Macrothink Institute™

Research in Applied Economics
ISSN 1948-5433
2014, Vol. 6, No. 2

Nonlinearities in the Economic Growth Rates of Taiwan and Hong Kong: A Bayesian Threshold Autoregression Approach

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Received: February 19, 2014 Accepted: May 1, 2014 Published: June 25, 2014

doi:10.5296/rae.v6i2.5149 URL: http://dx.doi.org/10.5296/rae.v6i2.5149

Abstract

We analyze the extent to which low frequency movements in the economic activity of Taiwan and Hong Kong can be explained by those of their largest trading partners. We estimate posterior marginal probabilities across 312 different specifications for each country and computes Bayes' Factors as a model selection mechanism. Data suggests that a best fitting model requires a different specification for Hong Kong and Taiwan. Results show that economic growth rates in both Hong Kong and Taiwan are well described by a threshold model but with different types of nonlinear effects. Hong Kong's economic growth has a nonlinear effect on its expected future growth, but is unaffected by growth in the US, Japan or Taiwan. In contrast, we find a significant nonlinear spillover effect from Japan to Taiwan.

JEL Classification: F17, C22, E32

Keywords: economic growth, knowledge spillovers, nonlinear effects, threshold autoregressions

1. Introduction

This paper investigates the extent to which the economic growth of some Southeast Asian countries can be explained by the economic growth of their more important trading partners. There is a vast literature on the relationship between trade and economic growth. For example, Levine and Renelt (1992) find a robust correlation between the ratio of international trade to GDP and economic growth and they posit that this relationship takes place through the investment channel. Borensztein et al (1998) and Frankle and Romer (1999) go as far as to imply causation from international trade to economic activity and they maintain that foreign direct investment (FDI) is an important determinant of a country's economic growth. Dollar and Kray (2003) find that FDI contributes to economic growth through institutions while Alvaro et al (2004) maintain that the contribution comes through the financial channel. Not everyone agrees, however. Rodriguez and Rodrick (2001) and Baldwin (2004) find that the relationship between trade policy (the former) or trade openness (the latter) and economic growth is weak at best.

A number of factors may be brought to bear on the debate. One is the perennial endogeneity issue—which one takes place first? Does trade lead to economic growth or does economic growth lead to trade? A common answer to this issue is to first assume a directionality (say trade leads to growth) and then find an instrument to prevent reverse causality.(Note 1) A second concern involves accounting for the different mechanisms through which trade might generate economic growth in a country. Thus it becomes important to allocate the extent to which do the benefits from trade come directly from its contribution to the current account or more indirectly though spillover effects on labor productivity or technological diffusion.(Note 2) Yet another channel for the relationship between trade and economic growth may ensue from trade liberalization as a catalyst for economic competition. For example Trefler (2004) shows that trade liberalization in Canada led to substantial increases in average productivity. An important concern, however, is whether the relationship between growth rates among trading partners is inherently nonlinear. If important nonlinearities in the economic growth rates among trading partners arise, then the standard cross-country regression methods motivated by the linearization of the technology process among those countries would be inadequate. This final concern informs our approach in this paper. Thus, we abstract from ascribing mechanisms that require the linearization of micro-founded first principle models. To our knowledge, the majority of the literature on this question relies on structurally imposing linear restrictions in the laws of motion that drive the dynamics of the relationships in question to motivate regression estimations. We depart from this standard approach by assuming that trade does contribute to economic growth to, subsequently, find statistical evidence of whether nonlinearities arise in the economic growth rates of major trading partners. Thus in this paper we investigate whether economic growth of Hong Kong and Taiwan can be explained by the economic growth of their more important trading partners and whether such spillovers are linear or not.

Taiwan has a significant trading relationship with the United States, Japan, and Hong Kong.

Table 1. Taiwanese Foreign Trade

Time period	Total[a]	Japan		USA		Hong Kong		China[c]	
		Total[a]	Share[b]	Total	Share	Total	Share	Total	Share
Imports									
1973-1979	8,374.34	2,696.37	32%	1,970.54	24%	135.87	02%	0	0%
1980-1989	28,327.19	8,259.10	29%	6,652.71	23%	711.50	03%	0	0%
1990-1999	88,876.43	24,907.25	28%	18,090.21	20%	1,827.93	02%	2,513.36	3%
2000-2006	149,146.84	37,241.99	25%	20.649.11	14%	2,078.20	01%	13,255.41	9%
Exports									
1973-1979	8,821.34	1,199.40	14%	3,267.71	37%	606.31	7%	0	0%
1980-1989	28,327.19	4,554.14	12%	15,485.92	42%	3,095.73	8%	0	0%
1990-1999	88,876.43	10,560.67	11%	25,968.70	26%	20,992.71	21%	661.55	01%
2000-2006	149,164.84	14,275.53	09%	29,695.50	18%	32,799.33	20%	24,929.47	15%

Source: Department of Statistics, Ministry of Finance, "Preliminary Statistics of Export and Import."

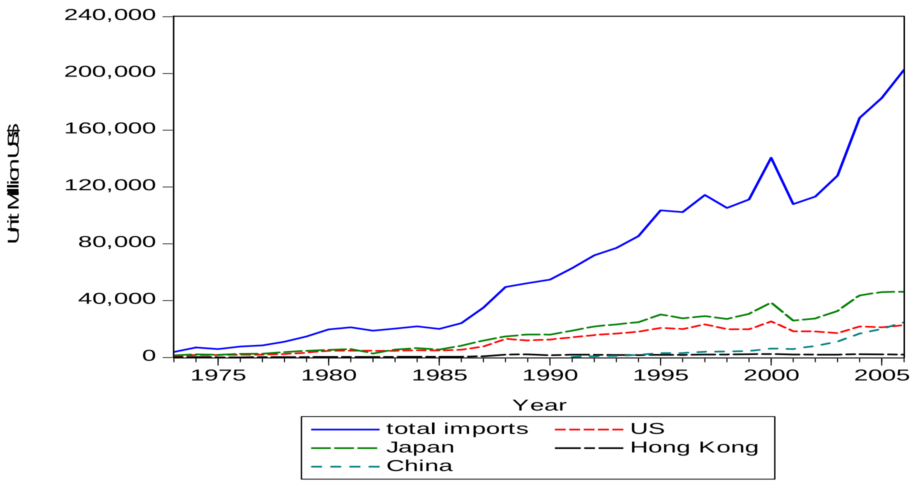
Notes:

[a] Average for period, millions of dollars.

[b] Average for period as a share of total.

[c] The data on Taiwan's imports from China begins in 1991.

Panel A— Import Trade Values with Trading Partners



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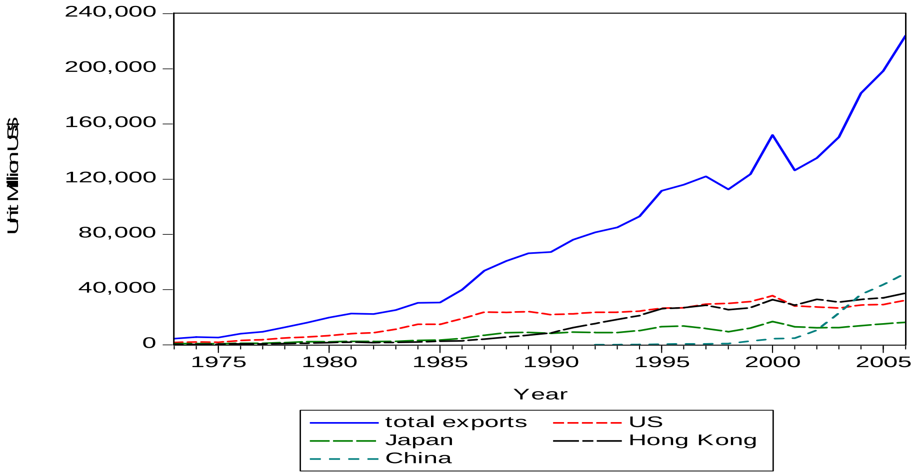
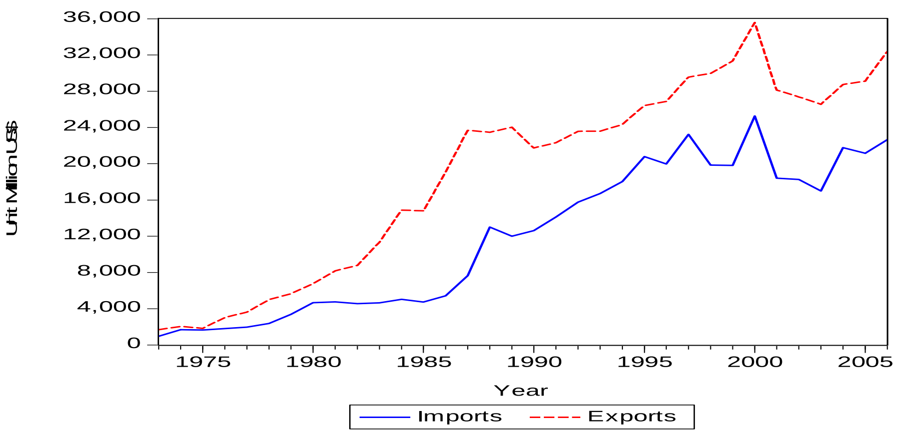
Research in Applied Economics
ISSN 1948-5433
2014, Vol. 6, No. 2

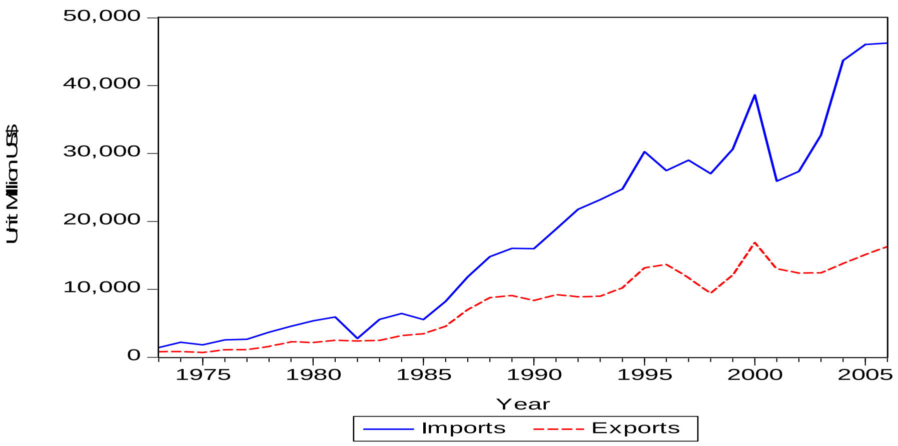
Panel B— Export Trade Values with Trading Partners



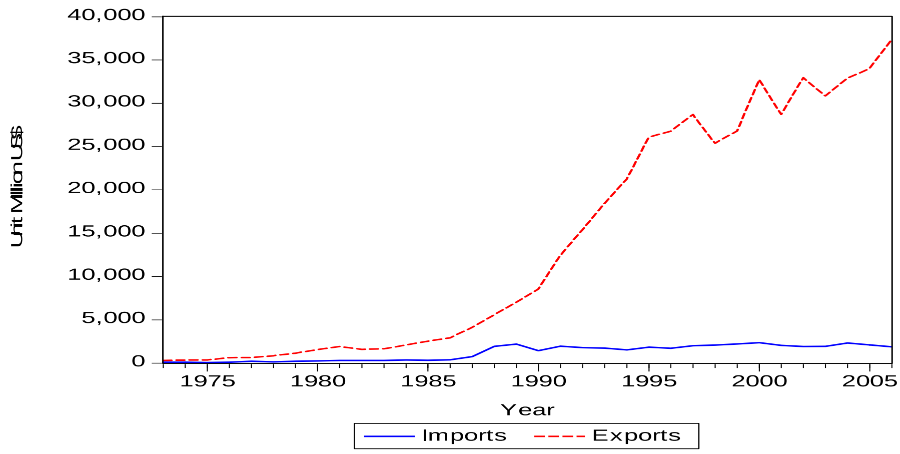
Panel C— Trade with the United States



Panel D— Trade with Japan



Panel E— Trade with Hong Kong



Panel F— Trade with China

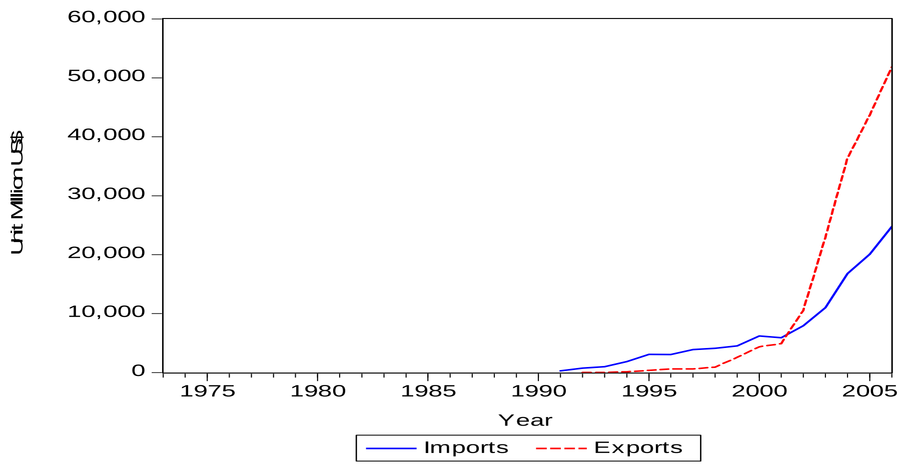


Figure 1. Taiwan’s Trade with Trading Partners

According to Table 1 and Figure 1, the United States was the biggest trade partner with Taiwan in the 1980s.(Note 3) Taiwan exported many industrial products such as mechanical appliances and accessories, electronics, electrical appliances, personal computers and peripherals, metal products and transport equipment, furniture, and clothing to the U.S. In Particular 40% of Taiwan’s exports were destined to go to the U.S. Until 1999, Japan was the second largest trading partner of Taiwan next to the U.S. After Hong Kong's annexation to China in 1997, however, Taiwan started to increasingly sell goods to China through Hong Kong. Since then Hong Kong replaced Japan and has been a major exporter to Taiwan. After 2000, exports to Hong Kong took 20% of Taiwan’s total exports, while 9% of the exports went to Japan.

Before being returned to mainland China, Hong Kong’s economy relied mainly on international trade due to its minimum trade restrictions and market mechanism.

Research in Applied Economics
ISSN 1948-5433
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Table 2. Hong Kong Foreign Trade

Imports									
Time period	Total[a]	Japan		USA		Taiwan		China	
		Total[a]	Share[b]	Total	Share	Total	Share	Total	Share
1973-1979	9,884.39	2,187.90	22%	1,216.96	12%	645.07	7%	1,753.46	18%
1980-1989	37,311.56	7,555.83	20%	3,469.50	9%	3,146.89	9%	10,638.56	29%
1990-1999	157,046.44	22,772.39	15%	11,834.24	8%	12,943.00	9%	60,206.34	38%
2000-2006	251,224.61	28,492.44	11%	13,993.70	6%	18,168.63	8%	111,191.23	44%
Exports									
1973-1979	8,847.11	625.59	7%	2,546.37	29%	277.70	3%	95.44	1%
1980-1989	36,309.91	1,873.18	5%	10,190.84	28%	1,148.81	3%	7,527.12	21%
1990-1999	147,717.00	8,399.88	6%	33,480.98	23%	4,125.46	3%	47,899.64	32%
2000-2006	240,127.13	12,825.06	5%	44,501.23	19%	5,571.47	2%	100,969.60	42%

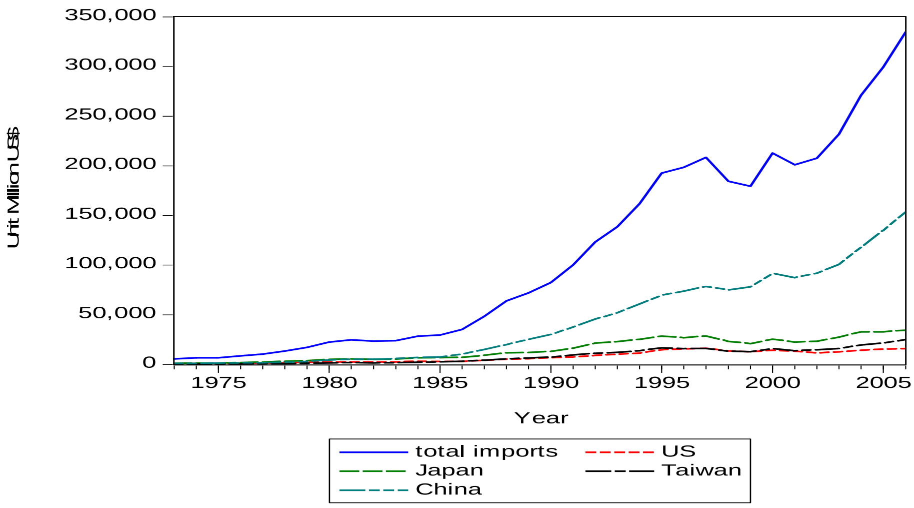
Source: Census and Statistics Department, the Government of the Hong Kong Special Administrative Region of the People's Republic of China, "Trade Analysis Section."

Notes:

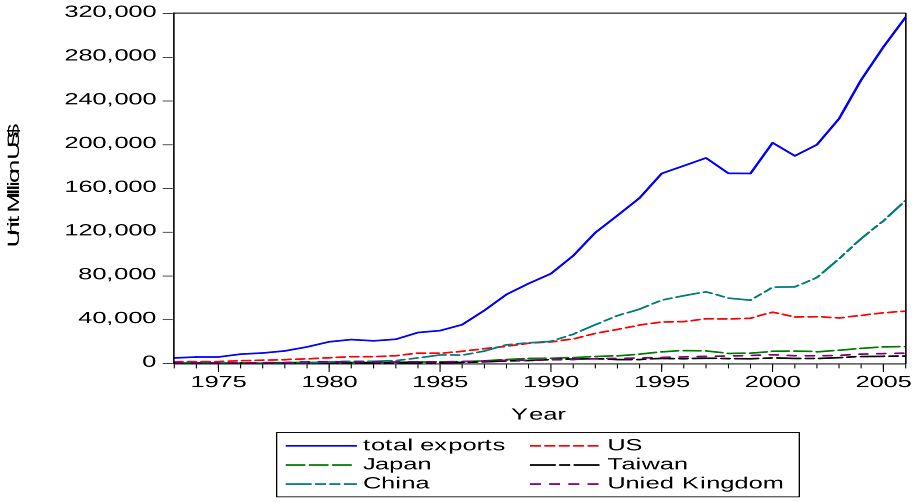
[a] Average for period, millions of dollars.

[b] Average for period as a share of total.

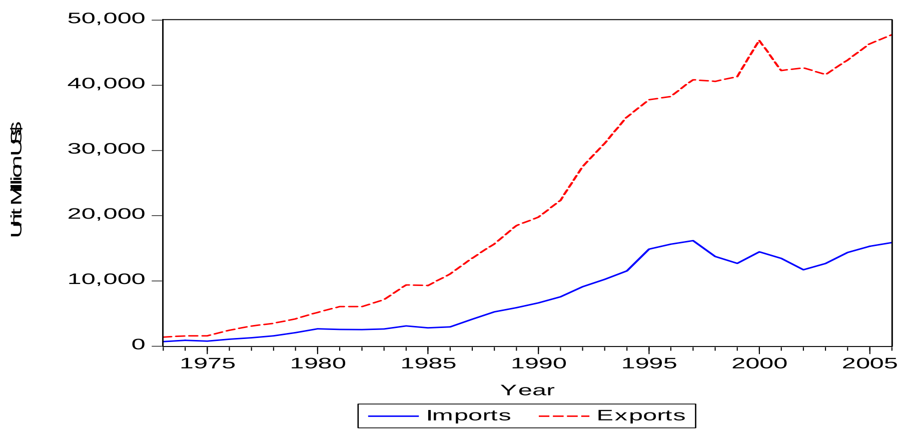
Panel A— Import Trade Values with Trading Partners



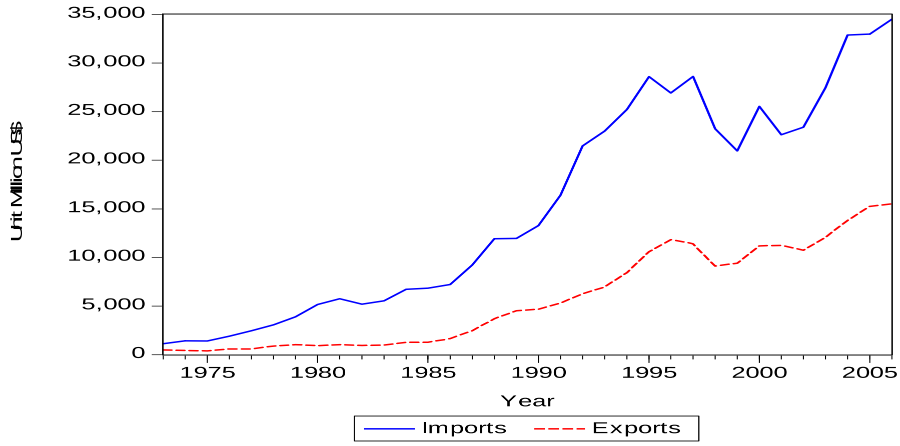
Panel B— Export Trade Values with Trading Partners



Panel C— Trade with the United States

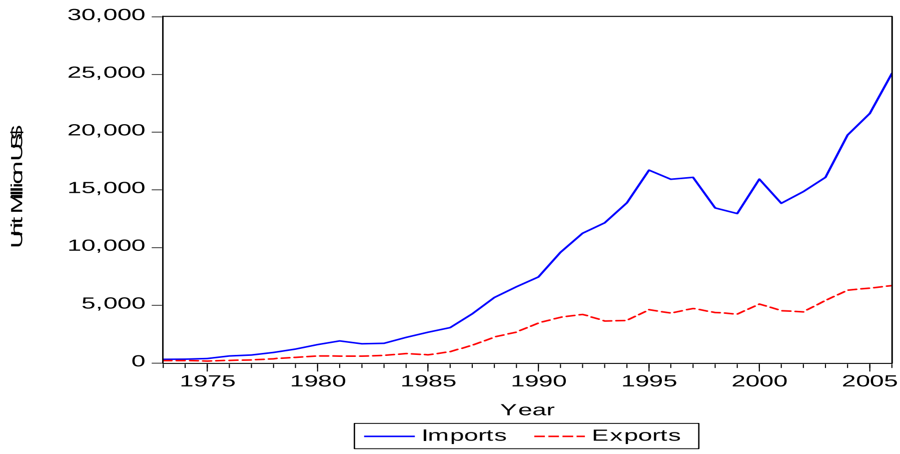


Panel D— Trade with Japan

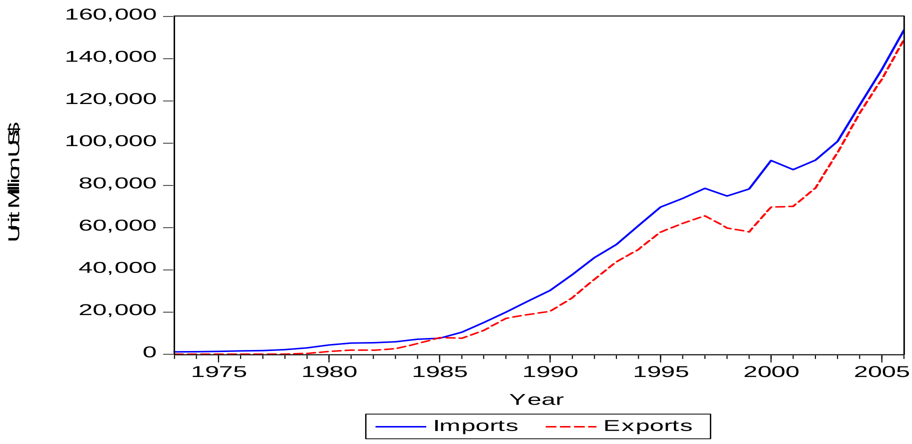


Research in Applied Economics
ISSN 1948-5433
2014, Vol. 6, No. 2

Panel E— Trade with Taiwan



Panel F— Trade with China



Panel G— Trade with the United Kingdom

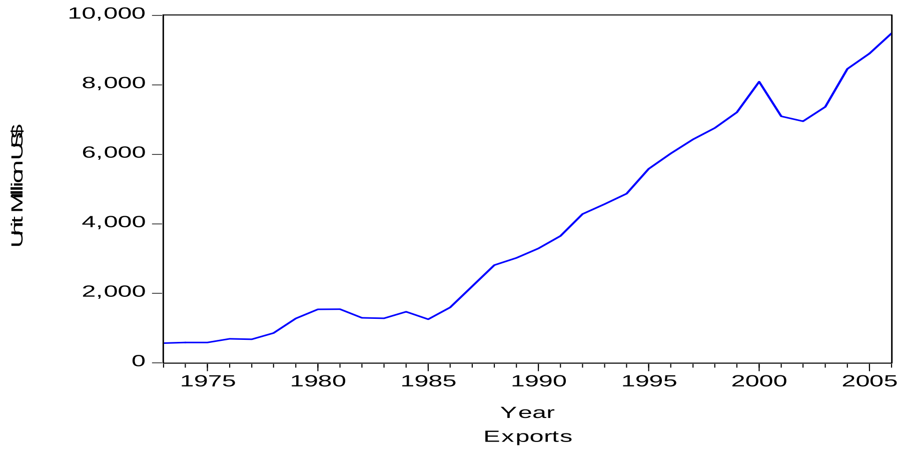


Figure 2. Hong Kong's Trade with Trading Partners

According to Table 2 and Figure 2, Hong Kong's exports grew from U.S.$8.85 billion in 1970s to U.S.$147.72 billion in 1990s. The largest recipients of Hong Kong's goods were the United Kingdom, the United States, and Japan. However, since 1997, China has replaced the United Kingdom to become the largest trading partner of Hong Kong. During the 2000s, 42% of Hong Kong's total exports went to China, 19% to the United States, 5% to Japan, and 3% to the United Kingdom, whereas 44% of its imports came from China, 11% from Japan, 8% from Taiwan, and 6% from the United States.

In this paper we examine how real GDP growth in Hong Kong and Taiwan may be affected by their own past rates as well as those of their trading partners. To that end, we estimate threshold autoregressions for each country. Several studies (Tsay, 1989; Das, 1993; Anderson, 1994; Terasvirta, 1994; Michael, Nobay, and Peel, 1997; Henry and Summers, 2000; and Abdulai, 2002) have found that the nonlinear model estimation may outperform the standard linear model. Various types of nonlinear models have been used to allow for possible asymmetries in various economic relationships. These models include the Markov switching models popularized by Hamilton (1988, 1989), as well as the threshold autoregressive (TAR) model used here, and its smooth transition (STAR) variant.

The remainder of this paper is organized as follows: Section 2 describes the empirical application, Section 3 presents data and discusses results, and Section 4 concludes.

2. Threshold Regression and Bayesian Approach

Like the Markov switching model, the TAR model splits the data into two or more regimes that are characterized by different parameter values. In TAR models however, the transitions between these regimes arise endogenously rather than being determined by an exogenous Markov chain. In this paper, we employ Bayesian estimation methods because they provide a straightforward means of assessing the relative support in the data for nonlinear versus linear models. In addition, these methods provide posterior probability distributions for various models, making for tractable model comparisons.(Note 4)

Following Koop and Potter (1998) and Henry and Summers (2000), we estimate a two-regime, first-order threshold autoregressive (TAR) model written as follows:

$$\text{Model G: } y_t = \left(\alpha_0 + \alpha_1 x_{t-1} + \varepsilon_{j1t}\right) I_{(z_{t-d} \le \gamma)} + \left(\beta_0 + \beta_1 x_{t-1} + \varepsilon_{j2t}\right) I_{(z_{t-d} > \gamma)} \qquad (0.1)$$

where $y_t = 100 \times (\ln GDP_t^j - \ln GDP_{t-1}^j)$ for j = HK (Hong Kong), TW (Taiwan), $x_{t-1} = 100 \times (\ln GDP_{t-1}^i - \ln GDP_{t-2}^i)$ for i = *US, Japan, Taiwan or Hong Kong* and the ε_j terms denote independently and identically distributed white noise processes. The indicator function $I(.)$ takes the value of one when the condition in its argument is true, and zero otherwise. The threshold variable z_t (which is a known function of the data), and the threshold value γ, govern the behavior of y_t. When $z_t \le \gamma$, the process evolves according to the α coefficients; the β coefficients apply in the other regime.

Thus, we consider various models in which z_t, the threshold variable, is a function of economic growth in the United States, Japan, Taiwan, or Hong Kong. Notice that overseas economic growth (e.g., in the U.S.) can only affect domestic growth indirectly; only lagged values of domestic growth appear on the right-hand side of (0.1). We refer to the model described by (0.1) as model 'G', in which the threshold variable is its value d periods ago (z_{t-d}) to be determined by the data.

In the interest of robustness, we allow for a more agnostic estimation of the timing dimension of the threshold variable by considering two additional specifications:

Model M: $$y_t = (\alpha_0 + \alpha_1 x_{t-1} + \varepsilon_{1t}) I_{(z_{t-d} - z_{t-d-1} \le \gamma)} + (\beta_0 + \beta_1 x_{t-1} + \varepsilon_{2t}) I_{(z_{t-d} - z_{t-d-1} > \gamma)} \quad (0.2)$$

Model A: $$y_t = (\alpha_0 + \alpha_1 x_{t-1} + \varepsilon_{1t}) I_{((z_{t-1} - z_{t-d})/d \le \gamma)} + (\beta_0 + \beta_1 x_{t-1} + \varepsilon_{2t}) I_{((z_{t-1} - z_{t-d})/n > \gamma)} \quad (0.3)$$

where 'M', and 'A' refer to models in which the threshold variable is its d^{th} lagged difference value ($z_{t-d} - z_{t-d-1}$); and its average value over the last d periods ($z_{t-1} - z_{t-d}$)/d, respectively. Again, in all these models, the unknown delay lag, d, is determined by the data. We also estimate homoskedastic versions of the three models, denoted as 'GH', 'MH', and 'AH.'

If for any of the three specifications (0.1)-(0.3), the threshold variable (contained in x_{t-1}) is the lagged dependent variable itself, then corresponding equation becomes the self-exciting threshold autoregression (SETAR) model. For example, the SETAR version of model G is:

$$y_t = (\alpha_1 y_{t-1} + \varepsilon_{j1t}) I_{(y_{t-d} \le \gamma)} + (\beta_1 y_{t-1} \varepsilon_{j2t}) I_{(y_{t-d} > \gamma)}. \quad (0.4)$$

We use Bayes factors to compare the various models. Given a data set D, and two models, H and K, the Bayes factor (BF) is defined as

$$BF = \frac{pr(D|H)}{pr(D|K)}, \quad (0.5)$$

which is the ratio of the marginal probability of the data under model H to its marginal probability under model K. The Bayes factor can be rewritten in terms of the prior and posterior odds ratios as follows:

$$BF = \frac{pr(D|H)}{pr(D|K)} = \frac{p(H|D)/p(H)}{p(K|D)/p(K)} \quad (0.6)$$

In equation (0.6), the prior odds and posterior odds in favor of model H are given by

$pr(H)/pr(K)$ and $pr(H|D)/pr(K|D)$ respectively. If all models are considered equally likely *a priori*, then the Bayes factor is equal to the posterior odds ratio. Higher values of BF (or the posterior odds ratio) indicate more support in the data for model H, and vice versa.(Note 5)

3. Data and Empirical Results

We collect data on real gross domestic product (GDP) at constant (2000) market prices in the United States, Japan, and Hong Kong from the St. Louis Fed Economic Data (FRED) and Census and Statistics Department of Hong Kong Special Administrative Region, respectively. Data on Taiwan's GDP at constant (2001) market prices come from National Statistics, Republic of China.(Note 6) The GDP data we extracted is in terms of local currencies of each country in order to investigate the impact of overseas economic activity fluctuations on Taiwan and Hong Kong's economic growth without exchange rate volatility. The data are quarterly and the sample runs from the first quarter of 1973 to the fourth quarter of 2006.(Note 7)

We estimated (0.2)-(0.3) allowing for up to 12 lags of the dependent variable. The posterior probabilities for all models are presented in Table 3. Note that the sum of G, GH, M, MH, A, and AH for a given lag length gives the marginal probability of a nonlinear model for that lag length.(Note 8) Thus we derive results shown in Table 3 (and later Table 4) which will serve as our model selection mechanism.

Table 3. Posterior Model Probabilities for Hong Kong

Panel A. Threshold in US GDP growth							
Lags	G	GH	M	MH	A	AH	Total
1	2.07	0.44	0.02	0.20	0.00	0.00	
2	0.29	0.00	0.00	0.00	0.00	0.00	
3	0.00	0.01	0.00	0.02	0.00	0.03	
4	0.00	0.00	0.00	0.00	0.00	0.00	
5	0.00	0.00	0.00	0.00	0.00	0.00	
6	0.00	0.00	0.00	0.00	0.00	0.00	
7	0.00	0.00	0.00	0.00	0.00	0.00	
8	0.00	0.00	0.00	0.00	0.00	0.00	
9	0.00	0.00	0.00	0.00	0.00	0.00	
10	0.00	0.00	0.00	0.00	0.00	0.00	
11	0.00	0.00	0.00	0.00	0.00	0.00	
12	0.00	0.00	0.00	0.00	0.00	0.00	
Marginal	2.36	0.45	0.02	0.22	0.0	0.03	3.08

Panel B. Threshold in Japanese GDP growth

1	4.28	2.16	0.05	0.16	0.00	0.00	
2	0.03	0.02	0.00	0.03	0.00	0.05	
3	0.00	0.00	0.00	0.00	0.00	0.00	
4	0.00	0.00	0.00	0.00	0.00	0.00	
5	0.00	0.00	0.00	0.00	0.00	0.00	
6	0.00	0.00	0.00	0.00	0.00	0.00	
7	0.00	0.00	0.00	0.00	0.00	0.00	
8	0.00	0.00	0.00	0.00	0.00	0.00	
9	0.00	0.00	0.00	0.00	0.00	0.00	
10	0.00	0.00	0.00	0.00	0.00	0.00	
11	0.00	0.00	0.00	0.00	0.00	0.00	
12	0.00	0.00	0.00	0.00	0.00	0.00	
Marginal	4.31	2.18	0.05	0.19	0.0	0.05	6.78

Panel C. Threshold in Taiwanese GDP growth

1	0.33	5.04	2.49	5.01	0.00	0.00	
2	0.00	0.01	0.00	0.04	0.01	0.08	
3	0.00	0.01	0.00	0.07	0.01	0.11	
4	0.00	0.00	0.00	0.00	0.00	0.00	
5	0.00	0.00	0.00	0.00	0.00	0.00	
6	0.00	0.00	0.00	0.00	0.00	0.00	
7	0.00	0.00	0.00	0.00	0.00	0.00	
8	0.00	0.00	0.00	0.00	0.00	0.00	
9	0.00	0.00	0.00	0.00	0.00	0.00	
10	0.00	0.00	0.00	0.00	0.00	0.00	
11	0.00	0.00	0.00	0.00	0.00	0.00	
12	0.00	0.00	0.00	0.00	0.00	0.00	
Marginal	0.33	5.06	2.49	5.12	0.02	0.19	13.21

Panel D. Threshold in Hong Kong GDP growth (SETAR)

Lags	G	GH	M	MH	A	AH	AR	VAR
1	18.37	8.95	7.71	0.21	0.00	0.00	7.70	0.33
2	0.01	0.05	0.45	4.04	0.03	0.01	0.34	0.00
3	0.00	0.00	0.00	0.00	0.27	0.00	0.29	0.00
4	28.12	0.00	0.00	0.00	0.00	0.00	0.02	0.00
5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Marginal	46.5	9	8.16	4.25	0.3	0.01	8.35	0.33

Notes: 'G', 'M' and 'A' refer to models in which the threshold variable is the growth rate; the momentum (i.e., the change in the growth rate); and the average growth rate, respectively, of real GDP growth. 'H' denotes the homoskedastic version of each model. 'AR' is a linear autoregression of the indicated order. 'VAR' refers to the 'Hong Kong equation' from a 4-variable vector autoregression with the growth rates of the US, Japan, Taiwan, and Hong Kong. The rows labeled 'Marginal' give the sum of the probabilities over all lag lengths. The column labeled 'Total' gives the sum of the probabilities for each panel. The sample is from 1973Q1 to 2006 Q4.

The row labeled 'marginal' gives the sum of the probabilities in each column, which indicates the overall support for each of the various model variants. The threshold variable in each model is listed at the top of each panel. Panel D represents the SETAR model and also includes probabilities for two linear specifications; a univariate autoregression (in column 'AR') and the "Hong Kong equation" from a vector autoregression (VAR) model of the four countries' growth rates, (in the 'VAR' column). The VAR model allows for direct linear effects on the Hong Kong economy from each of the other countries.

As is evident from Table 3, there is virtually no support in the data for nonlinear effects on GDP growth in Hong Kong GDP arising from growth rates in the US, Japan, or Taiwan. None of the individual models in panels A-C receives more than about 5% probability, and only in panel C does the total probability over all 72 models exceed 10%. The linear specifications in panel D likewise receive very little support from the data, although an AR(1) is more likely than any of the models in the first three panels.

Some form of a SETAR model with no more than four lags seems to be the best fit to the Hong Kong data. The G(4) model has the highest posterior probability at 28.1%, with the one-lag version of that model receiving 18.4% probability. These two models account for nearly half of the total posterior probability.

Corresponding results for Taiwan GDP growth are shown in Table 4.

Table 4. Posterior Model Probabilities for Taiwan

Panel A. Threshold in US GDP growth							
Lags	G	GH	M	MH	A	AH	Total
1	0.00	0.00	0.00	0.00	0.00	0.00	
2	0.01	0.01	0.01	0.03	0.03	0.05	
3	0.00	0.00	0.03	0.03	0.04	0.05	
4	0.00	0.00	0.00	0.00	0.00	0.00	
5	0.00	0.00	0.00	0.00	0.00	0.00	
6	0.00	0.00	0.00	0.00	0.00	0.00	
7	0.00	0.00	0.00	0.00	0.00	0.00	
8	0.00	0.00	0.00	0.00	0.00	0.00	
9	0.00	0.00	0.00	0.00	0.00	0.00	
10	0.00	0.00	0.00	0.00	0.00	0.00	
11	0.00	0.00	0.00	0.00	0.00	0.00	
12	0.00	0.00	0.00	0.00	0.00	0.00	
Marginal	0.01	0.01	0.04	0.06	0.07	0.1	0.29

Panel B. Threshold in Japanese GDP growth

1	0.00	0.00	0.00	0.00	0.00	0.00	
2	0.17	0.07	0.35	0.02	0.71	0.05	
3	0.00	0.00	30.92	0.09	46.38	0.14	
4	0.04	0.02	0.01	0.00	0.01	0.00	
5	0.00	0.00	0.00	0.00	0.00	0.00	
6	0.00	0.00	0.00	0.00	0.00	0.00	
7	0.00	0.00	0.00	0.00	0.00	0.00	
8	0.00	0.00	0.00	0.00	0.00	0.00	
9	0.00	0.00	0.00	0.00	0.00	0.00	
10	0.00	0.00	0.00	0.00	0.00	0.00	
11	0.00	0.00	0.00	0.00	0.00	0.00	
12	0.00	0.00	0.00	0.00	0.00	0.00	
Marginal	0.21	0.09	31.28	0.11	47.1	0.19	78.98

Panel C. Threshold in Hong Kong GDP growth

1	0.00	0.02	0.01	0.00	0.00	0.00	
2	0.17	0.03	0.36	2.08	0.73	4.17	
3	0.07	0.24	0.38	0.59	0.57	0.88	
4	0.00	0.00	0.02	0.00	0.03	0.00	
5	0.00	0.00	0.00	0.00	0.00	0.00	
6	0.00	0.00	0.00	0.00	0.00	0.00	
7	0.00	0.00	0.00	0.00	0.00	0.00	
8	0.00	0.00	0.00	0.00	0.00	0.00	
9	0.00	0.00	0.00	0.00	0.00	0.00	
10	0.00	0.00	0.00	0.00	0.00	0.00	
11	0.00	0.00	0.00	0.00	0.00	0.00	
12	0.00	0.00	0.00	0.00	0.00	0.00	
Marginal	0.24	0.29	0.77	2.67	1.33	5.05	10.35

Panel D. Threshold in Taiwan GDP growth (SETAR)

Lags	G	GH	M	MH	A	AH	AR	VAR
1	0.02	0.00	0.12	0.04	0.00	0.00	0.00	0.00
2	0.18	0.23	0.00	0.03	1.36	0.93	2.68	0.00
3	0.01	0.02	0.01	0.00	0.63	0.06	3.61	0.00
4	0.00	0.00	0.00	0.00	0.00	0.00	0.25	0.00
5	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00
6	0.00	0.00	0.00	0.00	0.02	0.06	0.02	0.00
7	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00
8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Marginal	0.21	0.25	0.13	0.07	2.01	1.05	6.6	0.0

Notes: 'G', 'M' and 'A' refer to models in which the threshold variable is the growth rate; the momentum (i.e., the change in the growth rate); and the average growth rate, respectively, of real GDP growth. 'H' denotes the homoskedastic version of each model. 'AR' is a linear autoregression of the indicated order. 'VAR' refers to the 'Hong Kong equation' from a 4-variable vector autoregression with the growth rates of the US, Japan, Taiwan, and Hong Kong. The rows labeled 'Marginal' give the sum of the probabilities over all lag lengths. The column labeled 'Total' gives the sum of the probabilities for each panel. The sample is from 1973Q1 to 2006 Q4.

In contrast to the results for Hong Kong, panel B of this table shows considerable support for a nonlinear specification with an external threshold in Japan. Nearly 80% of the total probability is allocated to models in this panel, with the majority going to the A(3) and M(3) models. Linear models receive roughly the same (lack of) support as in Table 3. There is also little or no evidence for nonlinear effects arising from past growth in the U.S. or Hong Kong.

We draw from the results of Table 3 and Table 4 to select an appropriate specification for Hong Kong and Taiwan. Thus, we estimate the highest-probability model, as suggested by tables 3 and 4, for each country in order to gain further insight into the different types of nonlinear effects that seem to be in evidence.(Note 9)

Table 5 shows the parameter estimates for the G(4) SETAR model for Hong Kong.

Table 5. Parameter Estimates, G(4) SETAR model for Hong Kong

Parameter	Posterior Mean	Posterior SD	MLE	Asymptotic SE
α_0	0.6706	0.1905	0.0890	0.6263
α_1	0.2899	0.0758	-0.0599	0.1969
α_2	0.1329	0.0614	-0.0555	0.1695
α_3	0.2196	0.0580	0.4977	0.1554
α_4	-0.2035	0.0954	-0.0049	0.1561
σ_1^2	1.1980	0.1408	4.3410	--
β_0	1.5810	0.9103	1.3870	0.3636
β_1	-0.0687	0.1789	0.0863	0.1269
β_2	-0.2733	0.1837	0.0640	0.0872
β_3	0.1609	0.2061	0.0796	0.1403
β_4	0.0465	0.2305	-0.0688	0.0943
σ_2^2	6.1600	0.8792	2.5330	--
γ	1.6990	--	-0.2054	--

Notes: The maximum likelihood estimates of the regime-specific variances are obtained by averaging the squared errors in each regime; no standard error is available for this procedure. Similarly, the MLE of γ is obtained via sequential OLS, which also yields no standard error.

Here, the threshold variable is the growth rate of Hong Kong GDP four quarters ago. (Note 10) Results suggest that when growth a year ago was below about 1.7% per quarter, Hong Kong GDP growth averages about 1.2% per quarter, with a standard deviation of 1.1% per quarter.(Note 11) All four lags are significant in this regime. On the other hand, when the growth rate was above the threshold a year ago, none of the AR lags are significant. The average growth rate in this regime is about 1.6% per quarter, with a standard deviation of 2.5%.

In Table 6, we show the A(3) model for Taiwan with a threshold effect in Japan. Specifically, the threshold variable now is the average growth rate in Japan over the previous three quarters. (Note 12)

Table 6. Parameter Estimates, A(3) Model for Taiwan, Threshold in Japanese GDP Growth

Parameter	Posterior Mean	Posterior SD	MLE	Asymptotic SE
α_0	0.3523	0.6784	0.4299	0.3434
α_1	0.8874	0.5063	0.5531	0.1771
α_2	0.5525	0.3754	0.3449	0.1405
α_3	-0.3735	0.4673	-0.0157	0.1758
σ_1^2	3.4200	0.7468	1.8810	--
β_0	0.6123	0.2153	0.9995	0.2941
β_1	0.2069	0.0768	0.0666	0.1074
β_2	0.2415	0.0757	0.1782	0.1066
β_3	0.2469	0.0734	0.3479	0.0889
σ_2^2	1.0250	0.1030	1.1110	--
γ	-0.2376	--	-0.1998	--

Notes: The maximum likelihood estimates of the regime-specific variances are obtained by averaging the squared errors in each regime; no standard error is available for this procedure. Similarly, the MLE of γ is obtained via sequential OLS, which also yields no standard error.

The parameter estimates suggest that relatively slow growth in Japan (less than -0.24% per quarter over the past three quarters) is bad news for Taiwan. Growth in this regime averages about 0.35% per quarter, with a standard deviation of about 1.8%. None of the AR lags are significant in this regime.(Note 13) Strong growth in Japan over the past three quarters results in average growth in Taiwan of about 2% per quarter, with a standard deviation of 1.01%. All of the AR coefficients are significant in this regime, and imply a stationary, mean-reverting process for GDP growth.

Taken together, the results of these models suggest that GDP growth in Japan may have significant spillover effects on the Taiwanese economy.

4. Conclusion

This paper employs a threshold autoregression model (TAR) estimated with Bayesian methods to examine how real GDP growth in Taiwan and Hong Kong is affected by domestic and overseas economic activity. Economic activity in both countries seems to be well-described by threshold models, but of significantly different kinds. GDP growth in Hong Kong's major trading partners does not seem to affect its own growth rate—either linearly or nonlinearly. A linear VAR receives little support in the data, whereas models with thresholds determined by GDP growth in the U.S., Japan or Taiwan account for, at most, a small fraction of the posterior probability. The nonlinearity for Hong Kong GDP growth seems to be of the SETAR type, with a delay of one year.

In contrast, there seems to be a significant spillover effect from the Japanese economy to that of Taiwan. Two models with thresholds determined by Japanese GDP growth receive over 75% posterior probability. As long as Japanese economic growth is faster than about -0.24% per quarter, Taiwan's growth averages about 2% per quarter.

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Notes

Note 1. See Frankle and Romer (1999) "gravity model".

Note 2. See Sachs and Warner (1995) and Keller (2004) for two such studies.

Note 3. Trade shares are from the Nations' Encyclopedia, available online at http://www.nationsencyclopedia.com/economies/Asia-and-the-Pacific/, under Taiwan-INTERNATIONAL-TRADE and Hong-Kong-INTERNATIONAL-TRADE, respectively.

Note 4. See Geweke and Terui, (1993) and Koop and Potter (1999), for more discussion of the advantages of Bayesian methods in this class of models.

Note 5. Koop and Potter (1998) and Henry and Summers (2000) show how Bayes factors can be used to select a leading model from among several alternatives.

Note 6. For consistency, the data were adjusted to be at constant (2000) in this study.

Note 7. The starting date is the earliest point at which Hong Kong's real GDP data are available. Hong Kong and Taiwanese GDP data were seasonally adjusted using the X-12 procedure implemented in gretl.

Note 8. As computed by the Bayes Factor.

Note 9. As an alternative, it would have been possible to compute parameter estimates that are averaged across all of the 312 different models for each country but we feel estimating the models that the BF selects is the better way to go.

Note 10. The estimates in Table 5 are actually weighted averages over all possible values of d from 1 to 4, with weights equal to the posterior model probability. However, the model with d = 4 receives at least 99.99% probability.

Note 11. The regime-specific average growth rates are computed as $\mu_1 = \alpha_0 \left(1 - \sum_{i=1}^{p} \alpha_i\right)^{-1}$ and $\mu_2 = \beta_0 \left(1 - \sum_{i=1}^{p} \beta_i\right)^{-1}$, respectively.

Note 12. As in Table 5, these estimates are weighted averages of models with d = 2 or 3. The posterior probability for the latter model is 99.6%.

Note 13. Note that the Bayesian point estimates imply that this regime is non-stationary, as the sum of the AR coefficients exceeds one. The average of 0.35% per quarter assumes that these coefficients are in fact zero.