 1-period IRFs; the 2-period CIRFs are the

sum of current-period, 1-period, and 2-period IRFs; and so forth. The CIRFs then represent the responses of the *levels* of variables X and Y, given that these variables are initially transformed to first differences. Therefore, the CIRFs can be a useful tool to examine the effect of a change in one variable on the level of another.

D. Standard Error Estimates for VDCs, IRFs, and CIRFs

Although the variance decompositions, impulse responses, and cumulative impulse responses generally provide some indications that one variable influences another over time, it is difficult to determine whether the effects are statistically meaningful at a given significance level. Runkle (1987) indicates that reporting the innovation accounting results without associated standard errors is similar to reporting regression parameter estimates without t-statistics. Therefore, a Monte Carlo integration procedure, which has been used by Burbidge and Harrison (1985) and Genberg et al. (1987), among others, is employed to estimate standard errors for the VDCs, IRFs, and CIRFs. As Doan and Litterman (1986) note, the Monte Carlo integration procedure computes the standard errors of the posterior distribution of the VDCs, IRFs, and CIRFs based, in this case, upon one thousand draws from the distribution.

Two standard error estimates are used as a rough test for statistical significance. For example, if the point estimates

of the VDCs are at least twice the standard errors, the null hypothesis of a zero effect will be rejected in favor of an alternative that there is a significant effect between the variables of interest. For the IRFs and CIRFs, however, confidence bands will be plotted by using two standard error estimates. If the confidence interval does not include zero, we conclude that the corresponding negative or positive effects are significant.

As noted above, this type of decision is our rule of thumb based upon two standard deviations from the point estimate of the VDCs, IRFs, and CIRFs. This suggests that rejecting the null hypothesis in accordance with our rule of thumb provides an intuitive guide that, if the null is true, there is only a 5 % probability that we will make the mistake of rejecting the null hypothesis.

VI. Concluding Remarks

We have noted first that a VAR approach is used for the dissertation research because the VAR approach is in general less restrictive than a traditional structural model approach. In particular, the standard Sims VAR is employed to characterize the dynamic relationship of the variables, because the Sims VAR, relative to the structural VARs, imposes few restrictions on how the variables interact. Furthermore, two important issues have been discussed: one is about model

specification issues and the other about innovation accounting results of the VAR.

For model specification issues, the VAR methodology entails three considerations. First, the unit root test is used to select appropriate transformation of data. Because choice of a wrong transformation or failure to account for nonstationarities has far-reaching consequences in interpreting the VAR model, it is important to investigate whether the time series used are characterized by trend stationarity or difference stationarity. Furthermore, the cointegration test evaluates the appropriateness of the VAR formulation in differences.

Second, the Akaike's information criterion (AIC) is used to determine the order p of the VAR model. Because economic theory is often not very explicit about the lags in time series relationships, the AIC criterion, which is an atheoretical statistical method, allows the data themselves to select the optimal, common lags for all equations of the standard Sims VAR.

Third, the standard Choleski decomposition is used to orthogonalize the VAR residuals. However, it is generally recognized that the innovation accounting results of the VAR are potentially sensitive to the ordering of variables. For this reason, theoretical and institutional considerations are used to determine appropriate orderings.

In order to assess the dynamic relationships among

macroeconomic time series, variance decompositions, impulse response functions, and cumulative impulse responses are computed. First, the variance decompositions show the proportions of forecast error variance of a variable that is accounted for by its own innovation and innovations in other variables, and hence the VDCs capture both direct and indirect effects. Second, the impulse response functions show the expected paths of the system of variables in response to a shock to a particular variable. Therefore, the IRFs, in addition to the VDCs, can be a useful tool to examine transmission channels through which one variable influences the other over time, since the IRFs indicate the direction of effect. Third, the cumulative impulse responses represent the responses of the levels of differenced data to shocks to the system variables.

Finally, the Monte Carlo integration procedure is employed to estimate standard errors for the VDCs, IRFs, and CIRFs. Two standard error estimates are used as a rough test for statistical significance of the innovation accounting results.

Endnotes

1. However, if the null hypothesis of no cointegration is rejected at a given significance level, a linear combination of the variables in levels may be cointegrated or stationary. If such is the case, error correction models are suggested as a possible remedy for cointegrated time series. See, for example, Engle and Granger (1987).

2. As is widely known, the Choleski decomposition is not a unique method to orthogonalize the VAR residuals. Bernanke (1986), Blanchard and Watson (1986), Sims (1986), Blanchard (1989), and Keating (1990), for example, propose alternative methods of orthogonalizing the residuals to identify "structural" shocks from the covariance matrix of the residuals.

3. Spencer (1989) provides evidence that variable ordering is of great importance for the role of money in explaining output.

CHAPTER 4

EMPIRICAL ANALYSIS OF THE KOREAN MACROECONOMY

I. Introduction

The aim of this chapter is to achieve two objectives. The first is to investigate the relevance of Ricardian equivalence to the Korean economy. To be specific, the effects of government debt on macroeconomic activity are analyzed empirically. That is, the impact of government debt on macroeconomic variables like output, the price level, the interest rate, and the real exchange rate is estimated. The second objective is to investigate the international transmission of foreign disturbances to the Korean economy. In particular, the dissertation will attempt to determine the importance of U.S. and Japanese shocks, relative to domestic shocks, to the Korean economy. The channels through which these foreign shocks are transmitted to Korea will also be analyzed.

The above two issues will be examined by specifying and estimating a vector autoregressive (VAR) model. Because the VAR technique, originally proposed by Sims (1980), is generally considered to be sensitive to the choice of data transformation, the selection of a VAR order, and the ordering

of variables, some explicit tests will be conducted for these model specification issues. In addition, the dynamic effects of government debt and foreign shocks will be evaluated by estimating variance decompositions (VDCs), impulse response functions (IRFs), and cumulative impulse responses (CIRFs). Furthermore, a Monte Carlo integration procedure will be employed to estimate the standard errors of the VDCs, IRFs, and CIRFs so that the significance of the effects of government debt and foreign shocks can be determined.

The remainder of the chapter is organized as follows. Section II discusses the choice of variables and a data set for estimation of the VAR model. The variables are chosen based on theoretical and institutional considerations. The data set is also selected based on relevant economic theory. Section III discusses some model specification methods that include stationarity tests, Akaike's information criterion (AIC), and alternative variable orderings. These considerations are important prior to estimation of the VAR model because innovation accounting results may be potentially sensitive to alternative model specifications. Section IV presents and discusses the empirical results. To check the robustness of our findings, two alternative model specifications are also examined. Finally, a brief summary and conclusion follow in section V.

II. Choice of Variables and a Data Set

A. Choice of Variables

A nine-variable vector autoregressive (VAR) model is specified as a small macro model of the Korean economy. The variables selected are consistent with the reduced form of an aggregate demand-aggregate supply model, where the IS-LM-BP model underlies the aggregate demand side. This is similar to McMillin and Koray (1989). The VAR model therefore includes interest rates, output, and the price level. In addition, a monetary policy variable, the money supply, and two fiscal policy variables, government spending and government bonds, are included along with the real exchange rate and two external shock variables. The VAR model is specified as:

$$X_t = A + B(L)\ X_t + u_t, \tag{4.1}$$

where $X = [y, r, P, M1, g, D, e, Y^*, P^*]'$, A is a 9x1 vector of constants, B(L) is a 9x9 matrix of polynomials in the lag operator L, and u is a 9x1 vector of serially uncorrelated white noise residuals.

The nine variables included in the model are the industrial production index (y), the yield on national housing bonds (r), the consumer price index (P), the narrowly defined money supply (M1), real government expenditures (g), private

holdings of government bonds in Korea (D), an index of the real effective exchange rate (e), an index of movements in output of the U.S. and Japan as external shocks to output (Y^*), and an index of movements in the price levels of the U.S. and Japan as external price shocks (P^*). The last four variables are chosen for the following reasons.

In order to test the Ricardian equivalence hypothesis, the par value of privately held government debt (D) is used in the VAR model. Although the market value of debt has often been used in the literature, Hafer and Hein (1988) argue that the par value of debt is a preferred measure. If the market rate of interest were stable over time, there would be little difference between the two measures. In actuality, however, the market interest rate fluctuates over time, and the market value of debt is inversely related to the interest rate. The market interest rate reflects changes in expected inflation and output, and the expectation of these variables affect the macroeconomy today. A relationship between the market value of debt and the macroeconomy may thus reflect the expectational effects of inflation and output embedded in the market interest rate rather than any wealth effect of government debt.

This argument is supported by the findings of Hafer and Hein (1988) that the market value of debt Granger-causes inflation in a bivariate model of debt and inflation, but no causality from the market value of debt to inflation is found

when the interest rate is added to the market value of debt-inflation model. Therefore, it would seem that the par value measure is preferable to the market value measure in testing Ricardian equivalence, and the VAR model uses the par value (rather than the market value) of privately held government debt in Korea.

A measure of the real effective exchange rate (e) is included in the VAR model. The model explicitly uses the exchange rate because open economy models suggest that the movements in the exchange rate are important to the determination of equilibrium. For example, a depreciation of the exchange rate may induce domestic exports to rise, which in turn leads to an increase in interest rates, output, and prices in the home country. In addition, since three closely related countries are simultaneously examined within the model, the appropriate measure of the exchange rate is a multilateral (or effective) exchange rate rather than a bilateral exchange rate. Further, the nominal effective exchange rate is converted to the real rate by multiplying the nominal rate by the relative prices of Korea and the rest-of-the world. Then, the real effective exchange rate will be an appropriate measure of the exchange rate for the current VAR model.

Following Rhomberg (1976), the measure of e is constructed by using an import-weighted index and an export-weighted index that are derived from foreign trade in Korea.

The weighted average of the two indexes are computed in accordance with shares of imports and exports in total trade. The countries used for constructing the effective exchange rate are Korea's two major trading partners, the United States and Japan.[1] The real effective exchange rate (or multilateral real exchange rate) is defined as

(4.2) $$e = [s_M \; EXCH_M + s_X \; (1/EXCH_X)](P^*/P) * 100,$$

where

$$s_M = M^T / (M^T + X^T),$$

$$s_X = X^T / (M^T + X^T),$$

$$EXCH_M = \Sigma(M_i / \Sigma M_i)(E_{it} / E_{i0}), \text{ and}$$

$$EXCH_X = \Sigma(X_i / \Sigma X_i)(E_{i0} / E_{it}).$$

The symbols used are defined as follows:

M^T = Korea's total imports from the world market as an annual average over the period 1973-1987, measured in U.S. dollars;[2]

X^T = Korea's total exports to the world market as an annual average, measured in U.S. dollars;

M_i = Korea's imports from country i (the U.S. and Japan) as an annual average, measured in U.S. dollars;

X_i = Korea's exports to country i (the U.S. and Japan) as an annual average, measured in U.S. dollars;

E_{it} = nominal exchange rate as the ratio of the Korean won over currency i at time t;

E_{i0} = nominal exchange rate as the ratio of the Korean won over currency i at the base period 0;

P = consumer price index in Korea; and

P^* = foreign price level defined below in equation (4.3).

The first term of the equation measures an import-weighted index ($EXCH_M$), while the second term measures the reciprocal of an export-weighted index ($EXCH_X$) relative to the base year 1985. The average of the two indexes, weighted respectively by import shares (s_M) and export shares (s_X) in total trade, represents a combined index of the effective exchange rate.

Two features of the combined index should be discussed: 1) The export-weighted index uses the inverse of the nominal exchange rate [i.e., $(E_{it} / E_{i0})^{-1}$]. The exchange rate can equally be defined as the ratio of a foreign currency over the Korean won or as the ratio of the Korean won over a foreign currency. The second definition is more appropriate for the construction of the import-weighted index since it reflects the price of foreign exchange confronting Korean importers, and, conversely, the first definition is more appropriate to the construction of the export-weighted index. Therefore, the nominal exchange rate used for the model (Korean won / U.S. dollar) should be inverted to construct the export-weighted

index. 2) The second feature of the combined index is that the reciprocal of the export-weighted index [i.e., $1/EXCH_X$] is used. Suppose that the Korean won depreciates. The depreciation of the Korean won causes the export-weighted index to fall and the import-weighted index to rise. Since the two indices move in opposite directions, "one of the indices must first be inverted" to construct the combined index (Rhomberg, 1976, p.96). Therefore, the export-weighted index is inverted in the second term prior to weighting by export shares.

Finally, two foreign shock variables (Y^* and P^*) are included in the VAR model to examine the international transmission of foreign disturbances to the Korean economy. Following Genberg et al. (1987), the foreign variables are closely related to foreign trade in Korea. For example, an increase in foreign income may raise exports in Korea, and an increase in foreign prices will also raise Korea's exports. Therefore, the first and second channels of transmission relate to an aggregate demand channel in which domestic income and prices are affected through the home country's exports, which in turn depend on foreign income and foreign prices.

Since the United States and Japan are two major trading partners in Korea, the foreign shock variables are measured as a linear combination of U.S. and Japanese variables, weighted by foreign trade in Korea; that is,

$$
(4.3) \qquad \begin{aligned} Y^* &= w_{US}\ Y_{US} + w_{JP}\ Y_{JP}, \\ P^* &= w_{US}\ P_{US} + w_{JP}\ P_{JP}, \end{aligned}
$$

where
$$
\begin{aligned} w_{US} &= s_X\ (X_{US} / \Sigma X_i) + s_M\ (M_{US} / \Sigma M_i), \\ w_{JP} &= s_X\ (X_{JP} / \Sigma X_i) + s_M\ (M_{JP} / \Sigma M_i), \end{aligned}
$$

where i = the United States and Japan. The symbols are analogously defined as in equation (4.2). However, the weighting schemes used here are different. These are considered as country-determined trade weights rather than as export or import weights. That is, w_{US} and w_{JP} are, respectively, Korea's trade weights with the United States and Japan, and the weights are annual averages over the period 1973-1987. Y_{US} and Y_{JP} are, respectively, industrial production indexes for the United States and Japan; P_{US} and P_{JP} are, respectively, wholesale price indexes for the United States and Japan.

B. A Data Set

Monthly Korean data for the period 1973:5 - 1989:11 are used in the analysis. Because of the size of the VAR system, monthly data are used in order to have enough degrees of freedom for the estimation. Data collection begins in 1973:5 since the series for the market rate of interest is available from this period. The sample period ends in 1989:11 since the

most current series end at this point. Data for 1973:5 - 1975:8 are used as presample data (e.g., 15 lags for the stationarity test, 1 lag for first differences, and 12 optimal lags for the VAR order).

The beginning of the estimation period is basically consistent with the year that the Korean government began to rely on non-central bank sources of finance by issuing government bonds to the public. During the 1960s, for example, the central bank in Korea held 50% to 90% of government bonds. In early 1970s the percentage fell to 20%, and a sharp decrease occurred in 1976 (Economic Statistics Yearbook, the Bank of Korea). In addition, the beginning of the estimation period corresponds with the breakdown of the Bretton Woods agreement. Since 1971, most industrial countries have switched from fixed to flexible exchange rate regimes. But in Korea, the exchange rate regime was changed from flexible to fixed rates in May 1974 (and again switched to managed floating rates in January 1980). It should be noted that the real exchange rate will fluctuate even in a regime of fixed nominal rates since both domestic and foreign prices change.

All data were taken from the March 1990 International Financial Statistics (IFS) data tape produced by the International Monetary Fund. The industrial production indexes are available only in seasonally adjusted form, and hence the price indexes, the money supply, government

expenditures, and government debt, which are available only in seasonally unadjusted form, are seasonally adjusted by X-11. Following conventional practice, the data for the interest rate and the exchange rate are not seasonally adjusted. These two series typically have no seasonal patterns. The data series for nine variables are plotted in Appendix A. The criteria for selecting the data set are as follows.

First, the industrial production (IP) index with a base year 1985 is used as a proxy for real income (y) in Korea. Real GNP is not used because monthly data are unavailable. Monthly series for IP for both the U.S. and Japan are used in the construction of the external output shock.

Second, data for 'yields on national housing bonds' are used as a proxy for the long-term interest rate (r). National housing bonds are a widely issued government bond in Korea. No other consistent series is available for the long-term rate. The model uses the long-term rather than the short-term interest rate, because residential construction and business plant and equipment spending, which are major components of private investment spending, are thought to be more sensitive to the long-term interest rate than to the short-term rate.[3]

In examining the series for r, we observe a spike in October 1977 (see the graph in Appendix A). It is important to identify whether or not this observation is an influential outlier. Following Neter et al. (1985), the procedure for identifying an influential outlier includes three steps. 1)

In order to examine how influential the observed spike is on the residuals of an autoregressive model, we employ the interest rate equation of the VAR model (4.1). 2) To identify the outlying observation of the interest rate, the so-called studentized deleted residual is calculated for the observation in October 1977 ($d^* = -4.76$),[4] and compared with the critical value of t(0.95, 89) = 1.66. Based on this comparison, the observation appears to be extreme enough to warrant studying whether it is influential in affecting the fit of the model. 3) Cook's distance measure is calculated to identify the overall impact of the outlying observation on the estimated regression coefficients when the outlying observation is deleted. The calculated Cook's distance measure (COOKD=0.38) clearly pinpoints the outlying observation as the most influential outlier among others. But referring to the corresponding F distribution, namely, F(109, 90) = 1.39, the extent of influence is not large enough to call for consideration of remedial measures. Therefore, it can be concluded that the spike in October 1977 is an outlying observation but does not significantly influence the regression fit. For this reason, the observation is retained as it is.[5]

Alternatively, the VAR model (4.1) is estimated using a dummy variable for the outlying observation of the interest rate. As is well known, using a dummy variable allows for a shift of intercepts, assuming slopes to remain constant. The

variance decompositions are computed. The use of a dummy variable is found not to materially affect the VDC results reported in Tables 4.4 and 4.5. This is, in general, consistent with the results of Cook's distance measure in which the single outlying observation does not significantly influence the estimated coefficients of the VAR model.

Third, the consumer price index (CPI) is used as a measure of the domestic price level (P) in Korea. For the U.S. and Japan, the wholesale price indexes (WPI_{US} and WPI_{JP}, respectively) are used to construct external price shocks and real exchange rates. Traditionally, the purchasing power parity measure of the real exchange rate uses the CPI for both domestic and foreign countries. Although the CPI provides a comprehensive measure of changes in competitiveness of nontradeable goods, this measure will reflect little of the changes in competitiveness of tradeable goods (Frenkel 1978). The real exchange rate constructed using the WPIs for both countries, on the other hand, may not measure actual changes in the degree of competitiveness because the WPIs contain highly homogeneous tradeable goods and tend to be equated across countries (Officer 1982). Alternatively, Edwards (1989b), among others, has suggested constructing the real exchange rate by using the relative price of tradeable to nontradeable goods. For practical purposes, the partner countries' WPIs are used as foreign price levels and the home country's CPI as the domestic price level. Then, the ratio of

foreign and domestic price levels represents a proxy for the relative price of tradeables to nontradeables. The merit of using this type of measure is that it enhances the variability of the real exchange rate, and thus the degree of competitiveness is well reflected in this alternative measure. The use of WPIs for foreign countries is also consistent with Genberg et al. (1987) who used the WPI of a major trading partner country to reflect external price shocks.

Fourth, the narrowly defined money supply (M1) is included in the model. M1 is the monetary aggregate that the central bank in Korea has most consistently targeted during the sample period. For a fiscal policy variable, real government expenditures (g) are used. The total expenditures of the consolidated central government, which include transfer payments and government foreign loans and repayments, are deflated by the consumer price index. Although government purchases of goods and services that exclude transfer payments are preferable for the fiscal policy variable, no such series is available monthly. Unless government expenditures are perfect substitutes for private expenditures, government expenditures can affect the macroeconomy even if Ricardian equivalence holds. Since government expenditures and debt are correlated, macro effects due to changes in government spending might be incorrectly attributed to government debt if government spending is excluded from the model. Thus, in order to properly test for Ricardian equivalence, government

spending must be included in the model. Ideally, tax rates would also be included in the model since variations in tax rates can affect the macroeconomy even if Ricardian equivalence holds. However, there are no reliable tax rate variables available for Korea.

Fifth, the series for private holdings of government debt (D) is constructed by subtracting the central bank's holdings of debt from the total amount of outstanding government debt. The total debt is taken from the IFS data tape, while the percentage of debt held by the Bank of Korea is separately calculated from the Monthly Statistical Bulletin, the Bank of Korea, various issues, because the series for private holdings of debt is not available for Korea in the IFS data source. The calculated percentage of debt held by the Bank of Korea is then multiplied by total debt in order to get the amount of debt held by the Bank of Korea. Subtracting that portion from total debt results in private holdings of government debt. It should be noted, however, that the measure of D includes debt held by the 'deposit money banks' (or commercial banks) in Korea. During the 1970s, the deposit money banks in Korea were private business firms with public responsibilities, and thus they had to pursue two conflicting aims--to make profits and to follow the government control of the financial system in Korea. Since 1981, however, the deposit banks have been placed under private management as a first step for financial liberalization in Korea (Banking System in Korea, the Bank of

Korea, 1986). Although the sample period used here includes not just the 1980s but the second half of the 1970s during which the deposit banks were under financial repression, the deposit money banks are treated here as private business firms throughout the sample period.

Finally, the exchange rate is a multilateral real rate (e), with the weights derived from foreign trade in Korea. The trade weights are, as noted earlier, annual averages over the period 1973-1987. The period ends in 1987 since the most current series for exports and imports end at this point. The countries used for constructing the trade weights are Korea's two major trading partners: the U.S. and Japan. For constructing the multilateral exchange rate, the series for period-average nominal exchange rates is used. The IFS data tape provides the nominal exchange rate that is defined as the price of a U.S. dollar in terms of the Korean won or Japanese yen. However, the Korean-Japanese exchange rate (E_{JP}), which is defined as the price of a Japanese yen in terms of the Korean won, is calculated by using the ratio of the Korean-U.S. exchange rate and the Japanese-U.S. exchange rate. The base year 1985 is used to construct the export- and import-weighted exchange rate indexes ($EXCH_X$ and $EXCH_M$, respectively), since other variables including IP, CPI, and WPI are also based on 1985. Then, the two indexes are combined appropriately as described earlier in equation (4.2). It is not surprising that the movements of the multilateral

real exchange rate (or real effective exchange rate) appear to be similar to those of Edwards (1989b) over the common sample period 1973 - 1982. He uses Korea's ten largest trade partners in a particular year, 1975, while I use the two largest trade partners over the entire sample period. He also uses a base year different from 1985.

So far, we have seen how the variables are defined and how the data set is chosen for the VAR model. We now move to some model specification methods which are important for: (a) the choice of appropriate transformation of the data, (b) the selection of an optimal lag length for the VAR model, and (c) the robustness of innovation accounting results that may be potentially sensitive to the ordering of variables. The three methods are discussed in the following section.

III. Model Specification Methods

A. Stationarity Tests

Whether economic time series are stationary or not is an important issue in selecting an appropriate transformation of the data. Because choice of a wrong transformation or failure to account for nonstationarities has far-reaching consequences in interpreting the VAR model, stationarity of the data series used is investigated prior to estimation of the VAR model. For the test of stationarity, both the unit root test and

cointegration tests are employed. If each series in levels contains unit roots and if there is no cointegration among the levels, the series are considered to follow difference-stationary processes and, hence, differencing will be appropriate for the VAR model. On the other hand, if the series is trend-stationary, use of levels with the inclusion of a deterministic time trend will induce stationarity.

For the augmented Dickey-Fuller unit root test, each variable is regressed on a constant, a deterministic linear time trend, a lagged dependent variable, and q lags of first differences. The model is specified as in equation (3.3) in chapter 3. Following Schwert (1987), the integer value of 12 * $(T/100)^{1/4}$, where T = the number of observations (185 observations used here), leads us to select the optimal lag length (q) at 13. All series except the interest rate are transformed to natural logs, and the model for each variable is estimated by least squares. The null hypothesis of one unit root (H_0 : rho=1) is tested against the stationary alternative.

The estimated test statistics are reported in the first column of Table 4.1. For most variables, the null hypothesis of one unit root cannot be rejected at the five percent significance level, since t-values are less than the critical values. Most series appear nonstationary in log levels, and the nonstationarities are more properly characterized as stochastic trends rather than deterministic trends.

Table 4.1---Unit Root and Cointegration Tests

Variable	Unit Root Test	Cointegration Test 1		Cointegration Test 2	
y	-2.54	-4.48	-4.60	-3.00	-3.12
r	-2.07	-2.92	-3.04	-2.15	-2.16
P	-1.69	-3.98	-4.17	-0.42	-0.41
M1	-1.45	-3.90	-4.13	-2.28	-2.19
g	-2.86	-3.30	-3.31	-3.26	-3.26
D	-2.91	-3.27	-3.47	-2.71	-2.67
e	-1.70	-3.48	-3.52	-0.85	-0.76
P^*	-1.05	-4.27	-4.35	-1.46	-1.62
Y^*	-3.78*		-2.90		-2.36

Note: The variables are industrial production index (y), government bond yield (r), consumer price index (P), money supply (M1), real government expenditures (g), private holdings of government debt (D), multilateral real exchange rate (e), external price shocks (P^*), and external output shocks (Y^*). The sample periods used are from 1974:7 to 1989:11 for the unit root and cointegration tests. '*' indicates significant at the 5 percent level.

For the unit root test, the critical values for the sample size (T=185) used here are approximately -3.46 and -4.04 at 5% and 1% significance levels, respectively [Guilkey and Schmidt (1989)]. For cointegration test 1, the critical values are -5.05 and -5.59 at 5% and 1% significance levels, respectively, when the number of variables are nine (k=9) [Boschen and Mills (1989)]. The last two columns report the cointegration test of the type proposed by Hansen (1990) which uses the Cochrane-Orcutt procedure and possesses the distribution of the standard unit root test as in column 1. Therefore, cointegration test 2 uses the critical values obtained from the Guilkey and Schmidt's table.

Therefore, differencing is suggested to transform the data for most variables. One exception is the external output shock variable (Y^*). Y^* does not contain one unit root at the 5 percent level, but it does at the 1 percent level.

The cointegration test evaluates whether some linear combination of the variables found to be nonstationary is stationary. If the series are cointegrated, differencing is not an appropriate transformation. The model for the Engle-Yoo (1987) cointegration test is specified as in equation (3.4) in chapter 3. As noted earlier in chapter 3, the test for cointegration is a two-step procedure. First, regressions are run with each nonstationary variable in the model serving as the dependent variable. The right hand side of each cointegrating regression includes the remaining nonstationary variables of the VAR system and is estimated by least squares. The second step is the augmented Dickey-Fuller test of the residuals obtained from the first step. The residuals are regressed on one lagged value of the residuals as well as q lags of their first differences. The same lag length (q=13) is used as in the unit root test.

The second and third columns in Table 4.1 report the estimated test statistics for the Engle-Yoo cointegration test. Since the cointegration test requires the use of nonstationary series only, the second column excludes external output shocks (Y^*). No evidence is found for cointegration. For all variables, the null of no cointegration cannot be

rejected at the 5% significance level. The third column includes Y^* in the cointegrating regression because that series was previously found stationary at the 5% significance level but not at the 1% level in the unit root test. Again no evidence of cointegration is found.

Hansen (1990) contends that power of the OLS residual-based approach of the Engle-Yoo cointegration test depends upon the number of variables in the system. In particular, the Engle-Yoo cointegration test has low power against reasonable alternatives as the size of the system increases. To avoid this problem, Hansen proposes an alternative GLS approach, which uses the Cochrane-Orcutt procedure, to estimate the cointegrating regression. The merit of using the Cochrane-Orcutt procedure is that the power is unaffected by the dimension of the system. Using the Cochrane-Orcutt procedure, the parameter estimates of the cointegrating regression converge to constants; least squares estimates, however, do not converge to constants but stay random. These random elements vary with the number of the system variables in the OLS residual-based approach. This source of the "curse of dimensionality" can be avoided in the Hansen-type cointegration test since the parameter estimates of the Cochrane-Orcutt procedure converge to constants.

The fourth and fifth columns in Table 4.1 report the t-statistics of the Hansen-type cointegration test that are distributed as in the standard unit root test. For all

variables, the null of no cointegration cannot be rejected at the 5% significance level. The results are thus consistent with those of the Engle-Yoo cointegration test.

In sum, the unit root tests suggest that eight of the system variables have a unit root. The evidence is weaker for the ninth variable, Y^*. The cointegration tests that exclude Y^* indicate no cointegrating relation among the nonstationary variables. Thus, first differencing seems to be appropriate for the eight variables, and levels for Y^*. Alternatively, all nine variables including Y^* could be transformed in first differences since no evidence of cointegration was found for all variables. Later in section IV.A, a more detailed discussion of the robustness of the results to these data transformation methods will be provided.

B. Selection of VAR Order

In addition to the explicit choice of data transformation in the previous sub-section, the selection of the appropriate lag length is another important issue for the VAR specification. Since the true lag lengths are unknown, it would seem to be important in practice to allow the data themselves to select appropriate lag lengths. Following Lutkepohl (1982), the Akaike information criterion (AIC) is used to select the VAR order. The minimum value of the AIC determines the optimal lag length for all equations of the VAR

system.

The results are reported in Table 4.2. Panel (a) reports the AICs estimated when Y^* is in levels and the other variables are in first differences. Panel (b) is for the case when all variables are in first differences. For both cases, the maximum lag length considered is initially set at 12, because it was felt that consideration of lags longer than 12 would undesirably reduce the degrees of freedom for estimation. The AIC criterion leads us to select the optimal lag length of 12 in both cases. The appropriateness of setting the VAR order at 12 months is further examined by checking the serial correlation of the estimated residuals. The Ljung-Box Q statistic is used to test for general serial correlation of the residuals. The marginal significance levels of the Q statistics range between 0.62 and 0.99 for the first case and between 0.71 and 0.99 for the second case. Accordingly, serial correlation is not a problem in the 12-lag model regardless of the data transformation methods. Although we defer discussion of an alternative lag length (e.g., 13 months) until end of section IV.A, it bears emphasis that we do not vary our specification of the 12 lags except for the case of a sensitivity check.[6]

Table 4.2---Selection of VAR Order: AIC Criterion

(a) Estimation of AICs with Y^* in Levels and Other Variables in First Differences

Lag	AIC
1	-63.200
2	-63.209
3	-62.942
4	-62.736
5	-62.682
6	-62.722
7	-62.546
8	-62.722
9	-62.075
10	-63.145
11	-63.400
12	-64.314*

(b) Estimation of AICs with All Variables in First Differences

Lag	AIC
1	-63.093
2	-63.152
3	-62.945
4	-62.781
5	-62.653
6	-62.595
7	-62.425
8	-62.658
9	-62.947
10	-63.014
11	-63.274
12	-64.126*

Note: The AICs are computed by using a full model rather than estimating each equation separately. '*' indicates a minimum value of AIC.

C. Variable Orderings

As noted earlier in Chapter 3, if the VAR residuals are highly contemporaneously correlated across equations, variable orderings can make a difference for variance decompositions and impulse responses.[7] Table 4.3 presents the contemporaneous correlation of the residuals estimated prior to orthogonalization of the residuals. The statistical significance of the correlation coefficients is determined by computing the statistic:

$$t = 0.5 \ln[(1+\rho)/(1-\rho)] (n-3)^{1/2},$$

where ρ = contemporaneous correlation coefficient and n = degrees of freedom (see Bickel and Doksum, 1977, p.222).[8] The statistic is distributed approximately as N(0,1) in a large sample under the null hypothesis that $\rho = 0$. With the degrees of freedom (n=171), the critical value for the correlation coefficient is approximately 0.15 in absolute value at the 5% significance level.

It appears that output is significantly correlated with most system variables. Innovations in output are contemporaneously, positively related to innovations in interest rates and negatively to price innovations. The output innovations are also positively related to monetary and fiscal policy variables as well as external output shocks. Furthermore, innovations in M1 and e are significantly

TABLE 4.3---Contemporaneous Correlation of Residuals

	y	r	P	M1	g	D	e	Y^*	P^*
y	1.00	.15*	-.22*	.32*	.23*	.26*	.07	.32*	-.03
r		1.00	-.14	.18*	.07	-.06	-.15*	.10	-.03
P			1.00	-.02	-.12	-.02	-.21*	-.30*	-.11
M1				1.00	.16*	.16*	.03	-.06	-.02
g					1.00	.17*	-.09	.00	-.14
D						1.00	.08	.21*	-.22*
e							1.00	-.01	-.01
Y^*								1.00	.17*
P^*									1.00

Note: See Table 4.1 for the variables used. Each element denotes the contemporaneous correlation coefficient of the residuals estimated prior to orthogonalization of the residuals. Under the null hypothesis that the correlation coefficient is zero across equations, the critical value for the correlation coefficient with the degrees of freedom (n = 171) is approximately 0.15 in absolute value at the 5 % significance level (see text). '*' indicates significant at the 5% level.

correlated with the interest rate; innovations in e and Y^* are inversely related to prices; and some significant correlations are found within domestic policy variables and within external shock variables. These non-trivial correlations of the residuals across equations may cause the innovation accounting results to vary, depending upon the variable orderings.

It is also interesting to note that if the residuals in each equation of the VAR system are contemporaneously correlated, a pure innovation in a particular variable cannot be isolated. For this reason, innovation accounting is often performed by orthogonalizing the VAR residuals. Although the Choleski decomposition of the residual variance-covariance matrix orthogonalizes the VAR residuals, it is generally recognized that the innovation accounting results may be potentially sensitive to the ordering of variables. Therefore, based upon theoretical and institutional considerations, three distinct orderings are considered:

(1) y^*, P^*, M1, g, D, e, r, y, P;

(2) y^*, P^*, M1, g, D, y, P, e, r;

(3) y^*, P^*, e, r, y, P, M1, g, D.

In ordering (1), foreign shock variables precede domestic variables, and the financial sector block precedes the goods market block. This order is chosen for the following reasons. First, two foreign shock variables (y^*, P^*) are placed on the

top. This is based upon the assumption that a small economy (like that of Korea) does not contemporaneously affect large economies (like those of the U.S. and Japan). The two external disturbances are allowed to contemporaneously alter domestic variables, but not the reverse. This order then allows only the past values of the domestic variables to affect the foreign variables. Second, within the financial sector block, monetary and fiscal policy variables (M1, g, D) precede exchange rates and interest rates (e, r). This means that policy variables are allowed to contemporaneously affect other financial variables, but contemporaneous innovations in e and r are assumed not to influence policy variables. This ordering also allows fiscal policy variables to respond contemporaneously to monetary shocks. Finally, the goods market variables (y, P) are placed in the last positions. Output and prices are allowed to respond contemporaneously to all other variable shocks. This type of relation has been employed previously in McMillin and Beard (1988), among others. In general, this type of order is consistent with the IS-LM-AS model, where interest rates, output, and prices respond to current innovations in domestic policy variables as well as foreign shock variables.

Ordering (2) is motivated by the efficient markets argument of Gordon and Veitch (1986). The efficient market hypothesis predicts that financial markets are efficient with respect to all available information. In particular, changes

in all other variables are assumed to be immediately reflected in the movements of the exchange rate and the interest rate. The interest rate (r) is placed last in the ordering, so that contemporaneous innovations in all other variables are allowed to alter r.

Finally, an extreme case is presented in ordering (3). Policy variables are placed last, so that policy variables respond to current and past shocks to all other variables. In this ordering, policy variables are passive rather than active. This order is considered to be extreme because the contemporaneous innovation in debt (D) is not allowed to contemporaneously influence the macro variables of interest. Only past values of debt are allowed to affect e, r, y, and P.

For the variable orderings (1) through (3), the variance decompositions (VDCs) have been computed. In addition, three more orderings have been considered by switching the monetary and fiscal policy variables because it seems plausible to assume that implementation of fiscal policy is contemporaneously independent of monetary policy. Thus, we examine a total of six alternative orderings. Interestingly, no significant differences are found among the six alternative orderings. Contrary to the criticism raised by Gordon and King (1982), Cooley and LeRoy (1985), Leamer (1985), and Spencer (1989), the VDC results of ordering (1) are fairly insensitive to different orderings (see Tables 4.4 and 4.5 and compare them with Tables B1 through B5 in Appendix B).[9]

IV. Empirical Results

Presented in this section are estimates of the effects of government debt on macroeconomic activity and the transmission of foreign disturbances to the Korean economy. The effects are evaluated using the variance decompositions (VDCs), impulse response functions (IRFs), and cumulative impulse responses (CIRFs) discussed earlier in chapter 3. Sample standard deviations for the VDCs, IRFs, and CIRFs are estimated by using a Monte Carlo integration procedure. One thousand draws are taken to estimate the standard errors. The standard error estimates then determine the significance of the VDCs, IRFs, and CIRFs.

The VDC results presented in Tables 4.4 and 4.5 are used. Table 4.4 reports the effects of domestic policy variables on the real exchange rate, the interest rate, output, and prices; Table 4.5 separately tabulates the impacts of foreign disturbances on these variables.[10] The two tables use ordering (1) since, as noted earlier, alternative orderings are found not to materially affect the VDC results. In addition, the VDC results reported here use the 12 optimal lags which are selected by the AIC criterion, and the Q statistics indicate white noise residuals. Furthermore, the VDCs are reported at horizons of 6, 12, 24, 36, and 48 months. In this way we can examine the dynamic behavior of the system variables in response to innovations in the variables of interest.

Table 4.4---Variance Decompositions for Policy Variables

Variable ordering (1): y^*, P^*, M1, g, D, e, r, y, P
Common lags = 12 months
Y^* in levels and other variables in differences

FEV in	Horizon (month)	VDCs explained by innovations in M1	g	D
e	6	8.4(3.4)*	1.7(2.1)	6.1(2.9)*
	12	9.5(3.2)*	3.2(2.3)	6.3(2.8)*
	24	9.6(3.1)*	8.1(2.8)*	6.3(2.7)*
	36	9.6(3.2)*	8.3(2.8)*	6.9(2.8)*
	48	9.8(3.6)*	8.5(3.1)*	7.1(3.0)*
r	6	8.0(3.1)*	8.0(3.3)*	3.1(1.9)
	12	8.1(2.7)*	11.7(3.8)*	7.3(2.7)*
	24	11.7(3.0)*	10.3(3.1)*	6.9(2.6)*
	36	11.1(3.3)*	9.9(3.2)*	9.1(3.2)*
	48	11.6(3.8)*	10.0(3.7)*	9.4(3.5)*
y	6	8.4(3.1)*	5.8(3.0)	4.4(2.6)
	12	10.5(3.4)*	5.3(2.7)	6.1(2.6)*
	24	12.6(3.6)*	5.5(3.0)	5.5(2.5)*
	36	11.9(3.7)*	5.6(3.3)	7.1(3.1)*
	48	11.9(4.1)*	5.5(3.8)	7.3(3.4)*
P	6	5.1(3.2)	4.8(2.4)*	12.7(4.2)*
	12	5.2(2.8)	4.2(2.4)	18.0(5.1)*
	24	9.2(4.6)*	5.1(2.8)	19.4(5.4)*
	36	10.5(5.1)*	5.1(3.0)	19.3(5.3)*
	48	10.4(5.2)*	5.1(3.3)	19.0(5.3)*

Note: See Table 4.1 for the variables used. Y^* is transformed in levels and the remaining eight variables in first differences. 12 optimal lags are used. FEV stands for forecast error variance. The numbers in parentheses are standard deviations estimated by using a Monte Carlo integration procedure. '*' indicates that the point estimate is at least twice the standard error.

Table 4.5---Variance Decompositions for Foreign Shocks

Variable ordering (1): y^*, P^*, M1, g, D, e, r, y, P
Common lags = 12 months
Y^* in levels and other variables in differences

FEV in	Horizon (month)	VDCs explained by innovations in	
		Y^*	P^*
e	6	3.1(2.5)	4.4(2.9)
	12	4.5(2.6)	9.4(3.6)*
	24	7.5(3.0)*	8.1(3.1)*
	36	8.1(3.1)*	8.4(3.3)*
	48	8.2(3.3)*	8.7(3.7)*
r	6	6.1(3.2)	4.0(2.2)
	12	5.8(2.9)*	7.8(2.7)*
	24	9.0(3.4)*	6.7(2.4)*
	36	9.1(3.6)*	6.7(2.6)*
	48	9.1(3.9)*	6.7(3.1)*
y	6	17.0(4.8)*	4.7(2.2)*
	12	15.9(3.8)*	6.8(2.6)*
	24	16.4(3.9)*	9.9(3.0)*
	36	15.1(3.8)*	10.2(3.4)*
	48	14.5(4.1)*	11.3(4.1)*
P	6	4.3(2.4)	15.7(5.3)*
	12	4.5(2.5)	19.6(6.4)*
	24	5.4(3.1)	20.4(7.2)*
	36	5.6(3.6)	18.6(6.4)*
	48	5.6(3.8)	18.3(6.5)*

Note: See Table 4.1 for the variables used. Y^* is transformed in levels and the remaining eight variables in first differences. 12 optimal lags are used. FEV stands for forecast error variance. The numbers in parentheses are standard deviations estimated by using a Monte Carlo integration procedure. '*' indicates that the point estimate is at least twice the standard error.

A. Ricardian Equivalence

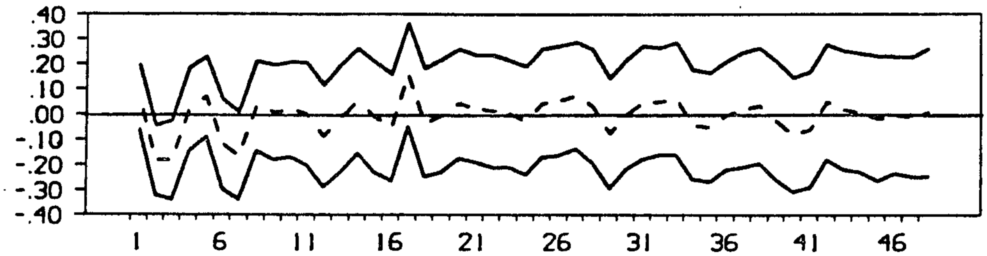
The Ricardian equivalence hypothesis predicts that government debt is not perceived as private sector wealth, and thereby does not have any effects on macroeconomic activity (Barro 1974). This hypothesis is in contrast with the traditional view that government debt is perceived as household wealth (Modigliani 1961; Blinder and Solow 1973). The effect of debt is empirically tested for the Korean economy by examining the percentage of the forecast error variance in real exchange rates, interest rates, output, and prices attributable to debt innovations.

In Table 4.4 the VDC results indicate that the effects of government debt (D) on e, r, y, and P appear to be significantly different from zero. The forecast error variance of real exchange rates explained by innovations in debt varies from 6.1 percent at the 6-month horizon to 7.1 percent at the 48-month horizon. The point estimates of the VDCs are greater than twice the standard errors--our rule of thumb for judging significance. This suggests that government debt has significant effects on real exchange rates. For interest rates, the effects of debt are also non-trivial and rise as the forecast horizon increases. The forecast error variance of interest rates accounted for by D innovations appears to be significant at the horizons of 12 months or longer. Similar patterns are found at all horizons for the

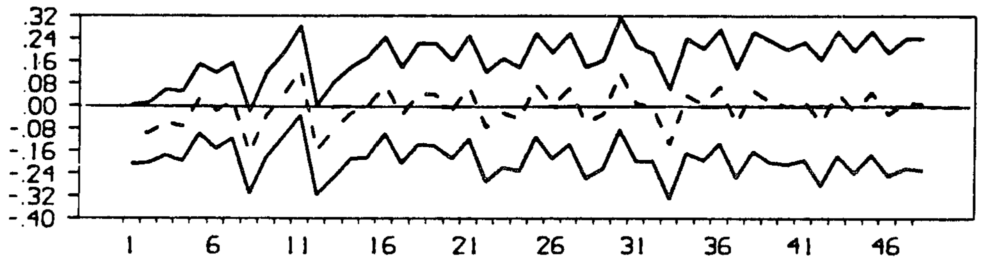
output effect of debt. For prices, the impact of debt is noticeable. The forecast error variance of prices attributable to debt innovations ranges from 12.7% at the 6-month horizon to 19.0% at the 48-month horizon, and the effects are significant at all horizons. Therefore, the role of government debt issue to finance budget deficits appears to be important in affecting macroeconomic activity in Korea.

Although the importance of debt is indicated by the variance decompositions, the directions of the effects of debt on e, r, y, and P are not clear. In particular, whether the effects of debt are positive or negative is investigated by computing the impulse response functions (IRFs). Figure 4.1 presents four plots of the IRFs. These are the impulse responses of real exchange rates, interest rates, output, and prices (the dotted lines) for a one standard innovation shock to government debt. The significance of these effects is determined by computing confidence intervals, two standard deviations wide, for the IRFs. The two solid lines indicate the upper and lower bounds of the confidence interval.

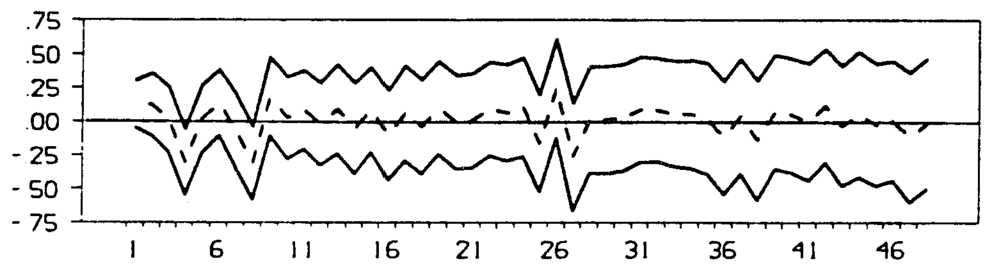
Interestingly, the four graphs in Figure 4.1 show a common feature that the significant effects of a one standard deviation shock to debt tend to be negative. That is to say, the upper bound of the confidence interval at some horizons falls below zero. For real exchange rates, for example, the impulse response to a one standard deviation shock to debt innovation is initially positive, but not significant, and



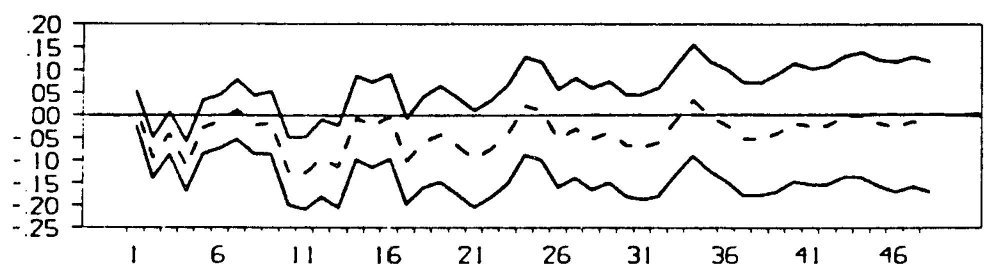
(a) Response of Real Exchange Rates to D Innovation



(b) Response of Interest Rates to D Innovation



(c) Response of Output to D Innovation



(d) Response of Prices to D Innovation

Figure 4.1. Responses to D Innovation

quickly becomes negative. The negative effects are significant at the 2-month and 3-month horizons. Note that the negative effects on e are referred to as an appreciation of the real exchange rate. Beginning from the 8-month horizon, the effects of debt insignificantly fluctuate around zero. For interest rates, the initial effects of debt are negative, and the negative effects are significant at the 8-month horizon. A marginal significance is observed at the 12-month horizon. After that, the effects of debt insignificantly fluctuate around zero. For output, the initial effects are insignificantly positive and then quickly become negative. The negative effects are significant at the 4-month and 8-month horizons, but then fluctuate around zero. For prices, the effects are significantly negative at the 2-month and 4-month horizons, and then become close to zero. After the 7-month horizon, the price effects of debt, again, become negative, and the negative effects remain significant for an extended period of time.

Because the model is fitted to differenced data, the foregoing results are the responses of the *rate of change* in e, r, y, and P to debt innovations. To get an idea of how the *level* of these variables responds to debt innovations, we compute cumulative impulse responses (CIRFs). As noted by McMillin and Koray (1990), the CIRFs of the current-period shock are obtained by adding up prior-period shocks. For example, the 2-month CIRFs are the sum of 1-month and 2-month

IRFs; the 3-month CIRFs are the sum of 1-month, 2-month, and 3-month IRFs; and so forth. The computed CIRFs then represent the responses of the levels of the variables.

The CIRF results are presented in Figure 4.2. Again, the point estimates of the CIRFs (the dotted lines) are plotted with upper and lower bounds of a two standard error confidence interval for the mean (the solid lines). It is not surprising that the responses of the levels of most variables remain significantly negative for longer horizons except for the level of output. The positive response of the level of output to debt innovations is marginally significant at the 2-month and 3-month horizons, but is not significantly different from zero at longer horizons. The observed positive effect on the level of output is consistent with the initially positive, but insignificant, effect on the growth rate of output found in Figure 4.1. For the levels of e, r, and P, the longer lasting negative effects of debt simply reflect the findings of the negative effects on their growth rates in Figure 4.1. In the long run, however, the effects on these variables are not significantly different from zero.

The IRF results that the effects of debt on r, y, and P are significantly negative do not support the conventional view that government bonds are wealth. The findings of negative effects also appear to be at odds with the Ricardian view that there will be no effects of debt. However, the negative effects of debt are generally consistent with the

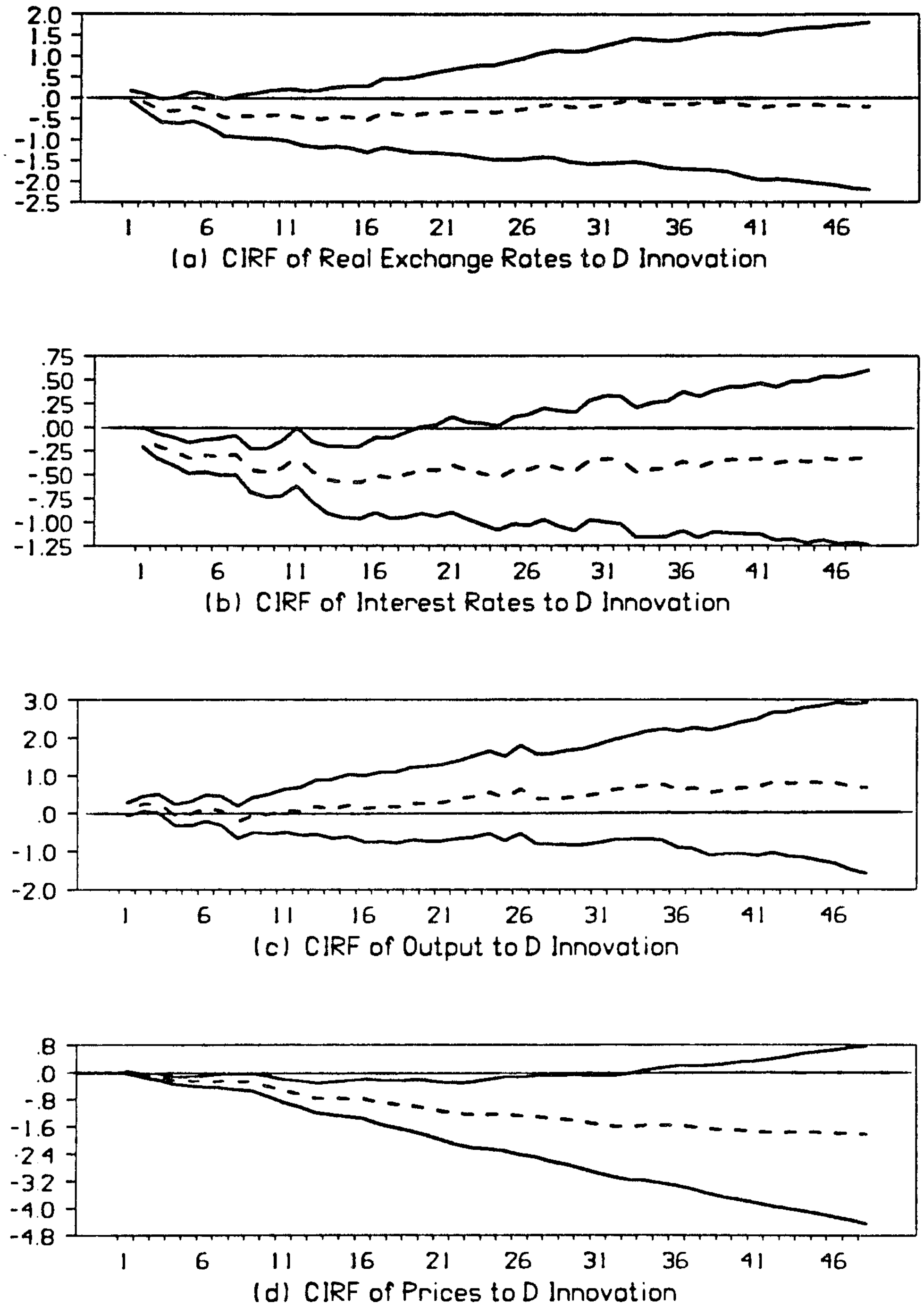


Figure 4.2. Cumulative Responses to D Innovation

finding of Evans (1990) for the Korean economy even though his methodology differs from that used here. Evans used a measure of budget deficits within the framework of a single-equation model of output and found a negative (but insignificant) effect of the deficit on output.[11]

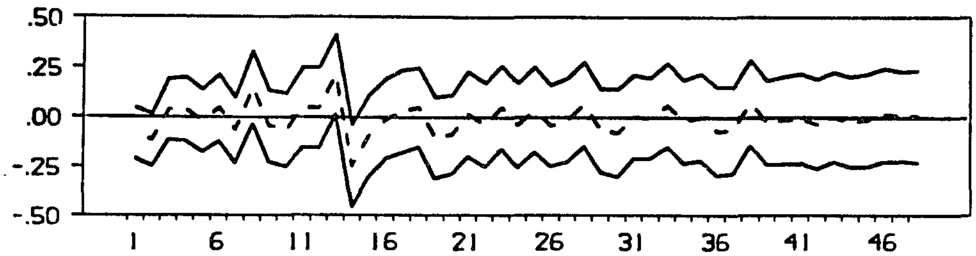
The findings of negative effects of debt are consistent with a prior argument by Barro (1974). Barro suggested that private sector wealth may fall due to uncertainty about the future tax liabilities implied by government debt issue and the timing of these taxes. When future tax liabilities and the timing of these taxes are uncertain, people may save more than the present value of the income streams associated with debt issue. This is because under uncertainty people may possibly perceive the present value of the implied future taxes to be greater than the present value of the income streams associated with government bonds. If such is the case, private sector wealth falls as bonds issued to finance a government deficit rise. As a result, increases in government debt may reduce aggregate demand, and hence interest rates, output, and prices will fall as debt rises.[12]

However, there seems to be no obvious explanation for the short-run negative effect of debt on the real exchange rate, because the appreciation of e found in panel (a) of Figure 4.1 is in contradiction with the other evidence that government debt may reduce private sector wealth in Korea. For example, the negative wealth effect of debt induces private consumption

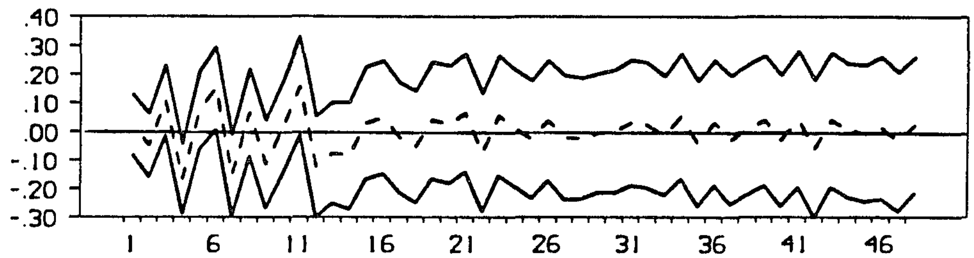
to fall and hence reduces domestic interest rates and prices. Under the assumption of perfect capital mobility, the low interest rate relative to the rest of the countries mitigates the relative attractiveness of Korean assets. The capital outflow due to the low interest rate creates a deficit in the balance of payments. A depreciation of the home currency is necessary to create a trade surplus and hence to offset the balance of payments deficit. The real exchange rate may also be depreciated more directly due to a decrease in domestic prices. Therefore, debt should have a positive effect on the real exchange rate (i.e., a depreciation of e) in order to be consistent with the negative effects of debt on interest rates and prices.[13] A positive response of the first-month horizon appears to support this line of reasoning, but the insignificant positive effect immediately fades. In the 2-month and 3-month horizons, the effect on the rate of change in e appears to be significantly negative. However, the transitory negative effect immediately becomes positive and insignificantly fluctuates around zero in the long run. The CIRFs in Figure 4.2 show that there is no lasting negative effect on the level of e, though a marginally significant negative effect is observed at short horizons. In the long run, the effect of debt on the level of e also appears to be zero.

It is interesting to contrast the effects of debt with those of government expenditures. In Table 4.4, innovations

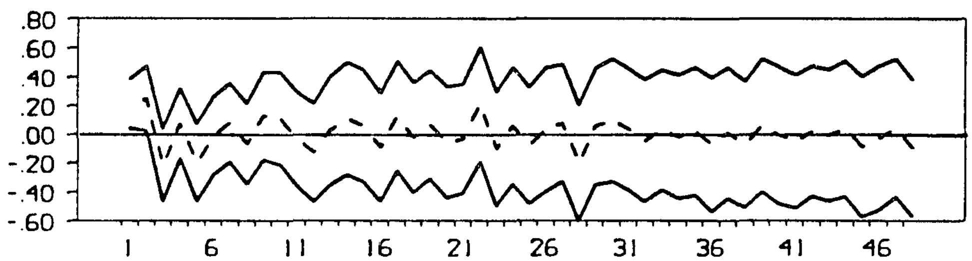
in government expenditures (g) are found to account for significant proportions of forecast error variance of the real exchange rate and the interest rate, but output and price effects are typically small and insignificant. However, the IRF results presented in Figure 4.3 indicate that the response of output to g innovations is initially positive and is significant at the first two periods, judging from the confidence band. The initial positive output effect of g is in striking contrast to the negative output effect of D, and supports the argument by Barro (1981) that unless government expenditures are perfect substitutes for private expenditures, government expenditures affect real output even if Ricardian equivalence holds. The initial positive output effect of g is also consistent with Evans (1990), who finds that government purchases in Korea have an expansionary effect on output.[14] The impulse responses of the interest rate and the real exchange rate display a wider swing around zero at short horizons, while the effect on prices is insignificantly different from zero. Similar results are found for the levels of e, r, y, and P in Figure 4.4, where the CIRFs are computed. In no cases are these effects significant except for the short-run output effect of g. The response of the level of output to g innovations appears to be positive, and is significant for the first four periods. After that, the effects are not significantly different from zero. For the



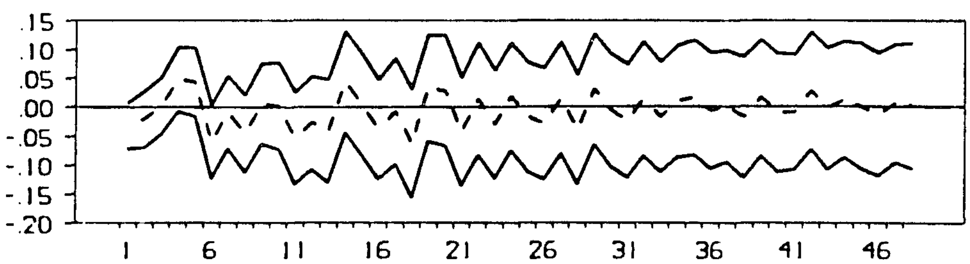
(a) Response of Real Exchange Rates to g Innovation



(b) Response of Interest Rates to g Innovation

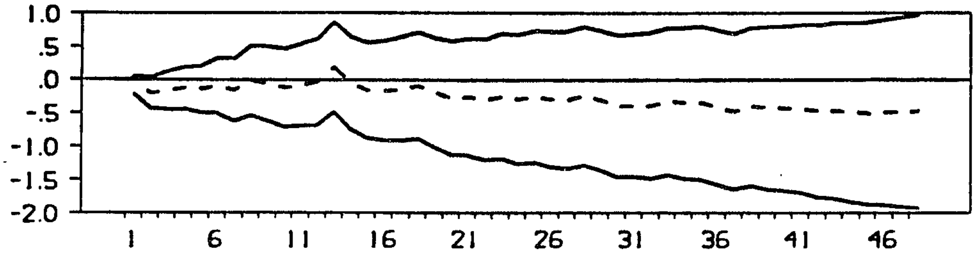


(c) Response of Output to g Innovation

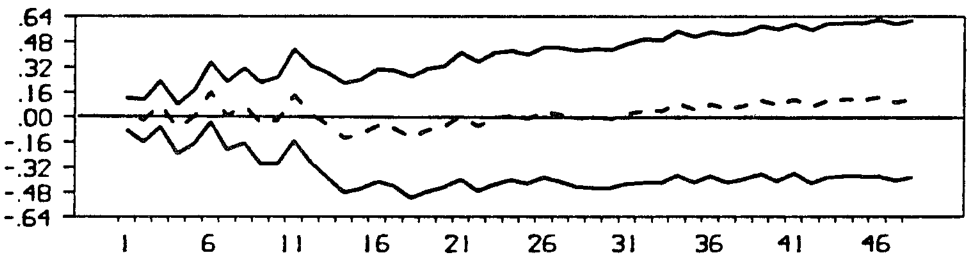


(d) Response of Prices to g Innovation

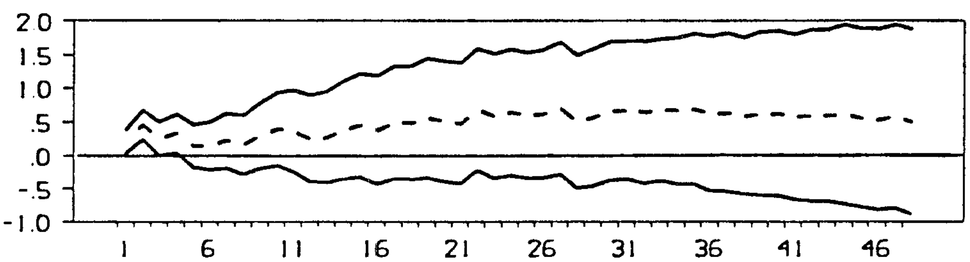
Figure 4.3. Responses to g Innovation



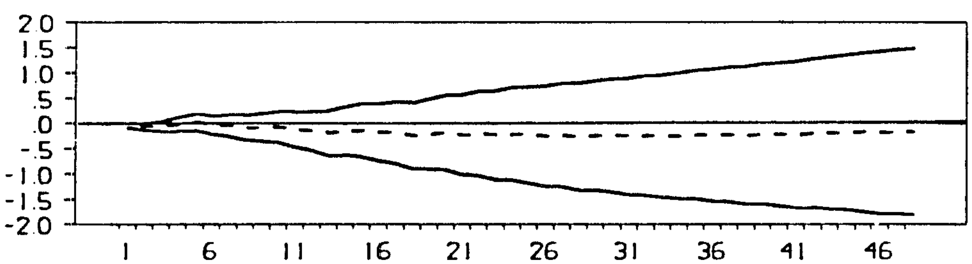
(a) CIRF of Real Exchange Rates to g Innovation



(b) CIRF of Interest Rates to g Innovation



(c) CIRF of Output to g Innovation

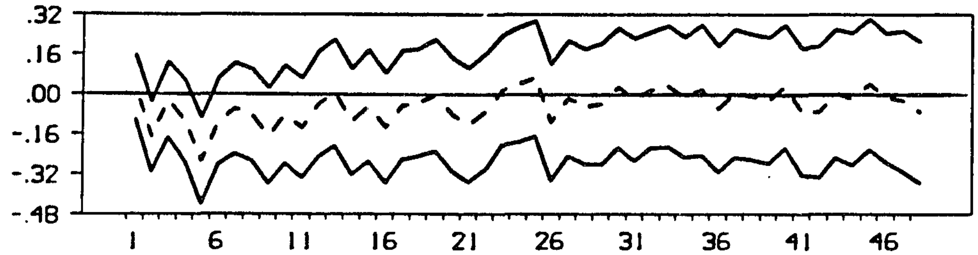


(d) CIRF of Prices to g Innovation

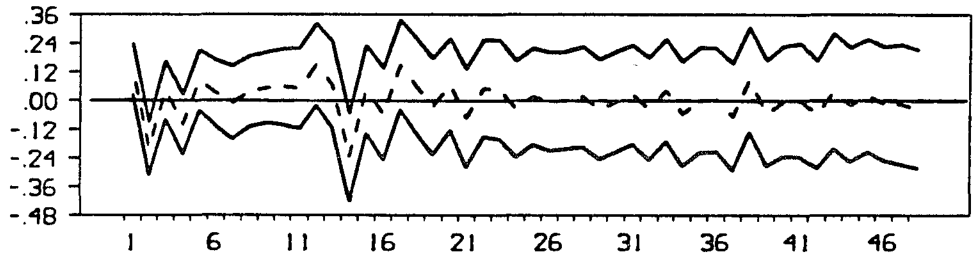
Figure 4.4. Cumulative Responses to g Innovation

levels of e, r, and P, no significant effects are found at any horizon.

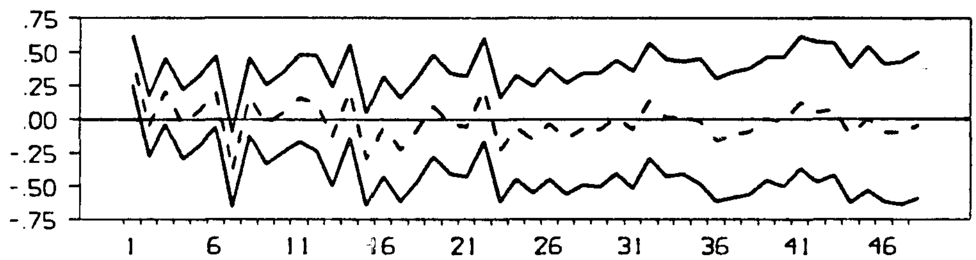
The VDC results in Table 4.4 also provide evidence that the effects of M1 are relatively large and significant. For e and r, the point estimates of the VDCs explained by M1, g, and D innovations are similar to each other. However, M1 has a larger effect on output than does g or D, while debt has a larger effect on prices than do g and M1. Figure 4.5 displays impulse responses to M1 innovations. Although the negative effect on e is difficult to explain within the conventional view of exchange rate movements, the effects on r, y, and P appear roughly consistent with the conventional theory of monetary policy effects. An increase in M1 induces the interest rate to fall and output and prices to rise in the short run. The effects on the rate of change in e, r, y, and P found in Figure 4.5 appear similar to the effects on the level of these variables reported in Figure 4.6. Although the short-run positive effect on the level of the interest rate at the 12-month and the 13-month horizons appears to be inconsistent with the short-run negative effect on the change in r at the 2-month and the 14-month horizons, no significant differences are found for the remaining variables. It is also interesting to note that M1 has a one-to-one relationship with the price level in the long run, as expected.



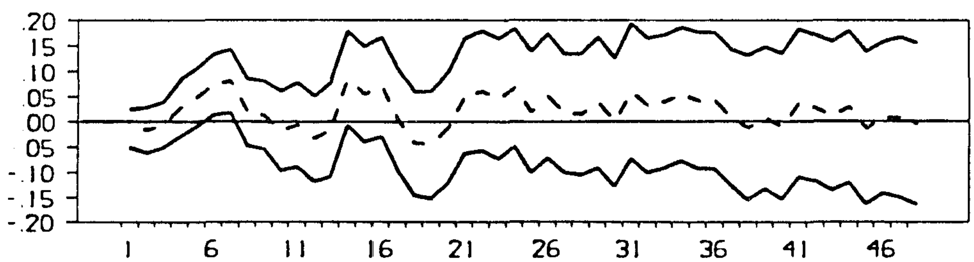
(a) Response of Real Exchange Rates to M1 Innovation



(b) Response of Interest Rates to M1 Innovation



(c) Response of Output to M1 Innovation



(d) Response of Prices to M1 Innovation

Figure 4.5. Responses to M1 Innovation

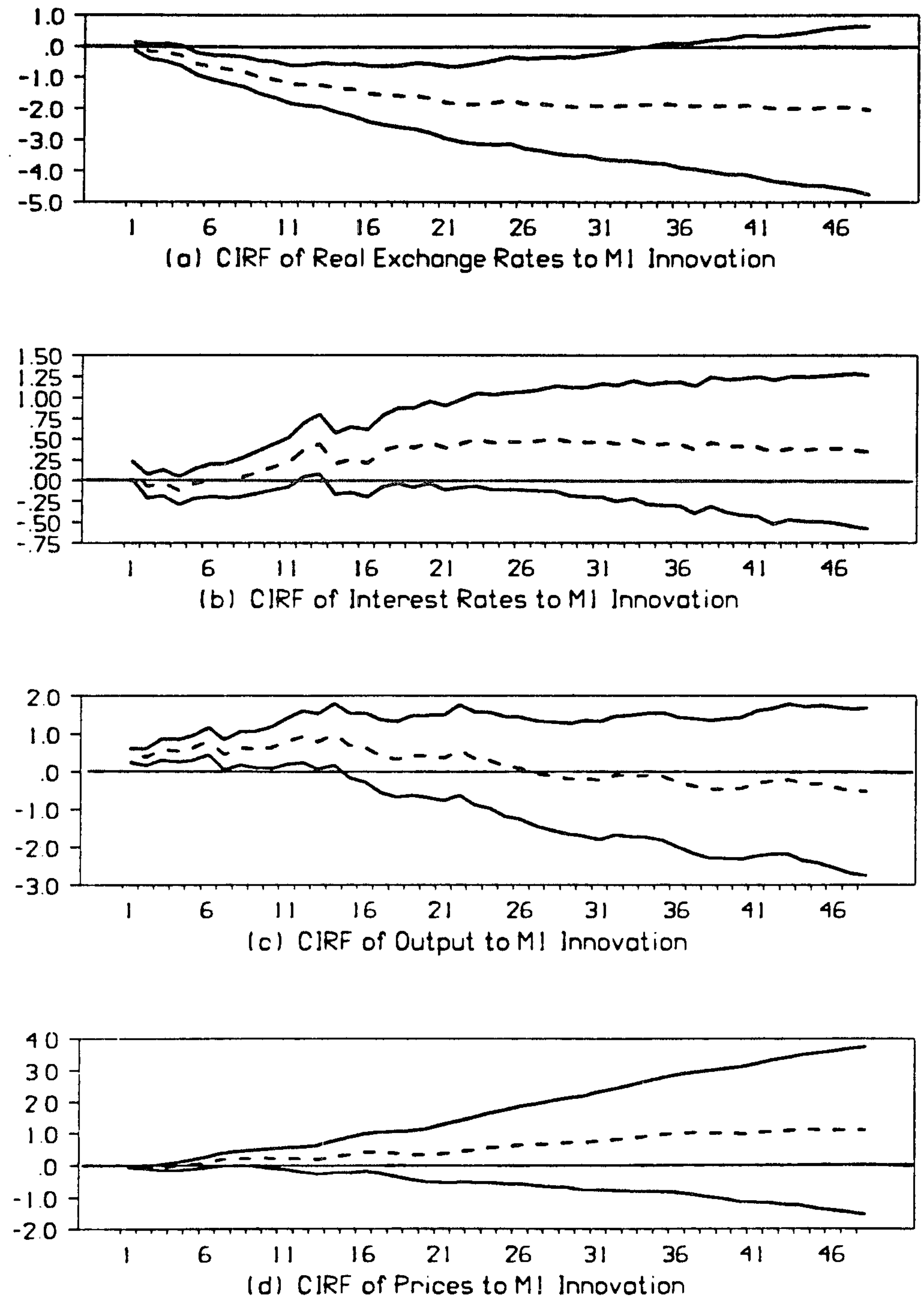


Figure 4.6. Cumulative Responses to M1 Innovation

In order to check the robustness of our findings, two alternative model specifications are examined. First, the VAR order of 12 months has been extended to 13 months since the optimal lag length determined by the AIC criterion turned out to be the maximum lag length. Note that other specifications (e.g., variable ordering and data transformation method) are unaltered. Tables 4.6 and 4.7 report the VDC results of the 13-lag model. The VDC results are changed little except for the effect of debt on the real exchange rate. For the effect of debt on e, the point estimates are less than but are close to twice the standard errors at the horizons longer than 24 months. There are also some changes in the price effects of Y^* and P^*, but these changes are within two standard deviations of those in Table 4.5.

In the second robustness check, all of the system variables are in first differences. This is an alternative to the previous specification in which Y^* was in levels and the remaining eight variables in first differences. In this specification the variable ordering (1) and the optimal lag length of 12 months do not vary. The VDC results are presented in Tables 4.8 and 4.9. No significant differences are found except for the real exchange rate effects of M1 and debt. As compared with the VDC results in Table 4.4, the effect of M1 on e mitigates and becomes insignificant, while the effect of debt on e becomes stronger. But these changes

Table 4.6---Variance Decompositions for Policy Variables

Variable ordering (1): y^*, P^*, M1, g, D, e, r, y, P
Common lags = 13 months
Y^* in levels and other variables in differences

FEV in	Horizon (month)	VDCs explained by innovations in		
		M1	g	D
e	6	9.6(3.6)*	1.9(2.1)	2.4(2.1)
	12	9.9(3.1)*	3.4(2.3)	3.6(2.5)
	24	8.9(2.8)*	8.3(3.0)*	5.5(2.8)
	36	9.0(3.0)*	8.1(3.0)*	5.8(2.9)*
	48	9.5(3.3)*	8.5(3.2)*	6.1(3.1)
r	6	9.2(3.1)*	10.0(3.6)*	5.6(2.2)*
	12	9.4(2.9)*	13.0(4.0)*	7.0(2.4)*
	24	12.5(3.1)*	13.5(3.6)*	7.2(2.5)*
	36	12.1(3.2)*	13.0(3.6)*	8.8(2.8)*
	48	12.4(3.6)*	13.1(3.9)*	9.3(3.1)*
y	6	7.0(2.6)*	5.3(2.8)	4.1(2.2)
	12	8.1(2.7)*	6.0(2.9)*	4.5(2.2)*
	24	11.6(3.4)*	5.6(3.2)	4.1(2.1)
	36	11.1(3.3)*	5.4(3.4)	6.1(2.5)*
	48	11.5(3.6)*	5.6(3.7)	6.1(2.9)*
P	6	4.2(2.6)	6.4(2.8)*	13.2(4.7)*
	12	5.4(2.6)*	4.8(2.6)	20.3(6.1)*
	24	8.8(3.7)*	5.8(3.0)	24.7(7.3)*
	36	9.5(4.0)*	5.7(3.2)	24.3(7.2)*
	48	9.6(4.2)*	5.5(3.5)	24.5(7.3)*

Note: See Table 4.1 for the variables used. Y^* is transformed in levels and the remaining eight variables in first differences. The lag length used here is 13 months. FEV stands for forecast error variance. The numbers in parentheses are standard deviations estimated by using a Monte Carlo integration procedure. '*' indicates that the point estimate is at least twice the standard error.

Table 4.7---Variance Decompositions for Foreign Shocks

Variable ordering (1): y^*, P^*, M1, g, D, e, r, y, P
Common lags = 13 months
Y^* in levels and other variables in differences

FEV in	Horizon (month)	VDCs explained by innovations in	
		y^*	P^*
e	6	3.3(2.9)	5.0(2.9)
	12	4.7(2.6)	10.1(3.8)*
	24	6.7(2.7)*	8.3(3.2)*
	36	7.6(2.9)*	8.8(3.3)*
	48	8.2(3.2)*	9.0(3.8)*
r	6	7.0(3.5)*	5.7(2.8)*
	12	7.3(3.3)*	7.4(2.8)*
	24	10.4(4.0)*	7.1(2.7)*
	36	10.4(4.1)*	7.5(2.9)*
	48	10.6(4.5)*	7.4(3.5)*
y	6	15.0(4.7)*	4.9(2.3)*
	12	14.7(3.9)*	6.4(2.6)*
	24	17.9(4.3)*	8.6(3.0)*
	36	16.6(4.4)*	9.4(3.4)*
	48	15.8(4.7)*	10.5(4.2)*
P	6	6.1(2.5)*	13.6(5.0)*
	12	7.0(2.7)*	16.2(5.8)*
	24	6.5(2.8)*	14.6(5.7)*
	36	6.4(3.3)	14.2(5.1)*
	48	7.0(3.7)	14.2(5.3)*

Note: See Table 4.1 for the variables used. Y^* is transformed in levels and the remaining eight variables in first differences. The lag length used here is 13 months. FEV stands for forecast error variance. The numbers in parentheses are standard deviations estimated by using a Monte Carlo integration procedure. '*' indicates that the point estimate is at least twice the standard error.

Table 4.8---Variance Decompositions for Policy Variables

Variable ordering (1): y^*, P^*, M1, g, D, e, r, y, P
Common lags = 12 months
All variables in differences

FEV in	Horizon (month)	VDCs explained by innovations in		
		M1	g	D
e	6	4.4(2.8)	2.3(2.1)	8.9(3.8)*
	12	4.3(2.6)	3.8(2.4)	10.2(3.8)*
	24	4.9(2.6)	8.7(2.8)*	9.8(3.4)*
	36	5.6(2.9)	9.0(2.9)*	9.7(3.4)*
	48	5.9(3.2)	9.1(3.1)*	9.9(3.6)*
r	6	7.7(3.2)*	8.0(3.3)*	2.4(1.8)
	12	7.4(2.7)*	11.8(3.8)*	6.7(2.8)*
	24	11.2(3.2)*	10.3(3.3)*	6.4(2.6)*
	36	10.5(3.4)*	9.9(3.4)*	8.7(3.0)*
	48	11.0(3.7)*	10.0(3.8)*	8.9(3.2)*
y	6	8.3(3.3)*	5.9(3.0)	4.4(2.4)
	12	11.0(3.5)*	5.3(2.7)	6.2(2.5)*
	24	12.4(3.7)*	5.3(3.1)	5.5(2.5)*
	36	11.6(3.8)*	5.7(3.4)	7.1(2.9)*
	48	11.7(4.2)*	5.6(3.8)	7.2(3.4)*
P	6	4.7(3.0)	4.6(2.3)*	11.6(3.9)*
	12	4.5(2.5)	4.4(2.3)	17.3(5.1)*
	24	8.2(4.0)*	5.2(2.9)	18.2(5.6)*
	36	9.6(4.4)*	5.2(2.9)	18.3(5.6)*
	48	9.9(4.6)*	5.1(3.3)	18.4(5.7)*

Note: See Table 4.1 for the variables used. All variables are in first differences. FEV stands for forecast error variance. The numbers in parentheses are standard deviations estimated by using a Monte Carlo integration procedure. '*' indicates that the point estimate is at least twice the standard error.

Table 4.9---Variance Decompositions for Foreign Shocks

Variable ordering (1): y^*, P^*, M1, g, D, e, r, y, P
Common lags = 12 months
All variables in differences

FEV in	Horizon (month)	VDCs explained by innovations in y^*	VDCs explained by innovations in P^*
e	6	2.0(2.5)	4.9(3.1)
	12	3.3(2.6)	9.1(3.7)*
	24	5.9(2.9)*	8.3(3.2)*
	36	6.7(2.9)*	8.5(3.3)*
	48	6.8(3.1)*	8.6(3.2)*
r	6	6.0(3.2)	4.0(2.4)
	12	5.8(2.9)*	7.9(2.7)*
	24	9.1(3.4)*	6.6(2.4)*
	36	9.1(3.5)*	6.6(2.7)*
	48	9.1(3.7)*	6.6(3.2)*
y	6	16.7(5.0)*	4.7(2.1)*
	12	15.5(3.8)*	6.9(2.5)*
	24	16.2(3.8)*	9.7(2.9)*
	36	15.2(3.8)*	10.0(3.3)*
	48	14.7(4.1)*	11.1(4.2)*
P	6	4.2(2.3)	15.6(5.5)*
	12	5.7(2.6)*	19.1(6.3)*
	24	5.7(3.3)	20.0(6.9)*
	36	5.9(3.7)	18.3(6.0)*
	48	5.9(4.0)	17.8(6.0)*

Note: See Table 4.1 for the variables used. All variables are in first differences. FEV stands for forecast error variance. The numbers in parentheses are standard deviations estimated by using a Monte Carlo integration procedure. '*' indicates that the point estimate is at least twice the standard error.

are also within two standard deviations of those reported in Table 4.4.

Therefore, the VDC results reported in Tables 4.4 and 4.5 seem fairly robust. Neither changing the lag length, altering the transformation of data series, nor using different variable orderings modifies the VDC results qualitatively.

B. Macroeconomic Interdependence

The degree to which the domestic economy is insulated from foreign disturbances has been a controversial issue since the demise of the Bretton Woods system. Traditionally, it was believed that a flexible exchange rate regime would insulate the domestic economy from the influence of foreign shocks (Friedman 1953; Johnson 1969). However, the traditional view of complete insulation under flexible rates appears to be incorrect. Most recent studies support the proposition of macroeconomic interdependence, i.e., one country's shocks are internationally transmitted to another via several channels (see, for example, Dornbusch 1983).

In this sub-section the degree of interdependence is examined for the Korean economy. In particular, the relative importance of foreign disturbances to the Korean economy is investigated based upon innovation accounting results. To focus on the mechanism of international transmission operating through Korea's foreign trade, we employ external output and

price shocks that are linear combinations of the corresponding U.S. and Japanese variables.

Table 4.5 presents the variance decompositions (VDCs) of the domestic variables of interest explained by innovations in foreign shock variables. The forecast error variance of real exchange rates accounted for by innovations in foreign output (Y^*) is 3.1 percent at the 6-month horizon. The effects rise and are significantly different from zero at the forecast horizons of 24 months and longer. For domestic interest rates, the point estimates of VDCs are, at most horizons, greater than twice the standard errors, so that external output shocks appear to have significant effects on the domestic interest rate. For domestic output, the effects are sizeable. The forecast error variance of domestic output attributable to innovations in foreign income disturbances is 17.0 % at the 6-month horizon and then slightly decreases to 14.5 % at the 48-month horizon. The large proportions of the variance are also significant according to our rule of thumb. However, the price effects of foreign income disturbances are relatively small and insignificant at all horizons.

Foreign price disturbances (P^*) also have significant effects on the Korean economy. In particular, the impact on domestic prices is sizeable. Innovations in foreign price shocks explain between 15 % and 20 % of the forecast error variance of domestic prices. The proportions are relatively large and exceed twice the standard errors. The output

effects of foreign price shocks are relatively small at short horizons but increase more than twice at longer horizons. All effects are significant. Finally, the effects on the interest rate and the real exchange rate also appear to be non-trivial and are, at most horizons, significant.

Therefore, the VDC results indicate that external output and price shocks significantly influence the domestic economy in Korea during the sample period. These findings are consistent with the results of Kim (1987). Kim estimated a small-size structural model of the Korean economy and provided evidence that U.S. monetary and fiscal policies are internationally transmitted into the Korean economy. These findings also support the argument by Genberg et al. (1987) that the inclusion of foreign variables can avoid a serious omission in structural modeling of a small open economy.

In addition to the general findings that the Korean economy is significantly affected by foreign disturbances, a question of practical interest is the importance of foreign disturbances relative to domestic policy shocks. For a given forecast horizon, the relative importance is measured as RATIOF = FEVF / (FEVF + FEVD) * 100. FEVF and FEVD are the proportions of the forecast error variance of a Korean variable explained, respectively, by the sum of foreign shock variables (Y^* and P^*) and the sum of domestic policy variables (M1, g, and D). From Tables 4.4 and 4.5, FEVF and FEVD are computed for each variable:

	e	r	y	P
FEVF	14.1 (39%)	14.2 (34%)	24.3 (52%)	23.6 (44%)
FEVD	21.9 (61%)	27.3 (66%)	22.8 (48%)	30.6 (56%)

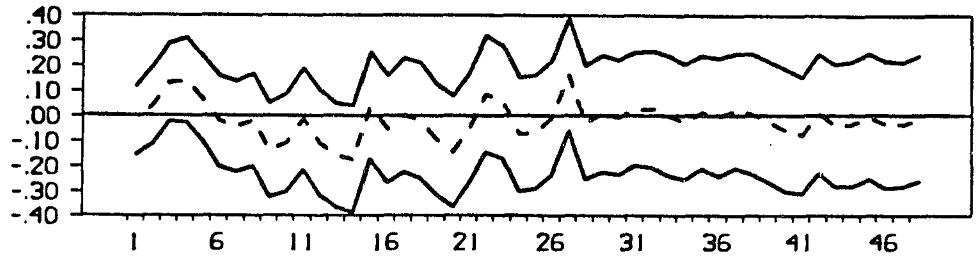
Each element represents the average of the forecast error variances at all horizons explained by the sum of foreign or domestic shocks. A measure of the relative importance, RATIOF (and analogously, RATIOD), is provided in parentheses. In this way, we can determine the importance of foreign disturbances to the Korean economy relative to domestic policy shocks.

Foreign disturbances appear to be relatively important in affecting domestic output and prices, whereas the impacts are not so strong for the real exchange rate and domestic interest rate. For domestic output, RATIOF is 52% on average at all horizons. This suggests that fluctuations in domestic output are more attributable to foreign shocks than domestic policy shocks. For domestic prices, RATIOF falls slightly to 44%. For both y and P, the magnitude of the effects of foreign shocks and domestic policy shocks is quite comparable to each other. For real exchange rates, however, RATIOF is 39%, and the ratio for the interest rate effect falls further to 34%. The relatively weak influence on the domestic interest rate of foreign output and price shocks is consistent with the findings of Genberg et al. (1987) for Switzerland and

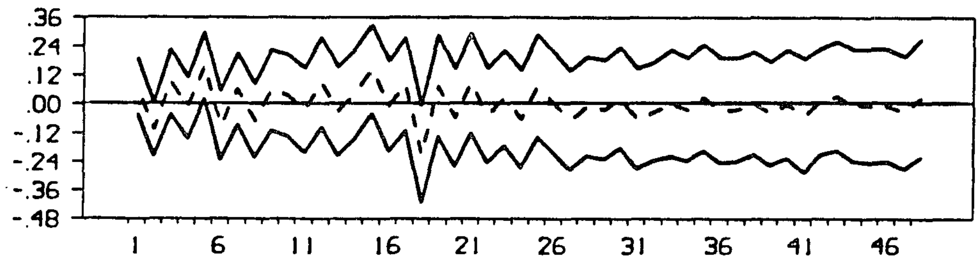
Lastrapes and Koray (1990) for other European countries.

Clearly a key feature of our finding from the VDC results is that foreign output shocks have had a substantial effect on domestic output. This may result from a heavy dependence of the Korean economy on foreign trade. An increase in foreign income raises exports in Korea. The increase in aggregate demand due to an increase in exports then raises domestic output. This line of reasoning is confirmed statistically by impulse response functions. Panel (c) in Figure 4.7 shows the impulse response of Korean output (the dotted line) to a one standard deviation shock to foreign income. The initial positive effect on output appears to be significant, judging from the confidence intervals (the solid lines). This significant, positive effect of Y^* on domestic output conforms to the aggregate demand channel of external output shocks described above. However, the initial positive effect quickly becomes negative and is also significant at the 2-month horizon. After that, the output effect fluctuates insignificantly around zero.

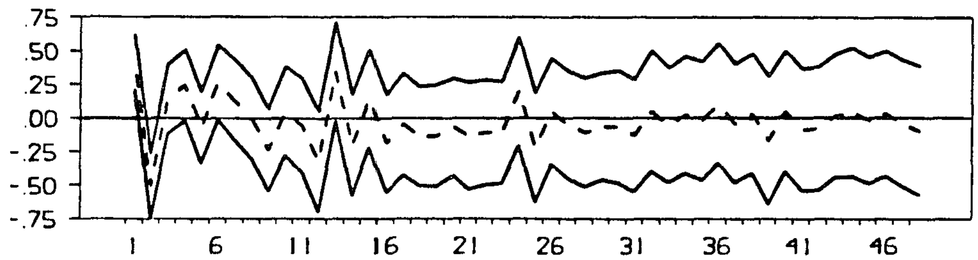
In response to Y^* innovations, the real exchange rate fluctuates insignificantly around zero at all horizons. The response of domestic interest rates appears to be initially positive, but is insignificant. Marginally significant positive and negative effects are observed at the 5-month and 18-month horizons, respectively. Domestic prices also tend to rise in response to foreign output shocks. The initial



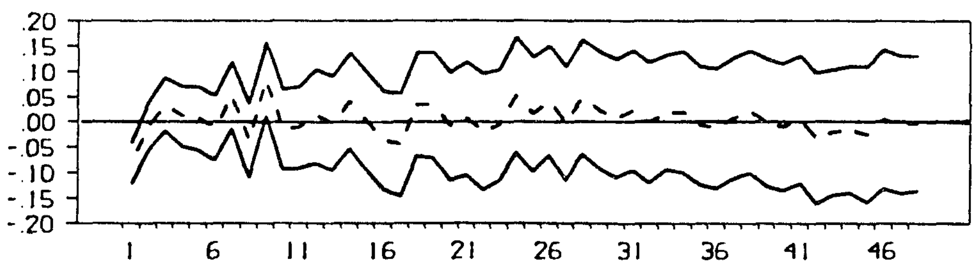
(a) Response of Real Exchange Rates to YSTAR Innovation



(b) Response of Interest Rates to YSTAR Innovation

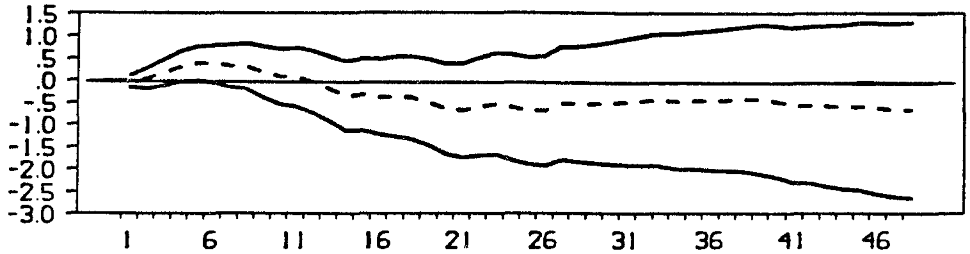


(c) Response of Output to YSTAR Innovation

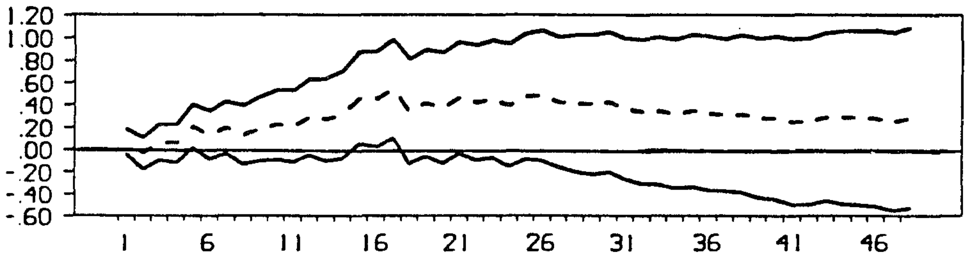


(d) Response of Prices to YSTAR Innovation

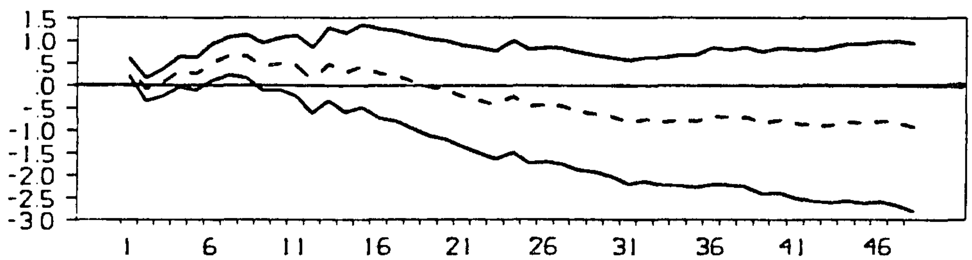
Figure 4.7. Responses to Y^* Innovation



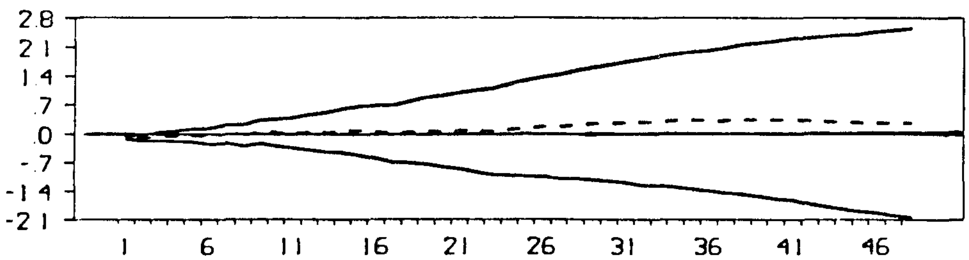
(a) CIRF of Real Exchange Rates to YSTAR Innovation



(b) CIRF of Interest Rates to YSTAR Innovation



(c) CIRF of Output to YSTAR Innovation



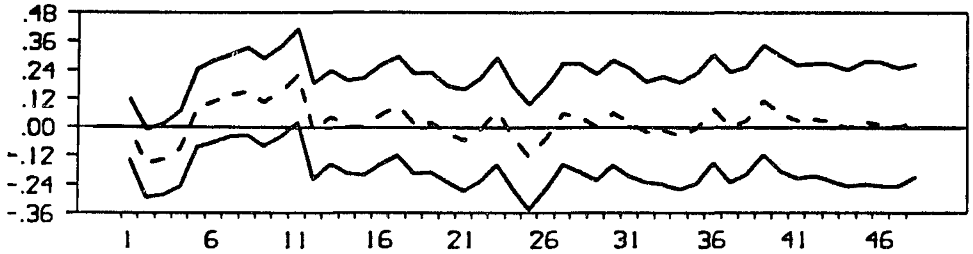
(d) CIRF of Prices to YSTAR Innovation

Figure 4.8. Cumulative Responses to Y^* Innovation

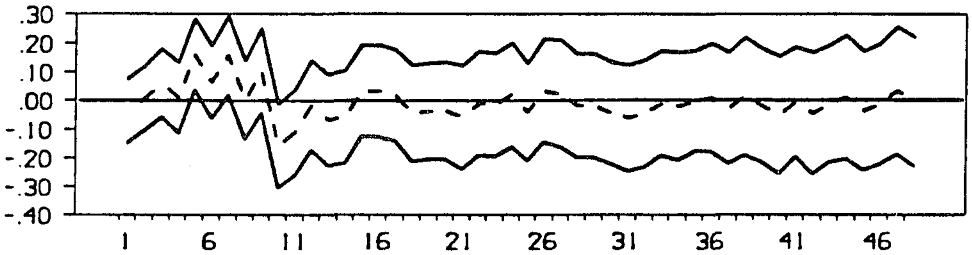
negative effect, for example, quickly becomes positive, and the positive effect is significant at the 9-month horizon. The lag in the significant effect on P may result from a short-run price rigidity in Korea.[15] These findings on r and P are consistent with the aggregate demand channel, in which an increase in foreign income induces domestic exports to rise and, hence, interest rates and prices may rise in the home country, Korea. In the long run, however, the effects on r and P fluctuate insignificantly around zero.

As noted earlier, the effect on the level of a variable can be examined by computing the cumulative IRFs. The CIRF results presented in Figure 4.8 indicate that the positive effects on the levels of r and y are significant at short horizons. No lasting effects on the levels of r and y are found in the long run. For the levels of e and P, however, the effects of Y^* are not significantly different from zero at any horizon.

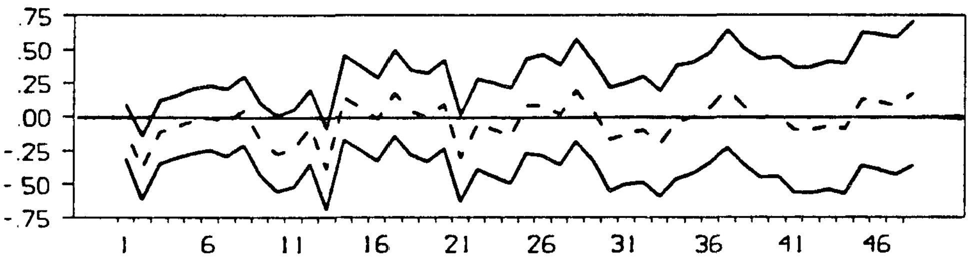
In addition, we note from the VDC results that foreign price shocks play an important role in the movements of domestic prices in Korea. The IRF result presented in panel (d) of Figure 4.9 further supports a positive transmission of foreign price disturbances into domestic inflation, where the positive response of domestic inflation remains significant for an extended period of time. The positive transmission of foreign price disturbances is consistent with the aggregate demand channel discussed earlier in chapter 2. For example,



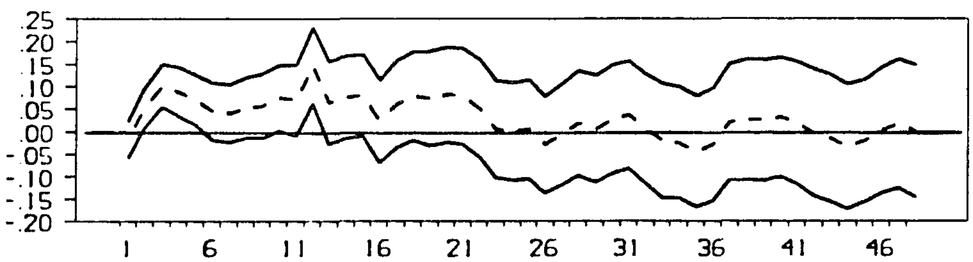
(a) Response of Real Exchange Rates to PSTAR Innovation



(b) Response of Interest Rates to PSTAR Innovation

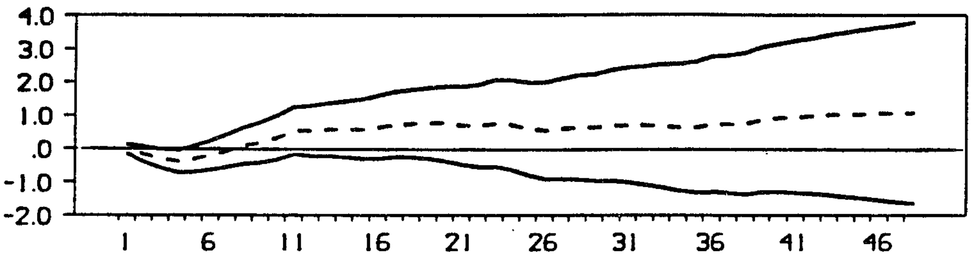


(c) Response of Output to PSTAR Innovation

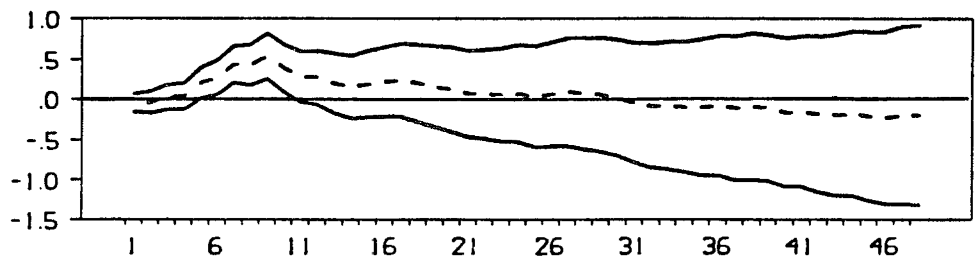


(d) Response of Prices to PSTAR Innovation

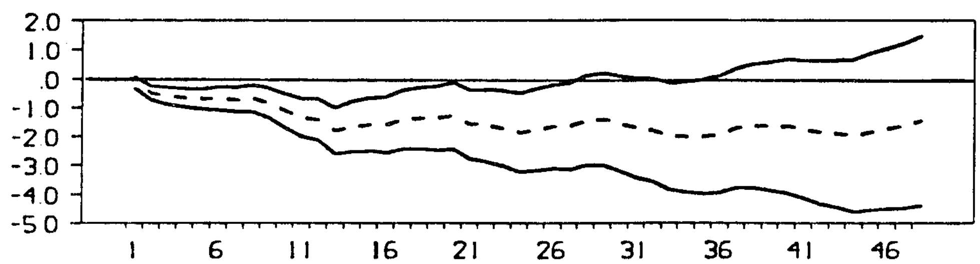
Figure 4.9. Responses to P^* Innovation



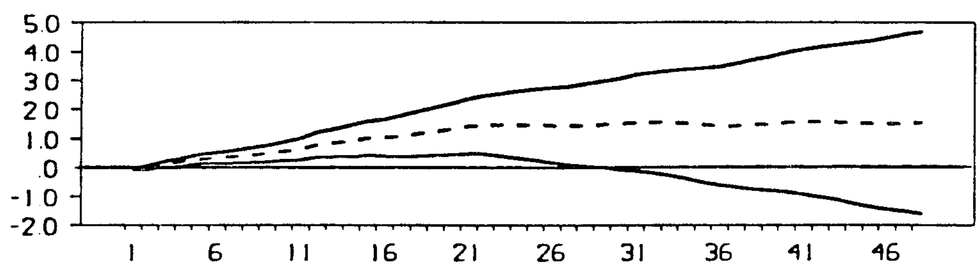
(a) CIRF of Real Exchange Rates to PSTAR Innovation



(b) CIRF of Interest Rates to PSTAR Innovation



(c) CIRF of Output to PSTAR Innovation



(d) CIRF of Prices to PSTAR Innovation

Figure 4.10. Cumulative Responses to P^* Innovation

an increase in foreign prices, ceteris paribus, depreciates real exchange rates; hence, exports rise and imports fall; and hence, the resulting increase in aggregate demand leads to an increase in domestic prices in the short run. The aggregate demand channel through which P^* is transmitted to the domestic economy is further confirmed by short-run positive effects on the domestic interest rate as found in panel (b).

However, the finding of a negative effect on domestic output in panel (c) is at odds with the aggregate demand channel. We may observe this pattern under the following case. A common worldwide supply shock (e.g., an oil embargo) may increase import prices in both domestic and foreign economies. The increase in import prices then shifts aggregate supply upward, so that prices increase further and output may fall. The CIRF results reported in panel (d) of Figure 4.10 further indicate that the domestic price level is affected greater than a one-to-one relationship by foreign price shocks.[16] This implies that the relative price defined as P^*/P falls, and thus the real exchange rate appreciates. Marginally significant negative effects on the rate of change and the level of e (i.e., an appreciation of e) are found in panel (a) of Figures 4.9 and 4.10, respectively. The appreciation of e will lead to a contraction of exports in Korea, and hence domestic output falls. The negative effects on the growth rate and the level of domestic output are also found in panel (c) in Figures 4.9 and 4.10, respectively.

V. Summary and Conclusion

We have noted first that the variables chosen for the vector autoregressive model were based on theoretical and institutional considerations. Because the VAR technique was generally considered to be sensitive to the choice of data transformation, the selection of a VAR order, and alternative orderings of variables, some explicit tests were conducted for these model specification issues. The dynamic effects of government debt and foreign disturbances were evaluated by estimating variance decompositions and impulse responses, and the significance of these effects was determined by estimating the standard errors of the VDCs and IRFs. In addition, cumulative IRFs were computed to get an idea of how the levels of the variables of interest respond to government debt and foreign shock innovations. Furthermore, alternative model specifications were examined to check the robustness of our findings. The empirical results seemed fairly robust, because alternative variable orderings, use of 13 lags, and transformation of all variables in first differences were found not to materially affect the VDC results. Two salient features of our empirical findings are summarized as follows.

First, government debt has, at least in the short run, negative effects on macroeconomic activity in Korea. The short-run negative effects on the interest rate, output, and prices suggest that increases in government bonds to finance

a deficit may reduce private sector wealth in Korea. Therefore, use of debt issue to finance budget deficits should be made with caution by the government, for private sector wealth falls if deficits are financed by issuing government bonds to the public.

Second, the proposition of macroeconomic interdependence has been supported for the Korean economy. The VDC results indicate that the domestic economy is significantly influenced by foreign output and price shocks. The international transmission of foreign disturbances to the Korean economy is due primarily to the fact that the Korean economy heavily depends on foreign trade. The IRF results further indicate that the transmission of foreign disturbances is significant in Korea. In particular, foreign output shocks raise domestic output in the short run, whereas domestic prices rise and domestic output falls due to foreign price disturbances.

Endnotes

1. In 1987, for example, exports to the U.S. and Japan accounted for 57 % of total Korean exports; imports from these two countries accounted for 55 % of total Korean imports.

2. The relevant annual series are obtained from the country section of the <u>International Trade Statistics Yearbook</u>, United Nations, various issues.

3. In addition, short-term interest rates such as the 'money market rate' and the 'yield on commercial paper' are unavailable for Korea over the entire sample period used here.

4. The studentized deleted residual is the residual divided by its standard error, where the error variance is estimated with the outlying observation deleted. To ascertain how far in the tails such an outlying observation falls, we use the t distribution with the degrees of freedom, (T-1)-K, where T = number of observations and K = number of explanatory variables including a constant term.

5. Pena (1990) provides evidence that Cook's (1979) approach fails to detect influential points for a given, particular data set. For current study, however, Cook's approach does not appear unreasonable to use because, as noted in the text, the computed Cook's distance measure clearly pinpoints the outlying observation in October 1977 as the most influential outlier among others.

6. Because the optimal lag length of 12 turned out to be the maximum lag length as reported in Table 4.2, a 13-lag model will be used to check the robustness of the results of the 12-lag model.

7. Because no contemporaneous terms enter the VAR, any contemporaneous relationships among the variables are reflected in the correlation of residuals across equations.

8. The statistic is slightly different from the use by Backus (1986). Backus uses the degrees of freedom n rather than n-3. As noted by Bickel and Doksum (1977), approximation to the power of this test will be better if $(n-3)^{1/2}$ is used rather than $n^{1/2}$. Backus also underestimates the critical value for ρ by increasing the so-called Fischer's z-transformation double.

9. In the alternative variable orderings reported in Appendix B, the VDC results for the foreign shock variables are not reported, simply because the results reported in Table

4.5 remain intact. Note that the foreign shock variables were placed on the top and this order has not been altered. Thus, the VDCs explained by foreign shock variables do not change even if alternative orderings are used for the domestic variables. Furthermore, for the tables reported in Appendix B, the point estimates of the VDC results appear identical if monetary and fiscal policy variables are placed in the same order. See, for example, orderings (1) and (2) (Table 4.4 reported in the text and Table B2 in Appendix B, respectively), and orderings (1′) and (2′) (Tables B1 and B3 in Appendix B, respectively). Although the point estimates are identical for the two pairs of orderings, the estimated standard errors are different since a Monte Carlo simulation was separately performed for each ordering.

10. In Tables 4.4 and 4.5, the feedback effects of domestic variables on the two foreign shock variables are not reported, because the feedback effects are found to be insignificant. The forecast error variances of Y^* and P^* explained by innovations in domestic variables appear to be trivial and, in most cases, the effects are insignificant. A marginal significance is observed only for the effect of the real exchange rate on P^*. But, in general, the insignificant feedback effects are consistent with the assumption that a small economy (like that of Korea) does not contemporaneously affect large economies (like those of the U.S. and Japan).

11. The negative wealth effects of debt were also found for the U.S. economy by Kormendi (1983), Evans (1985), and Fackler and McMillin (1989), and for Canada by McMillin and Koray (1989).

12. As noted earlier in chapter 2, another possible transmission channel of debt to prices will be the monetization of debt. If government debt is monetized, then the increase in the supply of money will raise prices. However, government debt in Korea is found to decrease the money supply, M1, in the 2-month and 3-month horizons. The short-run negative effect of debt on the money supply is not consistent with debt monetization. Beginning from the 4-month horizon, the effect of debt on M1 is found to fluctuate insignificantly around zero. This suggests that debt is not monetized for Korea over the sample period considered here.

13. Evans (1986) and McMillin and Koray (1990) found that the U.S. dollar depreciates as the U.S. budget deficit or government debt rises. These findings appear to be a sharp contrast to Feldstein (1986), who found an appreciation of the U.S. dollar as the deficit rises.

14. Lee (1990), however, finds that the share of government spending in GNP has an unfavorable effect on economic growth in Korea. He uses annual data over the period 1953-1986. The negative output effect of g may be due to the omitted variables such as money supply or distortionary tax rates from his model specification.

15. It makes sense to think of the short-run aggregate supply curve as being relatively flat with the price adjustment near zero. Because of this price rigidity, external output shocks do not increase domestic prices in the very short run. As time passes, the price adjustment will rise, and will steepen the aggregate supply curve.

16. It is also interesting to note that the domestic price level grows faster than the foreign price increase, as shown in Appendix A. The increase in external price shocks over time would be slower than the domestic price increase if the scale of the vertical axis were identical for both graphs.

CHAPTER 5

SUMMARY AND CONCLUSIONS

We briefly describe the two goals of the dissertation research and summarize the estimation procedures and outcome of the empirical analysis. We further present four distinct contributions of the dissertation research to knowledge about the Korean macroeconomy and finally conclude with some limitations and a suggestion for future study.

In chapter 1, we have noted first that the dissertation aimed to investigate the relevance of Ricardian equivalence to the Korean economy. The second objective was to investigate the extent to which foreign disturbances are transmitted to the Korean economy. For these two important issues, the Korean economy was chosen because remarkable economic growth in Korea over the last two decades was accompanied by persistent budget deficits and because the impact of external disturbances could not be ignored in the process of economic development in Korea.

Chapter 2 reviewed the literature relevant to the Ricardian equivalence hypothesis and the proposition of macroeconomic interdependence. Both the theoretical and empirical literature were discussed. The results of the

empirical studies appeared sensitive to the measurement of a deficit variable, the sample period used, and alternative transformation of data series in levels or in differences. For the proposition of macroeconomic interdependence, a number of studies indicated both theoretically and empirically that the insulation properties of flexible rates are achieved only in special cases because foreign shocks affect the domestic economy in many ways.

Chapter 3 discussed the VAR methodology. Motivations for using the VAR approach were first described. In particular, the standard Sims VAR avoids imposing potentially inappropriate a priori restrictions such as the assumption that a policy variable is exogenous as is often done in a traditional structural model approach. The Sims VAR may also avoid potentially spurious identifying restrictions on the lag structure of a dynamic macro model. In addition, the use of VDCs, IRFs, and CIRFs to determine the relative importance of one variable to another and to examine the dynamic characteristics of the system variables was described. A unit root test and cointegration tests for stationarity were also discussed.

Chapter 4 specified a nine-variable VAR model as a compact approximation of macroeconomic reality in Korea. The system variables were chosen based upon theoretical and institutional considerations. The variables include the industrial production index, the yield on national housing

bonds, the consumer price index, the narrowly defined money supply, real government expenditures, private holdings of government bonds, the real effective exchange rate, an index of movements in output of the U.S. and Japan as external output shocks, and an index of movements in the price levels of the U.S. and Japan as external price shocks.

For the empirical analysis, monthly data were used over the sample period 1973:5-1989:11. The beginning of the estimation period is basically consistent with the year in which the Korean government began to rely on non-central bank sources of finance by issuing government bonds to the public.

To determine the appropriate transformation of data series, both unit root and cointegration tests were employed. The results of the unit root test suggested that eight of the system variables have unit roots. The evidence was weaker for the external output shock variable Y^*. Thus, first differencing seemed appropriate for the eight variables, and levels for Y^*. Alternatively, all nine variables including Y^* were transformed in first differences. No evidence of cointegration was found. However, the VDC results were not significantly changed by the alternative transformation.

For selection of an appropriate lag length, the AIC criterion was used. The AIC criterion led us to select the optimal lag length at 12 months. The appropriateness of setting the VAR order at 12 months was further examined by Ljung-Box Q statistics. The marginal significance levels of

the Q statistics indicated that serial correlation was not a problem in the 12-lag model. Furthermore, in order to check the robustness of the results, the VAR order of 12 months was extended to 13 months, but the VDC results were little changed.

Because the VAR residuals appeared to be contemporaneously correlated across equations, several different orderings of variables were conducted based upon theoretical and institutional considerations. It was interesting to find that the VDC results were fairly insensitive to different orderings. Alternative orderings were found not to materially affect the VDC results. Note that the Choleski decomposition of the residual variance-covariance matrix was used to orthogonalize the VAR residuals.

Based upon the VDC, IRF, and CIRF results, the Ricardian equivalence hypothesis and the proposition of macroeconomic interdependence were examined. Note that the VDCs were used to examine both direct and indirect effects, and hence the strength of Granger-causal relations could be detected. In addition, the IRFs were used to investigate the directions of the effect of one variable on another. Furthermore, the CIRFs were used to get an idea of how the levels, rather than the changes, of variables responded to a particular innovation of interest. Finally, a Monte Carlo integration procedure was employed to estimate the standard errors of the VDCs, IRFs, and CIRFs so that the significance of the effects of

government debt and foreign shocks could be determined. One thousand draws were taken to estimate the standard errors, and two standard deviations were used as a rough test to determine the significance of the effect.

Four distinct findings and contributions of the dissertation research to the Korean macroeconomy can be summarized as follows. First, government debt has, at least in the short run, negative effects on macroeconomic activity in Korea. The results are generally consistent with Evans (1990) for the Korean economy, with Kormendi (1983), Evans (1985), and Fackler and McMillin (1989) for the U.S. economy, and with McMillin and Koray (1989) for the Canadian economy. As noted by Barro (1974), the short-run negative effects on the interest rate, output, and prices can be explained within the Ricardian equivalence framework. For example, people may save more than the present value of the income streams associated with bonds issued to finance a deficit because their share of future taxes and the timing of these taxes are uncertain when the government deficit rises. If such is the case, a fall in private consumption and hence aggregate demand will be expected. Therefore, use of debt issue to finance budget deficits should be made with caution by the government.

Second, government spending has a short-run positive effect on output. This is in striking contrast to the negative output effect of government debt, and supports the argument by Barro (1981) that unless government expenditures

are perfect substitutes for private consumption, government expenditures affect real output even if Ricardian equivalence holds. The initial positive output effect of government spending is also consistent with Evans (1990) who found that government purchases in Korea have an expansionary effect on output. The monetary policy variable, M1, also has a positive effect on output in the short run.

Third, the Korean economy is significantly influenced by foreign output and price shocks. In particular, foreign output shocks have a favorable impact on domestic output in the short run, whereas foreign price shocks increase domestic prices and reduce domestic output. The findings are generally consistent with Kim (1987) who found that U.S. fiscal and monetary policy shocks are internationally transmitted to the Korean economy. The international transmission of foreign disturbances to the Korean economy is due primarily to the fact that the Korean economy is heavily dependent on foreign trade.

Fourth, the significant effects of foreign shock variables support the proposition of macroeconomic interdependence in Korea, and suggest the crucial importance of foreign shock variables in constructing small open economy macro models. Because the importance of foreign shock variables, relative to domestic policy shocks, to the Korean economy appears to be substantial, it will cause a serious omission if foreign variables are excluded from the

construction of open economy models. This is, in general, consistent with the result of Genberg et al. (1987) for the Swiss economy.

Although the empirical results seemed fairly robust to alternative model specifications, there were several limitations on the current study. First, an empirical analysis cannot leave out the Lucas (1976) critique that parameter estimates of a reduced-form expression should not be assumed invariant to changes in the underlying policy process. Thus, one may want to determine whether the results found in the preceding chapter show stability throughout the sample period. Accordingly, the sample can be split into two sub-periods of the fixed exchange rate regime (1973:5-1979:12) and the managed floating rates (1980:1-1989:11) in Korea. However, it should be noted that, because of the size of the nine-variable VAR system, the current model could not be estimated for the two sub-periods.

Second, a measure of external oil shocks could be included in our VAR model if an appropriate measure of oil price shocks were available. Hamilton (1983) demonstrated that oil price shocks importantly influenced the U.S. economy, and Burbidge and Harrison (1984) provided similar evidence for Japan, Germany, the United Kingdom, and Canada. As a non-oil producing country, Korea may also have experienced unfavorable economic growth due to two waves of oil price increases: one resulted from the OPEC price increases in 1973 and the other

from the Iranian revolution in 1979. On the other hand, the low price of oil during late 1980s may have had a favorable impact on the Korean economy. However, the effects of external oil price shocks could not be examined for the Korean economy because neither an appropriate measure of the OPEC oil prices nor a Korean price index of crude oil were available for the entire sample period used here.

Finally, investigation of the international transmission of foreign fiscal policy shocks is left for future study. As indicated by Frenkel and Razin (1986, 1987), domestic budget deficits and government spending will be transmitted negatively to the foreign countries if Ricardian equivalence does not hold. This implies that foreign government deficits are predicted to lower domestic wealth, and thereby domestic consumption falls and so does aggregate demand. A transitory rise in government spending also lowers both domestic and foreign wealth, and hence private consumption falls at home and abroad. On the other hand, if Ricardian equivalence holds, the international transmission of foreign fiscal policy shocks will be trivial. The investigation of foreign fiscal policy effects on the domestic economy is beyond the scope of the current study, so it is left for future study.

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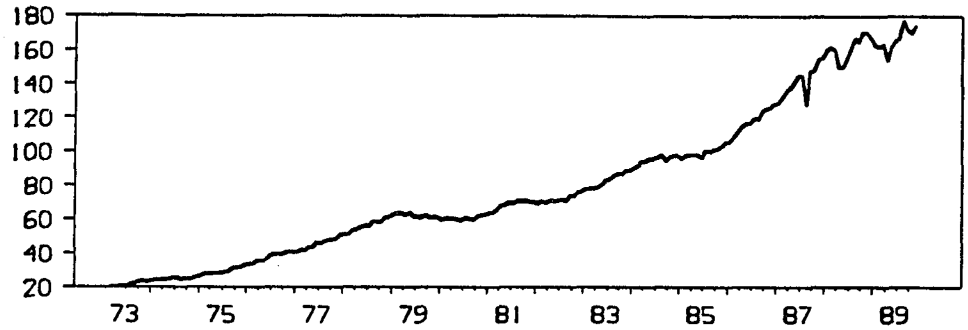
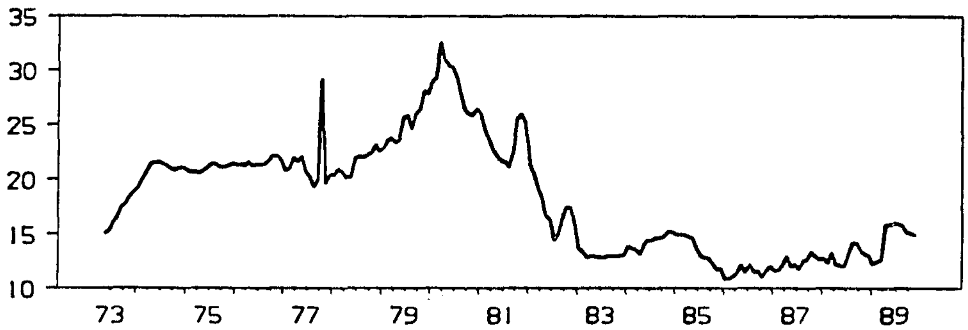
APPENDIX A

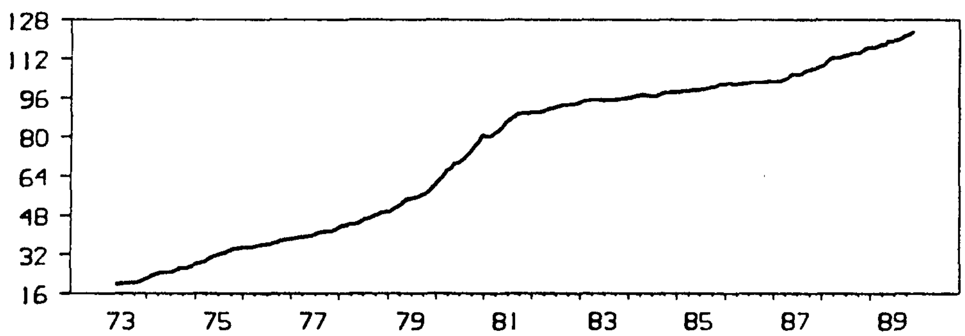
The Plots for Data Series



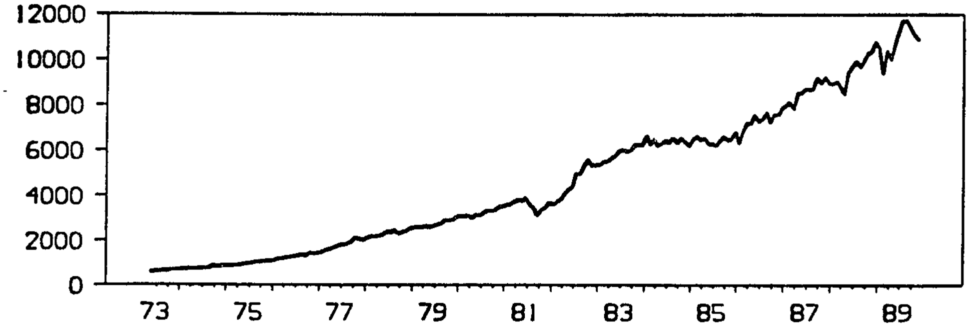
Industrial Production Index (1985=100)



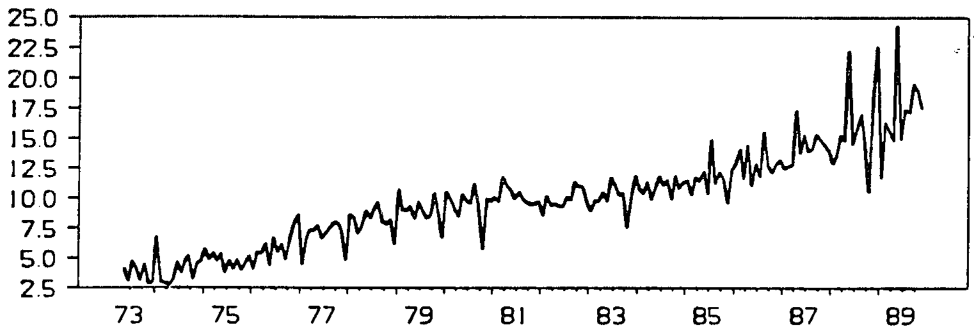
Yield on National Housing Bonds (%)



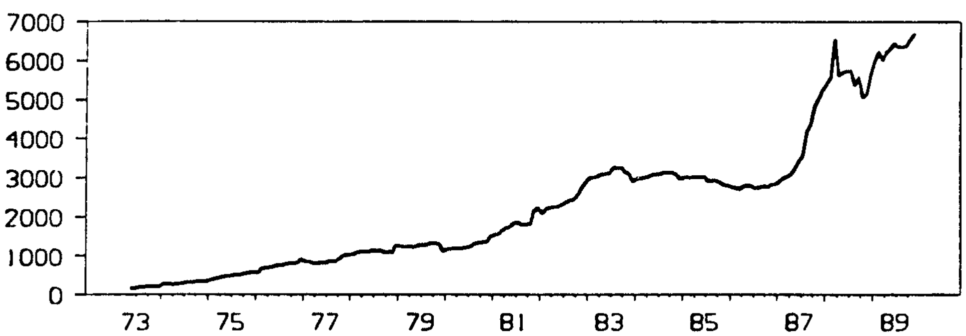
Consumer Price Index (1985=100)



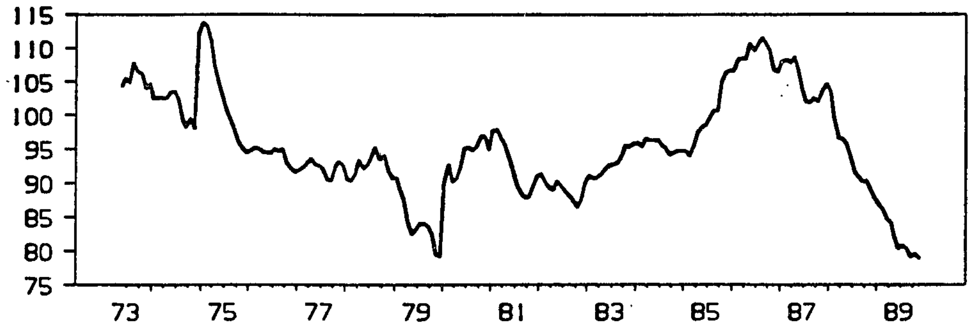
Money Supply (M1)



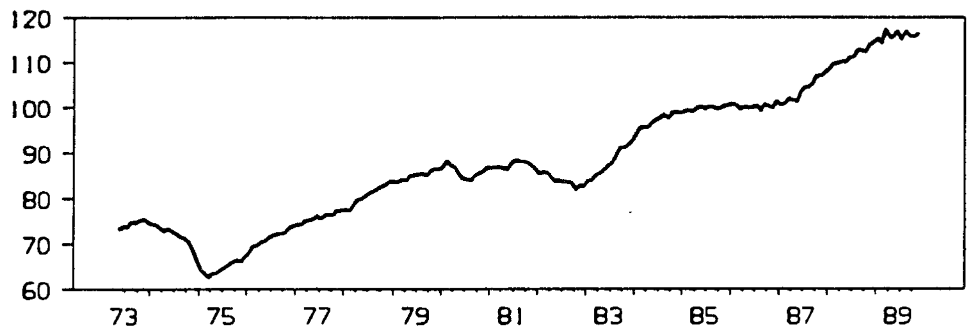
Real Government Expenditures



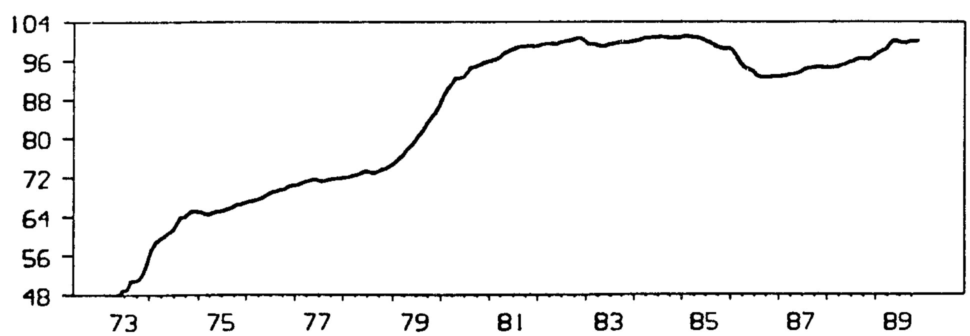
Private Holdings of Government Debt



Real Effective Exchange Rates



External Output Shocks



External Price Shocks

APPENDIX B

The VDC Results of Alternative Variable Orderings

Table B1---Variance Decompositions for Policy Variables

Variable ordering (1'): y^*, P^*, g, D, M1, e, r, y, P
Common lags = 12 months
Y^* in levels and other variables in differences

FEV in	Horizon (month)	VDCs explained by innovations in		
		M1	g	D
e	6	7.4(3.4)*	2.1(2.1)	6.6(3.0)*
	12	8.8(3.3)*	3.5(2.2)	6.8(2.9)*
	24	8.8(3.1)*	8.7(2.8)*	6.6(2.7)*
	36	8.8(3.3)*	8.9(2.9)*	7.1(2.8)*
	48	9.0(3.7)*	9.0(3.2)*	7.3(3.0)*
r	6	6.1(2.8)*	9.5(3.6)*	3.5(1.9)
	12	7.8(2.9)*	12.4(3.8)*	6.9(2.6)*
	24	11.6(3.1)*	10.9(3.3)*	6.5(2.4)*
	36	11.2(3.3)*	10.4(3.5)*	8.5(2.8)*
	48	11.4(3.7)*	10.6(4.0)*	9.0(3.0)*
y	6	7.1(3.1)*	6.1(2.9)*	5.3(2.7)
	12	10.0(3.5)*	5.2(2.7)	6.7(2.7)*
	24	12.1(3.6)*	5.8(3.3)	5.7(2.5)*
	36	11.2(3.6)*	5.9(3.9)	7.6(2.9)*
	48	11.2(3.9)*	5.8(4.3)	7.7(3.1)*
P	6	5.8(3.3)	4.8(2.4)*	12.0(4.0)*
	12	5.4(2.9)	4.1(2.3)	17.8(5.0)*
	24	9.5(4.7)*	5.3(2.7)	19.0(5.1)*
	36	11.1(5.3)*	5.2(2.9)	18.5(5.0)*
	48	10.9(5.5)	5.3(3.4)	18.3(5.1)*

Note: See Table 4.1 for the variables used. Y^* is transformed in levels and the remaining eight variables in first differences. Monetary and fiscal policy variables of ordering (1) are switched. FEV stands for forecast error variance. The numbers in parentheses are standard deviations estimated by using a Monte Carlo integration procedure. '*' indicates that the point estimate is at least twice the standard error.

Table B2---Variance Decompositions for Policy Variables

Variable ordering (2): y^*, P^*, M1, g, D, y, P, e, r
Common lags = 12 months
Y^* in levels and other variables in differences

FEV in	Horizon (month)	VDCs explained by innovations in M1	g	D
e	6	8.4(3.5)*	1.7(2.0)	6.1(2.9)*
	12	9.5(3.3)*	3.2(2.3)	6.3(2.8)*
	24	9.6(3.1)*	8.1(2.9)*	6.3(2.6)*
	36	9.6(3.3)*	8.3(2.8)*	6.9(2.7)*
	48	9.8(3.7)*	8.5(3.1)*	7.1(2.9)*
r	6	8.0(3.2)*	8.0(3.4)*	3.1(1.8)
	12	8.1(2.9)*	11.7(3.8)*	7.3(2.7)*
	24	11.7(3.2)*	10.3(3.2)*	6.9(2.5)*
	36	11.1(3.5)*	9.9(3.5)*	9.1(3.1)*
	48	11.6(3.9)*	10.0(3.9)*	9.4(3.4)*
y	6	8.3(3.3)*	5.8(3.0)	4.4(2.5)
	12	10.5(3.5)*	5.3(2.7)	6.1(2.6)*
	24	12.6(3.5)*	5.5(3.1)	5.5(2.5)*
	36	11.9(3.5)*	5.6(3.4)	7.1(2.8)*
	48	11.9(3.8)*	5.5(3.8)	7.3(3.2)*
P	6	5.1(3.2)	4.8(2.4)*	12.7(4.2)*
	12	5.2(2.7)	4.2(2.1)*	18.0(5.3)*
	24	9.2(4.5)*	5.1(2.7)	19.4(5.7)*
	36	10.5(5.2)*	5.1(2.9)	19.3(5.4)*
	48	10.4(5.6)	5.1(3.2)	19.0(5.4)*

Note: See Table 4.1 for the variables used. Y^* is transformed in levels and the remaining eight variables in first differences. FEV stands for forecast error variance. The numbers in parentheses are standard deviations estimated by using a Monte Carlo integration procedure. '*' indicates that the point estimate is at least twice the standard error.

Table B3---Variance Decompositions for Policy Variables

Variable ordering (2'): y^*, P^*, g, D, M1, y, P, e, r
Common lags = 12 months
Y^* in levels and other variables in differences

FEV in	Horizon (month)	VDCs explained by innovations in		
		M1	g	D
e	6	7.4(3.3)*	2.1(2.0)	6.6(3.1)*
	12	8.8(3.2)*	3.5(2.2)	6.8(2.9)*
	24	8.8(3.0)*	8.7(2.9)*	6.6(2.6)*
	36	8.8(3.3)*	8.9(2.9)*	7.1(2.8)*
	48	9.0(3.6)*	9.0(3.1)*	7.3(3.0)*
r	6	6.1(2.8)*	9.5(3.6)*	3.5(1.9)
	12	7.8(2.8)*	12.4(3.6)*	6.9(2.5)*
	24	11.6(3.1)*	10.9(3.1)*	6.5(2.3)*
	36	11.2(3.3)*	10.4(3.2)*	8.5(2.8)*
	48	11.4(3.7)*	10.6(3.6)*	9.0(3.2)*
y	6	7.1(3.1)*	6.1(3.1)	5.3(2.7)
	12	10.0(3.4)*	5.2(2.7)	6.7(2.6)*
	24	12.1(3.5)*	5.8(3.2)	5.7(2.5)*
	36	11.2(3.4)*	5.9(3.5)	7.6(3.0)*
	48	11.2(3.7)*	5.8(3.8)	7.8(3.4)*
P	6	5.8(3.6)	4.8(2.5)	12.0(4.1)*
	12	5.4(3.1)	4.1(2.2)	17.8(5.1)*
	24	9.5(5.1)	5.3(2.7)	19.0(5.3)*
	36	11.1(5.8)	5.2(2.9)	18.5(5.3)*
	48	10.9(5.9)	5.3(3.1)	18.3(5.2)*

Note: See Table 4.1 for the variables used. Y^* is transformed in levels and the remaining eight variables in first differences. Monetary and fiscal policy variables of ordering (2) are switched. FEV stands for forecast error variance. The numbers in parentheses are standard deviations estimated by using a Monte Carlo integration procedure. '*' indicates that the point estimate is at least twice the standard error.

Table B4---Variance Decompositions for Policy Variables

Variable ordering (3): y^*, P^*, e, r, y, P, M1, g, D
Common lags = 12 months
Y^* in levels and other variables in differences

FEV in	Horizon (month)	VDCs explained by innovations in		
		M1	g	D
e	6	6.9(2.5)*	1.6(1.7)	6.5(2.9)*
	12	7.5(2.4)*	2.4(1.9)	6.5(2.7)*
	24	7.9(2.5)*	7.4(2.6)*	6.3(2.5)*
	36	7.9(2.5)*	7.7(2.7)*	6.8(2.6)*
	48	8.0(2.8)*	7.9(2.9)*	7.1(2.9)*
r	6	7.0(2.8)*	10.4(3.3)*	3.2(1.8)
	12	7.6(2.5)*	13.9(3.4)*	6.0(2.4)*
	24	10.8(2.9)*	11.6(2.9)*	6.4(2.3)*
	36	10.3(2.9)*	11.3(3.1)*	8.2(2.7)*
	48	10.3(3.2)*	11.3(3.4)*	8.3(2.9)*
y	6	3.2(1.7)	7.2(3.2)*	4.3(2.3)
	12	5.0(2.5)*	6.5(2.9)*	5.5(2.2)*
	24	7.5(2.9)*	6.1(2.9)*	5.3(2.2)*
	36	6.8(2.9)*	6.1(3.2)	6.9(2.5)*
	48	7.0(3.4)*	6.1(3.6)	7.2(2.8)*
P	6	3.8(2.3)	5.0(2.4)*	12.5(4.0)*
	12	5.5(2.4)*	3.2(1.8)	17.9(4.8)*
	24	8.2(3.6)*	4.4(2.4)	18.1(5.0)*
	36	8.5(3.8)*	4.7(2.6)	18.0(4.9)*
	48	8.3(3.9)*	4.7(3.0)	17.6(4.9)*

Note: See Table 4.1 for the variables used. Y^* is transformed in levels and the remaining eight variables in first differences. FEV stands for forecast error variance. The numbers in parentheses are standard deviations estimated by using a Monte Carlo integration procedure. '*' indicates that the point estimate is at least twice the standard error.

Table B5---Variance Decompositions for Policy Variables

Variable ordering (3'): y^*, P^*, e, r, y, P, g, D, M1
Common lags = 12 months
Y^* in levels and other variables in differences

FEV in	Horizon (month)	VDCs explained by innovations in		
		M1	g	D
e	6	6.1(2.4)*	1.8(1.7)	7.2(3.1)*
	12	6.8(2.5)*	2.5(1.8)	7.1(2.8)*
	24	7.4(2.6)*	7.6(2.5)*	6.6(2.5)*
	36	7.5(2.7)*	7.9(2.6)*	7.0(2.6)*
	48	7.6(3.0)*	8.1(2.9)*	7.3(2.8)*
r	6	5.3(2.4)*	11.4(3.7)*	3.6(1.9)
	12	6.9(2.5)*	11.7(3.7)*	5.9(2.2)*
	24	10.5(2.9)*	12.2(3.2)*	6.1(2.2)*
	36	10.2(3.0)*	11.9(3.3)*	7.7(2.6)*
	48	10.1(3.2)*	11.9(3.7)*	8.0(2.8)*
y	6	2.1(1.7)	7.4(3.4)*	4.7(2.3)*
	12	4.8(2.6)	6.4(2.9)*	5.7(2.3)*
	24	7.5(2.9)*	6.1(3.0)*	5.3(2.2)*
	36	6.8(2.9)*	6.1(3.3)	6.9(2.6)*
	48	6.9(3.2)*	6.1(3.8)	7.3(2.9)*
P	6	3.8(2.5)	4.8(2.5)	12.6(3.9)*
	12	5.1(2.4)*	3.1(1.9)	18.4(4.5)*
	24	8.1(3.6)*	4.4(2.4)	18.3(4.7)*
	36	8.6(3.8)*	4.7(2.6)	17.9(4.6)*
	48	8.4(3.9)*	4.7(2.9)	17.5(4.6)*

Note: See Table 4.1 for the variables used. Y^* is transformed in levels and the remaining eight variables in first differences. Monetary and fiscal policy variables of ordering (3) are switched. FEV stands for forecast error variance. The numbers in parentheses are standard deviations estimated by using a Monte Carlo integration procedure. '*' indicates that the point estimate is at least twice the standard error.

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