THE EFFECT OF U. S. MAIN MACROECONOMIC VARIABLES ON TAIWAN'S EXPORTS TO THE U. S.: A VECTOR AUTOREGRESSION ANALYSIS*

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摘　要

在一相互依存的世界，每一個國家的財貨與資本市場緊相結合，財貨貿易與資本移動爲國與國之間經濟波動傳遞的兩個重要的管道。台灣直到1987年7月採取嚴格的資本管制，財貨貿易因此成爲中美之間經濟干擾傳遞的最重要管道。瞭解影響台灣出口到美國的變數將是認定中美兩國之間經濟干擾傳遞的關鍵。

本文以一結合貨幣方法與凱因斯方法的向量自我迴歸（VAR）模型來分析美國主要總體經濟變數對台灣出口到美國的影響。模型變數包括美國的貨幣供給、政府開支、國民生產毛額、實質匯率、及台灣對美國的出口。實證分析發現，所有美國的總體經濟變數與實質匯率對台灣對美國的出口均爲嚴格外生變數，這與小國的假說相符合。衝擊反應與變異數分解顯示，美國實質政府開支、實質國民生產毛額、及實質匯率的干擾對於台灣對美國的出口均有顯著而且持續的衝擊影響，並在台灣對美國的出口波動中扮演重要的角色。

Abstract

In an interdependent world where every country's goods market and capital market are closely integrated, goods trade and capital movement are two main channels to transmit economic disturbances between countries. Since Taiwan had adopted strict capital control until July 1987, goods trade became the most important channel to transmit economic disturbances between Taiwan and the U. S. Understanding the variables which affect Taiwan's exports to the U. S. is a key to identify the mechanism of economic transmission between these two countries.

In this paper, a vector autoregression (VAR) model combined with the monetary and the Keynesian approaches is used to find out what the main U. S. macro-variables determine Taiwan's exports to the U. S. The variables included in the model are the U. S. money supply, government expenditure, *GNP*, real exchange

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rate, and exports from Taiwan to the U. S. The empirical analysis finds that all of U. S. macro-variables and real exchange rate are strictly exogenous with respect to Taiwan's exports to the U. S., which is consistent with the small country hypothesis. The impulse response analysis and the variance decomposition analysis show that innovations in the U. S. real government expenditure, real *GNP*, and real exchange rate have significant and persistent impacts on Taiwan's exports to the U. S., and that they play an important role in the fluctuations of exports from Taiwan to the U. S.

1. Introduction

For an interdependent world, the transmission of economic disturbances between countries is ordinary via the channels of goods trade and capital mobility. But, until July 1987, Taiwan had strict capital control, goods trade became the most important channel of economic transmission between Taiwan and the U. S.[1]

For a small open economy, under the fixed exchange rates, exports are an exogenous variable that are mainly determined by the external foreign variables. According to the Keynesian approach, a country's exports are a function of foreign real income and real exchange rate. On the other hand, the monetary approach suggests that a country's exports are largely influenced by the foreign money stock.

The economies of Taiwan and the U. S. are linked mainly through the transaction of goods, Imports in Taiwan have always been under the strict control of the government, especially in the early stage of its economic development.[2]. It is

[1] After July 1987, in order to stabilize exchange rates and reduce arbitrage, Taiwan's monetary authorities adopted a policy that capital outflow control is looser than capital inflow control.

[2] In December 1968, total number 11,000 of imported items classified as prohibited was 209, controlled 4,551 (see Scott [6], p. 331). In September 1983, total number 2,6751 of imported items classified as prohibited reduced to 14, controlled reduced to 649. In 1978, the nominal tariff rate was about 48% (the actual tariff rate was much higher than this rate), it reduced to 31.77% and 22.83% in 1986. Until 1980, customs duties was much more important than income tax in government revenue, it accounted for over 20% of government revenue in the period from 1954 to 1980 (see *History of Economic Modernization Taiwan Area, the Republic of China* (Taipei: Council for Economic Planning and Development, 1986), p. 57; *Taiwan Statistic Data Book 1987* (Taipei: Council for Economic Planning and Development, 1987), p. 176. In the period from 1950 to 1976, the average ratio of customs revenues to imports was 18.19% (for net customs revenues) or 22.04% (for gross customs revenus—included rebates) (see Scott [6], p. 334). In addition to tariff and imports control, there existed a lot of nontariff barriers to imports. Those may give us idea of Taiwan's imports restrictions.

reasonable to believe that exports from Taiwan to the U. S. instead of imports by Taiwan from the U. S. played a much more important role in serving as the economic linkage between these two countries. An analysis of the determinants of Taiwan's exports to the U. S. therefore is essential in order to better understand the economic linkage relationship between these two countries.

Supposing there is no capital movement between countries, the Keynesian approach regards the trade balance as equivalent to the difference between domestic income and domestic demand. The transmission of trade disturbances between countries thus is via the channels of real income and real exchange rate. On the other hand, the monetary approach treats the trade balance as the difference between money demand and money supply, hence the transmission of trade disturbances between countries is via the channel of money stock.

Under a three-good market (commodities, money, and bonds) system, Walras's law shows that any one of these markets will be in equilibrium if the other two markets are in equilibrium. In general eqilibrium analysis, we can always drop any one market which typically is the bond market. The equilibrium of remaining goods market and money market are jointly determined.

The Keynesian approach assumes the money market held in equilibrium, the disturbances would only come from the goods market. On the other hand, the monetary approach assumes the goods market held in equilibrium, the disturbances would result only from the money market. (The Walrasian dependency between the goods market and money market implies that it makes as much sense to focus on the goods market as does to focus on the money market. But, focusing on the goods market is a real, flow equilibrium analysis, whereas focusing on the money market is a monetary, stock equilibrium analysis.)[3]

In 1987, 44.2% of Taiwan's exports and 20.6% of Taiwan's aggregate demand were accounted for by its exports to the U. S. Trade balance with the U. S. is the most important factor affecting Taiwan's overall trade balance position. If Taiwan had no access to the U. S. market, it would be very difficult for Taiwan to reach its present performance of foreign trade and economic growth. The high dependence of Taiwan's exports on the U. S. market makes it meaningful for us to understand the main U. S. Macroeconomic variable which are important in determining Taiwan's exports to the U. S.

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[3] A complete monetary model bridges the stock equilibrium with the flow equilibrium and emphasize the stock-flow-adjustment process. For example, Frenkle, Gylfason, and Helliwell [3] present a model to synthesize the Keynesian approach and the monetary approach.

In this paper, we construct a VAR model combining the Keynesian approach with the monetary approach to justify the relative importance of U. S. goods market or money market for the fluctuations of Taiwan's exports to the U. S.

2. Theoretical Model

In a model of a small (home) country facing a large country, with fixed exchange rates and immobility of capital between countries, the relationship between major economic variables in a home country is described by the Keynesian approach as follow:

$$Y = C(Y, r) + I(r) + G + E(Y^*, \frac{eP^*}{P}) - Z(Y, \frac{eP^*}{P}), \tag{1}$$

$$M = PL(Y, r), \tag{2}$$

$$M \equiv m(eR+D), \tag{3}$$

$$B \equiv \triangle R \equiv \frac{P}{e}\left[E(Y^*, \frac{eP^*}{P}) - Z\,(Y, \frac{eP^*}{P})\right]. \tag{4}$$

where:

* denote a foreign variables,

Y real income (or output),

C real consumption,

r interest rate,

I real investment,

G real government expenditure,

e exchange rate (units of home currency per unit of foreign currency),

P price level,

$\frac{eP^*}{P}$ real exchange rate,

E real exports,

Z real imports,

M nominal money supply,

L real money demand,

R foreign reserves measured in foreign currency,

m money multiplier,
D nominal domestic credit,
B trade balance measured in foreign currency,
$\triangle$ first difference operator.

Equation (1) is an equilibrium condition for the goods market (o *IS* curve). From this equation, we can see that (1) real consumption is a function of real output and interest rate; (2) real investment is a function of interest rate; (3) real government expenditure is an exogenous variable; (4) real exports are a function of foreign real income and real exchange rate (or relative price ratio of foreign price to domestic price) and (5) real imports are a function of home real income and real exchange rate.

Equation (2) is an equilibrium condition for the money market (or *LM* curve). In that equation M is narrowly defined as currency plus demand deposits. The equation implies that home currency is the only asset available for the domestic residents to hold and money demand is a function of the price level, real income, and interest rate. Equation (3) is money supply identity for an open economy, where R is net holdings of foreign reserves by the consolidated banking system (central bank and private bank), D is domestic credit, or net holding of domestic assets by the consolidated banking system. In economic analysis, we usually assume that the money multiplier $m=1$.

Equation (4) is the definition of trade balance. If there is no capital flow between countries, the trade balance is equivalent to the balance of payments represented by change in a country's foreign reserves. In a two-country model, home country's trade surplus is foreign country's trade deficit, and vice versa. That is

$$B = -B^*.$$

Equation (4) can be rewritten as

$$B \equiv \triangle R = \frac{P}{e}\,[Y - C(Y, r) - I(r) - G], \tag{6}$$

or

$$B \equiv \triangle R = \frac{P}{e}\,[Y - A\ (Y, r, \bar{A})], \tag{7}$$

where A is domestic absorption (the total spending of domestic residents), $\bar{A}$ is autonomous absorption.

Two of the best-known Keynesian approaches for the analysis of the balance of payments are the so-called "elasticities approach" and "absorption approach." The elasticities approach stresses the need for an explicit analysis of the exports and imports of a country in dissecting the balance of payments—such as equation (4), and emphasizes the importance of change in relative price (or real exchange rate) in the adjustment process of the balance of payments. The absorption approach treats the trade balance as the difference between income and absorption—such as equation (7), and emphasizes the importance of change in income in the adjustment process of the balance of payments. In fact, the two approaches are equivalent, it does not matter whether the trade balance is regarded as the difference between exports and imports or as the difference between income and absorption.

In contrast to the Keynesian approach, the monetary approach stresses that the balance of payments is essentially a monetary phenomena, and describes the relationships between major economic variables in a home country as follow:

$$M = PL(Y, r), \tag{8}$$

$$P = eP^*, \tag{9}$$

$$M \equiv (eR+D), \tag{10}$$

$$B \equiv \triangle R \equiv \lambda[\frac{1}{e}(PL - M)], \ 0 \leq \lambda \leq 1, \tag{11}$$

or

$$B \equiv \triangle R \equiv \frac{1}{me} \triangle PL(Y, r) - \frac{1}{e}\triangle D. \tag{12}$$

where all of symbols in the above equations are the same as those described by the Keynesian approach.

Equation (8) is an equilibrium condition for the money market. The money demand is a function of the price level, real income and interest rate. In the monetary approach, the real income is determined by the supply side of the system, hence it is exogenous to the model. Equation (9) is an equation of purchasing power parity, which describes the domestic price level as equal to the exchange rate times the foreign price. (This, in turn, with the domestic interest rate determines the desired

level of money demand.)[4] Equation (10) is a money supply identity. Assuming $m = 1$, the money supply is simply the sum of domestic credit and foreign reserves held by the monetary authorities.

Equation (11) or (12) defines the change in foreign reserves as the balance of payments, which is the difference between demand for money (PL) and supply of money (M), or the difference of change in money demand and change in domestic credit. In equation (11), λ is the coefficient of adjustment, it describes the response of domestic residents to a temporary disequilibrium in the monetary sector and represents the fraction of the gap between desired and actual money holdings that is eliminated in any given time period. The larger λ is, the large the proportion of excess money demand is eliminated and, consequently, the faster the adjustment toward long-run equilibrium. The function of λ in equation (11) is to transform the difference of two stock variables ($PL - M$) into a flow variable (B, or $\triangle R$).

According to the monetary approach, the balance of payments is the sum of the current account and capital account transactions other than those of the monetary authorities. On the other hand, the elasticities or absorption approach defines the balance of payments as the current account surplus or deficit. The monetary approach assumes that the balance of payments adjustment is costless and that individuals can carry out their desired transactions instantaneously. This implies that any excess stock of money is immediately reflected in a net flow of goods and assets of equal magnitude between countries. But, under the assumption of no capital flow between countries, the trade balance is equivalent to the balance of payments. Therefore, the difference between money demand and money supply, or any excess stock of money, is immediately reflected only in a net flow of goods of equal magnitude.

The equilibria in both goods and money markets for the home country can be expressed as

$$Y = C + I + G + E - Z, \tag{13}$$

$$M = PL. \tag{14}$$

In a two-country model, excess demand for money by one country is excess supply of money in other country, and trade balance between these two countries must be proportional to this excess stock of money. That is

[4] We assume no capital mobility between countries, domestic interest rate will not be equal to foreign interest rate.

$$\lambda(PL - M) = P(E - Z) = \lambda^*[e(M^* - P^*L^*)]. \tag{15}$$

Equation (15) can be rewritten as

$$E = Z + \lambda^*\left(\frac{e}{P} M^* - \frac{eP^*}{P} L^*\right). \tag{16}$$

Assuming that exchange rates are fixed, the home country is a small country, trade is free, and foreign country's money demand is constant, equation (16) shows that the home country's real exports have a positive relationship with foreign money supply and have a negative relationship with the real exchange rate.

Our empirical analysis of the effect of U. S. main macroeconomic variables on Taiwan's exports to the U. S. is based on both the Keynesian hypothesis and the monetary hypothesis. A VAR model is then constructed by combining the Keynesian approach with the monetary approach so as to analyze the variation of Taiwan's exports to the U. S.

3. Empirical Results

3.1 Variables Choice and Model Specification

According to the Keynesian approach, the major variable affecting Taiwan's exports to the U. S. are the U. S. real output (or income) and real exchange rate. On the other hand, according to the monetary approach, the major variable affecting Taiwan's exports to the U. S. is the U. S. money supply.[5] The variables we actually chose include the U. S. money supply, real government expenditure, real *GNP*, real exchange rate, and real exports from Taiwan to the U. S.

The reason for including the U. S. real government expenditure in the model is to evaluate the impact of the U. S. demand shock (or fiscal policy) on Taiwan's exports to the U. S. directly (or shocks in the U. S. aggregate demand are also represented by innovations in the U. S. real government expenditure which are independent of innovations in the U. S. real output). The theoretic reasonableness for including the U. S. real government expenditure in the model is that by the absorption approach, the change in the U. S. real government expenditure will cause

[5] The money balance affecting a country's exports or imports is real rather than nominal term.

the changes in the U. S. income and absorption, hence it will cause Taiwan's exports to change.

It is reasonable to assume that this five-variable VAR model captures the general contour of the Keynesian approach and the monetary approach for studying the fluctuations of Taiwan's exports to the U. S.

A quarterly time series data for the period 1961-1987 is used in our analysis. They are expressed in terms of logarithm and are seasonally adjusted.[6] The U. S. nominal money supply was narrowly defined as *M*1, both of U. S. real government expenditure and real *GNP* were at 1982 constant prices, real Taiwan's exports to the U.S. was at 1981 constant prices, and real exchange rate was calculated based on the exchange rate between New Taiwan dollar and the U. S. dollar and both countries' *GNP* deflator with 1981 as 100.[7] The way of detrending is by adding linear time trend terms in equations of the VAR model. (By including a linear time trend instead of using the difference to detrend the data implies that we assume that the evolutions of variables in the VAR model follow a deterministic trend process. If the assumption is not true, it cannot avoid anything.)[8]

In order to understand the general and specific effect of U. S. variables and real exchange rate on Taiwan's exports to the U. S., we built a five-variable VAR model and four two-variable VAR models—Taiwan's exports to the U. S. with each of the other four variables. By the five-variable model, we can see the general effect of U. S. variables and real exchange rate on Taiwan's exports to the U. S. simultaneously. By the two-variable models, we can see the specific effect of U. S. variables and real exchange rate on Taiwan's exports to the U. S. separately.

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[6] The U. S. data are from Citibase. Taiwan's data are from *Quarterly National Income Statistics in Taiwan Area, the Republic of China (1961-1984)* (Taipei: DGBAS, June 1986), and *Quarterly National Economic Trends Taiwan Area, the Republic of China* (Taipei: DGBAS, February 1988) respectively. Both data are seasonally adjusted by the moving average method.

[7] The U. S. *GNP* deflator was adjusted to in term of 1981 as 100, the same base year as Taiwan.

[8] If variables in the VAR model are co-integrated, then the system will have an unit root and standard statistical analysis does not apply. Engle and Yoo [2] claim that when a set of variables exhibits co-integration, it is inappropriate for a forecasting VAR model including the variables in differences. Fuller [4] shows that differencing produces no gain in asymptotic efficiency in an autoregression, even if it is appropriate. Doan [1] says that in a VAR model, differencing throws information away while it produces almost no gain. In practice, there are different methods used to filter the data in the empirical VAR models.

Mathematically, our five-variable VAR model can be written as

$$X_t = A(L)X_{t-1} + V_t, \tag{20}$$

where X_t is a 5×1 vector variables. By the order in our empirial analysis

$$X_t = [M_t^* \; G_t^* \; Y_t^* \; Q_t \; E_t]',$$

where M_t^*, G_t^*, Y_t^*, Q_t^* and E_t stand for the U. S. nominal money supply, real government expenditure, real *GNP*, real exchange rate, and Taiwan's real exports to the U. S. respectively, ′ denotes transpose. The order is determined by the monetary approach (M_t^*), the Keynesian approach (G_t^*, Y_t^* and Q), and the small country hypothesis—that is Taiwan's exports to the U. S. is determined by the U. S. variables and real exchange rate, not vice versa.[9]

$A(L)$ is a 5×5 matrix of autoregressive coefficients,

$$A(L) = \begin{bmatrix} a_1(L) & b_1(L) & c_1(L) & d_1(L) & e_1(L) \\ a_2(L) & b_2(L) & c_2(L) & d_2(L) & e_2(L) \\ a_3(L) & b_3(L) & c_3(L) & d_3(L) & e_3(L) \\ a_4(L) & b_4(L) & c_4(L) & d_4(L) & e_4(L) \\ a_5(L) & b_5(L) & c_5(L) & d_5(L) & e_5(L) \end{bmatrix}.$$

X_{t-1} is a 5×1 vector of lagged variables,

$$X_{t-1} = [M_{t-1}^* \; G_{t-1}^* \; Y_{t-1}^* \; Q_{t-1}^* \; E_{t-1}]',$$

where M_{t-1}^*, G_{t-1}^*, Y_{t-1}^*, Q_{t-1}^*, and E_{t-1} stand for lag one of U. S. nominal money supply, real government expenditure, real *GNP*, real exchange rate, and real Taiwan's exports to the U. S. respectively. V_t is a 5×1 vector of serially uncorrelated residual,[10]

9 The empirical result shows that innovations in the U. S. money supply have low correlation with innovations in the U. S. government expenditure, *GNP*, and real exchange rate. This means that empirical result is not sensitive to select the monetary variable or the Keynesian variables in the first order.

10 VAR model is a special case of vector autoregressive moving average (VARMA) model (see Tiao and Box [8]). The identification and estimation of VARMA model is much more difficult than VAR model. But, as the univariate model, the VARMA model and VAR model are convertible each other. A sufficient lag length VAR model is a good approximation of VARMA model, and it will make the residual serially uncorrelated.

$$V_t = [v_{1t}\ v_{2t}\ v_{3t}\ v_{4t}\ v_{5t}]',$$

where v_{1t}, v_{2t}, v_{3t}, v_{4t}, and v_{5t} are innovations of the M_t^*, G_t^*, Y_t^*, Q_t, and E_t respectively.

Our two-variable VAR models are

$$\begin{bmatrix} X_t \\ E_t \end{bmatrix} = \begin{bmatrix} A_{11}(L) & A_{12}(L) \\ A_{21}(L) & A_{22}(L) \end{bmatrix} \begin{bmatrix} X_{t-1} \\ E_{t-1} \end{bmatrix} + \begin{bmatrix} u_t \\ e_t \end{bmatrix},$$

where X_t stands for the U. S. nominal money supply, real government expenditure, real *GNP*, and real exchange rate respectively. E_t stands for Taiwan's real exports to the U. S. $A_{ij} = A_{ij0}+A_{ij1}L+A_{ij2}L^2 + \ldots + A_{ijp}L^p$ is autoregressive coefficients. X_{t-1} stands for lag one of U. S. nominal money supply, real government expenditure, real *GNP*, and real exchange rate respectively, E_{t-1} stands for lag one of Taiwan's real exports to the U. S. v_t is serially uncorrelated innovations in M_t^*, G_t^*, Y_t^*, Q_t^* and E_t respectively, e_t is serially uncorrelated innovations in real Taiwan's exports to the U. S.

The main questions addressed by our empirical work are:

(1) Is the hypothesis of a small country for the interpretation of fluctuations in exports from Taiwan to the U. S. valid? Alternatively, whether the variation in exports from Taiwan to the U. S. is Granger-caused by changes in the U. S. money supply, real government expenditure, real *GNP*, and real exchange rate?
(2) What is the impulse reponses of Taiwan's exports to the U. S. to the innovations in the U. S. variables and real exchange rate?
(3) To what extent the variation in Taiwan's exports to the U. S. can be explained by innovations in the U. S. money supply, government expenditure, *GNP*, and real exchange rate?

3.2 Hypothesis Testing

To conduct the hypothesis test, the first thing is to choose the lag lengths. Based

on the modified likelihood ratio statistic,[11] the eight lag lengths instead of six or ten lag lengths is chosen.[12]

The model is an unrestricted VAR model, and it is estimated by using version 3.01 of the Regression Analysis of Time Series (*RATS*) package.[13] Constants and linear time trends were included in all the equations. *F*-tests of block of coefficients is reported in Table 1 (five-variable model) and 2 (two-variable models). According to this test, we find that the U. S. money supply and real *GNP* are bidirectional causality at the 10% significance level; the U. S. government expenditure is strictly exogenous with respect to other variables in the model, and it is Granger-cause real exchange rate at the 5% significance level (see Table 1), this is consistent with the Keynesian hypothesis that aggregate demand determines price level. Real exchange rate Granger-causes the variation in Taiwan's exports to the U. S. at the 10% significance level (both five-variable and two-variable models), the U. S. real *GNP* Granger-causes the variation in Taiwan's exports to the U. S. at the 20% significance level (five-variable model), or at the 5% significance level (two-variable model).

All of U. S. variables—money supply, government expenditure, and *GNP* —and real exchange rate are strictly exogenous with respect to Taiwan's exports to the U. S., this indicates that the hypothesis of small country for Taiwan with respect to the U. S. is accepted. The causality test shows that we can accept the hypothesis that both real exchange rate and the U. S. *GNP* are Granger-cause Taiwan's exports to the U. S. This implies that the Keynesian approach rather than the monetary approach is more applicable to interpret the variation of Taiwan's exports to the U. S.

The contemporaneous correlation of innovations gives us additional information to test the applicability of the Keynesian approach and the monetary approach for the interpretation of variation in Taiwan's exports to the U. S. According to the

[11] See Sims [6]. The modified likelihood ratio statistic takes into account the fact that the degree of freedom in the asymptotic x^2 distribution for the likelihood ratio test statistic is not a different order of magnitude from the degree of freedom left in the data after VAR model is fitted, this make interpretation of the tests different.

[12] The model was estimated with lag lengths of six and eight. The test statistic of modified likelihood ratio statistic is $x^2(50) = 67.72$, the corresponding significance level is .048. The eight lag lengths is chosen. Furthermore, the model is estimated with lag lengths of eight and ten, the test statistic of modified likelihood ratio statistic is $x^2(50) = 54.27$, the corresponding significance level is .31. Therefore, the eight lag lengths is appropriate for the model.

[13] Contrast to unrestricted VAR model is restricted or Bayesian VAR model, which is developed by Litterman [5]. With the exception of having prior information about restrictions, unrestricted rather than restricted VAR model should be used in the study.

Table 1: *F*-Tests of Block of Coefficients (Five-Variable Model)

Equation	Block of Coefficients	F-statistic	Significance Level
Money Supply	Money Supply	41.23	.00
	Government Expenditure	1.09	.38
	GNP	3.52	.00
	Real Exchange Rate	1.33	.25
	Exports to the U. S.	1.31	.26
Government Expenditure	Money Supply	.29	.97
	Government Expenditure	23.04	.00
	GNP	.87	.55
	Real Exchange Rate	.99	.45
	Exports to the U. S.	.99	.45
GNP	Money Supply	1.95	.07
	Government Expenditure	.67	.71
	GNP	24.56	.00
	Real Exchange Rate	.65	.73
	Exports to the U.S.	.88	.54
Real Exchange rate	Money Supply	1.13	.36
	Government Expenditure	2.39	.03
	GNP	.81	.60
	Real Exchange Rate	46.74	.00
	Exports to the U. S.	1.14	.35
Exports to the U. S.	Money Supply	.56	.81
	Government Expenditure	1.43	.20
	GNP	1.49	.18
	Real Exchange Rate	1.88	.08
	Exports to the U. S.	11.17	.00

Note: Money supply, government expenditure, and *GNP* are variables of the U. S. With the exception of money supply, all the variables are in real terms. A low significance level means that the block of coefficients is significantly different from zero.

Table 2: *F*-Tests of Block of Coefficients (Two-Variable Models)

Equation	Block of Coefficients	F-statistic	Significance Level
Money Supply	Money Supply	177.90	.00
	Exports to the U. S.	1.21	.31
Exports to the U. S.	Money Supply	.85	.56
	Exports to the U. S.	39.54	.00
Government Expenditure	Government Expenditure	180.79	.00
	Exports to the U. S.	1.21	.30
Exports to the U. S.	Government Expenditure	1.40	.21
	Exports to the U. S.	32.97	.00
GNP	GNP	66.69	.00
	Exports to the U. S.	.74	.66
Exports to the U.S.	GNP	2.54	.02
	Exports to the U. S.	45.81	.00
Real Exchange Rate	Real Exchange Rate	83.50	.00
	Exports to the U. S.	1.40	.21
Exports to the U. S.	Real Exchange Rate	1.90	.07
	Exports to the U. S.	88.86	.00

Note: Money supply, government expenditure, and *GNP* are variables of the U. S. With the exception of money supply, all the variables are in real terms. A low significance level means that the block of coefficients is significantly different from zero.

monetary approach, Taiwan's exports to the U. S. presumably should have a positive relationship with the U. S. money supply and a negative relationship with real exchange rate.

However, Table 3 shows just the opposite. Innovations in Taiwan's exports to the U. S. had a significantly negative correlation with innovations in the U. S. money supply in the five-variable model, but the correlation is not significant in the two-variable model. Innovations in Taiwan's exports to the U. S. had significantly positive correlation with innovations in real exchange rate (at the 2.5% and 15% significance level for five-variable and two-variable model respectively). Empirical experience in

Table 3: Contemporaneous Correlation of Innovations

Variable	Money Supply	Government Expenditure	GNP	Real Exchange Rate	Exports to the U. S.
Money Supply	1.00	.10	−.12•	.05	−.23* (−.08)
Government Expenditure		1.00	.00	−.06	.03 (−.02)
GNP			1.00	−.36**	.27* (.23*)
Real Exchange Rate				1.00	.22* (.12•)
Exports to the U. S.					1.00

Note: Money supply, government expenditure, and *GNP* are variables of the U. S. With the exception of money supply, all the variables are in real terms. The numbers in paren theses are correlation coefficient of innovations in the two-variable models.
* : *t*-statistic is significant at the 2.5% level.
**: *t*-statistic is significant at the 0.5% level.
• : *t*-statistic is significant at the 15% level.

Taiwan therefore contradicts the hypothesis of the monetary approach.[14].

On the other hand, the Keynesian approach assumes that Taiwan's exports to the U. S. should have a positive relationship with the real *GNP* of the U. S. and the real exchange rate. This is confirmed by our empirical study. From Table 3, we can see that there exists a significant positive relationship (at the 2.5% significance level) between innovations in Taiwan's exports to the U. S. and innovations in the real *GNP* of the U. S. and the real exchange rate.

[14] The negative correlation between innovations in Taiwan's exports to the U. S. and innovations in the U. S. money supply may result from the negative correlation between innovations in the U. S. money supply and innovations in the U. S. real *GNP*. One possible explanation of negative relationship between innovations in the U. S. money supply and innovations in the U. S. real *GNP* is that money policy is adopted by the U. S. monetary authorities to counter the fluctuations of U. S. real *GNP*.

3.3 Impulse Responses of Taiwan's Exports to the U. S.

In this section, we attempt to use the impulse response analysis to identify the impact of innovations in the U. S. money supply, real government expenditure, real *GNP*, and the real exchange rate on the variation in Taiwan's exports to the U. S.[15] The analysis is based on the standard deviation of innovations in Table 4. The impulse responses of Taiwan's exports to the U. S. to a positive innovation in the U. S. money supply, real government expenditure, real *GNP*, real exchange rate, and its own innovations are depicted in Figure 1 to 9 respectively, and by these figures we can know the accumulated impulse responses too. Based on these figures, we have the following findings:

Table 4: Standard Deviation of Innovations

Variable	Money Supply	Government Expenditure	GNP	Real Exchange Rate	Exports to the U. S.
	.00179	.00954	.00707	.01887	.08631
	(.00243)	(.01104)	(.00857)	(.02298)	(.11565)
					(.11285)
					(.10771)
					(.11052)

Note: Money supply, government expenditure, and *GNP* are variables of the U. S. With the exception of money supply, all the variables are in real terms. The numbers in parentheses are standard deviations in the two-variable models. The standard deviations of Taiwan's exports to the U. S. in the two-variable models by the order are the pair of Taiwan's exports to the U. S. with the U. S. money supply, government expenditure, *GNP*, and real exchange rate respectively.

3.3.1 Responses to shocks in the U. S. Money Supply

Most of the impulse responses of Taiwan's exports to the U. S. to a positive

[15] In theory, the analyses of impulse response and decomposition of forecasting error variance assume that the innovations of variables in the model are contemporaneously uncorrelated. But, this condition is hardly satisfied in most empirical studies (including this paper). In addition, the outcome of impulse response and error decomposition have relations with the ordering of variables in the VAR model, but our empirical result is not the one sensitive to the ordering of variables (see footnote 9).

innovation in the U. S. money supply are negative, especially in the long time horizons. All of the accumulated responses of Taiwan's exports to the U. S. to a positive innovation in the U. S. money supply are negative (five-variable model) and only positive in the period from seven to eleven (two-variable model) (see Figure 1 and 2).

Figure 1: Impulse Responses of Taiwan's Real Exports to the U.S. to a Positive Shock in the U.S. Money Supply (Five-Variable Model)

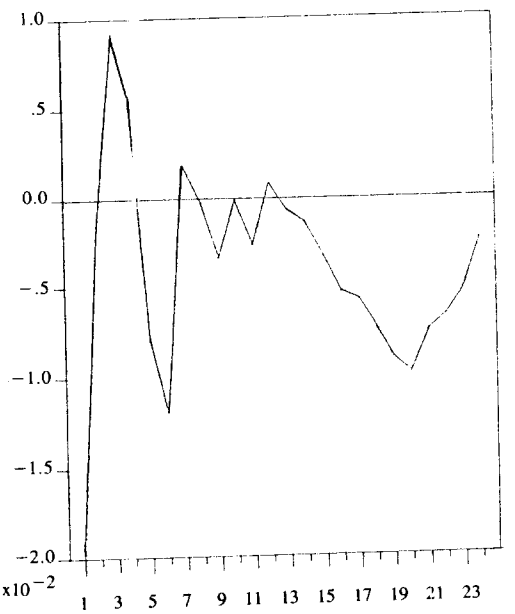
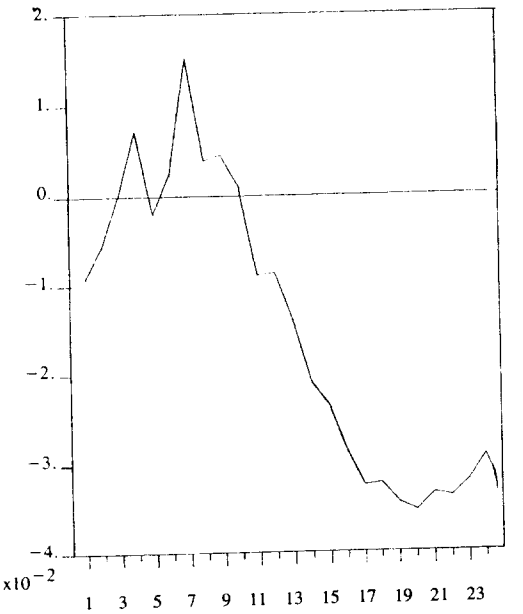


Figure 2: Impulse Responses of Taiwan's Real Exports to the U.S. to a Positive Shock in the U.S. Money Supply (Two-Variable Model)



The result of impulse responses indicates that unanticipated increase in the U. S. money supply has adverse effect on Taiwan's exports to the U. S. In the five-variable model, the impact of innovations in the U. S. money supply on Taiwan's exports to the U. S. is much smaller than innovations in other variables. In the two-variable model, only after the sixteenth period, the impact of innovations in the U. S. money supply on Taiwan's exports to the U. S. is greater than the impact of innovations in the real exchange rate on Taiwan's exports to the U. S. (absolute value). Therefore, we can conclude that the impact of innovations in the U. S. money supply on Taiwan's exports to the U. S. is negative but less important than innovations in other variables. The response pattern of Taiwan's exports to the U. S. also contradicts the monetary hypothesis.

3.3.2 Responses to Shocks in the U. S. Government Expenditure

Both five-variable and two-variable models show that innovations in the U. S. government expenditure have negative effects on Taiwan's exports to the U. S. in the short periods, but in longer periods they have strong, persistent and positive effect on Taiwan's exports to the U. S. (see Figure 3 and 4). This implies that positive innovations in the U. S. fiscal policy (or aggregate demand) help Taiwan increase its exports to the U. S. in the long run, the increase in the U. S. aggregate demand has spill over effect on Taiwan's exports.

Figure 3: Impulse Responses of Taiwan's Real Exports to the U.S. to a Positive Shock in the U.S. Real Government Expenditure (Five-Variable Model)

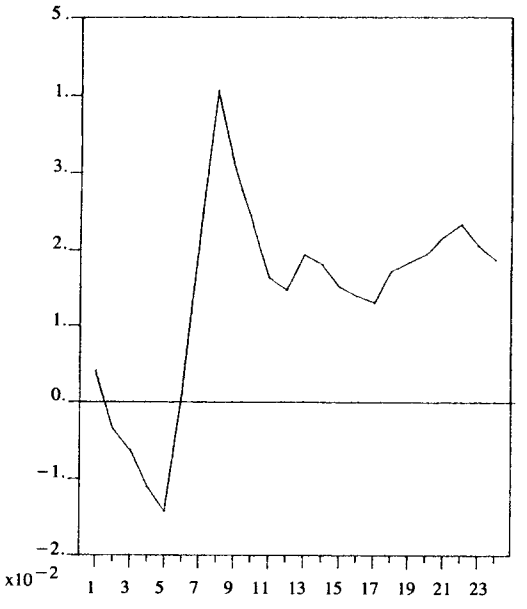
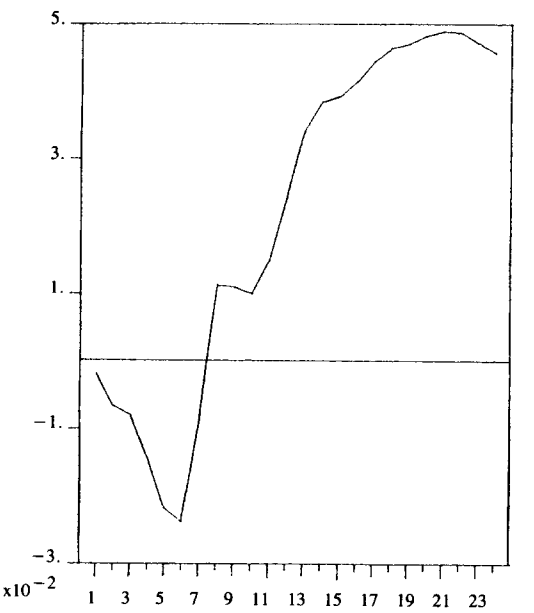


Figure 4: Impulse Responses of Taiwan's Real Exports to the U.S. to a Positive Shock in the U.S. Real Government Expenditure (Two-Variable Model)



3.3.3 Responses to Shocks in the U. S. GNP

The impact of innovations in the U. S. *GNP* on Taiwan's exports to the U. S. resembles an U in shape in both the five-variable and two-variable models. That

is, innovations in the U. S. *GNP* have positive effects on Taiwan's exports to the U. S. immediately, then the effect becomes negative shortly after, but it reverts to a positive effect on Taiwan's exports to the U. S. quickly. Therefore, all the accumulated responses of Taiwan's exports to the U. S. to innovations in the U. S. *GNP* are positive (see Figure 5 and 6). We can conclude that innovations in the U. S. *GNP* have a persistent and positive effect on Taiwan's exports to the U. S. This is consistent with the Keynesian hypothesis.

Figure 5 Inpulse Responses of Taiwan's Real Exports to the U.S. to a Positive Shock in the U.S. Real GNP (Five-Variable Model)

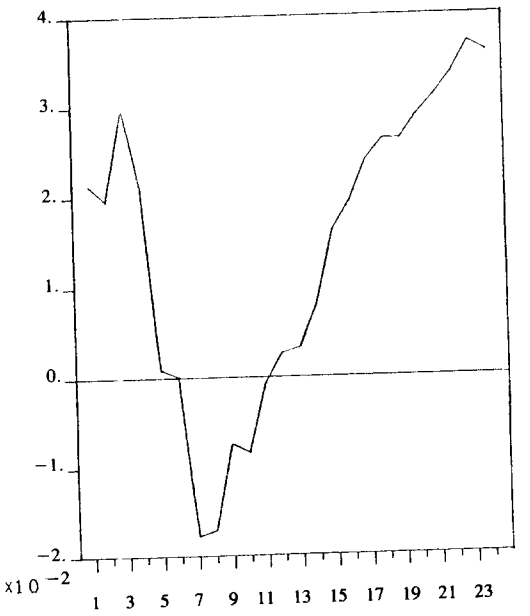
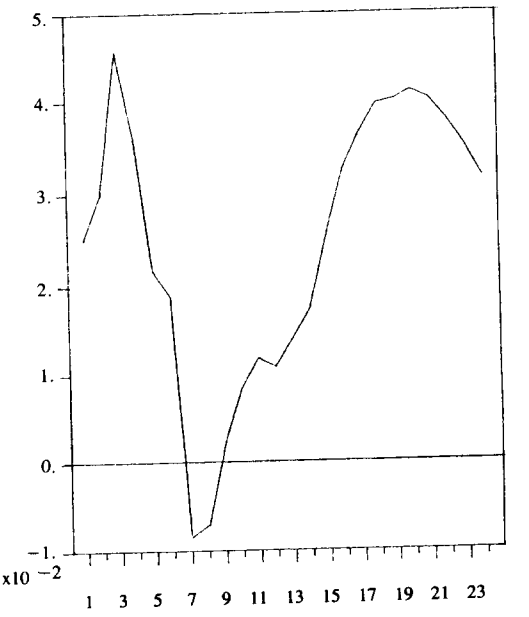


Figure 6: Impulse Responses of Taiwan's Real Exports to the U.S. to a Positive Shock in the U.S. Real GNP (Two-Variable Model)



3.3.4 Responses to Shocks in the Real Exchange Rate

The impulse responses of Taiwan's exports to the U. S. with respect to a positive innovation in the real exchange rate are positive at all time horizons shown (with the exception of one small negative response in the two-variable model). The effect of innovations in the real exchange rate on Taiwan's exports to the U. S. persistently produce the largest accumulated impulse responses on Taiwan's exports to the U. S. than innovations in any other variables included in our model (see Figure 7 and 8). This implies that prices and exchange rate together play an important role

Figure 7: Impulse Responses of Taiwan's Real Exports to the U.S. to a Positive Shock in the Real Exchange Rate (Five-Variable Model)

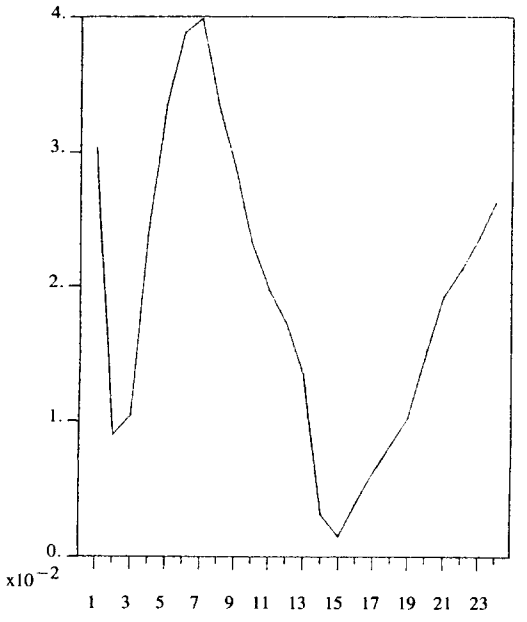
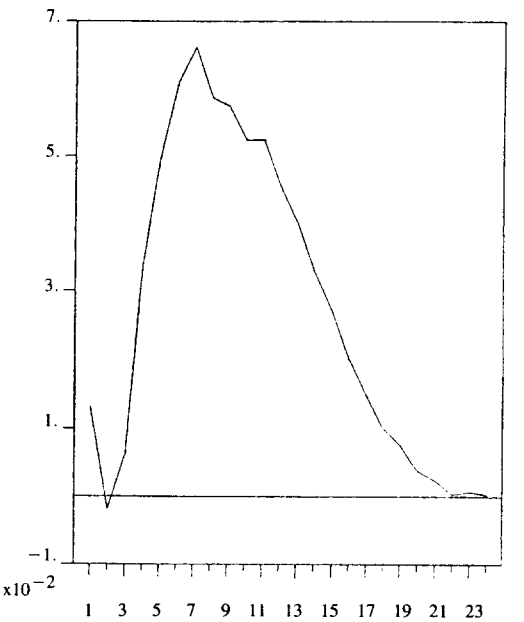


Figure 8: Impulse Responses of Taiwan's Real Exports to the U.S. to a Positive Shock in the Real Exchange Rate (Two-Variable Model)



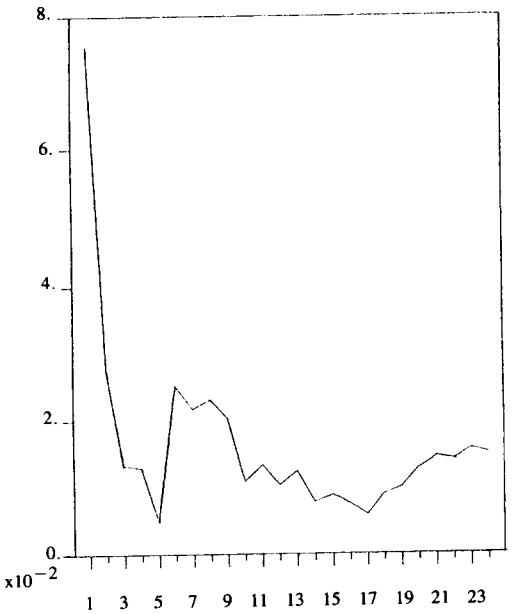
in determining Taiwan's exports to the U. S., and the responses of Taiwan's exports to the U. S. to innovations in the real exchange rate is consistent with the Keynesian hypothesis.

3.3.5 Responses to Shocks in Taiwan's Exports to the U. S.

The impulse response of Taiwan's exports to the U. S. with respect to its own innovations all are positive, but the magnitudes of the responses are smaller than the responses to the innovations in real exchange rate (see Figure 9).

In terms of elasticity, our calculation shows that in the five-variable model, the response of Taiwan's exports to the U. S. to a positive innovation in the U. S. government expenditure is .47, to a positive innovation in the U. S. *GNP* is .35, to a positive innovation in real exchange rate is .39. In the two-variable models, the response of Taiwan's exports to the U. S. to a positive innovation in the U. S. government expenditure is .34, to a positive innovation in the U. S.

Figure 9: Impulse Responses of Taiwan's Real Exports to the U.S. to a Positive Shock in Taiwan's Real Exports to the U.S. (Five-Variable Model)



GNP is .35, to a positive innovation in real exchange rate is .41 (all are calculated by the peak response). By this measure, we find that all innovations in the U. S. government expenditure, *GNP*, and the real exchange rate have a strong impact on Taiwan's exports to the U. S.

In sum, the impulse responses of Taiwan's exports to the U. S. with respect to innovations in the U. S. real government expenditure, real *GNP*, and the real exchange rate are confirmed by the Keynesian model. That is, a positive innovation in any one of these three variables produces a persistent and beneficial effect on Taiwan's exports to the U. S. The impulse response analysis further confirms that real variables rather than monetary variable are more important in determining the variation of Taiwan's exports to the U. S.

4. Decomposition of Variance in Taiwan's Exports to the U. S.

The decomposition of forecasting error variance of Taiwan's exports to the

U. S. is reported in Table 5 (five-variable model) and 6 (two-variable models). From these tables, we find that

Table 5: Decomposition of Variances in Taiwan's Exports to the U. S. (Unit: %) (Five-Variable Model)

Quarter	Stand. Devi. (ln)	U. S. Money Supply	U. S. Government Expenditure	U. S. GNP	Real Exchange Rate	Taiwan's Exports to the U. S.
1	.086	5.23	.23	6.11	12.24	76.19
2	.093	4.52	.34	9.66	11.42	74.06
3	.100	4.78	.68	17.33	11.02	66.19
4	.106	4.48	1.67	19.16	14.90	59.79
5	.133	4.47	3.07	17.03	22.09	53.33
6	.123	4.74	2.62	14.44	28.75	49.46
7	.134	4.01	4.69	13.93	33.09	44.29
8	.147	3.34	11.63	12.96	32.74	39.34
9	.154	3.07	14.50	11.95	33.13	37.35
10	.158	2.91	16.00	11.61	33.57	35.90
11	.161	2.84	16.51	11.24	33.98	35.42
12	.163	2.78	16.94	11.00	34.30	34.99
13	.165	2.71	17.87	10.75	34.05	34.63
14	.166	2.67	18.76	10.79	33.51	34.27
15	.168	2.65	19.18	11.50	32.83	33.84
16	.170	2.69	19.41	12.51	32.13	33.25
17	.173	2.73	19.43	14.08	31.35	32.42
18	.176	2.80	19.64	15.77	30.37	31.43
19	.180	2.94	19.89	17.24	29.46	30.46
20	.184	3.08	20.02	18.83	28.64	29.43
21	.190	3.06	20.19	20.40	28.02	28.33
22	.196	2.99	20.37	22.04	27.48	27.12
23	.203	2.87	20.10	23.95	27.09	25.99
24	.209	2.72	19.73	25.48	27.08	24.99

Note: Stand. Devi. is the standard deviation of forecasting error of Taiwan's exports to the U. S. The standard deviations are in terms of ln. Each entry in this table is the percentage of forecast error variance t quarters ahead of Taiwan's exports to the U. S. produced by a positive innovation of the variables in the columns.

Table 6: Decomposition of Variances in Taiwan's Exports to the U. S. (Unit: %) (Two-variable Models)

Quarter	Stand. Devi. (1)	U. S. Money Supply	Stand. Devi. (2)	U. S. Govern. Expend.	Stand. Devi. (3)	U. S. GNP	Stand. Devi. (4)	Real Exchange Rate
1	.116	.64	.113	.03	.108	5.45	.111	1.42
2	.150	.51	.140	.25	.133	8.71	.139	.92
3	.171	.40	.155	.47	.150	16.09	.153	.92
4	.186	.48	.164	1.17	.163	18.39	.167	4.96
5	.193	.46	.169	2.77	.171	18.35	.179	12.12
6	.206	.42	.177	4.30	.186	16.53	.201	18.90
7	.217	.86	.182	4.32	.197	14.86	.221	24.51
8	.228	.81	.188	4.41	.207	13.60	.241	26.63
9	.236	.79	.193	4.52	.213	12.89	.258	28.11
10	.240	.76	.195	4.67	.217	12.58	.272	29.07
11	.244	.87	.198	5.11	.221	12.40	.285	29.82
12	.247	.98	.201	6.39	.224	12.27	.295	30.25
13	.251	1.26	.206	8.79	.228	12.29	.304	30.18
14	.254	1.91	.213	11.56	.230	12.61	.311	29.88
15	.257	2.71	.219	14.15	.233	13.52	.318	29.43
16	.260	3.86	.225	16.86	.236	15.02	.323	28.86
17	.264	5.28	.230	19.79	.240	16.83	.327	28.32
18	.267	6.60	.236	22.68	.245	18.84	.331	27.78
19	.271	8.05	.242	25.36	.249	20.80	.334	27.31
20	.274	9.50	.248	27.93	.253	22.72	.337	26.87
21	.278	10.72	.254	30.40	.257	24.45	.340	26.46
22	.281	11.91	.259	32.71	.261	25.87	.342	26.10
23	.284	12.92	.264	34.76	.264	27.01	.344	25.77
24	.287	13.71	.268	36.58	.267	27.87	.344	25.47

Note: Stand. Devi. (1), (2), (3), and (4) are the standard deviation of forecasting errors of Taiwan's exports to the U.S. in the two variable models with the U. S. money supply, government expenditure, *GNP*, and real exchange rate respectively. The standard deviations are in terms of ln. Each entry in this table is the percentage of forecast error variance t quarters ahead of Taiwan's exports to the U. S. produced by a positive innovation of the variables in the columns.

(1) In the five-variable model, innovations in the U. S. money supply account for at most 5.23% (in the first period) of variation in Taiwan's exports to the U. S. at all time horizons shown. From eight to twenty four periods, innovations in the U. S. money supply account for only about 3% of variation in Taiwan's exports to the U. S. In the two-variable model, innovations in the U. S. money supply account for at most 13.7% (in the twenty fourth period) of the variance in Taiwan's exports to the U. S.

(2) As time passes, variation in Taiwan's exports to the U. S. accounted for by innovations in the U. S. real government expenditure increase. In the five-variable model, innovations in the U. S. real government expenditure accounted for 16% to 20.37% of variation in Taiwan's exports to the U. S. in the period from ten to twenty four. In the two-variable model, innovations in the U. S. real government expenditure account for 16.86% to 36.58% of the variance in Taiwan's exports to the U. S. in the period from sixteen to twenty four. Both models indicate that in the long term horizons, innovations in the U. S. real government expenditure (or the U. S. aggregate demand) play a relatively important role in the fluctuations of Taiwan's exports to the U. S.

(3) Both five-variable and two-variable models show that innovations in the U. S. real *GNP* account for a larger proportion of variation in Taiwan's exports to the U. S. in the period from three to six. It then decreases in the period from seven to thirteen. From the fourteenth period onward, variation in Taiwan's exports to the U. S. accounted for by innovation in the U. S. real *GNP* persistently increases and reaches the maximum of 25.48% (five-variable model) or 27.87% (two-variable model) in the twenty fourth period. Both the impulse response analysis and the variance decomposition analysis show that in the long time periods, innovations in the U. S. real *GNP* have a bigger effect on Taiwan's exports to the U. S.

(4) Both five-variable and two-variable models show that since the fifth period, innovations in the real exchange rate account for a big proprotion of variation in Taiwan's exports to the U. S. The maximum accounted proportion is 34.30% (five-variable model) or 30.25% (two-variable model) in the twelfth period. The evidences show that innovtions in the real exchange rate play a more important role in the fluctuations of Taiwan's exports to the U. S. than innovations in the U. S. money supply, government expenditure, and *GNP* in both five-variable and two-variable models for most periods.

(5) In the five-varible model, from the eighth period onward, variation in Taiwan's exports to the U. S. accounted for by own innovations is less than 40%. In the twenty fourth period, the proportion is reduced to 24.99%, which is smaller than the proportion accounted for by the innovations in the U. S. real *GNP* and real exchange rate.

The above variance decomposition shows that innovations in the Keynesian variables rather than the monetary variable play a relatively important role in the fluctuations of Taiwan's exports to the U. S. Innovations in the U. S. *GNP* generate a quicker and bigger effect on variation in Taiwan's exports to the U. S. On the other hand, innovations in the U. S. government expenditure have a slower effect on the fluctuations of Taiwan's exports to the U. S. than innovations in the U. S. *GNP* and real exchange rate, but in the longer run they account for the biggest proportion of the variation in Taiwan's exports to the U. S. (two-variable model). At all time horizons shown, innovations in the real exchange rate play a more important role in the fluctuations of Taiwan's exports to the U. S. than innovations in the U. S. government expenditure and *GNP*.

In the five-variable model, innovations in the U. S. government expenditure, *GNP*, and the real exchange rate together account for at most 72% of the variation in Taiwan's exports to the U. S. This indicates that the fluctuations in Taiwan's exports to the U. S. are largely caused by innovations in the U. S. government expenditure and *GNP*, and the real exchange rate. The hypothesis that exports from Taiwan to the U. S. is an exogenous variable with respect to Taiwan's economy therefore can be accepted.

5. Conclustion

Taiwan's exports to the U. S. is the most important channel through which the economies of these two countries are linked. A VAR model along with the Keynesian approach and the monetary approach are employed in our analysis to find out what are the important factors affecting Taiwan's exports to the U. S.

The result of our analysis shows that at the 20% significance level, the U. S. real government expenditure, real *GNP*, and the real exchange rate are Granger-cause (or strictly exogenous) to Taiwan's exports to the U. S. Our analysis also shows that there is a significant positive relationship between innovations in the U. S. real *GNP*, real exchange rate and innovations in Taiwan's exports to the U. S.

The impulse response analysis shows that a positive innovation in the U. S. real government expenditure, real *GNP*, and the real exchange rate has a positive and persistent impact on Taiwan's exports to the U. S. Furthermore, the variance decomposition analysis shows that the U. S. real government expenditure, real *GNP*, and real exchange rate together account for 72% of variation in Taiwan's exports to the U. S. All of these findings may mean that innovations in the U. S. real government expenditure, real *GNP*, and the real exchange rate play an important role in the fluctuations of Taiwan's exports to the U. S.

Our empirical work further shows that real exchange rate has the closest relationship with and the strongest impact effect on the variation of Taiwan's exports to the U. S., and the U. S. money supply does not play an important role in affecting Taiwan's exports to the U. S. In fact, the result of our empirical study seems to suggest that there is a negative relationship between the U. S. money supply and Taiwan's exports to the U. S. which is contrary to the prediction of the monetary approach.

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