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THE RELATIONSHIP BETWEEN EXPORTS AND ECONOMIC GROWTH IN EAST ASIAN COUNTRIES: A MULTIVARIATE THRESHOLD AUTOREGRESSIVE APPROACH

CHIEN-HUI LEE AND BWO-NUNG HUANG*

National Kaohsiung University of Applied Sciences
and National Chung-Cheng University

During the process of economic development, different economic policies are adopted in accordance with particular circumstances. Therefore, conventional methods of time-series analysis may give misleading results if the problems associated with regime switches are not considered. The relationship between export growth and output growth is explored using a multivariate threshold model with regimes defined by the export-import ratio. In the cases of five countries that are recognized as being outward-oriented, we find that, except for Hong Kong, the relationship whereby exports lead output prevails in at least one regime for each of four of the countries being studied. The regime-based threshold autoregressive model thus appears to possess certain advantages over the more conventional linear autoregressive model.

Keywords: Multivariate Threshold Autoregressive Model, Export Growth, Output Growth, Export-import Ratio
JEL classification: C32, F10, F43

1. INTRODUCTION

The relationship between export growth and economic growth has been a popular subject of debate among development economists. The successful records of the ‘Four Dragons’ or even ‘Four Tigers’ have received much attention in the literature on economic growth and have revived the debate on the effectiveness of outward

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orientation as a strategy for economic development. The literature on exports and economic growth has its source in the late 1970s. The methodology of the early studies relies on correlation coefficients between export growth and economic growth (as in Michaely (1977) Michalopoulos and Jay (1973)). In the 1980s, most studies used the Granger causality test method to investigate lead-and-lag relations. Notable examples include Chow (1987) and Jung and Marshall (1985). In the 1990s, the development of the concepts of unit root and cointegration added twist to studies employing the causality test (see for example, Bahmani-Oskooee *et al*. (1991), Sharma *et al*. (1991), Bahmani-Oskooee and Alse (1993), Sharma and Dhakal (1994), Ghartey (1993), Xu (1996), Riezman *et al*. (1996), Huang, Oh and Yang (2000), and Shan and Sun (1998)).

Broadly speaking, export growth can promote economic growth and vice versa. The theoretical justification for these hypotheses is discussed as follows.

From the growth-theory literature point of view, export expansion is the key factor promoting economic growth. There are various explanations that have been put forward to relate these two variables to each other. First, the growth of exports has a stimulating effect on total factor productivity growth through its positive impact on higher rates of capital formation. Second, the growth of exports helps relax the foreign exchange constraints, thereby facilitating imports of capital goods and hence faster growth. Third, competition from overseas ensures an efficient price mechanism that fosters optimum resource allocation and increases the pressure on industries that export goods to keep costs relatively low and to improve technological change, thereby promoting economic growth. Clearly, these arguments lead us to hypothesize that exports contribute positively to economic progress.

In contrast to the export-led growth hypothesis, it can also be argued that causality runs from the growth of output to the growth of exports. When we consider a growing economy, some industries face substantial changes in terms of learning and technological innovation, which are related to the accumulation of human capital, manufacturing experiences and the technology transfer or real capital accumulation arising from foreign direct investment. Such unbalanced growth has nothing to do with outward-oriented policies, i.e., output will still continue to grow even in the absence of these policies. Under such unbalanced growth, the growth of domestic demand will lag behind the growth of output in these prosperous industries and it is likely that the producers will sell their goods in overseas markets. Therefore, economic growth will promote the growth of exports.

Another plausible hypothesis is that negative causality runs from output growth to export growth. This would be likely to occur if consumer demand were concentrated in exportable and non-traded goods in which case an increase in domestic demand would induce an increase in output but a decrease in exports. As a result, output growth will lead to a reduction in the growth of exports. If an increase in exports arises as a result of inward foreign direct investment, the growth of exports will reduce the growth of output due to various distortions (Bhagwati (1979)), and it is therefore easier to identify the negative relationship between the growth of output and the growth of exports.

Although previous empirical work has been concentrated on a large number of both developed and developing countries, the economies of the Little Dragons have rarely been studied. The literature on this subject has largely neglected these countries owing to the non-availability of consistent data, quarterly data being particularly lacking or else the sample period for these countries not being long enough. In this study, the relevant quarterly data are used, Japan, a country that has lacked natural resources, adopted an export-oriented policy early on, thus providing a benchmark for comparison with the economies of the Little Dragons. In countries whose economic development is in a process of transition, it is particularly true that the policies adopted under different regimes are distinctive. Therefore, the conventional methods used to explore the relationship between export growth and economic growth that involves the pooling of data for estimation purposes may lead to misleading results if the problems associated with regime changes are not considered.

By contrast, the methodology used in this study is based on the Multivariate threshold autoregressive (MTAR) model introduced by Tsay (1998). The causal relationship between export growth and economic growth is explored using the MTAR model with two regimes defined by the threshold variable. Our results show that, for some outward-oriented countries, the conventional approach, which allows for just one regime, is not able to determine the existence of an exports-lead-growth relationship. However, if a two-regime MTAR model is applied, strong evidence of an exports-lead-growth relationship is found. The remainder of this paper is organized as follows. Section 2 describes the data, outlines the underlying fundamentals of the threshold autoregressive model; Section 3 summarizes the empirical results; and Section 4 presents the conclusions.

2. THE DATA, MODEL, ECONOMETRIC METHODOLOGY

All data are taken from Datastream and quarterly data are employed. The relevant tests are carried out for five Asian countries in this paper: Hong Kong (HKN), Korea (KOA), Taiwan (TWN), the Philippines (PHI) and Japan (JPN). The sample period, the sample size and the Datastream Codes for these economies are provided in Table 1.

Table 1. Data Sources, Variable Names and Datastream Code

Country	Frequency	Sample Period	N	Source
Hong Kong	Quarterly	1973：1 2000：1	109	Datastream
Japan	Quarterly	1955：1 2000：1	181	Datastream
Korea	Quarterly	1973：3 2000：1	107	Datastream
Philippines	Quarterly	1981：1 2000：1	77	Datastream
Taiwan	Quarterly	1961：1 2000：1	157	Datastream

Table 1. (Continued)

Country	GDP(Y)	*K*	EXPORTS(EX)	IMPORTS(IM)	CPI
Hong Kong	HKGDP...C	HKGFCF..C	HKEXPGDSA	HKIMPGDSA	HKCONPRCF
Japan	JPGDP...B	JPGFCF..B	JPEXNGS.B	JPIMNGS.B	JPCONPRCF
Korea	KOGDP...A	KOGFCF..A	KOEXNGS.A	KOIMNGS.A	KOCONPRCF
Philippines	PHGDP...A	PHGFCF..A	PHEXNGS.A	PHIMNGS.A	PHCONPRCF
Taiwan	TWGDP...A	TWGFCF..A	TWEXNGS.A	TWIMNGS.A	TWCONPRCF

Notes: *N* denotes the number of observations. *K* denotes gross fixed capital formation.

Our purpose in this paper is to investigate the causal relationship between exports and output. In previous studies (e.g., Bahmani-Oskooee *et al*. (1991), Sharma *et al*. (1991)), the export-output relationship is tested by including output (Y), capital (K), exports (EX), imports (IM), and the labor force (L), etc. as arguments, and applying multivariate Granger causality methodology. In other words, when exploring the causal relationship between exports and output, at least these variables need to be included in the model. However, the labor-force variable is dropped from our model due to the non-availability of data. Gross domestic product (GDP) is used as a measure of real total output and capital is measured in terms of gross fixed capital formation.[1] All of the variables used here are expressed in real terms by deflating them by the GDP deflator. Since the main purpose of this paper is to examine the causal linkage between exports and economic growth in the context of the export-led growth hypothesis, the autoregressive model is specified as follows:

$$\Delta ex_t = a_0 + \sum_{i=1}^{k} a_{1i}\Delta ex_{t-i} + \sum_{i=1}^{k} a_{2i}\Delta im_{t-i} + \sum_{i=1}^{k} a_{3i}\Delta k_{t-i} + \sum_{i=1}^{k} a_{4i}\Delta y_{t-i} + e_{1t} \ ,$$

$$\Delta y_t = b_0 + \sum_{j=1}^{k} b_{1j}\Delta ex_{t-j} + \sum_{j=1}^{k} b_{2j}\Delta im_{t-j} + \sum_{j=1}^{k} a_{3j}\Delta k_{t-j} + \sum_{j=1}^{k} a_{4j}\Delta y_{t-j} + e_{2t} \ , \tag{1}$$

where Δ denotes first differencing and the lower case is in logarithmic form. Failing to reject the null hypothesis $H_0 : a_{41} = a_{42} = \ldots = a_{4k} = 0$ implies that $\Delta y \not\rightarrow$ (does not Granger-cause) Δex; Similarly, failing to reject $H_0 : b_{11} = b_{12} = \ldots = b_{1k} = 0$ suggests that $\Delta ex \not\rightarrow \Delta y$. The symbol "$\rightarrow$" denotes the existence of a Granger causal relationship, and "$\leftrightarrow$" denotes that a feedback causal relationship prevails. Model (1) has only one regime, which is the conventional approach employed by previous studies. However, during the transition process of economic development, distinct policies may

[1] Since capital stock data are not easy to collect and measure, gross fixed capital formation is used as a proxy variable (see, for example, Sharma and Dhakal (1994)).

be adopted under different regimes. Therefore, conventional methods in autoregressive analysis, which allows for just one regime, may give misleading results if different policies are adopted in accordance with distinct regimes.

In addition, the question as to whether model (1) is a reasonable model depends on the cointegration relationship among the four variables. If these variables are cointegrated, model (1) will be misspecified due to the lack of error-correction terms. Following the conventional time series analysis approach, the Augmented Dickey-Fuller (ADF) test is employed as a first step to examine the hypothesis of a unit root among the variables. If a unit root exists in each variable, Johansen (1991) cointegration test is applied to test for cointegration in a multivariate framework. The results of the unit root test are presented in Table 2.

Table 2. Results of Unit Root Tests

Variable \ Country	Hong Kong	Japan	Korea	Philippines	Taiwan
y	-1.89	-0.83	-2.94	-2.88	-1.43
k	-3.07	-2.60	-2.39	-2.27	-1.69
ex	-3.04	-1.57	-1.74	-2.39	-1.91
im	-2.91	-2.70	-3.69**	-2.48	-1.83
Δy	-2.12**	-1.75**	-1.87**	-17.86*	-1.84**
Δk	-2.68*	-3.68*	-4.46*	-7.45*	-2.83*
Δex	-3.87*	-5.15*	-2.41**	-6.81*	-3.27*
Δim	-4.24*	-6.49*	-3.59*	-6.29*	-4.24*

Notes: Δ denotes first differences. All variables are in natural logarithms. t_t statistics are employed for the levels of variables (with a drift and a time-trend term). t statistics are employed for the first-differences of variables. * (**) indicates significance at 1% (5%) level.

Based on the results of the ADF test for the levels of the variables, the null hypothesis of a unit root cannot be rejected for all countries, except for the imports of Korea. After taking the first differences of the log series, the hypothesis of a unit root is tested again, and it is rejected in all cases. Hence four variables for the cointegration test are employed in five countries, while Korea uses a trivariate model. The results of the cointegration test for five countries are reported in Table 3.

Since the data used in this paper exhibit a linear deterministic trend, the Johansen cointegration test employs a model with a linear deterministic trend in terms of its data but the cointegrating equations have only intercepts. We test down from eight to choose the optimal lag length using the Akaike information criterion (AIC), and the results are reported in Table 3. As shown in Table 3, the null hypothesis of no cointegration cannot be rejected for all countries except for Japan. Therefore, we can employ the standard

Granger-causality test without the error-correction terms introduced in (1) for four countries, whereas the error- correction term is included in the case of Japan.[2] In other words, Equation (1) is used to test for the causal relationship between export growth and output growth under different regimes for four countries. For Japan, the error-correction term, ecm_{t-1}, is introduced in two equations of model (1).[3]

Table 3. Results of Johansen Cointegration Tests

	H_0	Trace Statistic	1% Critical Value	Number of Variables	N	lag
Hong Kong	$r = 0$	49.83	54.46	4	105	4
Korea	$r = 0$	17.52	35.65	3	104	4
Philippines	$r = 0$	53.88	54.46	4	73	4
Taiwan	$r = 0$	52.45	54.46	4	153	4
Japan	$r = 0$	66.75*	54.46			
	$r \leqq 1$	37.8*	35.65	4	175	6
	$r \leqq 2$	19.82	20.04			

Notes: Johansen (1995) suggested five possible test models based on the types of the data. We use the model allowed to assume linear deterministic trend in the data but the cointegrating equations have only intercepts. Because there are at most 175 observations under study, the critical value at 1% level is employed for comparison. N is the sample size; lag is the number of lags applied in each cointegration test based on the Akaike information criterion.

Threshold models were introduced by Tong (1978) and Tong and Lim (1980). The TAR model allows for the classification of the variable across regimes based on an estimate of the time series behavior that is consistent with reaching the threshold that separates the regimes. Consider a simple two-regime TAR model:

$$y_t = \begin{cases} f_{0,1} + f_{1,1} y_{t-1} + e_t & if \quad y_{t-1} \leq r, \\ f_{0,2} + f_{1,2} y_{t-1} + e_t & if \quad y_{t-1} > r, \end{cases} \tag{2}$$

[2] If the coefficient of log income variable is set to unity, the four-variable cointegration relationship for Japan can be described as follows:

$$ecm_{t-1} = y_{t-1} - 2.1132 ex_{t-1} + 1.7184 im_{t-1} + 1.6047 k_{t-1} - 1.0242.$$

[3] Since there are at most 175 observations (Japan) in the estimation; moreover, the lags are over 4 periods for each country (6 periods for Japan). Under the four-variable model, the degree of freedom is only 150 for Japan (the case with greatest sample size). However, the critical values for Johansen cointegration tests are obtained using 400 observations. To circumvent the low power problem, the one percent critical value is employed in the analysis.

where the lagged dependent variable (y_{t-1}) is referred to as the threshold variable, r is the threshold parameter, and the errors, e_t, are white-noise *iid*. To apply the TAR model and for ease of explanation, we assume that the optimal lag for Equation (1) is one. For four countries having no cointegration relationships, the two-regime TAR model may then be expressed as:

$$
\begin{aligned}
\Delta ex_t &= (a_{10} + a_{11}\Delta ex_{t-1} + a_{12}\Delta im_{t-1} + a_{13}\Delta k_{t-1} + a_{14}\Delta y_{t-1})(1 - I[z_t > r]) \\
&\quad + (a_{20} + a_{21}\Delta ex_{t-1} + a_{22}\Delta im_{t-1} + a_{23}\Delta k_{t-1} + a_{24}\Delta y_{t-1})(I[z_t > r]) + e^*_{1t}\ , \\
\Delta y_t &= (b_{10} + b_{11}\Delta ex_{t-1} + b_{12}\Delta im_{t-1} + b_{13}\Delta k_{t-1} + b_{14}\Delta y_{t-1})(1 - I[z_t > r]) \\
&\quad + (b_{20} + b_{21}\Delta ex_{t-1} + b_{22}\Delta im_{t-1} + b_{23}\Delta k_{t-1} + b_{24}\Delta y_{t-1})(I[z_t > r]) + e^*_{2t}\ ,
\end{aligned} \tag{3}
$$

where $I[A]$ is an indicator function with $I[A]=1$ if the event A occurs and $I[A]=0$ otherwise. z_t is the potential threshold variable. Since the purpose of this paper is to investigate the relationship between exports and economic growth and the export-import ratio is generally larger in the export-oriented economies, thus $ex_t / im_t = rexim_t$ is employed as the main threshold variable in the analysis.[4]

For the model with a cointegration relationship (Japan), Equation (3) becomes

$$
\begin{aligned}
\Delta ex_t &= (-a_{10} + a_{11}\Delta ex_{t-1} + a_{12}\Delta im_{t-1} + a_{13}\Delta k_{t-1} + a_{14}\Delta y_{t-1} + a_{15} ecm_{t-1})(1 - I[z_t > r]) \\
&\quad + (a_{20} + a_{21}\Delta ex_{t-1} + a_{22}\Delta im_{t-1} + a_{23}\Delta k_{t-1} + a_{24}\Delta y_{t-1} + a_{25} ecm_{t-1})(I[z_t > r]) + e^*_{1t}\ , \\
\Delta y_t &= (b_{10} + b_{11}\Delta ex_{t-1} + b_{12}\Delta im_{t-1} + b_{13}\Delta k_{t-1} + b_{14}\Delta y_{t-1} + b_{15} ecm_{t-1})(1 - I[z_t > r]) \\
&\quad + (b_{20} + b_{21}\Delta ex_{t-1} + b_{22}\Delta im_{t-1} + b_{23}\Delta k_{t-1} + b_{24}\Delta y_{t-1} + b_{25} ecm_{t-1})(I[z_t > r]) + e^*_{2t}\ .
\end{aligned} \tag{4}
$$

Before applying a TAR model such as models (3) or (4), we need to test for the threshold effects. It is analogous to test the null hypothesis of the linear model versus the alternative hypothesis of the two-regime model such as models (3) or (4).[5] Because of the difficulty with the threshold r being unidentified under the null hypothesis, conventional methods cannot be applied. Hansen (1996) suggested that relevant tests be conducted through the use of bootstrap methods. Although we may estimate Equations (3) or (4) by treating them as independent equations and then carry out the Granger causality tests, if our goal is to capture complicated and dynamic relations between

[4] We are grateful to an anonymous referee for suggesting our using the export-import ratio as the threshold variable.

[5] A regime larger than two is not considered here due to data constraints, since the largest sample period in this paper contains only 175 observations.

exports and economic growth via the impulse response analysis or variance decomposition, it may be better to treat the above models as multivariate models.[6] The multivariate TAR model proposed by Tsay (1998) is described as follows:

Assume that $\mathbf{y}_t$ is an endogenous variable vector, $\mathbf{x}_t$ denotes an exogenous variable vector, z_t is referred to as the threshold variable, p is the lag length of y_t, q is the lag length of x_t, and d is the threshold lag or delay. Given observation { $\mathbf{y}_t$, $\mathbf{x}_t$, z_t }, where $t = 1, 2, \ldots, n,$ and assuming that p, q and d are known, the goal is to detect the threshold nonlinearity of $\mathbf{y}_t$. First, the model is set up as a regression framework,

$$\mathbf{y}'_t = \mathbf{X}'_t \ddot{\mathbf{O}} + e'_t, \qquad t = h+1, \ldots, n, \tag{5}$$

where $h = max(p, q, d)$, $\mathbf{X}_t = (1, \mathbf{y}_{t-1}', \ldots, \mathbf{y}_{t-p}', \mathbf{x}_{t-1}', \ldots, \mathbf{x}_{t-q}')$ is a $(pg+qv+1)$-dimensional regressor, and $\ddot{\mathbf{O}}$ denotes the parameter matrix. If the null hypothesis that $\mathbf{y}_t$ is linear holds, then the least squares estimates of (5) are consistent. However, the OLS estimates are biased under the alternative hypothesis.

Equation (5) remains informative under the alternative hypothesis provided that we rearrange the ordering of the setup. In the case of Equation (5), the threshold variable z_{t-d} assumes values in $S = \{z_{h+1-d}, \ldots, z_{n-d}\}$. Let us consider the order statistics of S and denote the ith smallest element of S by $z_{(i)}$. Furthermore, let $t_{(i)}$ be the time index of $z_{(i)}$. Then the arranged regression based on the increasing order of the threshold variable z_{t-d} is

$$\mathbf{y}'_{t(i)+d} = \mathbf{X}'_{t(i)+d}\, \ddot{\mathbf{O}} + e'_{t(i)+d}, \qquad i = 1, \ldots, n-h. \tag{6}$$

To detect threshold nonlinearity of Model (6), Tsay (1998) generalized the test statistic of Tsay (1989) to the multivariate case. Tsay used the recursive least squares method (RLS) to obtain predicted residuals in the arranged regression and use the standardized predicted residuals to construct the proposed test statistic. Such procedure is simple. If $\mathbf{y}_t$ is linear, then the RLS estimator of the arranged regression (6) is consistent, so that the predicted residuals approach white noise. Consequently, predicted residuals are uncorrelated with the regressor $\mathbf{X}_{t(i)+d}$. Rather, if $\mathbf{y}_t$ follows a threshold model, then the predicted residuals are no longer white noise, because the least squares estimator is biased. In this case, the predicted residuals are correlated with the

[6] Another advantage in treating Equations (3) and (4) as a multivariate model is to find a single threshold variable that causes regime changes (e.g., export-import ratio).

regressor $\mathbf{X}_{t(i)+d}$.

Let $\hat{\ddot{\mathbf{O}}}_m$ be the least squares estimate of $\ddot{\mathbf{O}}$ of Equation (6) with $i = 1, \ldots, m$; that is , the estimate of arranged regression using data points associated with the m smallest values of z_{t-d} . Let

$$\hat{\mathbf{e}}_{t(m+1)+d} = \mathbf{y}_{t(m+1)+d} - \hat{\ddot{\mathbf{O}}}'_m \mathbf{X}_{t(m+1)+d} , \tag{7}$$

$$\hat{\varsigma}_{t(m+1)+d} = \hat{\mathbf{e}}_{t(m+1)+d} \big/ [1 + \mathbf{X}'_{t(m+1)+d} \mathbf{V}_m \mathbf{X}_{t(m+1)+d}]^{1/2} , \tag{8}$$

where $V_m = \left[\sum_{i=1}^{m} \mathbf{X}_{t(i)+d} \mathbf{X}'_{t(i)+d} \right]^{-1}$, be the predicted residual and the standardized predictive residual of regression (6). Consider the regression

$$\hat{\varsigma}'_{t(l)+d} = \mathbf{X}_{t(l)+d} \mathbf{Ø} + \mathbf{w}'_{t(l)+d} , \qquad l = m_0 + 1, \ldots, n-h, \tag{9}$$

where m_0 denotes the starting point of RLS estimation.[7] The problem is then to test the hypothesis $H_0 : \mathbf{Ø} = 0$. Tsay (1998) used the test statistic:

$$C(d) = [n - h - m_0 - (gp + vq + 1)] \times \{\ln[\det(\mathbf{S}_0)] - \ln[\det(\mathbf{S}_1)]\}, \tag{10}$$

where the delay d signifies that the test depends on the threshold variable z_{t-d} , *det*(*A*)denotes the determinant of the matrix *A*, ln is natural log, and

$$\mathbf{S}_0 = 1/(n - h - m_0) \sum_{l=m_0+1}^{n-h} \hat{\boldsymbol{\varsigma}}_{t(l)+d} \, \hat{\boldsymbol{\varsigma}}'_{t(l)+d} ,$$

and

$$\mathbf{S}_1 = 1/(n - h - m_0) \sum_{l=m_0+1}^{n-h} \hat{\mathbf{w}}_{t(l)+d} \, \hat{\mathbf{w}}'_{t(l)+d} ,$$

where $\hat{\mathbf{w}}_t$ is the least square residual of regression (9). Under the null hypothesis that $\mathbf{y}_t$ is linear and some regularity conditions, $C(d)$ is asymptotically a chi-square random variable with $k(pk + qv + 1)$ degree of freedom.

Assume that p , q and s are known and the threshold variable z_t is given. But the delay d and the thresholds r_1 are part of parameters. Focusing on the case of $s = 2$ and write the model as

[7] Tsay (1998) suggested using $m_0 \approx 3\sqrt{n}$ for the stationary case, where n is the sample size.

$$\mathbf{y}_t = \begin{cases} \mathbf{X}_t'\mathbf{\Phi}_1 + \Sigma_1^{1/2}\boldsymbol{a}_t & \text{if } z_{t-d} \le r_1, \\ \\ \mathbf{X}_t'\mathbf{\Phi}_2 + \Sigma_2^{1/2}\boldsymbol{a}_t & \text{if } z_{t-d} > r_1, \end{cases} \tag{11}$$

where $\boldsymbol{a}_t = (a_{1t}, \ldots, a_{kt})'$. We assume that (a) z_{t-d} is stationary and continuous with a positive density function *f(r)* on a bounded subset of the real line and (b) $d \in (1, \ldots, d_0)$, where d_0 is a fixed positive integer. The parameters of model (11) are $(\mathbf{\Phi}_1, \mathbf{\Phi}_2, \Sigma_1, \Sigma_2, r_1, d)$, and their conditional least square estimates can be obtained in two steps. First, for given d and r_1, model (11) reduced to two separates multivariate linear regressions from which the least squares estimates of Φ_i and $\hat{\Sigma}_i (i = 1,2)$ are readily available. The estimates are

$$\hat{\mathbf{\Phi}}_i(r_1, d) = \left(\sum_t^{(i)} \mathbf{X}_t \mathbf{X}_t' \right)^{-1} \left(\sum_t^{(i)} \mathbf{X}_t \mathbf{y}_t' \right),$$

and

$$\hat{\Sigma}_i(r_1, d) = \frac{\sum_t^{(i)} (\mathbf{y}_t - \mathbf{X}_t'\hat{\mathbf{\Phi}}_i^*)(\mathbf{y}_t - \mathbf{X}_t'\hat{\mathbf{\Phi}}_i^*)'}{n_i - k}, \tag{12}$$

where $\Sigma_t^{(i)}$ denotes summing over observations in regime i, $\mathbf{\Phi}_i^* = \mathbf{\Phi}_i(r_1, d)$, n_i is the number of data points in regime i and k is the dimension of $\mathbf{X}_t$ satisfying $k < n$, for $i = 1,2$. Denote the sum of squares of residuals by

$$S(r_1, d) = S_1(r_1, d) + S_2(r_2, d),$$

where $S_i(r_1, d)$ denotes the trace of $(n_i - k)\Sigma_i'(r_1, d)$. In steps 2 the conditional least square estimates of r_1 and d are obtained by

$$(r_1, d) = \underset{r_1, d}{\arg\min}\, S(r_1, d), \tag{13}$$

where $1 \le d \le d_0$ and $r_1 \in R_0$.

When z_t and s are given, Tsay (1998) used the AIC in model selection, assuming that $0 \le p \le p_0; 0 \le q \le q_0; 1 \le l \le d_0$. In some cases, one may use the test results of (10), $C(d)$, for different d to select the delay parameter, resulting in further simplification.

Given p, q, d and s, the AIC of a multivariate threshold model is

$$AIC(p,q,d,s) = \sum_{j=1}^{s} \left[2\ln(L_j(p,q,d,s)) + 2g(gp + vq + 1)\right], \tag{14}$$

where $L_j(p,q,d,s)$ is the likelihood function of regime j. If the innovations are multivariate normal, then AIC reduces to

$$AIC(p,q,d,s) = \sum_{j=1}^{s} \left[n_j \cdot \ln(|\hat{\Sigma}_j|) + 2g(gp + vq + 1)\right], \tag{15}$$

where $\hat{\Sigma}_j$ is the estimated variance-covariance matrix, and n_j is the sample size in regime j.

3. EMPIRICAL RESULTS AND DISCUSSION

For ease of comparison, the conventional one-regime VAR of model (1) is used for testing the Granger relationship between exports and economic growth. The optimal lag length in the one-regime VAR system is selected using the AIC criterion. The lag length of the VAR is 4 in all countries considered here except Japan, for which the lag length is 6. The results of the Granger causality test of the one-regime VAR model are shown in row (1) of Table 4. They reveal that export growth leads economic growth negatively but insignificantly in Hong Kong. On the other hand, economic growth contributes both positively and significantly to export growth. In the case of Japan, the results from using the error correction model reveal that, in the short run, export growth leads economic growth both positively and significantly, while export growth contributes negatively but insignificantly to economic growth. However, if the coefficient of the error-correction term is considered, export growth leads economic growth both positively and significantly. For Korea, economic growth leads export growth both positively and significantly, and Granger no-causality from export growth to economic growth is found. In the Philippines, no causal relationship between Δy and Δex is observed. In the case of Taiwan, a well-known export-led country, a positive feedback relationship between Δy and Δex is found using a one-regime VAR model.

The above results in the case of the one-regime model have much in common with those of previous studies. For instance, Bahmani-Oskooee (1991), Bahmani-Oskooee *et al*. (1993) and Chow (1987) supported the finding of $\Delta ex \leftrightarrow \Delta y$ for Korea, Xu (1996) found $\Delta ex \rightarrow \Delta y$ for the Philippines, Jung and Marshall (1985) found $\Delta y \rightarrow \Delta ex$ for Taiwan, and Sharma *et al*. (1991) found $\Delta ex \rightarrow \Delta y$ for Japan. However, evidence from previous studies is also mixed and conflicting.

Table 4. Results of Granger Causality Tests Using Conventional VAR and Two-Regime TAR Models

Method \ Country	hkn	Jpn	koa	phi	twn
One regime VAR	$\Delta ex \not\to \Delta y$ $\Delta y \overset{+}{\to} \Delta ex^{*}$	$\Delta ex \overset{+}{\to} \Delta y^{**}$ $\Delta y \overset{+}{\to} \Delta ex^{**}$	$\Delta ex \not\to \Delta y$ $\Delta y \overset{+}{\to} \Delta ex^{*}$	$\Delta ex \not\to \Delta y$ $\Delta y \not\to \Delta ex$	$\Delta ex \overset{+}{\to} \Delta y^{*}$ $\Delta y \overset{+}{\to} \Delta ex^{**}$
Two-regime VAR Regime 1 (not more than the thresholds)	$\Delta ex \not\to \Delta y$ $\Delta y \not\to \Delta ex$	$\Delta ex \overset{+}{\to} \Delta y^{**}$ $\Delta y \overset{-}{\to} \Delta ex^{*}$	$\Delta ex \overset{+}{\to} \Delta y^{***}$ $\Delta y \overset{-}{\to} \Delta ex^{*}$	$\Delta ex \not\to \Delta y$ $\Delta y \not\to \Delta ex$	$\Delta ex \not\to \Delta y$ $\Delta y \not\to \Delta ex$
Two-regime VAR Regime 2 (greater than the thresholds)	$\Delta ex \not\to \Delta y$ $\Delta y \overset{+}{\to} \Delta ex^{***}$	$\Delta ex \overset{+}{\to} \Delta y^{*}$ $\Delta y \overset{-}{\to} \Delta ex^{***}$	$\Delta ex \not\to \Delta y$ $\Delta y \not\to \Delta ex$	$\Delta ex \overset{+}{\to} \Delta y^{**}$ $\Delta y \not\to \Delta ex$	$\Delta ex \overset{+}{\to} \Delta y^{*}$ $\Delta y \overset{+}{\to} \Delta ex^{**}$

Notes: $\not\to$ denotes statistically insignificant and hence fails to reject the null hypothesis of no-Granger causality. $\to$ denotes the rejection of the null hypothesis of no-Granger causality. *, **, and *** denote statistical significance at 1%, 5% and 10% levels, respectively. The sign (+ or -) denotes the direction of lead-lag relationship between two variables and is determined by the impulse response function (see Figure 1).

For instance, Ghartey (1993) found $\Delta ex \leftrightarrow \Delta y$ for Japan. In the case of Korea, Jung and Marshall (1985) found $\Delta y \to \Delta ex$, while Xu (1996) found $\Delta ex \leftrightarrow \Delta y$. For the Philippines, $\Delta ex \leftrightarrow \Delta y$ was also observed by Sharma and Dhakal (1994) and by Bahmani-Oskooee and Alse (1993). In Taiwan, besides $\Delta y \to \Delta ex$, both $\Delta ex \to \Delta y$ (e.g., Ghartey (1993), Bahmani-Oskooee *et al.* (1991)) and $\Delta ex \leftrightarrow \Delta y$ (Chow (1987)) were also found. This mixed and inconsistent evidence is possibly the result of using different models (e.g., bivariate or multivariate), or different econometric methodologies (e.g., whether the problems associated with cointegration need to be considered or not) and may also depend on the sample period.

When using the conventional one-regime VAR model we found no evidence of $\Delta ex \to \Delta y$ for most countries where export promotion policies had been adopted. It is possible that the sample period spanned different stages of economic development across countries. Hence we here re-estimate the relationship between Δex and Δy using the multivariate TAR model. First, we use the $C(d)$ statistic of Equation (10) to detect the need of using such a model. Second, we use Equation (13) to choose the optimal thresholds for different p values that are chosen based on information provided by the AIC (Equation (14)). The potential threshold variable used is lagged values of the export-import ratio with 0 to 6 lags for Japan, and 0 to 4 lags for the other countries. Table 5 presents the results of the threshold nonlinearity test.

Table 5. The $C(d)$ Statistic of Multivariate Threshold Effects

	VAR (1)					VAR (2)				
Country \ *d*	0	1	2	3	4	0	1	2	3	4
Hkn	29.37	18.41	**44.03**	18.91	28.96	40.22	23.21	47.10	**48.66**	47.88
	(0.08)	(0.56)	**(0.00)**	(0.53)	(0.09)	(0.29)	(0.95)	(0.10)	**(0.08)**	(0.09)
Koa	24.82	**24.95**	20.70	20.15	21.28	**51.98**	44.51	32.71	34.81	36.29
	(0.21)	**(0.20)**	(0.42)	(0.45)	(0.38)	**(0.04)**	(0.16)	(0.63)	(0.53)	(0.45)
Phi	13.22	**26.65**	9.48	25.81	16.10	33.49	27.45	25.80	**47.37**	25.99
	(0.87)	**(0.15)**	(0.98)	(0.17)	(0.71)	(0.59)	(0.85)	(0.90)	**(0.10)**	(0.89)
Twn	37.34	**40.45**	30.04	32.70	31.74	**70.42**	63.39	50.85	49.79	45.52
	(0.01)	**(0.00)**	(0.07)	(0.04)	(0.05)	**(0.00)**	(0.00)	(0.05)	(0.06)	(0.13)

	VAR (3)					VAR (4)				
Country \ *d*	0	1	2	3	4	0	1	2	3	4
Hkn	54.27	50.59	**65.09**	32.27	55.41	73.53	61.16	**93.81**	43.16	67.18
	(0.39)	(0.53)	**(0.10)**	(0.99)	(0.35)	(0.30)	(0.71)	**(0.02)**	(0.99)	(0.50)
Koa	75.11	70.64	41.38	**78.55**	85.16	88.51	97.04	70.53	**100.84**	97.26
	(0.02)	(0.04)	(0.85)	**(0.01)**	(0.00)	(0.05)	(0.01)	(0.39)	**(0.01)**	(0.01)
Phi	44.05	36.10	33.82	**44.80**	31.90	55.90	50.25	**60.43**	54.12	48.08
	(0.78)	(0.95)	(0.98)	**(0.75)**	(0.99)	(0.85)	(0.95)	**(0.73)**	(0.89)	(0.97)
Twn	94.87	65.60	92.56	56.51	**125.20**	101.28	106.26	112.42	81.44	**152.82**
	(0.00)	(0.10)	(0.00)	(0.31)	**(0.00)**	(0.01)	(0.01)	(0.00)	(0.13)	**(0.00)**

	VAR (1)							VAR (2)						
Country \ *d*	0	1	2	3	4	5	6	0	1	2	3	4	5	6
jpn	27.79	41.18	33.76	37.95	20.57	28.50	**56.59**	40.48	42.76	41.60	78.62	65.08	82.58	**94.29**
	(0.11)	(0.00)	(0.03)	(0.01)	(0.42)	(0.10)	**(0.00)**	(0.28)	(0.20)	(0.24)	(0.00)	(0.00)	(0.00)	**(0.00)**
	VAR (3)							VAR (4)						
Country \ *d*	0	1	2	3	4	5	6	0	1	2	3	4	5	6
jpn	54.22	87.83	103.29	88.80	81.62	**112.04**	93.70	64.07	89.66	28.45	**100.64**	95.62	88.80	84.78
	(0.39)	(0.00)	(0.00)	(0.00)	(0.01)	**(0.00)**	(0.00)	(0.61)	(0.04)	(0.00)	**(0.01)**	(0.02)	(0.05)	(0.08)
	VAR (5)							VAR (6)						
Country \ *d*	0	1	2	3	4	5	6	0	1	2	3	4	5	6
jpn	102.23	118.89	147.92	113.79	130.26	**138.89**	124.85	105.88	128.80	**168.19**	139.46	131.88	128.45	144.67
	(0.09)	(0.01)	(0.00)	(0.02)	(0.00)	**(0.00)**	(0.00)	(0.32)	(0.03)	**(0.00)**	(0.01)	(0.02)	(0.03)	(0.00)

Notes: d = delay and the threshold variable is the export-import ratio. Values in parentheses are p values. The boldface denotes the minimum p value for all cases. hkn = Hong Kong, jpn = Japan, koa = Korea, phi = Philippines, twn = Taiwan. VAR (k) is a VAR with k lags.

As shown in Table 5, for the four-variable model for Hong Kong, the export-import ratio with two delay lags using either the VAR(1) or VAR(4) model is statistically significant at the 5 percent level. Whether the VAR(1) or VAR(4) model should be employed for Hong Kong can be determined by the minimum AIC (Equations (14) or (15)). Moreover, since the sample size is not long enough, if the VAR model with too high order is used in estimation, it may not be estimated due to insufficient data under certain regime. Therefore, when the problem of inadequate data arises, the VAR model with lower order is selected in estimation. Under this rule, we select the export-import ratio with six delay lags as the threshold variable for Japan using the VAR(1) model. In the case of Korea, the selected threshold variable is the export-import ratio with four delay lags using the VAR(3) model. For the Philippines, the export-import ratio with three delay lags using the VAR(2) model has the smallest p value, and for Taiwan, the export-import ratio with four delay lags using the VAR(1) model is selected.

Table 6 shows the estimated thresholds based on minimum $S(r_1, d)$ and the relevant sample data under distinct regimes.

Table 6. The Estimated Threshold Variable and the Thresholds

Country	Threshold Variable	The Thresholds	Regime 1 Sample Size	Regime 2 Sample Size
Hong Kong	Export/Import ratio with 2 lags VAR (1)	1.0968	96	14
Japan	Export/Import ratio with 6 lags VAR (1)	0.9048	15	161
Korea	Export/Import ratio with 4 lags VAR (3)	1.092	87	18
Philippines	Export/Import ratio with 3 lags VAR (2)	0.8942	36	39
Taiwan	Export/Import ratio with 4 lags VAR (1)	1.2928	140	16

Notes: The thresholds are obtained by the minimum sum of the squared residuals. Regime 1 denotes the case where the threshold variable is not more than the threshold value, and regime 2 denotes the case where the threshold variable is greater than the threshold value.

As shown in Table 6, the overall $S(r_1, d)$ selects thresholds of 1.0968 for Hong Kong, 0.9048 for Japan, 1.0920 for Korea, 0.8942 for the Philippines, and 1.2928 for Taiwan. The sample size for each regime is reported in Columns (4) and (5) of Table 6, respectively. Of the five countries, Taiwan has the highest threshold with the export-import ratio is 1.2928, while the smallest export-import ratio is 0.8942 for the Philippines.[8] Rows (2) and (4) of Table 4 present the results of the Granger causality test using the two-regime model.

Row (2) of Table 4 presents the results of Granger causality test when the export-import ratio is not more than the threshold value (under regime 1) for each country, and row (3) of Table 4 shows the results when the export-import ratio is greater than the threshold value (under regime 2). The symbol "$\rightarrow$" denotes the rejection of the null hypothesis of no-Granger causality, while "$\not\rightarrow$" denotes statistically insignificant and hence fails to reject the null hypothesis of no-Granger causality. Only in the case of statistical significance will we report the dynamic relationship between export growth and economic growth, for which the sign is determined by the impulse response function (up to twelve periods, see Figure 1).

The results reported in Table 4 suggest that, in the case of Hong Kong, we found that there exists no significant lead-lag relationship between Δy and Δex under regime 1, while Δy leads Δex positively and significantly at the 10% level under regime 2. The dynamic relationship between two variables can also be observed from Figure 1 in which a one standard error shock from the economic growth will first produce a negative then a positive impulse response in export growth and the response decays to zero gradually after 4 periods. The role played by Hong Kong as an entrepot trade center (re-exporting of Taiwan goods to Mainland China) would explain reasonably that there is no evidence of export-led growth for Hong Kong in both the one and two-regime models.

In Japan, the results using the two-regime model are very similar to those obtained using the one-regime model. However, they have different meanings. The fact that Δex leads Δy in the one-regime model is mainly due to the statistically significant coefficient in the error-correction term; however, it is not the case in the two-regime environment. Moreover, export growth leads economic growth at around 5% level of significance under one-regime model and regime 1 of the two-regime model, while the significance level is less than 1% under regime 2. Obviously, when the Japanese export-import ratio is greater than the threshold value, we find strong evidence of export-led growth in this country. On the other hand, there is strong evidence that economic growth leads to a decrease in exports significantly for Japan in both regimes using the two-regime model. The negative causal relationship between Δy and Δex

[8] For the sake of brevity, we do not report the estimating results of the two-regime VAR model; however, they are available from the authors upon request.

is more in line with the finding of Lee and Huang (2002) using developed countries' data. Such findings are reasonable when the Japanese consumer demand is concentrated in exportable and non-traded goods. In addition, Figure 1 also reveals that the responses of export growth from a one-unit shock of economic growth are vary similar under different regimes, but the positive responses of economic growth from a one-unit shock of export growth in regime 2 tend to be larger than those in regime 1.

In the case of Korea, the evidence that economic growth leads export growth positively is found using the one-regime model, but we find no evidence that export growth leads economic growth. However, under the two-regime environment, we find that economic growth leads export growth negatively and export growth leads economic growth positively. More specifically, there is evidence that export-led growth hypothesis has been supported for Korea at least when the ratio of exports to imports lies below 1.092. Such results are much in agreement with those of previous studies. It is well known that Korea has in the past pursued aggressive outward-oriented policies and indeed witnessed fast economic growth. In this paper, we provide empirical evidence that export growth contributes positively to economic growth for Korea in regime 1 by applying regime-based TAR models. However, since the main focus of development in Korea has been on the big industries that are highly capital-intensive, it throws doubt upon whether export promotion continues to be an effective device to achieve rapid economic growth.

In the Philippines, there exists no causal relationship between exports and economic growth using the one-regime model. Export promotion policies had also been adopted in her early days (1984~1988). However, the export-import ratio decreased all the way to no more than 0.75 in 1996 when the economic and political environments in this country have deteriorated. It is not until 1999 did the export-import ratio once again exceed unity. Therefore, if we split the regression function in terms of the threshold variable, we find evident that export growth leads economic growth both positively and significantly at the 10% level when the export-import ratio is greater than 0.9. Such positively dynamic relationship can also be found from the impulse response relationship in Figure 1.

For a well-known export-oriented country, Taiwan, we find that Δex leads Δy positively and vice versa using the one-regime model. Actually, the results using the two-regime model reveal that such positive feedback relationship between Δy and Δex under the one-regime model mainly emerges when the export-import ratio lies above 1.2928. Figure 1 in the case of Taiwan also provides some evidence of the positive responses of both Δex from a one-unit shock of Δy and Δy from a one-unit shock of Δex in regime 2. In the overall sample period (1960~2000), the phase when the export-import ratio is greater than 1.2928 for Taiwan spans form 1985 through 1990 roughly. During this phase, the NT/USD exchange rate declined from 1:40 to 1:26 due to the huge trade surplus in Taiwan, which had been followed by large portfolio capital flows (often referred as hot-money flows) into the domestic stock and real estate markets and resulted in asset prices overshooting and thus became speculative bubbles in the economy. When the bubbles boomed and burst, the export-import ratio declined considerably and the remarkable record of growth for Taiwan is no longer sustainable. This reflects in the paper that we find no evidence of export-led growth for Taiwan in regime 1 when the export-import ratio lies below 1.2928.

(a) Hong Kong

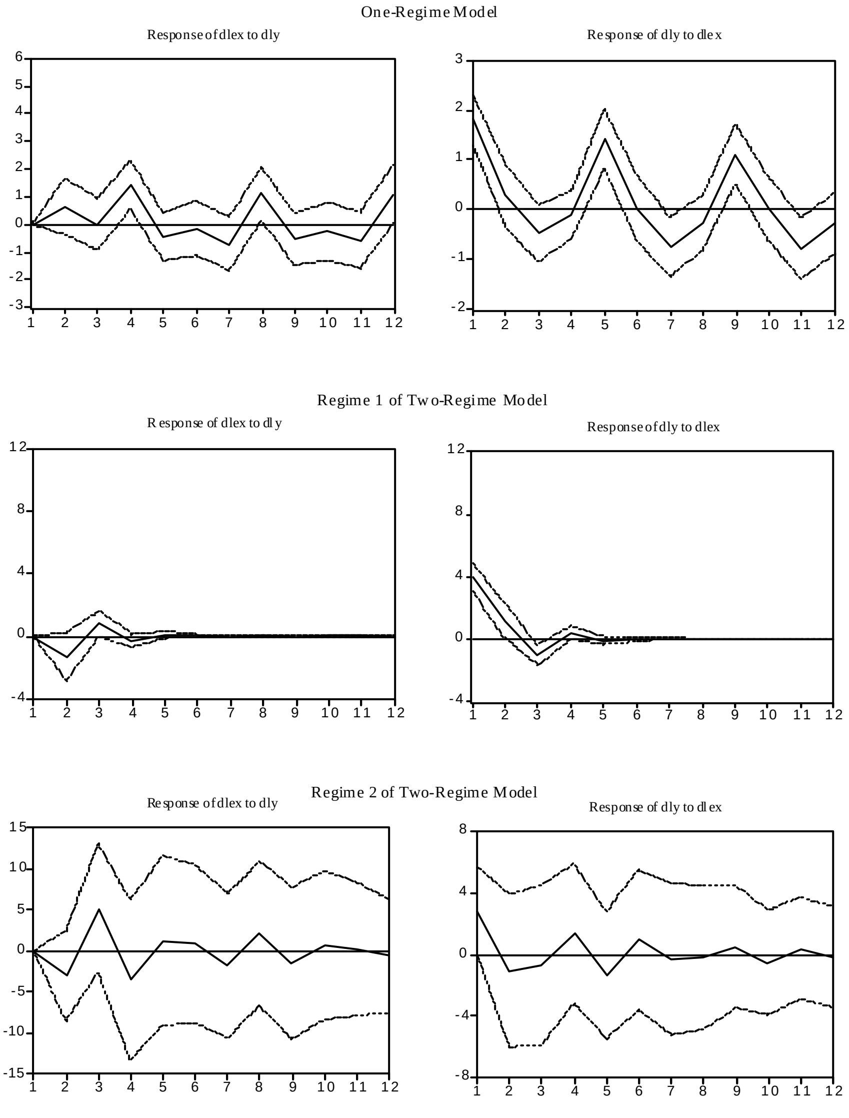


Figure 1. VAR Impulse Response Analysis of Export Growth and Economic Growth Up to 12 Periods from a One-Unit Shock of Each Variable

(b) Japan

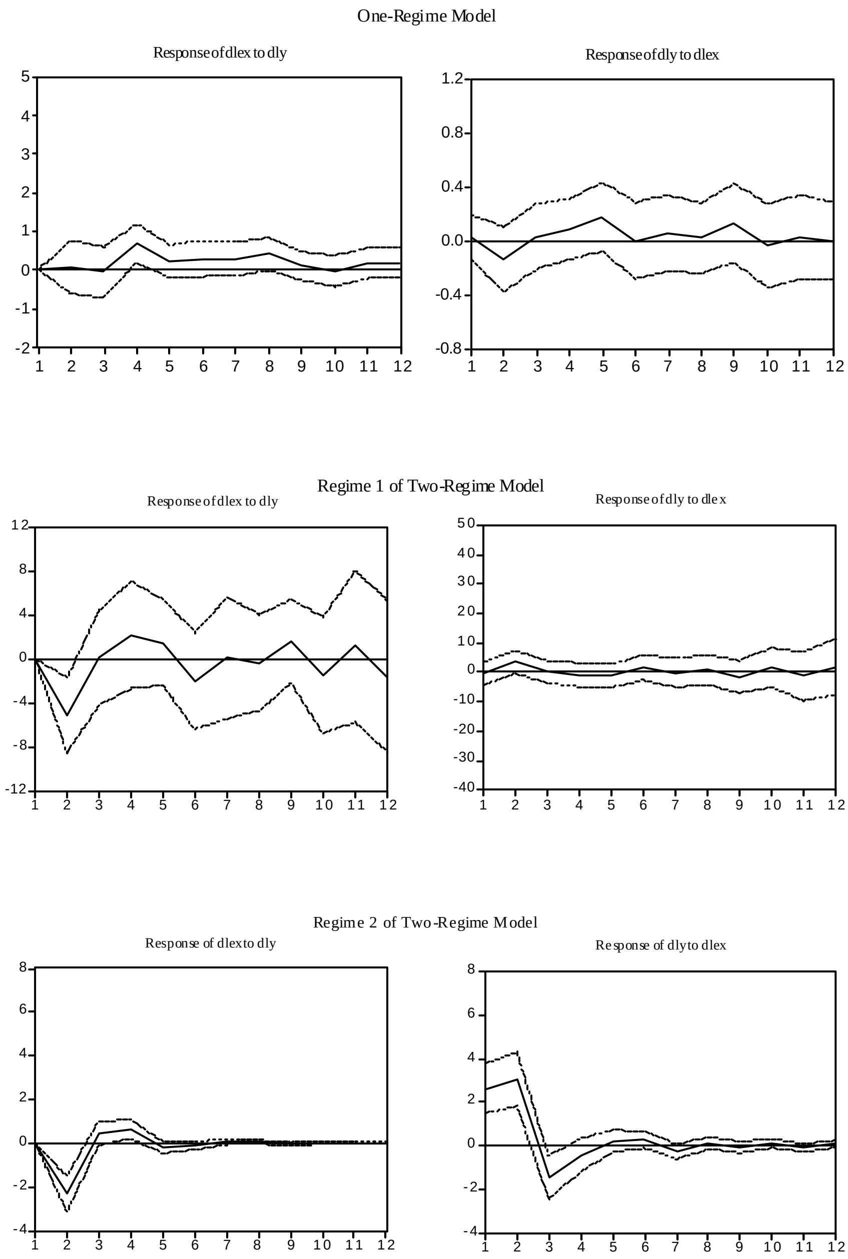


Figure 1. (Continued)

(c) Korea

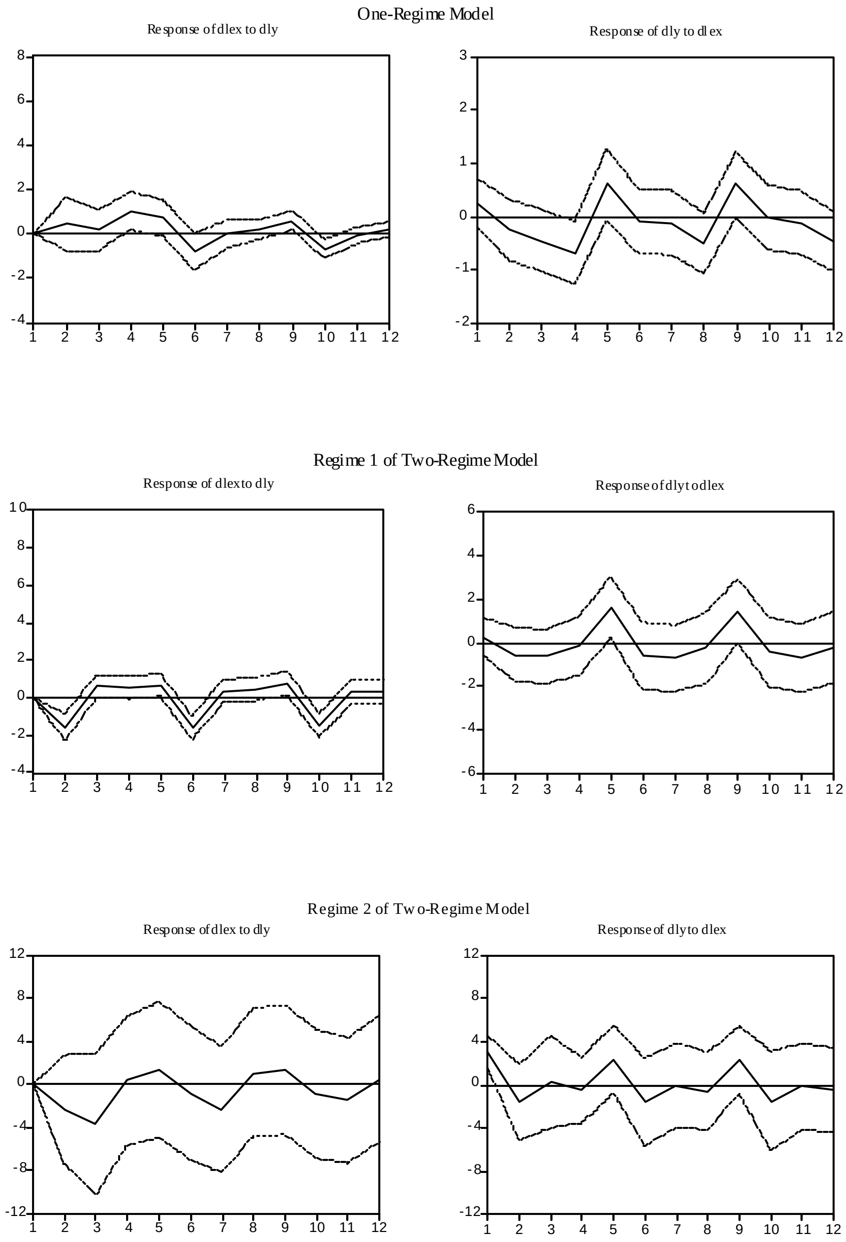


Figure 1. (Continued)

(d) Philippines

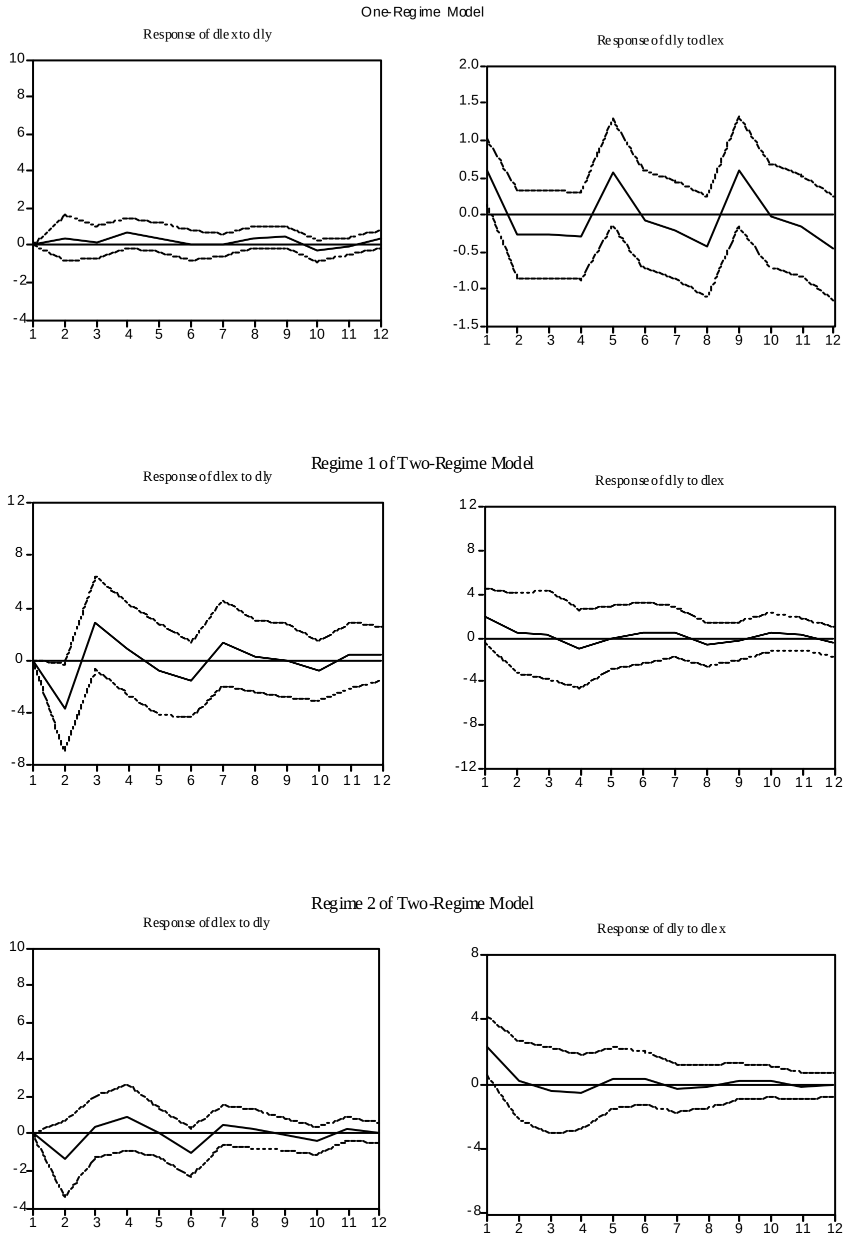
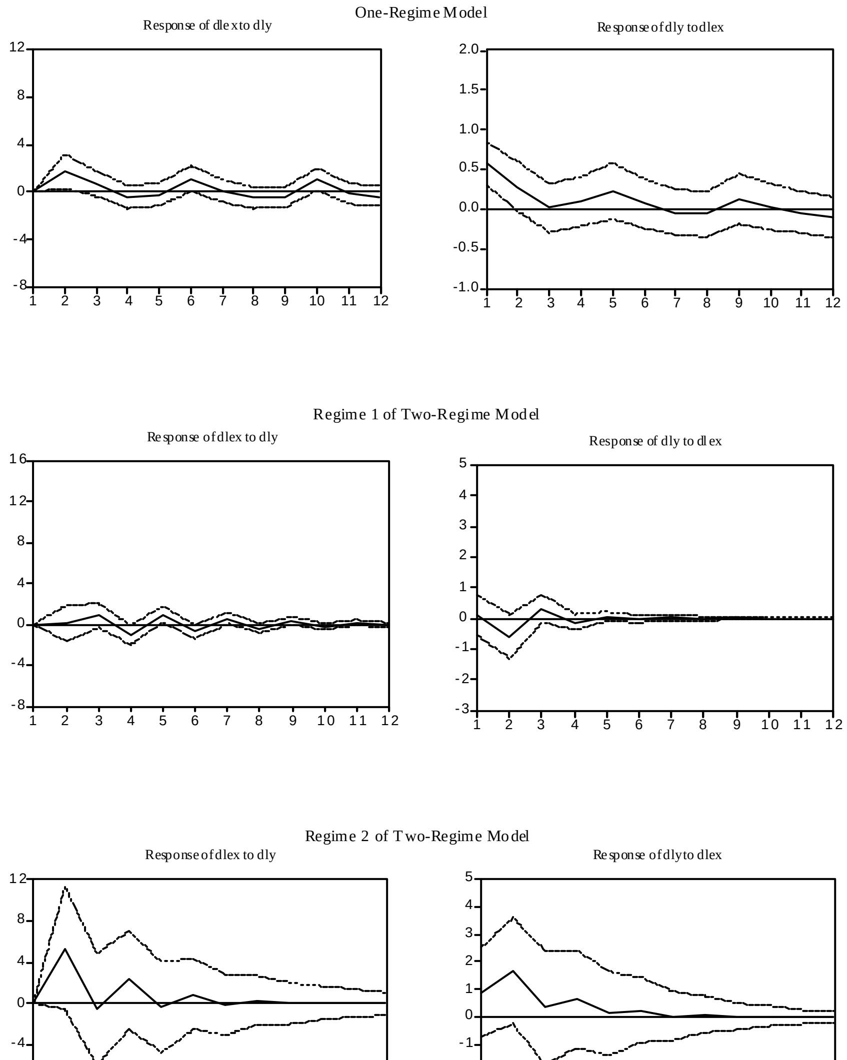


Figure 1. (Continued)

(e) Taiwan



Notes: dlex = change in real export. dly = change in real output. Solid lines represent response paths and dotted lines are bands for the 95% confidence interval around the impulse response coefficients.

Figure 1. (Continued)

4. CONCLUSION

The success of the Asian newly industrializing economies in expanding their exports and achieving high rates of economic growth is due to their adoption of an outwardly-oriented development strategy in the early 1960s. However, there is some doubt as to whether export-led growth continues to be an effective strategy for these economies as their income has increased and their industrial structures have changed. The earlier studies on Asian newly industrializing economies were focused on Taiwan, Korea, Japan, the Philippines and Hong Kong using annual data. The evidence was, however, found to be mixed and inconclusive. In this paper, we use quarterly data instead.

This paper uses the two-regime multivariate TAR model to investigate the causal relationships between export growth and output growth for five countries. The results indicate that, except for Hong Kong, for which we failed to find evidence of export-led growth, the relationship $\Delta ex \rightarrow \Delta y$ was found for the remaining four countries under certain specified regimes. Among them, we cannot find any export-led growth relationships for Korea, Japan (at least in the short-run) and the Philippines using the conventional one-regime model.

The regime-based TAR models appear to possess certain advantages over the more conventional linear autoregressive models. They are particularly useful when trying to conceptualize what will be the most appropriate policy to adopt under a distinct regime. Under such circumstances, the conventional linear model, which allows for just one regime, is unable to fully explore the causal relationship between export growth and output growth.

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Mailing Address: Chien-Hui Lee, Department of International Trade, National Kaohsiung University of Applied Sciences, Kaohsiung, Taiwan 807. E-mail: chlee@cc.kuas.edu.tw

Mailing Address: Bwo-Nung Huang, Department of Economics, and Research Center for Industry Analysis, Development & Forecasting, National Chung-Cheng University, Chia-Yi, Taiwan 621. E-mail: ecdbnh@ccunix.ccu.edu.tw