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# Regime-dependent synchronization of growth cycles between Japan and East Asia*

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# Abstract

The sign of correlations between GDP growth in Japan and in emerging East Asian countries is ambiguous. Previous work found either consistently positive or consistently negative correlations. We propose using an integrated framework where cross-country correlations depend on the phase of the business cycle. For ten East Asian countries over 1975-2002 with quarterly GDP data, we consider a three-regime growth cycle setting in order to allow for catching-up effects. We examine to what extent correlations are sensitive to third country effects, transmission mechanisms and the quality of Japanese output data. When controlling for third-country effects correlations with Japan are almost uniformly negative. By contrast, when we take into account transmission variables, positive correlations appear during rapid-growth periods for a core-group of five East Asian countries composed of China, Malaysia, Singapore, Taiwan, and Korea. With higher quality data for output growth in Japan, symmetry of disturbances with Japan appears for the same group of countries in both growth-recessions and rapid-growth regimes. However synchronization with Japan is never present in the normal-growth regime. Since this core group of five countries is far from being fully synchronized with Japan, it may be somewhat premature even for them to engage in exchange rate arrangements involving the yen.

## 1. Introduction

Especially under the impetus of the 1997-98 crisis, there has been a growing concern in East Asia about the necessity of developing regional cooperation. One of the factors of the crisis was the common de facto (uncoordinated) peg to an external currency (the dollar), and one of the manifestations of the crisis was competitive depreciation. As a result, the desirability of cooperation in the monetary field, particularly with some form of regional exchange rate arrangement, has monopolized the attention of a large part of the academic community. Coincidentally, this trend has been reinforced by emulation generated by the start of the last phase of monetary integration in Western Europe, with the locking of parities in early 1999.

Analytically, it is acknowledged, mainly on the basis of the forty-year-old theory of optimum currency areas (Mundell, 1961) that the presence of co-fluctuations, or symmetry of shocks, among countries participating in regional currency arrangements, is one of the prerequisites for the success of such ventures.

Empirically, active research has developed over the last five years to examine the extent of correlation of output shocks among East Asian countries with contradictory results. Evidence based on annual GDP growth data, using either simple correlations or correlations between supply shocks extracted from the residuals of structural vector autoregressive systems (SVARs), indicates high positive correlations between Japan and other East Asian countries. This would make a core group composed of Indonesia, Korea, Malaysia, Thailand and Taiwan (Baek and Song, 2002) ripe for pegging to a basket giving a substantial weight to the yen (for a recent view on basket peg proposals: Ito and Park, 2002). By contrast, work using quarterly data and focusing on transmission mechanisms of shocks, essentially through bilateral trade, finds that correlations of

Japanese growth with GDP growth in many East Asian countries are negative (Abesinghe and Forbes, 2002). Such asymmetries would imply that arguments in favor of exchange rate arrangements giving some role to the yen in East Asia lack empirical support.

The present paper aims at remedying some weaknesses of previous work which may explain such conflicting evidence. We document that correlations of East Asian countries' growth with Japan depend on the phase of a common growth cycle. Most existing work which claims to study growth cycle synchronization, actually does not distinguish growth cycle phases. Such work just postulates that the clustering of turning points, i.e. synchronization between two countries' growth series, is the same in recessions and expansions. We follow here an alternative approach, in which interdependencies and co-movements among countries are conditioned by the state of the growth cycle (Krolzig and Toro, 2001). Growth cycles are identified as regime shifts occurring simultaneously across countries. The international correlation of shocks may then differ between different growth cycle regimes. The growth cycle classification that we use leaves room for a regime of very fast growth corresponding to a 'third' state in growth cycle dynamics (Potter, 1995; Sichel, 1994). This third state could occur at the beginning of expansions (the 'recovery' stage, Friedman, 1993; Kim and Nelson, 1999), if high flexibility allows a quick recovery, or after expansions when cross-country catching up effects are at work.

Previous work has suggested that the magnitude of cross-country growth correlations is mainly a function of bilateral trade flows. Inter-industry specialization would lead to less synchronization (Krugman, 1973) and intra-industry trade to more symmetry (Frankel and Rose, 1998). This overlooks the importance of further factors which can condition correlations: third country effects which take into account the influence of world or regional cycles; multilateral trade flows, reflecting in particular common external shocks from a large country or competition in the domestic market of that country; and multilateral capital flows, such as FDI…, which play a major role in generating interdependencies in economic activity between countries, particularly as a source of intra-industry trade.

Apart from these factors, very little attention has been granted to possible distortions in correlations due to data mismeasurement. When such worries are raised, they concern the reliability of high frequency data for GDP in developing countries, particularly in the early part of samples (Abesinghe and Forbes, 2002). However, it is acknowledged among specialists of Japanese national accounts that quarterly GDP estimations are not reliable (DNA, 2000), while alternative, higher quality, measures of Japanese output are available.

We propose here an integrated approach aimed at taking into account all three aspects: the regime-dependent nature, and possible reversal, of correlations; missing variables; and the role of data mismeasurement. The basic methodological tool of the paper is a Markov-switching trivariate vector autoregressive (VAR) system which includes real GDP growth in an emerging East Asian country, as well as growth in Japan and in a third country, the U.S. This reflects our presumption that for an East Asian emerging country there are two anchor economies to which it is likely to be affiliated (Artis and Zhang, 1997, for the European case). However, we also consider other third countries within the region: Korea or China, and alternatively include transmission variables like export growth or the Japanese financial account. We use such regime-dependent systems to examine correlation patterns for GDP growth between Japan and nine East Asian countries involving both NIEs (Hong Kong, Korea, Taiwan and Singapore) and ASEAN-4 (Indonesia, Malaysia, the Philippines, and Thailand*)* as well as

China, over the longest available sample, i.e. the last 27 years with quarterly data[1]. We finally consider alternative higher quality data for economic activity in Japan.

We first provide in section two a sketch of the lessons to be drawn from previous work. We then present in section three a descriptive analysis of the data and the methodology used in the tests. Section four investigates correlations with Japan of East Asian countries over different phases of the growth cycle in systems allowing in turn for third country effects, transmission variables, and mismeasurement of the data. Section five offers an interpretation of the results and examines their implications for monetary integration in East Asia. Section six gives some conclusions.

## 2. Previous work: sometimes positive, sometimes negative correlations

Typically, studies of economic linkages between Japan and East Asian countries (Goto and Hamada, 1994; Goto and Kawai, 2001) find a high degree of trade interdependence, particularly a high intensity of intra-industry trade (see below section 5). Substantially positive correlations of GDP growth should be a natural byproduct of such high interdependence.

**From simple to conditional correlations in a two-step framework** With annual data over the 1970-1995 period, Diwan and Hoekman (1999) examine relations between GDP growth in each of seven East-Asian economies and Japanese growth. They find a positive association, which tends to weaken over time, and turns negative for Hong Kong and China in the 1990s. They infer complementarity between Japan and East-Asian countries[2].

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[1] Indeed over a too short sample, the estimation may suffer from a Peso problem to the extent that the fraction of observations drawn from one particular regime in the available sample may not correspond to the population frequency of that regime. In such a case the estimation may be biased (Bekaert, Hodrick and Marshall, 1998).

[2] Kim, Kose and Plummer (2002) still with annual data, examine a longer sample, 1960 to 1996, with an imposed split in 1985, on Hodrick-Prescott filtered series, but do not consider correlations with Japan.

Going further than simply looking at unconditional correlations, other work has conditioned on the past history of the variables, using standard linear VAR techniques (Selover, 1999 and 2003; Lee, Huh and Harris,1999; and Hsiao, Hsiao and Yamashita, 2003) but only for a few pairs of East Asian countries. A weakness of such work is that it either postulates stability or decides a priori on dates of structural breaks. Finally, this work assumes linearity without ever testing for it.

Other work uses annual data over 1970-1998 on linear bivariate VARs including GDP growth and inflation to decompose the residuals into supply and demand shocks depending on their (imposed) permanent or temporary effects (Bayoumi and Eichengreen, 1994). In their updating of such tests, Baek and Song (2002) mainly stress the results obtained for supply disturbances, since these disturbances are associated with the shocks to the real economy which shift the long run equilibrium in a permanent way. They identify a core group of East Asian countries characterized by positive correlations of their supply disturbances with similar disturbances in Japan. This core group includes Indonesia, Korea, Malaysia, Thailand and Taiwan. By contrast such disturbances in China, the Philippines and Singapore are not significantly correlated with Japan. As we know, shocks to GDP growth include both supply and demand disturbances. Still, Baek and Song (2002) find that their core group of economies are also the only countries characterized by a high (positive) unconditional correlation of their growth rates with Japanese growth. This roughly suggests that GDP growth rates are closely associated with permanent or supply shocks.

The following step in this line of enquiry consists in using trade flows as an explanatory variable of cross-country growth correlations. However, by themselves larger trade flows will not a priori lead to higher correlations. Greater inter-industry specialization would lead to a fall in the correlation of growth cycles (Krugman, 1993), while, when intra-industry trade is the major component of international trade (Frankel and Rose, 1998), trade integration would lead to a rise in cross-country growth correlations. According to existing theory, higher trade integration can thus lead to either higher or lower growth cycle synchronization between countries, and the issue can only be resolved by empirical work (Kang and Wang, 2002). Since Frankel and Rose (1998), it has become customary to examine to what extent increased trade integration leads to higher growth correlations. After unconditional (or conditional) cross-country correlations have been computed, they are usually regressed on a number of candidate explanatory factors, such as trade flows. This line of enquiry has been pursued for East Asia for example by Crosby and Voss (2002) or Shin and Wang (2003).

**Transmission variables and third country effects** It is tempting to integrate the two steps of the previous approach into a single one, by taking into account explanatory variables (such as trade flows, etc.) as transmission channels when measuring correlations[3]. Thus Abeysinghe and Forbes (2001) use bilateral trade flows in East Asia over 1978-1998 to estimate a model linking output growth across countries. With quarterly data for real GDP, in a large number of cases the correlation between the residuals of a SVAR model is negative in East Asia. This is particularly the case between Japan and either (by decreasing order) Thailand, Singapore and, to a much lesser extent, Malaysia and Korea.

There is thus conflicting evidence, with positive correlations between Japan and other East Asian countries, found in the previous approach, as opposed to negative correlations when accounting properly for bilateral trade flows. Apart from the poor quality of data, Abeysinghe and Forbes (2001) put forward two possible explanations of

[3] Along another route, Marcellino et al. (2002) focus on a particular class of linear VARs whose parameters can change abruptly when a transition variable reaches a certain threshold. By contrast, we will allow

such negative correlations: i) omitted variables, especially cross-country linkages through other channels than direct (bilateral) trade flows -competition in third markets would be one such omitted variable-; ii) and mismeasurement of data.

The literature which focused on bilateral trade flows has thus potentially missed a major variable: say if both Japan and Korea send a high share of their total exports to the United States, an additional channel of co-movement arises from such trade flows with third countries. If U.S. growth falls, growth will fall in both Japan and Korea. By contrast, if Korea out competes Japan in the U.S. market, a negative co-movement between Japanese and Korean growth will ensue. The major implication of this proposition is that, when measuring the correlation of output growth between two economies within a region, neglecting to condition on multilateral trade flows and/or growth in a large country outside the region, will bias the intra-regional correlations. This is true even if one controls for intra-regional bilateral trade.

A complementary way to look at the same issue considers that the study of co-movements, or cross-country growth correlations, should not be conducted only within a bilateral context. Indeed, if growth falls in Japan and this does not affect directly growth in Singapore, but generates a sharp fall in Korean growth, then the latter may lead to a fall in Singaporean growth. At the end of the day, movements in the Japanese growth cycle affect the growth cycle in Singapore. Indirect effects through third countries could thus magnify or invert direct, bilateral, effects.

Another missing variable in existing work on co-fluctuations in East Asia is Japanese capital flows. Indeed, the integration of the production process in the region has relied heavily on foreign direct investment, in particular from Japan. This has been

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transition variables to affect the business cycle dynamics and thus the correlation pattern of growth shocks between Japan and emerging East Asian countries.

shown to be a major engine of intra-industry trade in the region (see section 5 below), which itself generates growth cycle symmetries across countries. More generally, Japan has been a major source of other capital inflows for East Asian countries. Overall, the financial account of the Japanese balance of payments may be a good proxy for all these transmission mechanisms.

**Regime-dependent correlations: concordance and common cycles** Most of the above-mentioned literature aims at studying growth cycle synchronization, and emphasizes linear models of aggregate output, but it does not distinguish growth cycle phases. Since Slutsky (1927) and Yule (1921) it is acknowledged that autoregressive processes convert serially uncorrelated shocks into persistent outputs and the dynamics then resembles closely the processes followed by growth cycle indicators. Such a tradition has led to multivariate analyses, as in the vector autoregressive model a la Sims (1980). An alternative tradition, a la Burns and Mitchell (1946) favors non linearities, through its emphasis on successive periods of expansion and contraction. This second tradition is able to identify turning points in economic activity. Indeed "it is only within a regime-switching framework that the concept of a turning point has intrinsic meaning…In linear frameworks, by way of contrast, there are no turning points, or switch times, in probabilistic structure" (Diebold and Rudebusch, 1999, p. 15). In a multivariate context, the combination of the two traditions has led to the development of regime-switching VAR models (Krolzig, 2000).

This new wave of empirical modeling considers it likely that cross-country correlations differ between different phases of the business cycle, when a large part of previous work just postulated that the clustering of turning points -i.e. synchronization[4]

[4] As defined rigorously by Harding and Pagan (2002), synchronization can be viewed as the phenomenon whereby turning points of two series cluster at particular dates. To measure it one has to determine the co-movements among the two series through their correlation coefficient. Perfect positive synchronization

between two countries' output series- is the same in recessions and expansions. An avenue worth exploring for explaining the conflicting evidence on correlations in East Asia is that the degree, and even the sign, of international interdependence could vary over different growth-cycle regimes. Such a possibility has been considered for G7 countries by Krolzig (2000) who uncovered negative correlations with the U.S. prior to 1973 and positive ones subsequently (on west European economies, see Artis, Krolzig and Toro, 1999) but was overlooked by previous work dealing with East Asia.

In the study of the similarities between different countries' growth cycles it is necessary to identify coincident turning points for the set of economies, but this is not a sufficient condition for synchronization (Krolzig and Toro, 2001). In order to measure co-movements[5] between output growth among different economies we should test for both concordance and correlation (Harding and Pagan, 2002b). Concordance refers to the fraction of time that two countries spend in the same growth cycle phase, while correlation measures the extent to which turning points in the two growth cycles occur near each other. A country by country analysis of growth cycles phases can be used to conduct concordance tests, while a multicountry system analysis of such phases allows us to compute regime-dependent correlations.

Regime-switching techniques are used by Girardin (2003) to examine the asymmetry and synchronization of quarterly industrial output growth cycles between eight North and South-East Asian countries. Based on the estimated Markov-switching models for each individual country, non-parametric tests of concordance of growth

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obtains when all specific cycles are in the same phase at the same time, and thus have identical turning points.

[5] Lee Park and Shin (2002) extract East Asian common shocks with Kalman filters and, in the spirit of the two-step approach, regress the fraction of a country's output variation due to that common shock on a number of potential explanatory variables. However the unobserved component model is unfortunately estimated with annual data.

cycles imply that there is asymmetry and low synchronization between Japan's growth cycle and the cycle of other East Asian nations

In the common cycle VAR approach, the interdependence and co-movements among countries are conditioned by the state of the growth cycle (Krolzig and Toro, 2001). Growth cycles are identified as regime shifts occurring simultaneously across countries. The international correlation of shocks may differ between different growth cycle regimes. The regime in which a given country is at the time of a major shock, like a sharp fall in output growth in one country, say Japan, could affect the magnitude and possibly the sign of the transmission of such a shock. Imagine that the correlation is high during expansions but low or even negative during growth recessions. In that case the shock could make the region switch to a recessionary regime, leading to a sharp fall in correlations. In other words, a negative growth shock in Japan would lead other East Asian economies to disconnect themselves from growth movements in Japan. The shock would lead to a shift in the pattern of interdependence among output growth rates in the region, a regime shift.

## 3. Stylized facts and methodology.

### 3.1. Stylized facts

We will focus here on growth cycles. This is an old concept (Zarnowitz, 1991) which was used in early indexes of general business conditions and trade. Growth cycles differ from business cycles not only quantitatively but qualitatively. A lot of work on growth cycles in numerous Western (but few, mostly north, East Asian) countries was conducted by Mintz at the NBER and Moore at the CIBCR. When carefully interpreted, growth cycles provide lessons on when and how expansions speed up and slow down, and retardations do not develop into contractions. The usefulness of the distinction was emphasized by Zarnowitz (1991) in the case of Japan where slowdowns without recession prevailed strongly before the 1990s, while slowdowns with recession were more common in other G7 countries. “Growth cycles include both types of slowdown, hence are much more numerous than business cycles that are defined by the presence of absolute decreases in aggregate activity (recessions)” (Zarnowitz, 1991, p. 42).

The quarterly data for GDP (Taiwan GNP) that we use for ten East Asian countries plus the United States start in the first quarter of 1975 for all countries except China, 1978. The source of the GDP data is the International Financial Statistics CD Rom of the I.M.F., except for Singapore, Hong Kong and Taiwan, where the source is national statistical offices. For five countries, quarterly data was unavailable in the earlier part of the sample. For China, Malaysia, Indonesia, the Philippines and Thailand, we thus used the data interpolated with the Chow-Lin related series technique, as computed by Abeysinghe and Gulasekaran at the University of Singapore. For all countries our sample ends with the third quarter of 2002. Our choice of countries is thus the same as in Abeysinghe and Forbes (2002) but our sample is three years longer at the beginning as well as at the end. Subsequently we will use export growth (in dollars) for nine East Asian countries (given the unavailability of data on export volumes for most countries in the sample) and the Japanese financial account (JFA) as a proportion of Japanese GDP. Such data come from the International Financial Statistics CD Rom of the I.M.F. Finally we will use a high quality quarterly output series for (“all industrial” activity) in Japan (see section 4.4. below), starting in 1993, computed by METI, which covers the construction sector (weight 8.24), the industrial sector (22.8), the tertiary sector (60.6), and public administration (8.35). All series were deseasonalized with Census X12.

[Table 1 about here]

Descriptive statistics for the quarterly growth rate of GDP are given in table 1 for the last 27 years. The lowest average growth is noticeable for both Japan and the

Philippines, while China enjoyed GDP growth three times as fast as the worst performers. Volatility of output growth is larger in emerging countries than in Japan. It is highest in Hong Kong and Korea. Only for Indonesia are the largest quarterly downturns more severe than the largest quarterly upturns, while for Japan, Korea, Malaysia and Thailand downturns and upturns are almost as equally severe. Signs of asymmetry in the distribution of the growth series are widespread. Skewness is particularly negative for Indonesia. It is also negative for most other countries, except Hong Kong and Taiwan. Excess kurtosis is mostly present in Korea and Malaysia, but it is particularly striking for Indonesia.

Unit-root tests both on the level (in log) and the growth rate of output using both the Augmented Dickey Fuller (ADF) and the Philipps-Peron (PP) tests, should enable us to get information on the stationarity of the data. According to both tests (not reported for lack of space) the level of real GDP would have a unit root for all countries. We also used the KPSS test (Kwiatkowski et al, 1992) which has stationarity as the null. Such a null is rejected for the level of output. Nelson, Piger and Zivot (2000) evaluated the performance of unit root tests when the true data generating process undergoes regime switching but is otherwise stationary. Their work implies that ADF tests do a poor job of distinguishing such a model from an integrated process, and that Philipps-Perron tests, which allow for structural breaks, also have very low power in such a case. A similar problem is met when considering the growth rate of GDP where all tests (again not reported) mostly conclude at stationarity. We still decided to implement the regime switching analysis on the growth rate of output since we are interested in studying growth correlations.

[Table 2 about here]

As a benchmark for subsequent estimates we present unconditional correlations on annual data in the second column of table 2. For all East Asian countries, except China and the Philippines, the correlation of annual GDP growth rates with Japan is positive and significant and varies between 0.3 and 0.6. With official Japanese quarterly data the unconditional correlation of growth rates (table 2, column 3) remains consistently positive between Japan and six other East Asian countries over the last 27 years but drops substantially (it ranges from 0.1 to 0.25). China, Korea and the Philippines share a correlation with Japanese growth close to zero. The use of higher quality data for Japanese output (see below section 4.4) generates much larger cross-country correlations (by a factor of 0.5 to 3) which are all significant, except for China (table 2 column 4). The low quality of official quarterly Japanese data is thus a source of underestimation of correlations.

[Tables 3a, 3b, 3c about here]

With annual data, in a bivariate linear VAR (with one lag), correlations of growth in an East Asian country with Japanese growth are positive and similar to the unconditional ones, except for a sharp rise for Korea, Malaysia and Singapore, and a substantial fall for Taiwan (table 3a columns 5). Controlling for a third country effect by including GDP growth of the United States leads to a marginal rise in correlations with Japan for most countries, but no change for China, the Philippines and Taiwan (table 3a columns 2). When China or Korea are included as an alternative third country there is almost not change in correlations compared to the bivariate case (table 3a columns 3 and 4).

With quarterly data in a similar trivariate VAR (with two lags) including either the U.S., Korea or China as a third country, conditional correlations with Japan are not significant, except in the case of Malaysia, and Hong Kong, but only when China is included. (table 3b, columns 2 to 4). The inclusion of transmission mechanisms like own-country export growth, or the Japanese financial account (as a ratio to GDP), as alternative control variables delivers a similar message (table 3b, columns 5 and 6). By itself the use of high-quality Japanese output data does not alter much the general picture on correlation patterns but in addition to the rise in the correlation with Malaysia, there is some weak evidence of a positive correlation with Japan for Hong Kong, Indonesia and the Philippines in the system with the United States (table 3c, column 2). Conditioning on export growth delivers a significant positive correlation with China.

These results show how the use of low-frequency (annual) data leads to an impression of high GDP growth correlation between Japan and other East Asian countries which nearly vanishes when turning to quarterly data. The use of high quality Japanese output data improves correlations, but only at the margin. The fall as the frequency rises is important because the optimum currency area criterion on co-fluctuations refers to cycles, which in the tradition of NBER methodology are always empirically examined at a quarterly frequency.

### 3.2. Methodology.

**From two to three growth regimes** In the regime-switching literature, it is customary since Hamilton (1989) to divide the growth cycle into two phases, negative trend growth and positive trend growth, and to assume that the economy switches between them according to a latent state variable. Accordingly, following the trough of a recession, since output switches back to the expansion growth phase, it will never regain the ground lost during the downturn. The effects of growth recessions on the level of output will thus be permanent. This is a strong view of growth cycle patterns which has been challenged by some authors (Kim and Piger, 2000) on the basis of an alternative model where recessions are characterized as periods where output is hit by large negative transitory shocks, labeled 'plucks' by Friedman (1993). According to such a view, following the trough, output enters a high- growth recovery phase, returning to the trend. This 'bounceback effect' or 'peak reversion' is the critical phase of Friedman's (1993) model, revived by Kim and Nelson (1999). Output then begins a normal, slower-growth, expansion phase (see also Sichel, 1994). On this basis a number of researchers have suggested using a three-regime model of the growth cycle to capture recessions as well as rapid-growth episodes, viewed respectively as persistent positive and negative deviations in the mean growth rate from the 'normal' long term growth rate (Krolzig, 2000). Alternatively, the rapid-growth regime has been viewed as accounting for the convergence process or the catching up of middle income countries. Rapid growth would thus follow expansions, and precede recessions. While the latter view has been essentially focused on the South European case, it is of clear relevance to the East Asian one. In the light of this, it is important to allow for the possibility of a third regime for output growth and examine the validity of either of the alternative views.

**Regime switching in a VAR framework** In the literature on growth cycle co-movements among macroeconomic time series have increasingly been examined within a framework allowing for regime-switching (Krolzig, 2001). In a regime-switching model of the growth cycle some or all parameters of a time-series model of several output variables depend on an underlying unobservable stochastic variable $s_t$, which aims at representing the phases of the cycle. This approach enables us to assign probabilities to the occurrence of the different regimes. In its most popular version, which we will use here, such a model assumes that the process $s_t$ is a first-order Markov process (Hamilton, 1994).

Hamilton's (1989) original specification assumed that a change in regime corresponds to an immediate one-time jump in the process mean. We rather consider the possibility that the mean would smoothly approach a new level after the transition from one regime to another[6]. We do it in an extension of Hamilton's approach to a regime-switching VAR system (Krolzig, 1998). For a VAR of order two with a vector of output growth ($\Delta y_t$) for n countries, such a specification would imply a model such as:

$$\Delta y_t = \Theta(s_t) + A_1(s_t)\ \Delta y_{t-1} + A_2(s_t)\ \Delta y_{t-2} + (\Sigma_m)^{1/2}(s_t)\ \varepsilon_t \qquad (1)$$

We allow for the vectors of intercepts or variances and the matrices of auto-regressive parameters to differ between three regimes[7]. The vector of intercepts $\Theta(s_t)$ thus switches between three states: a first regime with negative or very low growth ('growth recessions'), a second regime of moderate growth ('normal growth'), and a regime of accelerated growth ('rapid growth'). With Markov-switching heteroscedasticity, the variance of errors can differ between the three regimes ($(\Sigma_m)^{1/2}$ is the square root of the variance-covariance matrix). After the change in regime there is an immediate one-time jump in the variance of errors. It is expected that the variance will be higher during the rapid growth than during the growth-recession regime. The normal-growth regime is expected to be the least volatile. In the presence of such regime-dependent variances, the cross-country correlation of shocks will change between regimes. Such regime-dependent correlations represent the maintained hypothesis of this paper. The autoregressive parameters given by the A matrices are also allowed to switch between states. We use likelihood ratio tests to check that any of these three sources of switching is statistically acceptable[8]. For a given parametric specification of the model,

[6] The specification in (1) thus differs from Hamilton's since it implies different dynamic adjustments of the observed variables after a change in regime. Indeed the permanent regime shift in the mean would lead to an immediate jump of the growth rate of output to its new level. By contrast, a once-and-for all shift in the intercept generates a dynamic response of the growth rate which is similar to the response to an equivalent shock in the white noise series of the residuals.

[7] We take the example of two lags which will be used in the subsequent tests.

[8] When testing the Markov-switching model against the linear alternative or a *m* regime model against an (*m*-1) regime model, standard distribution theory does not apply (Davies, 1977) since a nuisance parameter (i.e. the transition probabilities) is not identified under the null hypothesis. The test proposed by Hansen (1992) and Garcia (1998) is conservative, tending to be under-sized and of low power. Ang and Bekaert (1998) conducted Monte Carlo experiments which imply that the true underlying distribution may be approximated by a $\chi^2(q)$ distribution, with q the sum of the linear restrictions and nuisance parameters.

(constant) probabilities are assigned to the unobserved regimes –recession, expansion and rapid-growth- conditional on the available information set which constitute an optimal inference on the latent state of the economy. We thus obtain the probability of staying in a given regime when starting from that regime, as well as the probabilities of shifting to another regime.

The classification of regimes and the dating of the growth cycle imply that every observation in the sample is assigned to a regime s (s=1,2,3). The rule followed to assign an observation at time t to a specific regime depends on the highest smoothed probability. The smoothed probability of being in a given regime is computed by using all the observations in the sample. We assign an observation to a specific regime when the smoothed probability of being in that regime is higher than one half. Generally, one also reports the filtered probability, which is computed by using only observations in the sample up to time t-1.

The multivariate Markov-switching model as represented in equation (1) can both picture the non linear nature of the growth cycle through regime switching, and the common factor structure of the cycle (Krolzig, 2001). Such a Markov-switching vector autoregressive model will characterize growth cycles for different countries as common regime shifts in the stochastic process of the series.

## 4. Correlation of output shocks in regime-switching VARs.

The initial regime-switching VAR specification that we use includes growth in an East Asian country of interest, plus Japanese growth and growth in a large third country. The third country is the United States in the basic specification in order to allow for the impact of world growth cycles. The economies of Japan and the U.S. are taken as the leading ‘anchor’ economies which may provide an attractor for the East Asian economies under study. We then consider regional growth cycles in systems where China or Korea is the third country. In a further step, the third variable in the system controls for multilateral export growth of the country of interest or for the Japanese multilateral financial account. We then consider the impact on correlations of correcting for data mismeasurement, both with the initial specifications and when controlling for transmission variables.

### 4.1.Basic specification with the USA as a third country

**Specification search** For the choice of lag length for each system, there is a trade-off between the precision of the estimation and the optimum lag. On this basis, the lag of the autoregression is taken equal to two for all systems, even though information criteria (Akaike, Hannah-Quinn and Schwartz) would often favor using only one lag. Indeed, with only one lag the variance-covariance matrix is often non-invertible.

When testing for the relevant specification we considered four stages. In the first stage when we test (with a likelihood ratio test) for a two-regime model against the linear VAR, we uniformly reject the latter (table 4, column 4). This shows that previous work using time invariant linear VARs missed an important dimension. Second, a two-regime model is not a full description of the growth cycle for systems including any East Asian country over the last three decades. The test of three versus two regimes rejects the lower number of states (table 4, column 3). The assumption of a data generating process shifting between only two regimes seems too restrictive to account for rapid-growth episodes. The third important step is whether the variance switches between regimes. The last column of table 4 implies that for all countries such a shifting-variance hypothesis is accepted at the five percent level (except Taiwan 10%). Finally, we select a switching-intercept model with shifting variance and autoregressive coefficients for all trivariate systems except in the case of Singapore where autoregressive parameters do not shift (column 5 of table 4).

[Table 4 about here]

For systems with any of the nine East Asian countries, we thus reject the linear model and accept the existence of a third regime on top of the usual regimes of growth recession and normal growth. Moreover, we accept the assumption of cross-country growth correlations depending on the growth cycle regime.

**Regime-dependent growth and volatility** We identify regimes on the basis of the regime characterizing the emerging country of interest and disregard the regime in Japan or the United States. As reported in table 5 (columns 2 to 4), three countries, Indonesia, Malaysia and Thailand, are characterized by negative growth during growth recessions (from -1 to nearly -3 percent per quarter). Hong Kong, the Philippines, Singapore and Taiwan have zero growth during growth recessions and China has positive growth (1.44 percent per quarter). Korea is special, with two regimes of negative growth, a low-volatility one (regime 3) and a high-volatility one (regime 1). By contrast, Singapore has two regimes of normal growth, respectively with high (regime 2) and low volatility (regime 3). For five countries (Indonesia, Korea, Malaysia, the Philippines and Singapore) growth recessions are the most volatile regime. For China, Hong Kong and Taiwan, the most volatile regime is the rapid-growth one, while for Thailand it is the normal-growth regime (table 5 columns 4 to 6). The fall in output growth between normal-growth and growth-recession regimes is small for China, Hong Kong, the Philippines and Taiwan (less than one percent at a quarterly rate), sizeable for Indonesia, Singapore and Thailand (2.5 percent) and very large for Korea and Malaysia (around 4 percent). The rise in output growth between the normal and rapid-growth regimes is generally around 2.5 percent with a smaller rise for Indonesia (1.5) and Thailand (0.5).

[Table 5 about here]

As is apparent from table 6 (columns 5 to 7), the duration of rapid-growth episodes is longer than for growth recessions, and the normal-growth regime is always the longest lasting, with China as a special case. There is a low probability of persistence of growth recessions in Malaysia and the Philippines, where the duration of this regime is lower than two quarters.

Figures plotting the estimated smoothed (using the whole sample) and filtered (using only past data) probabilities of the three regimes for all nine systems are given in the Appendix. In the overwhelming majority of cases (Hong Kong, Indonesia, Malaysia, the Philippines, Taiwan and Thailand), the rapid-growth regime follows the normal-growth regime and not the growth-recession regime. This result invalidates Friedman's plucking model for East Asia, but supports the catching up hypothesis. Available evidence for Western Europe over 1970-1997 similarly supports the catching up hypothesis (Artis, Krolzig and Toro, 1999).

[Table 6 about here]

As seen on the graphs in the Appendix, a remarkable feature of systems involving ASEAN4 countries is that the rapid-growth regime almost vanished after 1990. Among the NIEs, catching up was already over after 1980 in Korea, and 1985 in Hong Kong, but seems to have lasted for Taiwan as late as for ASEAN4.

**Regime-dependent correlations** In the trivariate Markov-switching VARs including Japanese growth and U.S. growth (table 7, columns 2 to 4), for two groups of countries, correlations with Japan keep the same sign between the extreme regimes: rapid growth (regime 1) and growth recessions (regime 3). Indeed, a positive correlation is maintained for Malaysia and Thailand, but the correlation with Japan remains high during growth recessions for Malaysia (which are always short-lived, see Appendix), while it falls considerably (by three fourths) for Thailand. By contrast, a negative correlation is kept between the two extreme regimes for Hong Kong. A negative correlation is also present for Korea in its two growth-recession regimes and for Singapore in its growth-recession and low-volatility normal-growth regimes.

Correlations change sign between the rapid-growth and growth-recession regimes for Indonesia, the Philippines and Taiwan, where they go from positive to negative, and for China where they switch from negative to zero. In the normal-growth regime, correlations with Japan are zero or close to it (Malaysia) for all countries, except Taiwan, where the correlation is negative. We included the bivariate system, without a third country, for comparison in table 7 (columns 5 to 7). The omission of the U.S. gives the impression that Hong Kong (Indonesia and Korea) is (are) positively correlated with Japan in (the rapid-growth regime) both growth-recession and normal-growth regimes.

[Table 7 about here]

All this implies that negative correlations with Japan are the rule in the growth-recession regime. In the normal-growth regime correlations are generally zero, while evidence of positive correlations is manifest in the rapid-growth regime only for ASEAN4 countries, as well as Taiwan.

**4.2. China or Korea as a third country**

In the trivariate regime-switching systems including Korea as an alternative third country, correlations with Japan are no more positive and significant in the rapid-growth regime for Indonesia, Malaysia, the Philippines, and Taiwan, but are slightly positive for China (table 8 columns 2 to 4). Taiwan has a very substantial negative correlation with Japan. Correlations with Japan are still zero in the normal-growth regime, with the exception of China, Indonesia and the Philippines with negative correlations. In the growth-recession regime correlations with Japan are hardly affected and remain negative.

[Table 8 about here]

When China is included in the trivariate regime-switching systems instead of Korea, in the rapid-growth regime, there are far less positive correlations with Japan than in the systems with U.S. growth (table 8 columns five to seven). In that regime, positive correlations are present only for the Philippines, Singapore, and Thailand. Positive correlations with Japan are present neither in the growth-recession regime, nor in the normal-growth regime, except for Malaysia in the latter regime.

Overall, the inclusion of alternative third countries to the U.S. confirms the negative sign of correlations with Japan in the growth-recession regime, with only a few exceptions. In the normal-growth regime correlations remain close to zero. Positive correlations remain for only a few South-East Asian countries in the normal-growth regime.

### 4.3. Multilateral trade or financial flows as transmission variables

We now study the impact of the inclusion of either multilateral trade growth or of the Japanese financial account as a third variable in the system. This should enable us to control for transmission variables which are likely to play a major role in East Asia, given the importance of intra-regional trade as well as of financial flows from Japan to its regional partners in the form of both foreign direct investment and bank lending.

**Export growth** In the regime-switching systems including multilateral export growth[9] of the country of interest as a third variable alongside Japanese growth, positive correlations with Japan in the rapid-growth regime appear like in the system with U.S. growth for ASEAN4 countries, with the addition of China, Korea and Singapore. The correlation for Taiwan becomes insignificant (table 9, column 4). A negative correlation remains only for Hong Kong. In the normal-growth regime, the correlation remains close to zero for most countries, but Korea now has a positive correlation with Japan. A substantial negative correlation with Japan is present for Indonesia and Thailand (table 9, column 3).

In the growth-recession regime, correlations with Japan are uniformly negative, except for Malaysia and Thailand (zero correlation).

**Capital flows** When the third variable in the regime-switching system is the Japanese financial account (JFA) as a share of Japanese GDP, compared with the system including trade flows, in the rapid-growth regime Taiwan is added to the group of countries with positive correlations with Japan, but the correlation turns negative for the Philippines. In the normal-growth regime, correlations with Japan become negative for China, Singapore and Taiwan, but no more so for Indonesia. In the growth-recession regime correlations become even more negative for most countries.

[Table 9 about here]

Accounting for transmission mechanisms instead of third country effects thus does not alter correlations with Japan in the growth-recession regime. By contrast, in the rapid-growth regime, the inclusion of export growth tends to enlarge the group of economies positively correlated with Japan to all countries except Hong Kong. A similar movement is not present in the normal-growth regime.

### 4.4. Low quality of data as a source of distortion

It is tempting to explain the overall lack of symmetry with Japan, especially in the growth-recession regime, by the dismal and atypical performance of Japan in the 1990s, or by the observation that Japan did not suffer from contagion and did not aggravate the impact of the crisis of its partners. It could be a reassuring fact that East Asian countries were not correlated with Japanese output growth movements over this period. However, before concluding too readily in favor of such a view, one should examine the validity of an alternative reason for the counterintuitive finding of negative correlations with Japan.

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[9] We obtained similar results with real export growth for countries where such data is available (Hong Kong, Korea, Singapore, Taiwan and Thailand).

Such a particularly robust pattern in the growth-recession regime could be due to distortions in the measure of GDP.

Abeysinghe and Forbes (2002) refer to the poor quality of East Asian GDP data, but they apparently have in mind the early part of the sample for emerging countries. However, doubts have often been raised about the quality of Japanese quarterly GDP statistics. The National Accounts Department (NAD, 2000) itself acknowledged that while the annual estimation of GDP employs reliable supply-side statistics, the split of such data between quarters mainly depends on the quarterly pattern in demand side statistics, which is sometimes considered far less accurate given the sampling nature of such data. This was mainly due to the fact that, for a long time, supply-side data were considered not as reliable as demand-side data at the quarterly frequency. Very recently (DNA, 2002) the method employed for the quarterly GDP estimates was put in partial conformity with the method used for annual estimates and thus now uses supply-side statistics and demand-side ones at the same time. However since such data are not available over a long sample, another avenue seems worth exploring. Since 1993, METI computes a measure of all-industry output for Japan, which is generally considered to be of much better quality than official GDP series[10].

[Table 10 about here]

We thus generated a mixed series of Japanese growth by using the official GDP series[11] up to the first quarter of 1993 and the all-industry output series subsequently. As shown in table 10, column 2, when controlling for the U.S. as a third country, for the growth-recession regime, correlations obtained with this mixed series yield strong

[10] I am grateful to Alistair Barr, at the Japanese desk of the Bank of England, for pointing to the existence of such data.

[11] Such a stacking may be reasonable since, in private conversation K. Nishimura indicated that the bias in quarterly official GDP data may have been less severe until the late 1980s because less-sampled small-to-

evidence of symmetry between Japan and either China, Hong-Kong, Korea, Malaysia or Taiwan. The third-country effect plays an important role here since such positive correlations are absent in the bivariate system, except for Hong-Kong (table 10, column 5). When we alternatively control for the Japanese financial account (table 11, column 4) we also get symmetry with Japan in the growth-recession regime for the same group of countries, but Singapore replaces Taiwan. When own-country multilateral export growth is controlled for, during growth-recessions symmetry with Japan is only valid for Singapore, and Korea (table 11 column 2).

[Table 11 about here]

In the rapid-growth regime, symmetry with Japan occurs again for Indonesia, Malaysia and Taiwan in the system with U.S. growth (table 10 column 4). This result is similar to what we obtained in the basic specification above (table 7), except that the Philippines and Thailand have been left out. Such a similarity would not be surprising since, for the former countries, rapid-growth episodes concern mostly periods up to 1990, while our high quality data for Japanese output only start in 1993. Symmetry in the rapid-growth regime is present only for China, when accounting for either transmission mechanism, as well as for Singapore (Taiwan), when controlling for export growth (Japanese financial flows). In the normal-growth regime, ASEAN3 (Malaysia, the Philippines, and Thailand) and Korea have now positive correlation with Japan in the systems including either U.S. growth or own-export growth, and Hong Kong in the system with Japanese financial flows.

The surprising negative correlations with Japan in the growth-recession regime, which characterized low quality Japanese output data, almost vanish. Indeed, with high

medium sized firms' investment behaviour was much more in conformity with all-sampled large firms' one until then.

quality data, the correlations very often turn positive. This is particularly the case for China, Malaysia, Singapore, and Taiwan, which share a positive correlation with Japan in the rapid-growth regime, while Korea joins this group with positive correlations (with Japan) in the growth-recession regime. Such symmetries are mostly robust to the inclusion of financial flows as a transmission variable in the system.

## 5. Interpretation and implications for East Asian monetary integration

In the previous section, we have provided some evidence on regime-dependent growth cycle interdependencies within East Asia. As seen in section two above, previous work ignoring such regime-dependence found that a core group of East Asian countries positively correlated with Japan included ASEAN countries like Indonesia, Malaysia, and Thailand. Using official GDP data, we find that such countries do belong to this core group only during the rapid-growth regime, which almost vanished in the 1990s after the end of catching up. However, with the exception of Malaysia, this evidence disappears when we control for transmission variables like export growth or Japanese financial flows. In the rapid-growth regime, such control leads to positive correlations with Japan for an alternative core group of countries composed of China, Singapore, Taiwan, and possibly Korea. The use of high quality Japanese output data after 1992, controlling for transmission variables, confirms the evidence of symmetry with Japan for this core group plus Malaysia both during growth-recession and rapid-growth regimes (except for Korea). In the rapid-growth regime, such evidence of symmetry with Japan is most robust for China. This raises two questions: Can we explain the importance of transmission mechanisms and is there any evidence of a change in the 1990s?

**Transmission mechanisms** There is only limited available systematic empirical evidence on the structure of East Asian trading relationships and of trade links with countries outside the region. However, existing empirical work shows that the transmission of shocks through trade flows, which derive from the location of the production process in different countries, may be substantially different from that of the traditional trade in final goods. In other words, bilateral trade, which is the usual channel for international transmission of a shock or cyclical phase, may not be able to capture all the components of international transmission. Indirect trade channels running along the chain of production may be equally –if not more- relevant. This has important consequences for the international propagation of shocks. Isogai, Morishita and Rüffer (2002) emphasize this point in their statistical analysis of the relationships between Japan and East Asia, taking the latter as a block. They focus on the nature of dynamic trade interdependencies created by increasing integration of East Asia into the global trading and production systems, leading to increasing internationalization of the production process. The main result of their study is that indirect shock transmission channels along the production chain are quantitatively significant. An increase in Japanese exports (parts and intermediate inputs) to other East Asian countries is followed by a rise in intra East Asian trade, and subsequently by a rise in East Asian exports to the US. Such patterns of globalization are very likely to play a major role behind the finding of a third-country effect in accounting for correlations of growth cycles between Japan and any East Asian country. This would also explain why multilateral exports from an East Asian country do seem to be the relevant transmission variable.

The rapid development of intra-industry trade in the region seems to be highly dependent on the rise in foreign direct investment in East Asia. In an econometric study of the electrical machinery industry in East Asia, Fukao, Ishido and Ito (2003) find that FDI has a strongly positive impact on vertical intra-industry trade[12]. Controlling for the Japanese financial account of the balance of payments in the estimations presented in section four above aimed at accounting for such a role of foreign direct investment as a transmission variable.

**Rise in intra-industry trade in the 1990s** Would the rise in intra-industry trade with Japan in the 1990s seem sufficient to generate the symmetry in some phases of the growth cycles we found between Japan and a group of five East Asian countries, including particularly China? It may not be a coincidence that China itself is a good example of the rise of vertical intra-industry trade with Japan in the 1990s. This is apparent when considering Japanese bilateral trade data (Fukao, Ishido and Ito, 2003). In the late nineties, Japan imported from China and Hong Kong around 220 (39.5) billion yens of telecommunication equipment and parts (television sets), and exported more than 270 (37.5) billion to the same area. In the electrical machinery industry, the share of vertical intra-industry trade in China's trade with Japan is now larger than in Taiwanese or Korean trade. For China the share rose remarkably from less than 10 percent in 1988 to 20 percent in 1992 and nearly 60 percent in 2000, thus overtaking Taiwan. Among East Asian countries, only Korea has ever reached such a high share. The other country for which the share has witnessed a spectacular growth is Singapore, with 20 percent up to the mid nineties, and more than 40 percent by 2000. As for other ASEAN countries, Malaysia has seen a declining share. From more than 50 percent in 1994, it went down to 34 percent in 2000 (Fukao, Ishido and Ito, 2003)

Isogai, Morishita and Rüffer (2002) computed intra-industry indices, using Aquino's Q, which removes the distortion in the Grubel-Lloyd index[13] induced by unbalanced trade (exports and imports differing by a wide margin). In their computations for all industries (SITC 1 digit base) and the 1990s, the NIE3 (excluding Taiwan) are

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[12] Horizontal intra-industry trade corresponds to products differentiated by attributes, while vertical intraindustry trade corresponds to products differentiated by quality (Fukao, Ishido and Ito, 2003).

close to 80 (among which Singapore has the highest level with over 90), China is just above 60 and the ASEAN4 under 70, with Japan under 50. By contrast, when considering trade in machinery and transportation equipment, the NIEs have reached 75 in the second half of the nineties, with Singapore, like Japan, close to 80, and China rapidly rising, with over 70 (65 in the first half of the nineties), while the ASEAN4 have only reached 64, rising only slowly (with the exception of the Philippines with a very fast rise).

**Implications for monetary integration in East Asia** As far as East Asian monetary integration is concerned, the evidence gathered in this paper has mixed implications. On the one hand, in the 1990s, since China, Malaysia, Singapore, Taiwan (and possibly Korea) have shown signs of synchronization with Japan during the recession and rapid-growth phases of their growth cycle, such countries would seem to be in the core group possibly suitable for some form of exchange rate arrangement involving the yen. This result is in stark contrast to both the estimations of linear VARs presented in section two above, and the results based on the correlation of supply shocks extracted from SVARs (Baek and Song, 2002), which exclude China and Singapore from the core group but include Hong Kong, Indonesia and Thailand. Our results with regime-dependent correlations would thus seem to overturn conventional wisdom on the appropriate members of an "optimum currency area" in East Asia. However, for at least two reasons, this does not imply that monetary integration in East Asia should proceed quickly. First, possibly either because of the low quality of Japanese output data prior to 1993 or of Japanese quasi-stagnation in the 1990s, in the normal-growth regime of the growth cycle our core group of countries show no sign of symmetry with Japan. Second, a large part of the symmetries uncovered may be driven by the common factor of exports to the U.S.,

[13] The Grubel-Lloyd index was used by Murshed (2001) in his study of the pattern of intra-industry trade in

which is certainly a very different situation from the one which characterized West European countries. By the 1980s, when they pegged their mutual exchange rates, the latter had refocused their growth cycle dependence on Germany and no more on the US (Artis and Zhang, 1997). A similar refocusing towards Japan may not yet be over in the East Asian case.

## 6. Conclusion

We obtained three series of results in the study of output growth correlations between Japan and other East Asian countries over the 1975-2002 period.

First, the use of low frequency (annual) data with unconditional correlations generates a core group of East Asian countries significantly positively correlated with Japan: Hong Kong, Indonesia, Korea, Malaysia, Taiwan and Thailand, and a non-core group of economies which are negatively or not correlated with Japan: China, the Philippines and Singapore. This remains true (with the exception of Singapore) in a linear vector autoregressive system either with the USA, Korea or China as a third country. This split matches the classification obtained by previous work on the basis of correlations of supply disturbances with annual data and structural VARs (Baek and Song, 2002). However, using quarterly data, we find, with similar unconditional or conditional correlations, that this classification collapses.

Second, in a framework where cross-country correlations depend on the phase of the growth cycle, there is an apparent asymmetry between Japanese disturbances and other East Asian countries' disturbances in the growth-recession regime. Such an asymmetry is robust to the choice of third country alongside Japan (i.e. the U.S., Korea or China) and the inclusion of transmission variables such as multilateral export growth by the domestic country or Japanese financial flows. However, this result seems to be

the ASEAN4 and three NIEs (excluding Taiwan) for 1980, 1985 and 1992.

due to measurement problems in the collection of quarterly national accounts, which are well known in the Japanese case. When we substitute a better quality series for Japanese output since 1993, we get evidence of symmetry in growth recessions between Japan and either China, Korea, Malaysia, Singapore and Taiwan.

Third, with the low quality Japanese data, the symmetry of disturbances in the 'rapid-growth', or catching-up, regime concerns Indonesia, Malaysia and Thailand, and weakly the Philippines. When transmission variables such as export growth, or the Japanese financial account, are controlled for, such evidence vanishes. Instead, China, Malaysia, Singapore and Taiwan become positively correlated with Japan. The use of high quality Japanese output data confirms this classification. Besides, in the normal-growth regime disturbances are never symmetric with Japanese growth shocks.

The conflicting evidence about East Asian growth cycle correlations in previous literature seems to have arisen from the reliance on linearity assumptions which were never tested, the neglect of more powerful transmission mechanisms than simply bilateral trade, or the use of low quality output data. The extent of intra-industry trade in East Asia, both inside the region and with the outside world, mostly generated by a spectacular wave of foreign direct investment, in particular from Japan, is quickly generating strong interdependencies between Japan and other East Asian countries. The synchronization of these countries' cycles with Japan is not yet full. The results we obtained indicate that during the 1990s symmetry of disturbances with Japan in both growth-recessions and rapid-growth regimes, concerns five out of nine East Asian countries (China, Malaysia, Singapore, Taiwan and possibly Korea). On the basis of these results, it would still seem premature for such a set of East Asian countries to engage in monetary cooperation on the basis of exchange rate arrangements giving a substantial weight to the yen. Given the speed at which East Asian trade integration has proceeded in the 1990s, it may not take long for synchronization with Japan to reach a high degree. However, a significant part of the common movements are driven by U.S. growth, given the dependence of most countries in the region on exports to the U.S. and FDI from the U.S.

On a methodological front, the estimations conducted in this paper for cross-country synchronization have shown the importance of controlling for the presence of appropriate transmission variables and of ensuring the reliability of the data used. Further work in this field would gain from putting more effort in these directions.

## Appendix

**Probabilities of regimes for trivariate VAR with GDP growth in country X, Japan and the Unites States.**

### Figure A.1. China

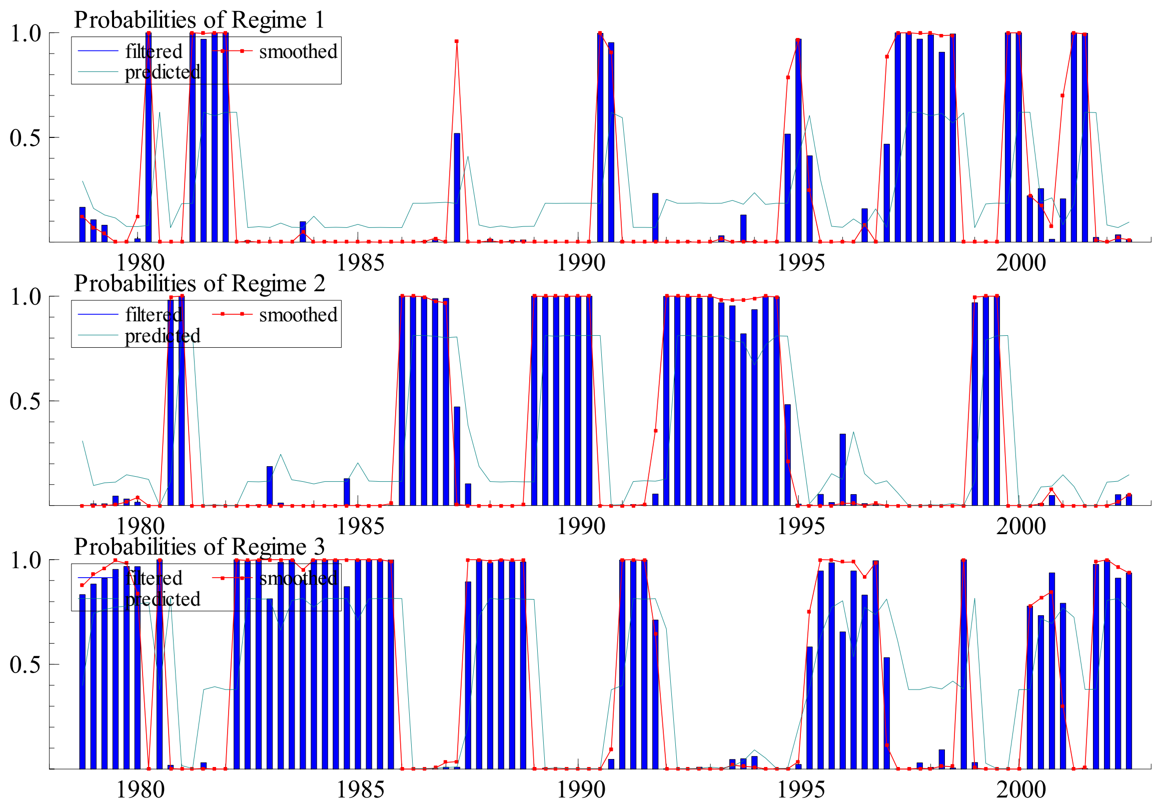


**Figure A.2. Hong Kong**

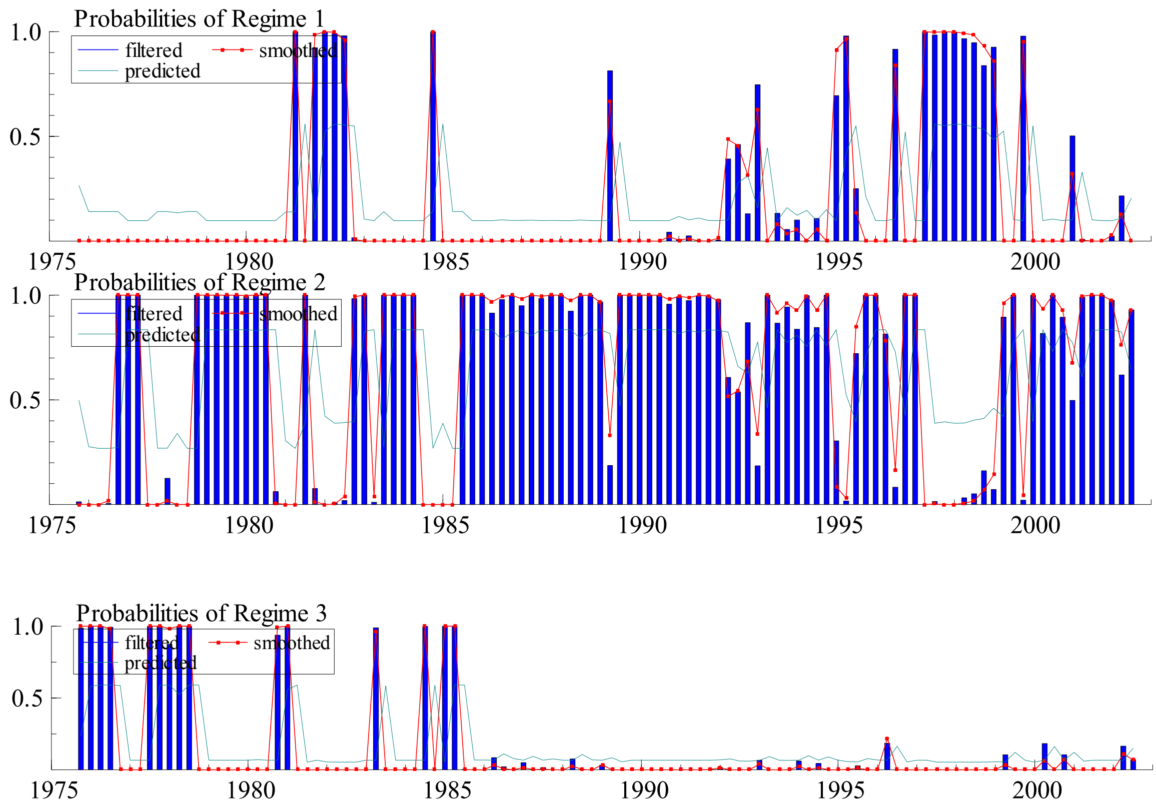
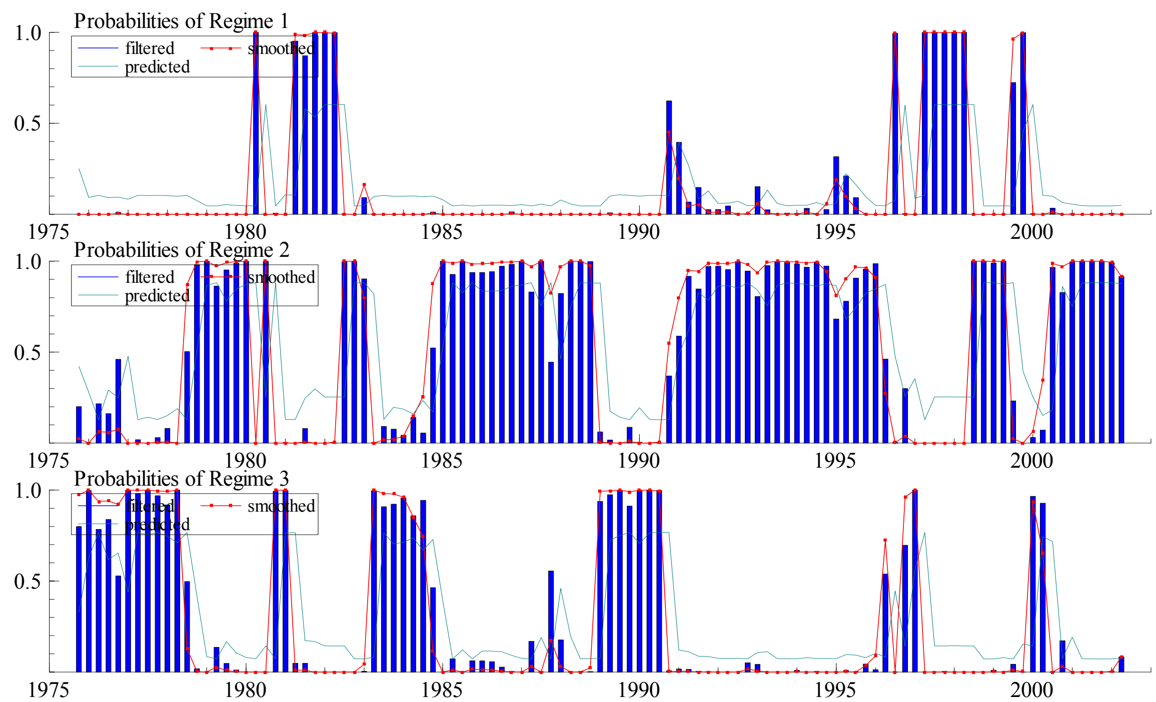
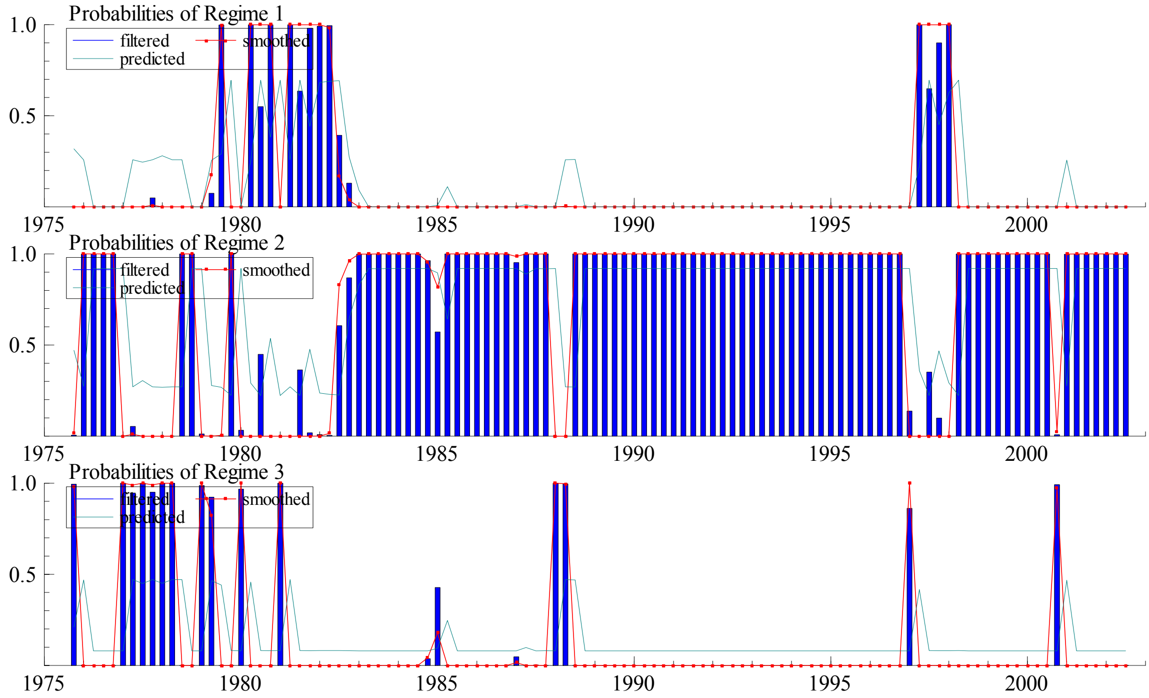


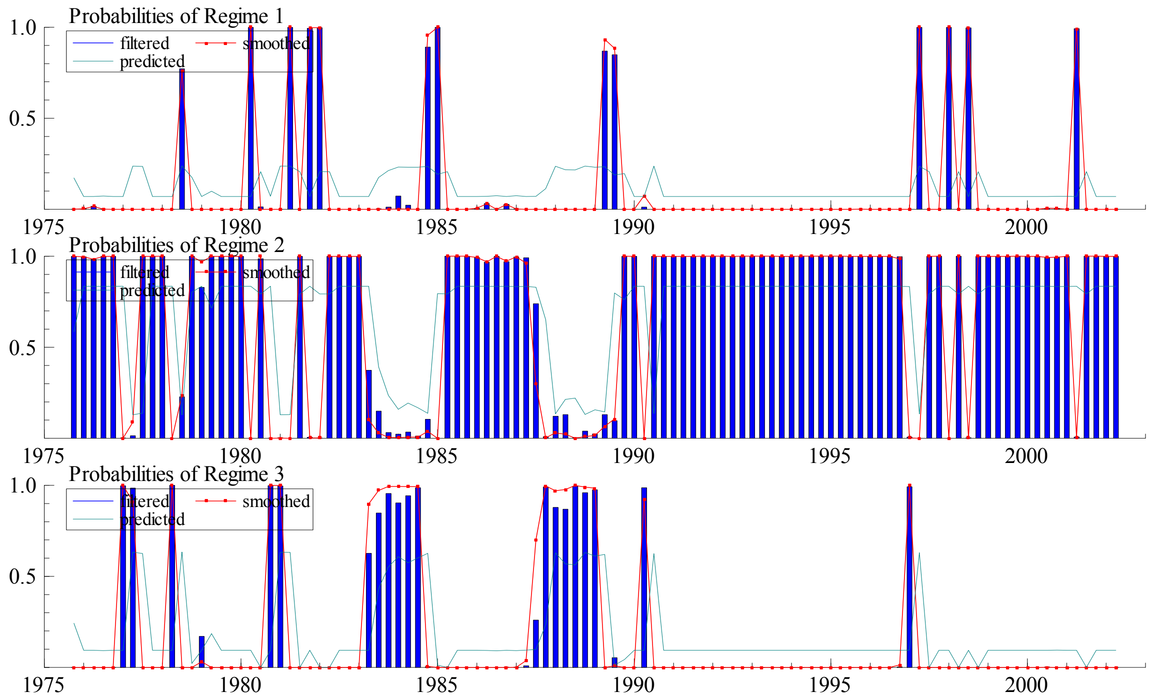

**Figure A.3. Indonesia**



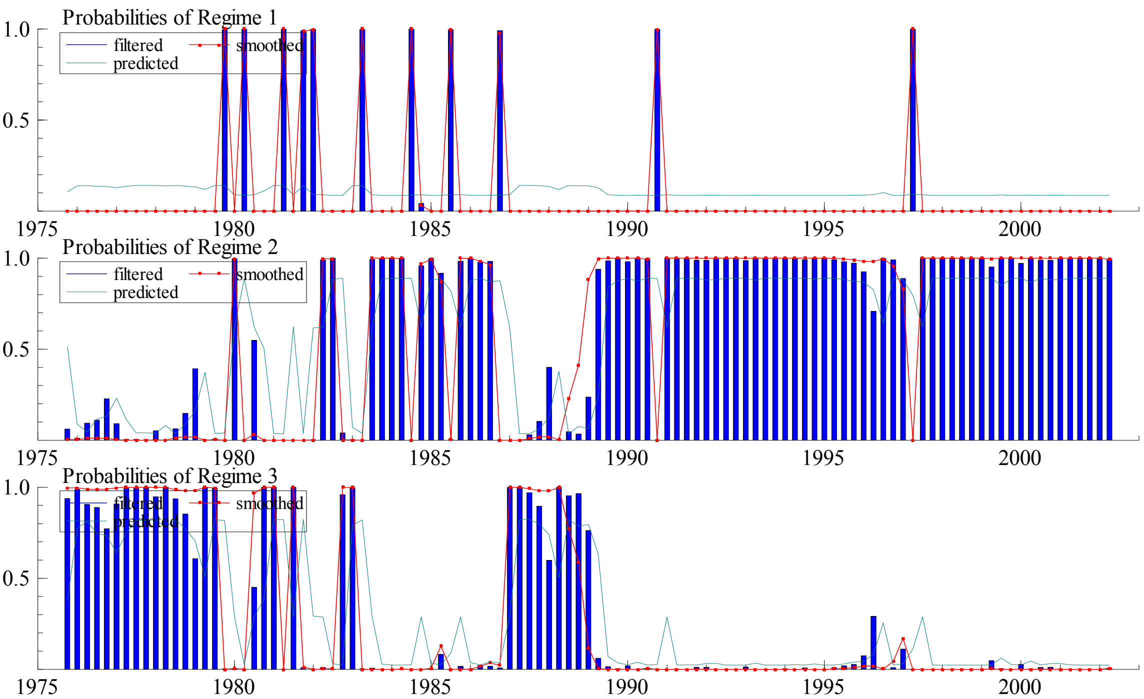
## Figure A.4. Korea



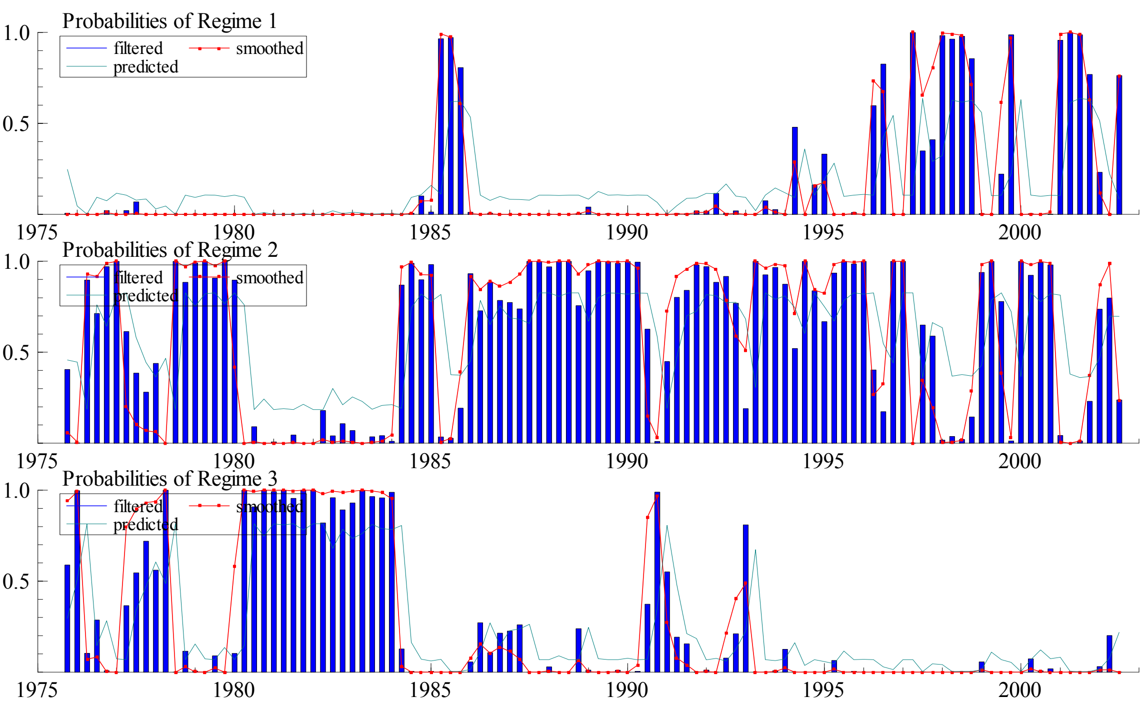

## Figure A.5. Malaysia



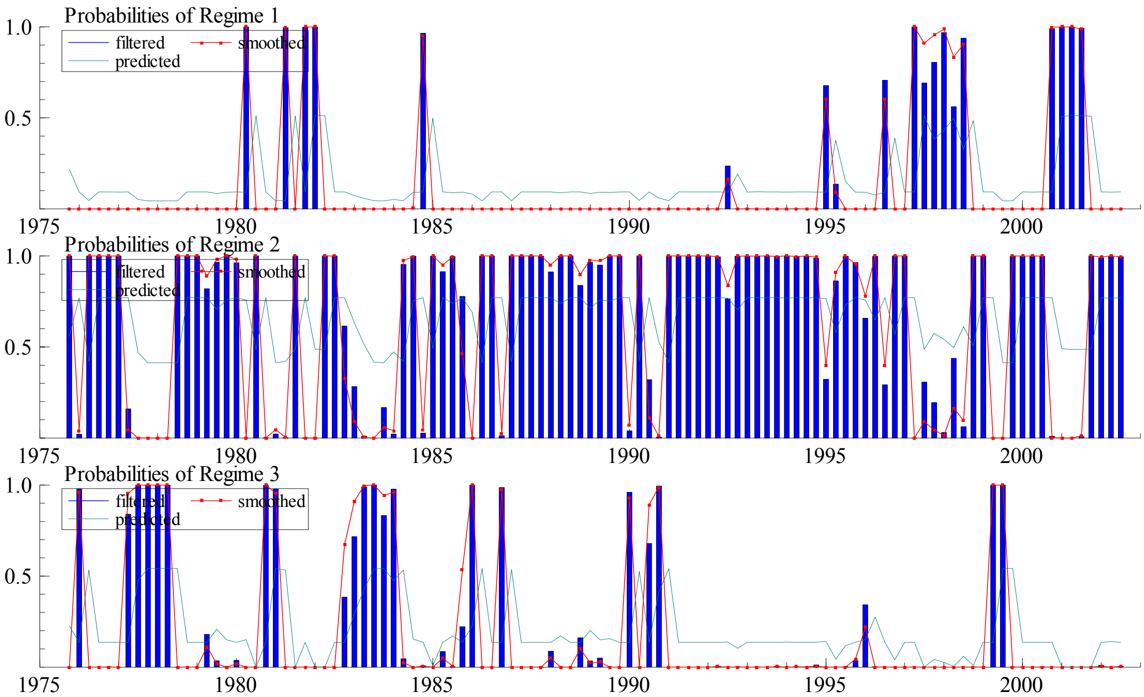
## Figure A.6. Philippines




## Figure A.7. Singapore



## Figure A.8. Taiwan




## Figure A.9. Thailand

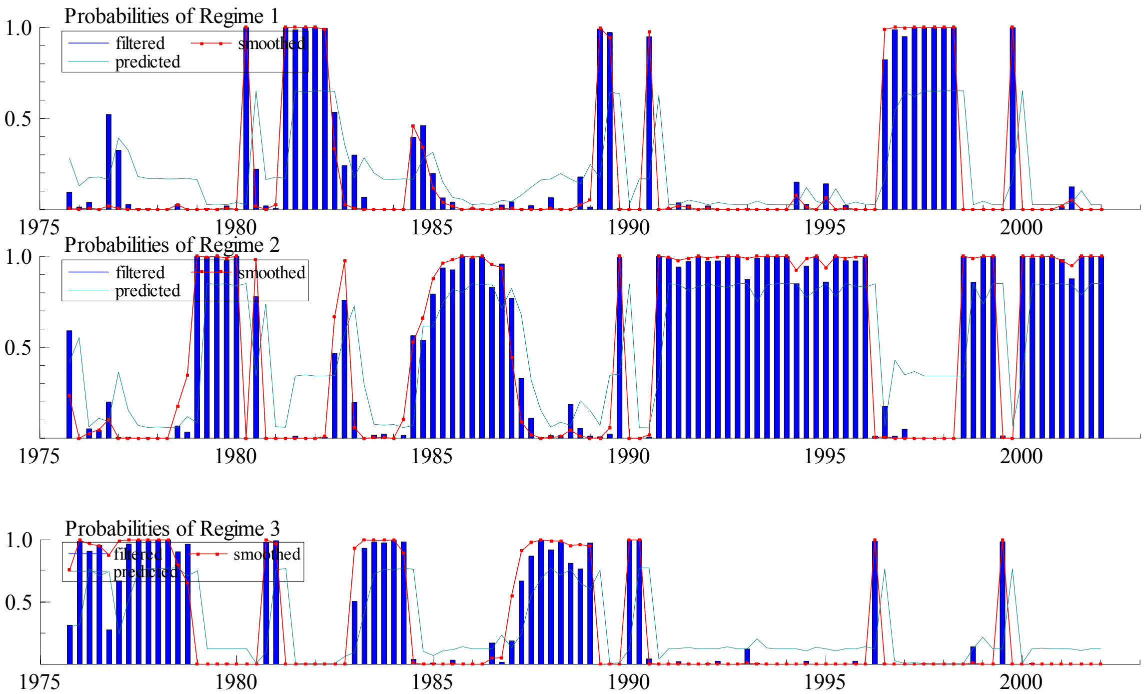


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Table 1: Descriptive statistics for growth rates of seasonally adjusted real GDP (quarter to quarter, %).

| 1975:2-2002:3 | Mean | Standard deviation | Minimum | Maximum | Skewness | Excess kurtosis |
|---|---|---|---|---|---|---|
| China* | 2.22 | 1.21 | -1.60 | 5.79 | -0.34 | 1.65 |
| Hong Kong | 1.54 | 2.20 | -4.47 | 10.84 | 0.56 | 2.49 |
| Indonesia | 1.25 | 1.67 | -10.4 | 4.31 | -3.96 | 23.3 |
| Japan | 0.74 | 0.91 | -3.19 | 2.86 | -0.72 | 2.62 |
| Korea | 1.74 | 2.01 | -7.76 | 7.34 | -0.97 | 5.05 |
| Malaysia | 1.60 | 1.67 | -6.98 | 5.30 | -1.56 | 5.49 |
| Philippines | 0.77 | 1.76 | -5.67 | 6.54 | -1.30 | 3.77 |
| Singapore | 1.68 | 1.53 | -2.95 | 5.98 | -0.58 | 1.19 |
| Taiwan** | 1.82 | 1.21 | -1.50 | 6.05 | 0.23 | 1.67 |
| Thailand | 1.53 | 1.62 | -4.96 | 5.26 | -1.30 | 3.77 |

*1978:2-2002:3
** GNP

Table 2: Unconditional correlation[a] with Japanese growth[c].

| | Annual data | Quarterly data | |
|---|---|---|---|
| | 1975-2001 | 1975:2- 2002:2 | |
| | | Low quality | High quality |
| China[b] | -0.19 | -0.067 | 0.03 |
| Hong Kong | 0.52*** | 0.177** | 0.26*** |
| Indonesia | 0.52*** | 0.163** | 0.32*** |
| Korea | 0.46** | 0.068 | 0.15* |
| Malaysia | 0.41** | 0.254*** | 0.35*** |
| Philippines | 0.22 | 0.094 | 0.13* |
| Singapore | 0.31* | 0.146* | 0.22** |
| Taiwan | 0.55*** | 0.239*** | 0.31*** |
| Thailand | 0.64*** | 0.106 | 0.30*** |

a) The significance of correlations is assessed using Anderson's (1958) z test. Denoting ρ the correlation coefficient, we compute z as $z = \{(1/2)\log[(1+\rho)/(1-\rho)]\}/[1/(T-3)]^{(1/2)}$ . Critical values are obtained from a normal distribution with (T-3) degrees of freedom, where T is the number of observations.
b)1978:2-2002:2;
c) significant at the *10%, **5%, *** 1% level

Table 3a: Linear VAR: correlations between annual growth rates of GDP with Japan: 1977-2001

| | Trivariate VAR[b] | | | Bivariate VAR[b] |
|---|---|---|---|---|
| | With USA | With Korea | With China[a] | |
| China[a] | 0.07 | -0.07 | - | 0.03 |
| Hong Kong | 0.53*** | 0.46** | 0.36* | 0.46** |
| Indonesia | 0.57*** | 0.49** | 0.49** | 0.49** |
| Korea | 0.71*** | - | 0.62*** | 0.65*** |
| Malaysia | 0.68*** | 0.57*** | 0.53*** | 0.54*** |
| Philippines | 0.16 | 0.16 | 0.11 | 0.13 |
| Singapore | 0.59*** | 0.48** | 0.36* | 0.46** |
| Taiwan | 0.35* | 0.35* | 0.25 | 0.34* |
| Thailand | 0.70*** | 0.67*** | 0.64*** | 0.63*** |

a) 1979-2001.
b) significant at the *10%, **5%, *** 1% level

Table 3b: Linear VAR: correlations between quarterly growth rates with official Japanese GDP data: 1975:2-2002:2

| Trivariate VAR | With USA | With Korea | With China | With export growth | With JFA/GDP |
|---|---|---|---|---|---|
| China[a] | -0.06 | -0.07 | - | 0.00 | -0.04 |
| Hong Kong | 0.12 | 0.10 | 0.16** | 0.09 | 0.14* |
| Indonesia | 0.014 | 0.00 | -0.00 | 0.00 | 0.00 |
| Korea | 0.012 | - | 0.08 | 0.06 | 0.10 |
| Malaysia | 0.177** | 0.17** | 0.18** | 0.19** | 0.16** |
| Philippines | 0.107 | 0.05 | 0.04 | 0.06 | 0.05 |
| Singapore | 0.026 | 0.01 | 0.02 | -0.00 | 0.00 |
| Taiwan | 0.086 | 0.06 | 0.04 | 0.08 | 0.12 |
| Thailand | -0.083 | -0.09 | -0.13 | -0.11 | -0.11 |

a) 1978:2-2002:2.
b) significant at the *10%, **5%, *** 1% level

Table 3c: Linear VAR: correlations between quarterly growth rates with high quality Japanese output data: 1975:2-2002:2

| Trivariate VAR | With USA | With Korea | With China | With export growth | With JFA/GDP |
|---|---|---|---|---|---|
| China* | 0.09 | 0.12 | - | 0.19** | 0.11 |
| Hong Kong | 0.15* | 0.13* | 0.19** | 0.13* | 0.17** |
| Indonesia | 0.14* | 0.13* | 0.12 | 0.18** | 0.12 |
| Korea | 0.027 | - | 0.11 | 0.12 | 0.13* |
| Malaysia | 0.23** | 0.22** | 0.25** | 0.24** | 0.22** |
| Philippines | 0.14* | 0.09 | 0.05 | 0.09 | 0.09 |
| Singapore | 0.06 | 0.05 | 0.07 | 0.02 | 0.02 |
| Taiwan | 0.11 | 0.09 | 0.08 | 0.02 | 0.14* |
| Thailand | 0.04 | 0.02 | -0.01 | 0.00 | 0.02 |

*1978:2-2002:2.

Table 4: Trivariate Markov-switching VAR with Japan and the U.S: Specification search**

| 1975:2-2002:2 | Log Likelihood | 3 vs. 2 regimes: LR[a] | 2 regimes vs. linear: LR[d] | 3 regimes MSIAH vs. MSIH. LR[e] | 3 regimes MSIAH vs. MSIA. LR[f] |
|---|---|---|---|---|---|
| China | - 303.28 | 48.84 | 87.8 | n.a. | 73.8 |
| Hong Kong | - 406.51 | 71.00 | 98.18 | n.a. | 58.8 |
| Indonesia | - 349.5 | 94.4 | 107.0 | 76.1 | 32.0 |
| Korea | -391.7 | 100.8 | 78.8 | 67.5 | 29.9 |
| Malaysia | -377.06 | 109.28 | 45.8 | 75.3 | 70.2 |
| Philippines | -383.66 | 91.88 | 76.4 | 74.6 | 63.9 |
| Singapore* | - 394.3 | 36.2[b] | 69.8[c] | n.a. | 65.5 |
| Taiwan | - 325.6 | 74.6 | 89.8 | 85.7 | 19.4 |
| Thailand | - 357.0 | 102.06 | 89.0 | 58.7 | 51.2 |

* MSIH model; Markov Switching (MS) models have a switching intercept (I), switching variance (H) and/or switching autoregressive coefficients (A). LR=Likelihood Ratio.

** Critical value (0.95): a) $\chi^2_{(13)}=22.36$; b) $\chi^2_{(31)}=44.97$; c) $\chi^2_{(11)}=19.6$; d) $\chi^2_{(29)}= 42.5$. e) $\chi^2_{(36)}= 50.9$; f) $\chi^2_{(12)} = 21.0$;

Table 5: Regime-dependent growth and volatility: basic specification (with Japan and USA).

| 1975:2-2002:2 | Constant[a] (t) | | | Standard deviation | | |
|---|---|---|---|---|---|---|
| Regime | 1 | 2 | 3 | 1 | 2 | 3 |
| China[b] | 1.93 | 4.26 | 1.44 | 0.40 | 1.49 | 0.68 |
| | (5.17) | (3.88) | (4.00) | | | |
| Hong Kong | 0.09 | 0.53 | 3.44 | 0.65 | 1.23 | 2.40 |
| | (0.33) | (1.63) | (1.85) | | | |
| Indonesia | -1.50 | 1.01 | 2.58 | 1.45 | 0.85 | 0.48 |
| | (1.68) | (5.17) | (6.38) | | | |
| Korea | -2.26 | 1.61 | -2.64 | 2.42 | 0.97 | 1.29 |
| | (1.73) | (6.68) | (2.18) | | | |
| Malaysia | -2.83 | 1.02 | 2.91 | 2.11 | 1.08 | 0.83 |
| | (1.90) | (4.15) | (3.88) | | | |
| Philippines | 0.00 | 0.57 | 3.06 | 1.47 | 0.86 | 1.39 |
| | (0.00) | (2.85) | (3.18) | | | |
| Singapore | -0.48 | 2.04 | 1.99 | 1.69 | 1.29 | 0.46 |
| | (0.98) | (5.91) | (6.94) | | | |
| Taiwan | 0.17 | 0.97 | 3.74 | 0.45 | 0.54 | 1.34 |
| | (0.68) | (5.91) | (3.96) | | | |
| Thailand | -1.03 | 1.64 | 2.06 | 0.55 | 1.23 | 0.69 |
| | (3.93) | (4.62) | (4.05) | | | |

a) Growth at quarterly rate; t statistic between brackets.

b) 1978:2-2002:2

Table 6: Persistence and duration of regimes: basic specification[a]

| 1975:2-2002:2 | Probability of persistence of the current regime | | | Duration (quarters) | | |
|---|---|---|---|---|---|---|
| Regime | 1 | 2 | 3 | 1 | 2 | 3 |
| China* | 0.62 | 0.81 | 0.81 | 2.63 | 5.32 | 5.42 |
| Hong Kong | 0.56 | 0.83 | 0.58 | 2.27 | 6.06 | 2.44 |
| Indonesia | 0.50 | 0.95 | 0.89 | 2.03 | 21.6 | 9.2 |
| Korea | 0.69 | 0.92 | 0.47 | 3.29 | 12.5 | 1.89 |
| Malaysia | 0.20 | 0.83 | 0.63 | 1.26 | 6.09 | 2.73 |
| Philippines | 0.09 | 0.89 | 0.82 | 1.10 | 9.12 | 5.64 |
| Singapore | 0.63 | 0.82 | 0.81 | 2.76 | 5.76 | 5.40 |
| Taiwan | 0.51 | 0.77 | 0.54 | 2.05 | 4.36 | 2.18 |
| Thailand | 0.65 | 0.85 | 0.77 | 2.87 | 6.67 | 4.44 |

* 1978:2-2002:2; a) regimes as defined in table 5

Table 7: Regime-dependent correlations: with and without third country (USA)[a]

| 1975:2-2002:2 | With third country[e] | | | Bivariate VAR[e] | | |
|---|---|---|---|---|---|---|
| Correlation with Japan | Regime 1 | Regime 2 | Regime 3 | Regime 1 | Regime 2 | Regime 3 |
| China^[b] | -0.04 | -0.42** | 0.05 | 0.05 | -0.02 | -0.52*** |
| Hong Kong | -0.65*** | 0.01 | -0.18** | 0.99*** | 0.23** | 0.00 |
| Indonesia | -0.54*** | -0.01 | 0.43*** | -0.20* | -0.04 | 0.63*** |
| Korea[c] | -0.33** | 0.13* | -0.76*** | -0.78*** | 0.10 | 0.29** |
| Malaysia | 0.88*** | 0.13* | 0.71*** | -0.47*** | 0.25** | 0.00 |
| Philippines | -0.68*** | 0.01 | 0.21** | -0.55*** | 0.07 | 0.11 |
| Singapore[d] | -0.59*** | -0.00 | -0.50*** | -0.21** | 0.01 | -0.23** |
| Taiwan | -0.31** | -0.25** | 0.28** | -0.49*** | -0.20** | 0.31** |
| Thailand | 0.12* | -0.06 | 0.47*** | -0.30*** | 0.13* | -0.30** |

a) Regime 1= growth recessions; regime 2= normal growth; regime 3= rapid growth;
b) Regime 1= normal growth; regime 2= rapid growth; regime 3= growth recessions;
c) Regime 1= growth recessions, high volatility; regime 3= growth recessions, low volatility;
d) regime 2= normal growth, high volatility; regime 3= normal growth, low volatility.
^ 1978:2-2002:2
e) significant at the *10%, **5%, *** 1% level

Table 8: Regime-switching VAR with Korea or China[a]

| Correlation with Japan | VAR with Korea | | | VAR with China | | |
|---|---|---|---|---|---|---|
| 1975:2-2002:2 | Regime 1 | Regime 2 | Regime 3 | Regime 1 | Regime 2 | Regime 3 |
| China[b] | -0.01 | -0.30*** | 0.19** | - | - | - |
| Hong Kong | -0.20** | -0.00 | -0.10 | 0.01 | -0.05 | -0.66*** |
| Indonesia | -0.45*** | -0.20** | -0.04 | -0.12 | -0.10 | -0.13* |
| Korea | - | - | - | -0.05 | 0.11 | -0.18** |
| Malaysia | 0.25** | -0.07 | -0.09 | 0.03 | 0.47*** | -0.06 |
| Philippines | -0.71*** | 0.10 | -0.21** | -0.91*** | 0.12 | 0.43*** |
| Singapore | -0.68*** | -0.06 | -0.17** | -0.52*** | -0.49*** | 0.57*** |
| Taiwan | -0.57*** | -0.00 | -0.66*** | -0.45*** | -0.06 | -0.38*** |
| Thailand | 0.19** | -0.31*** | 0.32*** | -0.32*** | -0.01 | 0.17** |

a) Regime 1= growth recessions; regime 2= normal growth; regime 3= rapid growth
b) 1978:2-2002:2;
c) significant at the *10%, **5%, *** 1% level

Table 9: Regime-switching VAR with country GDP growth, export growth (or Japanese financial account) and Japanese growth[a].

| 1975:2-2002:2 | VAR | with | export growth | VAR | with | JFA/ GDP |
|---|---|---|---|---|---|---|
| Correlation with Japan[d] | Regime 1 | Regime 2 | Regime 3 | Regime 1 | Regime 2 | Regime 3 |
| China[b] | -0.34*** | 0.01 | 0.44*** | -0.45*** | -0.34*** | 0.49*** |
| Hong Kong | -0.29*** | 0.02 | -0.19** | -0.68*** | 0.11 | -0.13* |
| Indonesia[c] | -0.17** | -0.42*** | 0.10 | -0.44*** | -0.07 | 0.12 |
| Korea[c] | -0.51*** | 0.21** | 0.20** | -0.45*** | 0.02 | 0.30*** |
| Malaysia | 0.01 | 0.10 | 0.17** | 0.02 | -0.03 | 0.33*** |
| Philippines | -0.27*** | -0.13* | 0.26** | -0.45*** | -0.05 | -0.23*** |
| Singapore | -0.21*** | -0.03 | 0.70*** | -0.57*** | -0.14* | 0.22*** |
| Taiwan | -0.36*** | -0.29*** | 0.09 | -0.26*** | -0.30*** | 0.58*** |
| Thailand | -0.09 | -0.43*** | 0.28*** | -0.05 | -0.22*** | 0.13* |

a) Regime 1= growth recessions; regime 2= normal growth; regime 3= rapid growth
b) 1978:2-2002:2;
c) One lag.
d) Significant at the *10%, **5%, *** 1% level

Table 10: Regime-switching VAR with and without USA (mixed Japanese series).

| 1975:2-2002:2 | With | third | Country[d] | Bivariate | VAR[d] | |
|---|---|---|---|---|---|---|
| Correlation with Japan[a] | Regime 1 | Regime 2 | Regime 3 | Regime 1 | Regime 2 | Regime 3 |
| China[c] | 0.69*** | 0.04 | -0.31*** | -0.09 | -0.35*** | -0.25*** |
| Hong Kong | 0.18** | 0.10 | -0.10 | 0.33*** | 0.07 | -0.29*** |
| Indonesia | 0.10 | -0.15* | 0.52*** | 0.15* | -0.14* | -0.00 |
| Korea[b] | 0.47*** | 0.04 | -0.75*** | -0.01 | 0.04 | -0.40*** |
| Malaysia | 0.47*** | 0.26*** | 0.76*** | 0.03 | 0.20** | -0.03 |
| Philippines | -0.75*** | 0.33*** | 0.09 | -0.23*** | 0.18** | -0.15* |
| Singapore | 0.11 | -0.15* | -0.08 | -0.32*** | 0.01 | -0.21** |
| Taiwan | 0.45*** | -0.10 | 0.24*** | -0.75*** | -0.09 | -0.02 |
| Thailand | -0.55*** | 0.35*** | -0.33*** | -0.72*** | 0.49*** | -0.63*** |

a) Regime 1= growth recessions; regime 2= normal growth; regime 3= rapid growth
b) Regime 1= growth recessions, high volatility; regime 2= normal growth; regime 3= growth recessions, low volatility, for trivariate VAR.
c) 1978:2-2002:2
d) Significant at the *10%, **5%, *** 1% level

Table 11: Japanese mixed data: Regime-switching VAR with domestic country's GDP growth, export growth (or Japanese financial account) and Japanese growth.

| 1975:2-2002:2 | VAR | with | export growth[c] | VAR | with | JFA/ GDP[c] |
|---|---|---|---|---|---|---|
| Correlation with Japan[a] | Regime 1 | Regime 2 | Regime 3 | Regime 1 | Regime 2 | Regime 3 |
| China[b] | -0.96*** | 0.07 | 0.46*** | 0.32*** | -0.13* | 0.38*** |
| Hong Kong | -0.17** | -0.00 | -0.13 | -0.00 | 0.41*** | 0.10 |
| Indonesia | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. |
| Korea | 0.23*** | 0.38*** | -0.29*** | 0.28*** | -0.01 | -0.75*** |
| Malaysia | -0.26*** | 0.30*** | 0.11 | 0.32*** | 0.01 | -0.08 |
| Philippines | -0.00 | 0.20*** | -0.29*** | 0.14* | -0.39*** | -0.47*** |
| Singapore | 0.55*** | -0.23*** | 0.70*** | 0.49*** | 0.10 | -0.24*** |
| Taiwan | -0.21** | -0.35*** | -0.02 | 0.18** | -0.23*** | 0.48*** |
| Thailand | -0.33*** | 0.29*** | -0.54*** | -0.18** | -0.14* | -0.47*** |

a) Regime 1= growth recessions; regime 2= normal growth; regime 3= rapid growth
b) 1978:2-2002:2
c) Significant at the *10%, **5%, *** 1% level