ASIAN BUSINESS CYCLE SYNCHRONISATION

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Abstract

This paper studies Asian business cycle synchronization in the framework of a multi-level factor model. Using quarterly data of sixteen economies' real GDP growth, we estimate a global factor and two regional factors. We find that, while the role of the global common factor has intensified over the past fifteen years for most of the economies, output fluctuations in Asia have remained less synchronised with the global common factor than the industrial countries. The Asian regional factor has become increasingly important in tightening the interdependence within the region over time, while the co-movement among the G-7 economies has been mainly driven by the global factor. Through a further investigation of the co-movement of underlying structural shocks, we find that synchronised supply shocks contributed more to the observed synchronization in output fluctuations among the Asian economies than demand shocks. This points to the role of productivity enhancement through vertical trade integration, rather than dependence on external demand, as the primary source of business cycle synchronisation in Asia.

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I. INTRODUCTION

In the last decade, economic growth in East Asia contributed almost 1/3 of global economic growth, according to data compiled for the World Economic Outlook of the IMF. It is now widely perceived that the centre of gravity of global economic activities is shifting from the West to the East. Yet, at the same time, it is also commonly argued that, despite East Asia's growing share, its growth can hardly stand on its own. According to this line of argument, the engine of Asia's growth lies outside the region in the form of final consumer demand in the United States and in Europe (Mohommad et al (2010)). The view that Asia's dependence on external demand is excessive lies at the heart of the debate on whether Asia can decouple from the West and manage a self-sustaining growth path in the future (He et al (2007)).

The accelerated pace of globalisation in the past fifteen years has led to a high degree of economic integration of Asian economies with the rest of the world, particularly through trade of goods and services. Nevertheless, theoretically both trade and financial integration can result in ambiguous effects on output co-movement. While trade linkages can generate demand-supply spill-over across countries, resulting higher correlation in output fluctuations, free capital allocation, and free trade among countries can stimulate international production specialisation, which will potentially reduce output correlations. Free capital flows may reduce the correlation between savings and investment and thereby increase the correlation of demand cross different economies. On the other hand, volatility of such flows may instead increase financial fragility and expose economies, particularly emerging market economies, to greater output fluctuations.

However, trade in East Asia is characterised by a high degree of vertical trade. At the centre of the globalization process in East Asia is a rapid development of vertical trade integration in the region, with China becoming a trading hub of manufactured goods after its accession to the WTO in 2001. The East Asian supply chain is particularly dominant in electronic products, as illustrated by Koopman, Wang, and Wei (2008). While increased trade in substitutes can generate resource-shifting effect, leading to more asymmetric business cycles across countries, trade in compliments such as vertical trade will have opposite effect and strengthen the output co-movement (Burstein, 2008). Giovanni and Levchenko (2009) and Ng (2010) find that the vertical production linkage is the main channel through which trade synchronizes business cycles between economies. Thus, business cycles in East Asia may have become more synchronised as a result of increasing vertical trade integration in the region.

Theoretically, vertical trade integration in a region can affect business cycle synchronisation among the economies in the region through a number of channels. On the demand side, since the regional production network is organised to serve a common market or source of final demand, common demand shocks that originate outside the region may lead to common movement of business cycles in the region. On the supply side, the regional production network implies that producers along the production chain are pushed or pulled together toward the frontier of technology. For instance, a positive supply shock to computer technologies may lead to producers in different countries along the supply chain to move to higher efficiency simultaneously. Such supply side shocks may thus lead to higher synchronisation of business cycles among the economies that form the production network. He and Zhang (2010) argue, for example, that the role of export in promoting economic growth in China should best be appreciated from its effect on the supply side, rather than on the demand side.

Empirically, several papers have investigated the business cycle synchronization in East Asia. One strand (e.g., Kim, Lee, and Park (2009)) is to employ a structural VAR model and examine the impact on Asian economies of global shocks and regional shocks. However, the results of SVAR models are in general sensitive to the identification assumptions, and it is not trivial to separate regional shocks from global shocks. Another strand (e.g., Eichengreen and Bayoumi (1996)) is to assess bilateral correlations. However, it is not clear whether the observed bilateral correlation is due to global co-movement or regional integration, and the business cycle synchronization should conceptually be multilateral. Genberg and Siklos (2010) raised concern about the role of shocks originating from the US (or more broadly, from the rest of the world) when studying the correlation of demand or supply shocks between two economies. They find fewer statistically significant correlations of underlying shocks in Asia once the external effects are considered. They use the US GDP to control for the global effect when identifying the underlying domestic shocks, thus the results will be subject to the choice of the country which serves as the origin of external shocks.

A further strand of the literature is to use multi-level factor models to study both global and regional co-movement. Under such a framework, Kose, Otrok, and Whiteman (2003) studied output co-movement of a large number of economies using annual data. Nevertheless, business cycle dynamics may not be fully captured by data at annual frequency.

In this paper we use a multi-level factor model built upon the work of Kose, Otrok, and Whiteman (2003) to decompose the business cycles into a global component and a regional component for both the East Asian economies and the G-7 group. Using a quarterly data set covering 16 economies from 1981 to 2008, we are able to conduct subsample analysis to examine the evolution of both world and region business cycle synchronizations over the last three decades. The findings are rich and intriguing. Using a full sample analysis, we identified notable roles for both the global factor and regional specific factors in explaining the output fluctuations across sixteen economies. The impact of factors on each country is heterogeneous, though. For example, China's output fluctuations are mostly explained by its country-specific component.[2] A further investigation using subsamples suggests that the role played by global factor has intensified over the decades, implying a stronger global business cycle. For both the Asian group and the industrial countries group, on average the variances explained by global factors increased dramatically after mid 90s. However, the influences of the Asian regional factor and the G-7 group factor exhibit very different evolution patterns. The Asian regional factor has played an increasingly important role in strengthening the business synchronization within the group, while the G-7 group economic co-movement has been mainly driven by the global factor.

To better understand the observed evolution of the respective roles of the global and regional factors in driving business cycle synchronisation, we also explore the co-movement in the underlying shocks in different economies. We employ a structural VAR model to identify a supply shock and a demand shock for each economy, and then conduct a multi-lateral study on the co-movement of the identified underlying shocks, instead of the conventional bilateral correlation analysis in earlier literature. This approach enables us to further investigate the role played by different structural economic shocks in explaining output fluctuations on both the global and the regional group level. The supply shock has long run impact on output growth and can be interpreted as productivity shock, whereas the demand shock only affects the output temporarily and is conventionally considered caused by monetary policy shock or other short-lived factors.[3]

We find that East Asian economies have had a sharply increased degree of synchronization in terms of the supply shocks at both the regional level and the global level after 1995. For the G-7 group, we only observe a slightly higher degree of synchronization at the global level, with no significant change at the regional level. In contrast, in terms of the demand shocks, East Asian economies have had a smaller increase in the degree of synchronisation at the global level, and no change at the regional level. The G-7 economies have had a significant increase in the degree of synchronisation at the global level, but little change at the regional level. These findings

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2 As a sensitivity check, we estimate the model using data from 1999 Q1 to 2008 Q2, in which both the 1997 Asian Crisis and the recent financial crisis are excluded. The results show that the Asian regional factor can explain around 22% of China's output fluctuations in such a subperiod. Therefore, China's seemingly delinking from other countries found in full-sample analysis may due to its resilience in the two crises.

3 It should be noted that the shocks we identify from each SVAR model contain both domestic and external components. Our multi-level factor model then allows us to separate the regional co-movement apart from the global co-movement.

imply that the more synchronized business cycles among the East Asian economies are largely due to more synchronized shocks from the productivity side.

Our findings have rich policy implications. First, they cast doubt on the thesis that Asia has been excessively dependent on external demand and, in order to make future growth more self-sustainable, the region needs to switch to a domestic demand-led growth model. On the basis of the findings of this paper, we can argue that the Asian economies are not as dependent on external demand as headline numbers appear to suggest, and share a strong region-specific business cycle as we find in this paper. There is a need to appreciate the role of productivity enhancement through vertical trade integration, rather than excessive dependence on external demand, as the primary source of business cycle synchronisation in Asia. A drive to reduce the openness of Asian economies will deprive the region of the opportunity of further productivity enhancements through active participation in global production networks (He et al (2007)).

Our findings also shed light on the feasibility of monetary and exchange rate policy coordination within the East Asian region. Mundell (1961)'s "optimal currency area" suggests that the business cycle synchronization is a crucial criterion for whether the common currency is the favourable choice. Regarding East Asia, a number of proposals have also been made, mainly but not exclusively from academic circles, regarding cooperation on exchange rate policy (e.g., Ogawa and Ito (2002)). Our findings cast doubt on the feasibility of a common Asian currency. Although our estimation shows that Asian regional factor plays a more important role after the middle 1990s, it also suggests that observed increase in the Asian business cycle synchronization has been greatly due to the region's integration into the world economy, and the overall degree of synchronization has still been lower than in G-7 group in the recent years. The study on underlying shocks delivers the same message. We find that the Asian economies are exposed to more asymmetric shocks than the G-7 countries overall, therefore requiring flexible monetary policies. This is consistent with the arguments in Genberg and He (2009).

On the other hand, our findings lend support to policy initiatives to enhance regional financial cooperation and to set up arrangements for mutual emergency liquidity assistance, such as the Chiang Mai Initiative. Such schemes of crisis insurance are most effective if the underlying shocks affecting different economies are uncorrelated. If the shocks were significantly correlated then all economies would tend to need to borrow from each other at the same time, which would make the insurance schemes unworkable. Our results suggest that such a regional crisis insurance schemes have a positive role to play, since overall the underlying shocks are more asymmetric in Asian economies than in the G-7 group. For example, we find that China's growth performance has been resilient against either regional or global shocks, which may suggest that China can serve as a stabilising force when other Asian economies are hit by crises.

The paper is organized as follows. We describe the data and the methodology in Section II and discuss the extensive empirical results in Section III. Section IV concludes.

II. METHODOLOGY AND DATA

To study Asian regional business cycle synchronization, it is important to separate the global effect from the regional-specific co-movement. As documented in Kose, Otrok, and Whiteman (2003), a global business cycle exists and plays an important role in explaining the fluctuations in output. A rising tide lifts all boats, hence the observed co-movement among Asian economies is partly due to the global trend of synchronization. In order to answer the question how the Asian regional business cycle co-movement pattern is different from the global trend, we need to look into the regional specific co-movement, netting out the effect of synchronization at the global level. Most of the existing literature that studies Asian business cycle co-movement generally ignores the effect of globalization on the Asian regional integration, and thus lead to mischaracterization regarding the regional commonality, because the group co-movement pattern could be the mixture of the global factor and the group-specific factor. An exception is Kose, Otrok and Whiteman (2003). They developed a multi-level factor model using Bayesian estimation method and successfully identified regional-specific co-movement and a global factor, with a wide coverage of countries.

We adopt a factor model with multi-level factors, which is a parsimonious way to deal with commonality among a large dataset. There are many economic fundamentals driving the global and regional economic fluctuations. However, it is not clear that in which way, for example, linear or nonlinear, they affect business cycle movement and how they should be included in the econometric model. Furthermore, too many explanatory variables would cause problems such as multicollinearity in regression models, while including too few variables leads to the misspecification and omitted variable problem. Instead of explicitly considering all the possible observed factors, the latent factor model identifies the unobserved factors, which could be interpreted as a combination of various fundamentals that affects the economies, such as technology progress, monetary shocks, oil prices, etc.

Another advantage of the factor models is that it is a multi-lateral approach. Conventionally, bilateral correlations are used to measure co-movement of two time series. Researchers use average pair-wise correlation over a group of countries to gauge the synchronization within the group. If one uses a reference country, the results will depend on the selection of the benchmark. Factor models can avoid such problems, and thus have been extensively used to quantify the extent of co-movement among time series. Sargent (1989) shows that the factor structure is directly motivated by general equilibrium models. Norrbin and Schlagenhauf (1996) use the model to study the role of international factors in 9 OECD countries, while Kose, Otrok and Whiteman (2003) conduct a more comprehensive world-wide investigation.

The Econometric Model

A latent factor model is used to decompose a country's output growth into a world component, a regional component, and a country-specific component. For country i which belongs to region k, its output growth at time t, y_{it}, is modelled as follows,

$$y_{it} = \lambda_i^g g_t + \lambda_i^k f_t^k + u_{it} \tag{1}$$

$$E(u_{it}\, u_{j,t-s}) = 0, \text{ for } i \neq j \text{, and } s \neq 0 \tag{2}$$

$$E(u_{it} u_{it}) = \sigma_i^2 \tag{3}$$

where g_t is the global factor which captures the world-wide co-movement in output growth, f_t^k is the factor specific to region k which only affects countries in that region, and u_{it} is the country-specific cyclical movement. The impact of latent factors is not homogeneous to all countries. This is captured by the country-specific coefficients or factor loadings λ_i^g, λ_i^k, which measure country i's heterogeneous response to the latent common factors. To complete the econometric model, we use auto-regressive processes to model the dynamics of the factors:

$$g_t = \Phi_g(L) \cdot g_{t-1} + \eta_t^g \tag{4}$$

$$f_t^k = \Phi_k(L) \cdot f_{t-1}^k + \eta_t^k \tag{5}$$

$$E(\eta_t^g\, \eta_{t-s}^g) = 0, \text{ for } s \neq 0,\ E(\eta_t^g \eta_t^g) = \sigma_g^2 \tag{6}$$

$$E(\eta_t^k\, \eta_{t-s}^k) = 0, \text{ for } s \neq 0,\ E(\eta_t^k \eta_t^k) = \sigma_k^2 \text{ for all k} \tag{7}$$

$$E(\eta_t^k\, \eta_{t-s}^g) = 0, \text{ for all t,s} \tag{8}$$

In line with the representation of the model in Stock and Waston (2005), the above system can be conveniently cast into a state-space form:

$$Y_t = \Lambda F_t + u_t \quad (9)$$

$$F_t = \Phi F_{t-1} + G\eta_t \quad (10)$$

where F_t is the collection of current and lagged latent factors, and Y_t is the vector of all countries' current output growth.

We estimate the above model using the maximum likelihood method with the help of Kalman filter. Due to the large dimensionality of the parameters, the shape of the likelihood function is rather complicated, making it computationally intensive to find the global maxima by the conventional hill-climbing method. We use the Expectation-Maximization (EM) recursive algorithm to calculate the MLE.[4] To ensure that the outcome from EM algorithm is indeed a global maximum, we conduct robustness check by trying different starting values, employing several convergence criteria, and increasing the number of iterations.

We firstly apply the model to a panel data of output growth to study the business cycle co-movement. We then use a structural VAR model to identify the underlying demand and supply shocks, and study the international co-movement of different shocks. Following Blanchard and Quah (1989), we use long-run restrictions in a structural VAR model to identify the underlying demand and supply shocks. Let y_{it} and π_{it} be the output growth and inflation for country i at time t. A reduced form VAR is estimated in the first stage,

$$\begin{bmatrix} y_{it} \\ \pi_{it} \end{bmatrix} = B_1 \begin{bmatrix} y_{i,t-1} \\ \pi_{i,t-1} \end{bmatrix} + B_2 \begin{bmatrix} y_{i,t-2} \\ \pi_{i,t-2} \end{bmatrix} + \begin{bmatrix} e_{it}^{y} \\ e_{it}^{\pi} \end{bmatrix} \quad (11)$$

The structural VAR takes the following form,

$$A_0 \begin{bmatrix} y_{it} \\ \pi_{it} \end{bmatrix} = A_1 \begin{bmatrix} y_{i,t-1} \\ \pi_{i,t-1} \end{bmatrix} + A_2 \begin{bmatrix} y_{i,t-2} \\ \pi_{i,t-2} \end{bmatrix} + \begin{bmatrix} u_{it}^{s} \\ u_{it}^{d} \end{bmatrix}, \text{ where } \begin{bmatrix} u_{it}^{s} \\ u_{it}^{d} \end{bmatrix} \sim \left(\begin{bmatrix} 0 \\ 0 \end{bmatrix}, \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix} \right). \quad (12)$$

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4 The EM algorithm iterates between an E-step, where the first two moments of the hidden state vector are calculated conditional on the complete data and the given parameter values, and an M-step, where an expected log likelihood is maximized to yield an update of the parameter estimates. The expected log likelihood in the M-step is fully characterized using the first two moments of the hidden state vector. As proved in Watson and Engle (1983) and Dempster, et al. (1977), the EM algorithm always increases the likelihood value in each step towards a local maximum.

The structural shocks u_{it}^s and u_{it}^d are called supply shock and demand shock respectively. Notice that we drop the country index for the coefficient matrices to save on notation. We may rewrite the reduced form as

$$\begin{bmatrix} y_{it} \\ \pi_{it} \end{bmatrix} = B_1 \begin{bmatrix} y_{i,t-1} \\ \pi_{i,t-1} \end{bmatrix} + B_2 \begin{bmatrix} y_{i,t-2} \\ \pi_{i,t-2} \end{bmatrix} + A_0^{-1} \begin{bmatrix} u_{it}^s \\ u_{it}^d \end{bmatrix}, \tag{13}$$

which implies a moving average representation,

$$\begin{bmatrix} y_{it} \\ \pi_{it} \end{bmatrix} = (I - B_1 L - B_2 L^2)^{-1} A_0^{-1} \begin{bmatrix} u_{it}^s \\ u_{it}^d \end{bmatrix}, \tag{14}$$

where L denotes the lag operator. Because we can identify the reduced form shocks in the first stage VAR regression, the structural shocks are identified as long as the matrix A_0 is identified. Blanchard and Quah (1989) assume that the supply shock has a long-run effect on both output and the price while the demand shock has no long-run effect on the output. If we use M to denote the matrix $(I - B_1 - B_2)^{-1} A_0^{-1}$, this amounts to the restriction such that the (1,2)-th element of M is zero. Coupled with the restriction that $A_0^{-1} A_0^{-1}{}' = \text{var}\begin{bmatrix} e_{it}^y \\ e_{it}^\pi \end{bmatrix}$, we are able to uniquely pin down the matrix A_0, and thus the structural shocks are identified. We then use the same factor models to decompose both types of shocks into a world component and a regional component.

Next, we estimate the model for supply shocks:

$$u_{it}^s = \gamma_i^{s,g} g_t^s + \gamma_i^{s,k} f_t^{s,k} + \vartheta_{it}^s; \tag{15}$$

and for demand shocks:

$$u_{it}^d = \gamma_i^{d,g} g_t^d + \gamma_i^{d,k} f_t^{d,k} + \vartheta_{it}^d \tag{16}$$

where g_t^s is the global supply factor, and g_t^d the global demand factor, which are common to all economies, and $f_t^{s,k}$ is the group-specific supply factor, and $f_t^{d,k}$ the group-specific demand factor, for group k which is common to economies in the k-th group, k =Asian region, or G-7 group.

From equation (14), a Wold representation of y_{it}, is as follows:

$$y_{it} = C(L) u_{it}^s + D(L) u_{it}^d \tag{17}$$

Combining equation (15), (16), and (17), we get

$$y_{it} = C(L)(\gamma_i^{s,g} g_t^s + \gamma_i^{s,k} f_t^{s,k} + \vartheta_{it}^s) + D(L)(\gamma_i^{d,g} g_t^d + \gamma_i^{d,k} f_t^{d,k} + \vartheta_{it}^d) \quad (18)$$

$$= (C(L)\gamma_i^{s,g} g_t^s + D(L)\gamma_i^{d,g} g_t^d) + (C(L)\gamma_i^{s,k} f_t^{s,k} + D(L)\gamma_i^{d,k} f_t^{d,k}) + (C(L)\vartheta_{it}^s + D(L)\vartheta_{it}^d)$$

Equation (18) bears a similar structure as equation (1), but decomposes the global factor into the global supply and demand factors, and decomposes the group factor into group-specific supply and demand factors. This allows a further investigation of the role played by different structural economic shocks in explaining output fluctuations at both the global and the group levels.

The data

We use quarterly data instead of the annual data as in most other related research, which enables us to study the characteristics of business cycle synchronization after 1980 at quarterly frequency, which may not be captured at annual frequency. In addition, since the econometric model has a large-dimension of parameter-to-be-estimated and requires relatively long time series to achieve accurate estimation, with quarterly data for almost three decades, we can slice the sample into two sub periods, with mid 90s as the dividing point.

We collect quarterly data for 16 economies from 1981Q1 to 2008 Q4. The list includes nine emerging Asian markets, namely Hong Kong, China, Indonesia, South Korea, Malaysia, Philippine, Singapore, Taiwan, and Thailand,[5] and the industrial countries that comprise the G-7. Most GDP, CPI, and trade data are downloaded from the International Financial Statistics CD-Rom and CEIC data base. Data for several Asian countries are taken from other estimation in existing research since the available data series are too short. Series are seasonally adjusted using Census X-12. Output growth and inflation are calculated as the log difference.[6] All the time series used in the econometric model passed the unit root test and are stationary.

[5] We choose the nine Asian emerging markets following Williamson (1996), who argued that the nine economies should adopt a common basket peg, with fluctuation bands of 10% on both sides.

[6] West Germany and East Germany united in 1990. The IFS data combine the GDP for the two regions starting 1991 Q1, thus there was a large jump in the output for Germany in one quarter. To take into account this break, we follow Engel and West (2006)'s method to smooth out the jump.

III. EMPIRICAL RESULTS

Output co-movement

We estimate the multi-level factor model described in section II for the output growth data. We split our sample into two groups: the emerging East Asia and the industrial country group, hence we have three factors: the global factor which drives global economic fluctuations, and two regional factors which capture the co-movement within the respective region. By assumption, the global factor is orthogonal to the two regional factors.

a. Full sample analysis

We first estimate the model using the full sample, 1981Q2 to 2008 Q4. The estimated factor loadings are reported in Table 1, along with the standard errors. Table 2 reports the autocorrelation coefficients of the three factors. The Asian regional factor is more persistent than the industrial countries' group factor, and the global factor is the most persistent among the three factors. The variances of the economy-specific components which could not be explained by either the global factor or the regional factor are shown in table 3. By model assumption, the country-specific cycles which are represented by the residuals are mutually orthogonal, and thus the covariance matrix R is diagonal. The estimated global factor and the two group factors are depicted in Figure 1. The dotted line is the Asian factor, and it picks up the 1997 Crisis. The solid line is the global factor, and it plummets deeply at the end of this sample, a reflection of the global financial crisis.

Table 1. Factor loadings

	Global Factor	Asian Regional Factor	Industrial-country factor
HKSAR	0.2332 (0.07)	0.35 (0.073)	0
China, Mainland	0.1477 (0.0633)	0.0994 (0.0733)	0
Indonesia	0.1433 (0.0763)	0.4414 (0.075)	0
Korea	0.2455 (0.0745)	0.379 (0.073)	0
MYS	0.1652 (0.0784)	0.4783 (0.0767)	0
PHL	0.0594 (0.0618)	0.1007 (0.0726)	0
SGP	0.2911 (0.0734)	0.3991 (0.0716)	0
TWN	0.2506 (0.0645)	0.2193 (0.0704)	0
THA	0.1102 (0.0696)	0.342 (0.0704)	0
JAP	0.2187 (0.0786)	0	0.4316 (0.1061)
FRA	0.3297 (0.0849)	0	0.4911 (0.1165)
DEU	0.2292 (0.074)	0	0.3833 (0.1175)
ITA	0.3213 (0.0762)	0	0.4203 (0.1172)
GBR	0.3833 (0.0579)	0	0.0694 (0.1038)
CAD	0.4344 (0.063)	0	-0.2992 (0.1117)
USA	0.4146 (0.0599)	0	-0.2058 (0.1051)

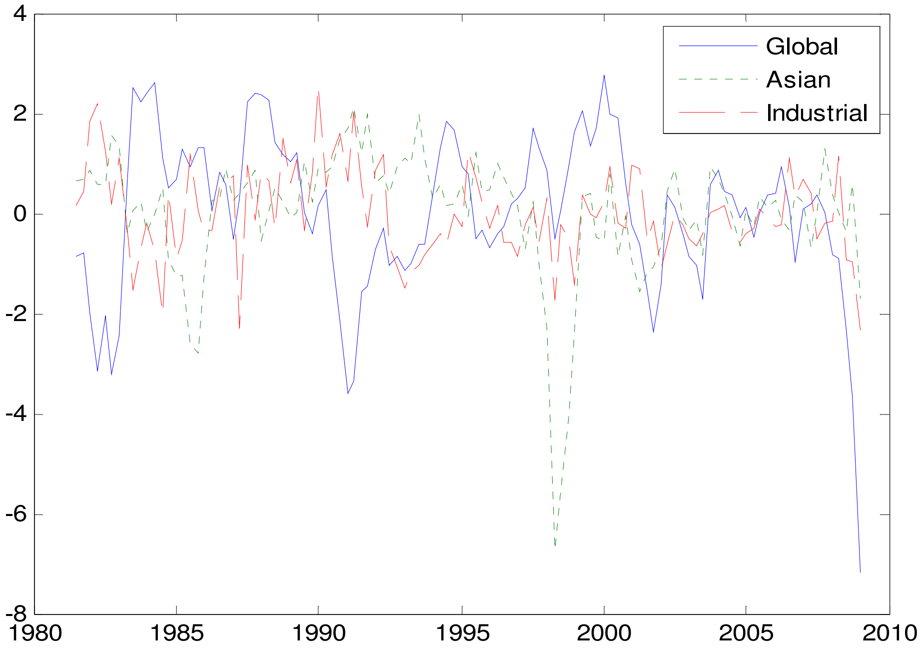
Table 2. The persistence of the factors, measured by the autocorrelations of the factors

Global Factor	Asian Regional Factor	Industrial-country factor
0.8788 (0.0692)	0.7352 (0.0857)	0.3947 (0.1716)

Table 3. The Variance matrix R

	Variance of the country cycles	Standard Error
HKSAR	0.66	0.0974
China, Mainland	0.9235	0.1256
Indonesia	0.5813	0.0924
Korea	0.6101	0.091
MYS	0.506	0.0846
PHL	0.9655	0.1302
SGP	0.5316	0.0838
TWN	0.768	0.1073
THA	0.7453	0.1075
JAP	0.6617	0.11
FRA	0.4427	0.0956
DEU	0.6929	0.1077
ITA	0.527	0.092
GBR	0.5773	0.086
CAD	0.3194	0.0753
USA	0.4337	0.0742

Figure 1. The estimated factors (full sample, 1981 Q2 to 2008 Q4)



For the industrial group, we notice that Canada and the US respond to the industrial factor in the opposite direction from the other industrial countries on our list, while the European countries respond to it positively, as indicated in Table 1. This suggests that the US and Canada might form a North America group, different from the other industrial countries. However, the industrial countries in our sample are only used to help identify the global factor, so that we can study the Asian region-specific factor independently from the global trend. Thus we don't go further to estimate the North American factor, but instead treat Canada and the US as members of our industrial group.

To measure business cycle synchronization, we conduct variance decomposition, and calculate the relative contributions to its total economic fluctuations by different factors for each country. Recall the growth rate of country i can be written in the following form:

$$y_{it} = \lambda_i^g g_t + \lambda_i^k f_t^k + u_{it}$$

Therefore

$$\text{var}(y_{it}) = (\lambda_i^g)^2 \text{var}(g_t) + (\lambda_i^k)^2 \text{var}(f_t^k) + \text{var}(u_{it}) \tag{19}$$

The contribution of the global factor to country i's GDP growth volatility is

$$\frac{(\lambda_i^g)^2 \, \mathrm{var}(g_t)}{\mathrm{var}(y_{it})}$$

The contribution of the regional factor to country i's GDP growth volatility is

$$\frac{(\lambda_i^k)^2 \, \mathrm{var}(f_t^k)}{\mathrm{var}(y_{it})}$$

The variance decomposition results are shown in Table 4. We find a strong world business cycle, which on average can explain 18% of output volatility. However, the global factor is less influential on Asian countries, explaining 9.5% percent output fluctuations on average, while it contributes nearly 29% of G-7's output volatility. There is some evidence supporting the argument that China is de-linked from other countries, in the sense that both Asian regional factor and global factor can only explain a small portion of its GDP volatility. However, the variance decomposition here is conducted using the full sample without considering the possible time-varying structure of business cycle co-movement, thus we will need to further investigate the evolution of the business cycle synchronization in subsamples.

Table 4. Variance decomposition
(full sample, 1981 Q2 to 2008 Q4)

	Global Factor	Asian Factor	Industrial Factor
HKSAR	0.134361	0.20784	0
China, Mainland	0.053874	0.01676	0
Indonesia	0.050741	0.33057	0
Korea	0.148865	0.24369	0
MYS	0.067456	0.38808	0
PHL	0.008727	0.01719	0
SGP	0.209354	0.27023	0
TWN	0.155146	0.08157	0
THA	0.030008	0.19842	0
JAP	0.118146	0	0.148223
FRA	0.26864	0	0.191863
DEU	0.12976	0	0.116887
ITA	0.255106	0	0.140516
GBR	0.363086	0	0.003836
CAD	0.466184	0	0.071234
USA	0.424718	0	0.033711
World Average	0.180261		
Asian group average	0.095392	0.194928	
G-7 Group average	0.289377		0.100896

b. Subsample Analysis

The above full sample estimation assumes that the factor structure and the loadings stay the same over the whole sample period. However, East Asia has been experiencing rapid economic growth and structural changes in many aspects, such as China's joining the WTO in early 2000, and the 1997 Asian financial crisis, etc. The possibility of time-varying synchronization pattern may lead to misleading results.

To study the time-varying property of business cycle synchronization, we conduct a preliminary subsample analysis by dividing the entire sample into two subsamples: 1981Q2 – 1994Q4, 1995Q1 –2008Q4. Lane and Milesi-Ferretti(2006a), and Fujiki and Terada-Hagiwara (2007) both document an accelerated financial openness around the middle of 90s worldwide. On the international trade side, East Asian countries have negotiated 25 free trade agreements (FTAs) since the mid-1990s. Since it also requires long enough time series to consistently estimate the model parameters given such a complex structure of the model, we slice our sample into two subsamples, with 1995Q1 as the break point. For each subsample, we re-estimate the whole model.

Figure 2 depicts the estimated factors for the sub-period of 1981Q2 to 1994Q4. Table 5 collects the results from variance decomposition, which measures the degree of synchronization in outputs. Figure 3 and the Table 6 are the counterparts for the second subsample, 1995Q1 to 2008Q4. Table 7 shows the evolution of the synchronization over the two sub-periods.

Figure 2. The estimated factors
(subsample 1981 Q2 to 1994 Q4)

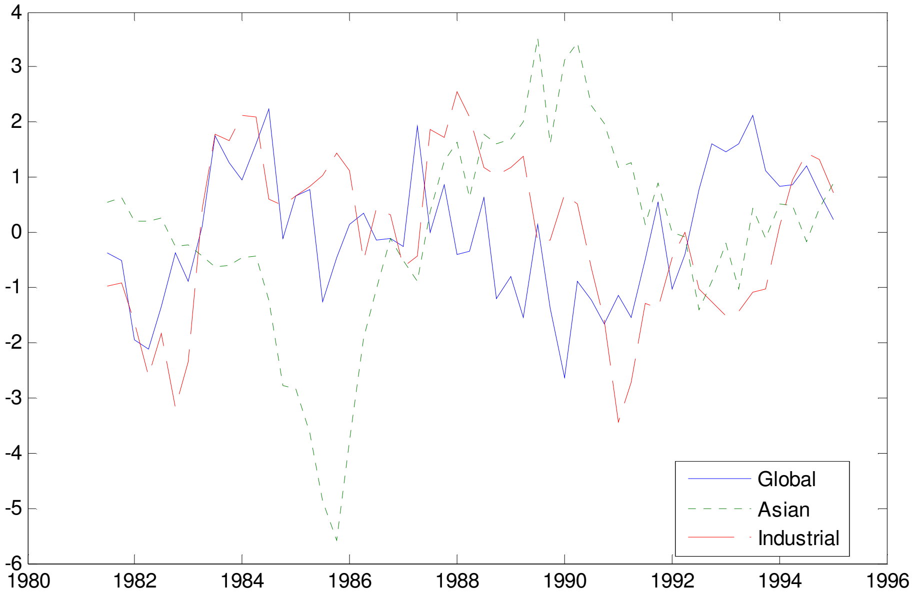


Figure 3. The estimated factors
(subsample 1995 Q1 to 2008 Q4)

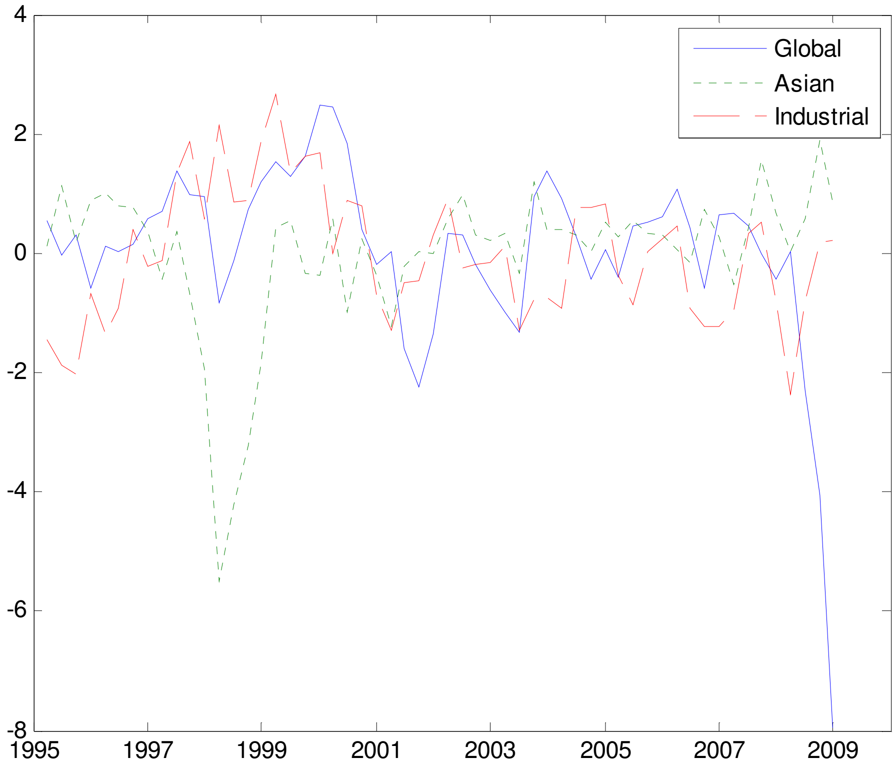


Table 5. Variance decomposition
(81 Q2 to 94 Q4)

	Global Factor	Asian Factor	Industrial factor
HKSAR	0.081861	0.027737	0
China, Mainland	0.178682	0.066211	0
Indonesia	0.080448	0.102722	0
Korea	8.49E-06	0.003558	0
MYS	0.068604	0.255522	0
PHL	0.038203	0.115668	0
SGP	0.186469	0.365573	0
TWN	0.012371	0.008046	0
THA	0.01075	0.12733	0
JAP	0.160566	0	0.134769
FRA	0.327157	0	0.247338
DEU	0.11471	0	0.142327
ITA	0.114548	0	0.338226
GBR	0.004476	0	0.205225
CAD	0.10444	0	0.355556
USA	0.095647	0	0.295648
World Average	0.098684		
Asian group average	0.073044	0.119152	
Industrial Group average	0.131649		0.245584

Table 6. Variance decomposition
(Subsample 95 Q1 to 08 Q4)

	Global Factor	Asian Factor	Industrial factor
HKSAR	0.324226	0.271917	0
China, Mainland	0.07529	0.033866	0
Indonesia	0.071715	0.407365	0
Korea	0.281181	0.237885	0
MYS	0.186563	0.420745	0
PHL	0.028385	0.050892	0
SGP	0.449832	0.155649	0
TWN	0.382041	0.022914	0
THA	0.039861	0.192248	0
JAP	0.463136	0	0.159249
FRA	0.491234	0	0.009361
DEU	0.378824	0	0.009651
ITA	0.350352	0	0.0187
GBR	0.660945	0	0.002592
CAD	0.333564	0	0.146754
USA	0.381905	0	0.03132
World Average	0.306191		
Asian group average	0.204344	0.199276	
Industrial Group average	0.437137		0.053947

Table 7. The evolution of synchronization

		1981Q2 – 1994Q4	1995Q1 – 2008Q4
HKSAR,	global	0.081861	0.324226
	regional	0.027737	0.271917
China, Mainland,	global	0.178682	0.07529
	regional	0.066211	0.033866
Asian group average,	global	0.073044	0.204344
	regional	0.119152	0.199276
Industrial group average,	global	0.131649	0.437137
	regional	0.245584	0.053947

We summarize the findings as follows.

First, the role played by the global factor intensified over the two subsamples. For both the Asian group and the industrial countries group, on average the variances explained by the global factor increase by a significant amount over time (from 7% to 20.4% for the Asian group, while from 13% to 43% for the G-7). This suggests a stronger global business cycle in the past 15 years.

Secondly, the Asian regional factor and the G-7 group factor show different performances. The contribution of the regional factors increased from 12% to near 19.9% (on average) for East Asian countries, while the G-7 factor's influence weakened substantially, from 24.6% in the first subsample to only around 5% in the later subsample. This is a very intriguing finding and would not have been obvious without analyzing the multi-level factor structure.

Suppose we do not separate the regional factor from the global factor, we will find that a common factor (a combination of regional factor and global factor) can account for 19% in Asian output growth fluctuation and 38% for the G-7 group during 1981 to 1995, while the numbers become 40% and 49% respectively in the second subsample. Those numbers are provided in Table 8. The G-7 group still exhibits a higher degree of business cycle synchronization than the East Asian group does in both subsamples. However, by looking into the different influences of the global factor and the regional factors, the picture changes greatly. The global factor's impact almost tripled for both groups from the first period to the second period, while Asian countries show a much tighter regional interdependence than the G-7 group does. This finding indicates that there is some unique underlying driving force within the East Asian region, apart from the common driving force towards greater globalization.

Table 8. The evolution of synchronization

		1981Q2 – 1994Q4	1995Q1 – 2008Q4	1981Q1 – 2008Q4
Asian group average,	global	0.073044	0.204344	0.095392
	regional	0.119152	0.199276	0.194928
	Total	0.192196	0.40362	0.29032
Industrial group average,	global	0.131649	0.437137	0.289377
	Regional	0.245584	0.053947	0.100896
	Total	0.377233	0.491084	0.390273

Thirdly, there is a significant degree of heterogeneity in how synchronised each individual Asian economy has been with the global and the regional common factors. Since the mid-1990s, Singapore has had the highest synchronisation with the global factor, and Malaysia has had the highest synchronisation with the Asian regional factor. In the case of China, contrary to the common perception that the Mainland economy has been heavily dependent on external demand, the role of both global factor and regional factor has diminished significantly, accounting for only 7.5% and 3% respectively after 1995, a drop from 18% and 6.6% respectively during 1981-1994. While this finding is consistent with our view that shocks hitting the Chinese economies are largely domestic and idiosyncratic, the very low contribution by the global and regional factors may be a reflection of data issues, in that only production-based GDP numbers are available at quarterly frequency in China, and they tend to be much smoother than expenditure-based quarterly GDP.

Another possible explanation of the low degree of synchronization between China and the both the world and regional cycles is that China's resilience against the adverse external shocks. As a sensitivity check, we re-estimate the model using data from 1999 Q1 to 2008 Q2, in which both the 1997 Asian Crisis and the recent financial crisis are excluded. The results are reported in Table 9. Indeed, we find that including the crisis period will result in a higher level of global synchronization of output, for both Asian economies and the G-7 countries. The results also show that the Asian regional factor can now explain around 22% of China's output fluctuations during 1999 Q1 to 2008 Q2 (crisis periods are exclude), while the global factor still plays a very insignificant role. Such a finding suggests that China may have stronger interaction with the Asian region during normal time while its seemingly delinking from other countries found in full-sample analysis may be also partly due to its resilience in the two crises.

Table 9. The crisis versus non-crisis period

	1981Q2 to 1994Q4		95Q1 to 08Q4		99Q1 to 08Q2 (excluding Crisis period)	
	Global	Regional	Global	Regional	Global	Regional
China	0.1787	0.0662	0.0753	0.0339	0.0923	0.2167
Asian Average	0.0730	0.1192	0.2043	0.1993	0.1234	0.1883
G-7 Average	0.1316	0.2456	0.4371	0.0539	0.2881	0.1364
World Average	0.0987		0.3062		0.2009	

How do our results compare with the findings in the earlier literature? Using annual data, Kose, Otrok and Prasad (KOP, 2008) find that the average contribution of the global factor to output growth fluctuations is 7% during 1985-2005, while we find a much higher number 18% for 1981 to 2008. The reason that we find a stronger global co-movement is that we cover the periods of the recent crisis. If drop the data after 2005Q4, the number decreases to 6%, which is close to what KOP (2008) finds. Similarly, we also find larger average contribution of the global factor within each group (9.5% versus 4% in KOP in the case of emerging markets, and 29% versus 9 in the industrial group), due to the same reason. Once the data after 2005 are dropped, our results are also close to their estimation (our 4.6% versus KOP's 4% for emerging markets, and 7.6% versus 9% for industrial group). Without including the recent financial crisis data, they find a much weaker global factor and dominate group-specific factors for each group, and conclude that there is evidence supporting the decoupling conjecture. As a sensitivity check, we estimate the model using data from 1999 Q1 to

2008 Q2, in which both the 1997 Asian Crisis and the recent financial crisis are excluded. We find a weaker global factor than in the sample including the crisis period, as expected. However, the global factor is stronger (explaining a higher share of output volatility) in the recent years than in the earlier period (before middle 90s).

The co-movement in underlying shocks

In this section, we report the results of our investigation into the co-movement in the underlying shocks in different economies. The supply shock has long run impact on output growth and can be interpreted as productivity shock, while the demand shock only affects the output temporarily and is conventionally considered caused by monetary policy shock or other short-lived factors. By studying the co-movement in different shocks, we can better understand the driving force behind output synchronization.

Theoretically, vertical trade across borders can affect business cycle synchronisation among the economies in the region through both the demand and the supply channels. On the demand side, since the regional production network is organised to serve a common market, common demand shocks that originate outside the region may lead to common movement of business cycles in the region. Therefore we should expect a higher degree of co-movement between the final market and the economies within the production chain when the vertical trade pattern becomes pervasive in the region.

On the supply side, the regional production network implies that producers along the production chain are pushed or pulled together toward the frontier of technology. For instance, a positive supply shock in one country on the fragmented production chain will lower the price of the intermediate goods used by other countries, causing the spillover of the positive supply shocks. Such supply side shocks may thus lead to higher synchronisation of business cycles among the economies that form the production network. Studying the co-movement in those underlying shock and its evolution pattern will help shed light on whether such theoretically hypotheses are valid.

To study the symmetry of the underlying shocks across economies, we take a two step approach. In the first step, we use the model 2 described in Section II to identify the demand shocks and supply shocks for each economy in our sample. However, the bilateral correlations of the demand shocks (or supply shocks) between two units could not capture the difference in global co-movement and regional symmetry. Therefore, in the second step, we employ the multi-level factor model again on the demand shocks (or supply shocks), and study the global and regional co-movement in the shocks as well.

Figure 4 and Figure 5 depict the estimated factors for demand shocks and supply shocks respectively. Again, the solid line represents the global factor; the dotted line describes the Asian regional factor: and the dashed line is the estimated G-7 group factor. Table 10 and Table 11 report the variance decomposition results, for demand shocks and supply shocks respectively.

Figure 4. Estimated factors for demand shocks
(full sample)

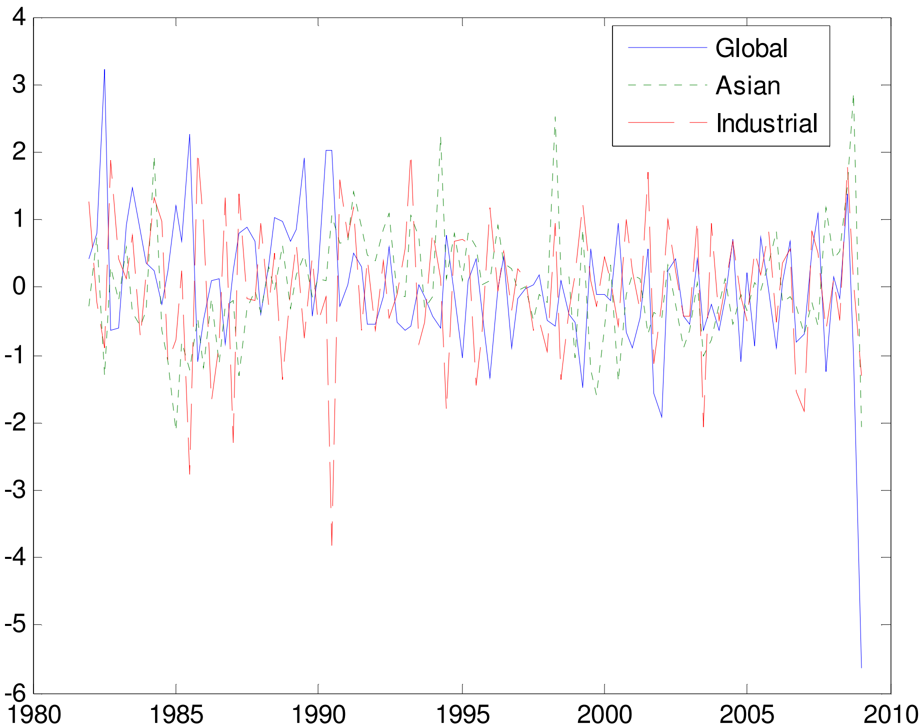


Figure 5. Estimated factors for supply shocks (full sample)

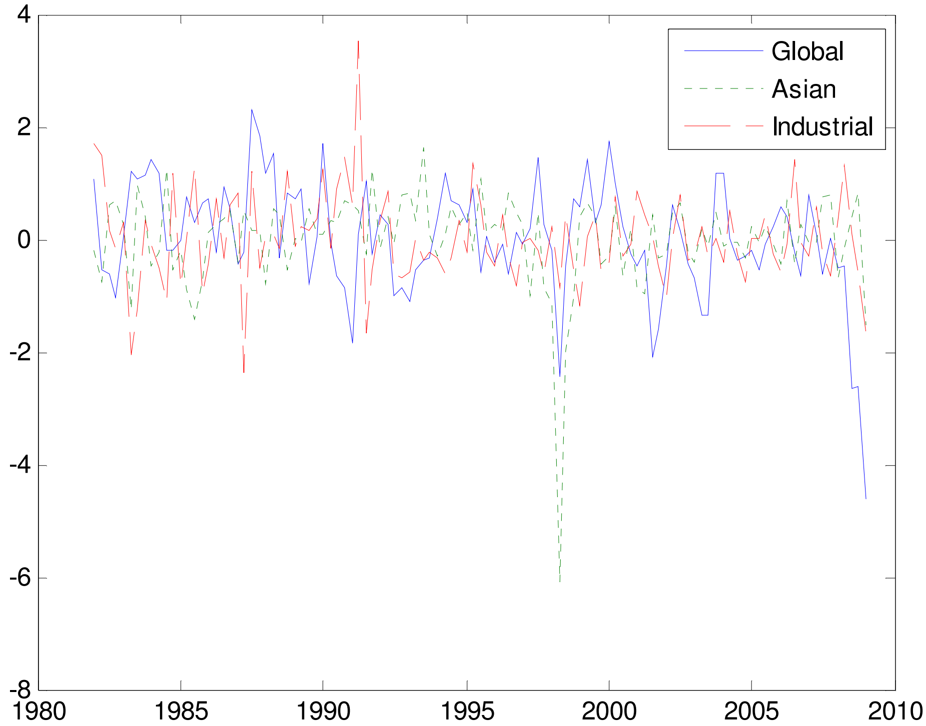


Table 10. Variance decomposition for demand shock (81 Q4 – 08 Q4)

	Global Factor	Asian Factor	Industrial factor
HKSAR	0.063091	0.0117345	0
China, Mainland	0.037977	0.0109517	0
Indonesia	0.001973	0.2201463	0
Korea	0.112531	0.1397670	0
MYS	0.035147	0.2888564	0
PHL	0.013875	0.0001812	0
SGP	0.00962	0.0799979	0
TWN	0.007174	0.1088068	0
THA	0.176658	0.0097215	0
JAP	0.05819	0	0.028969
FRA	0.356644	0	0.033961
DEU	0.151791	0	0.075172
ITA	0.025681	0	0.074302
GBR	0.681406	0	0.340761
CAD	0.442701	0	0.24406
USA	0.534826	0	0.097169
World Average	0.16933		
Asian group average	0.050894	0.0966848	
Industrial Group average	0.321606		0.127771

Table 11. Variance decomposition, supply shocks

	Global Factor	Asian Factor	Industrial factor
HKSAR	0.081767	0.059745	0
China, Mainland	0.018594	0.040611	0
Indonesia	0.028003	0.285397	0
Korea	0.154601	0.189863	0
MYS	0.041014	0.25718	0
PHL	0.001448	0.001205	0
SGP	0.085602	0.058968	0
TWN	0.118938	0.013661	0
THA	0.013487	0.043084	0
JAP	0.1434	0	0.068989
FRA	0.244421	0	0.024463
DEU	0.04047	0	0.121344
ITA	0.212708	0	0.068725
GBR	0.090178	0	0.000757
CAD	0.083118	0	0.265976
USA	0.05698	0	0.1139
World Average	0.088421		
Asian group average	0.060384	0.105524	
Industrial Group average	0.124468		0.094879

Furthermore, we conduct subsample analysis and re-estimate the models for demand shocks and supply shocks separately for the two sub-periods, 1981Q2 to 1994Q4, and 1995Q1 to 2008Q4 respectively. The results are collected in Table 12 and Table 13.

Table 12. Evolution of co-movement in demand shocks

		1981Q2 – 1995Q4	1995Q1 – 2008Q4	1981Q1 – 2008Q4
Asian group average,	global	0.037745	0.095653	0.050894
	regional	0.129421	0.127214	0.0966848
Industrial group average,	global	0.112882	0.392968	0.321606
	regional	0.079057	0.08968	0.127771

Table 13. Evolution of co-movement in supply shocks

		1981Q2 – 1995Q4	1995Q1 – 2008Q4	1981Q1 – 2008Q4
Asian group average,	global	0.022386	0.169345	0.060384
	regional	0.053581	0.120328	0.105524
Industrial group average,	global	0.161484	0.206125	0.124468
	regional	0.108793	0.101154	0.094879

We find that East Asian economies have had a sharply increased degree of synchronization in terms of the supply shocks in both the regional level and the global level after 1995. For the G-7 group, we only observe a slightly higher degree of synchronization with common supply shocks at the global level, with no significant change in the regional level co-movement. These findings are consistent with the theoretical prediction about the effect of vertical trade on the symmetry of supply shocks, given that the vertical trade has become particularly pervasive in East Asia since middle of 90s.

As for the demand shocks, we observe a much higher degree of demand shock co-movement at the global level for the G-7 group, in contrast to an unchanging role played by the group factor. A similar pattern is also observed for the Asian group. However, the magnitude of global demand factor's influence on Asian economies is much smaller than that on the G-7, with 3.8% and 9.6% respectively in the two sub periods for Asia, in contrast to 11% and 39% respectively for G-7. These findings imply that the observed synchronized business cycles within the East Asian economies have largely been due to more synchronized shocks from the productivity side. The common productivity shocks were likely to have arisen in the process of regional integration of production networks and supply chain management.

To access the explanatory power of supply and demand factors for each economy, we conduct the following regression for each economy:

$$y_t = c + \alpha_1 g_t^d + \alpha_2 g_t^s + \alpha_3 f_t^d + \alpha_4 f_t^s + \varepsilon_t \qquad (20)$$

The results are collected in Table 14. Almost all the coefficients of the regional supply factors are significant (except for Taiwan), with a magnitude much larger than the coefficients of the other factors. At the same time, most coefficients of the global supply factor are also significant, with only a few exceptions. However, both regional and global demand factors appear not having much explanation power for output fluctuations in most economies in our sample. This finding suggests that the regional supply factor is indeed the main driving force behind the economic fluctuations for each economy.

Table 14. Regress the output of each economy on the factors

	Global Demand Factor	Global Supply Factor	Group Demand Factor	Group Supply Factor
HKSAR	-0.157	0.735*	0.162	0.720*
	(0.158)	(0.154)	(0.181)	(0.179)
CHN	0.114	0.130	0.002	0.286*
	(0.095)	(0.092)	(0.108)	(0.107)
IDN	-0.085	0.321*	0.458*	1.431*
	(0.126)	(0.123)	(0.144)	(0.143)
KOR	0.163	0.790*	-0.120	1.160*
	(0.104)	(0.102)	(0.119)	(0.118)
MYS	-0.033	0.310*	0.360*	1.429*
	(0.108)	(0.106)	(0.124)	(0.123)
PHL	0.042	-0.082	-0.339	0.442*
	(0.223)	(0.218)	(0.255)	(0.253)
SGP	0.310*	0.718*	0.379*	0.734*
	(0.140)	(0.137)	(0.160)	(0.158)
TWN	0.135	0.711*	0.186	0.229
	(0.151)	(0.148)	(0.173)	(0.171)
THA	0.036	0.350*	-0.133	0.802*
	(0.193)	(0.188)	(0.220)	(0.218)
JAP	0.130	0.491*	-0.036	0.409*
	(0.079)	(0.074)	(0.072)	(0.092)
FRA	0.016	0.329*	-0.008	0.152*
	(0.036)	(0.033)	(0.032)	(0.042)
DEU	-0.013	0.297*	0.026	0.841*
	(0.115)	(0.107)	(0.104)	(0.134)
ITA	-0.041	0.477*	-0.013	0.314*
	(0.050)	(0.047)	(0.045)	(0.058)
GBR	0.163*	0.270*	-0.166*	-0.100*
	(0.045)	(0.042)	(0.041)	(0.053)
CAD	0.088*	0.378*	0.124*	--0.540*
	(0.048)	(0.045)	(0.044)	(0.057)
USA	0.171*	0.301*	0.025	-0.396*
	(0.053)	(0.050)	(0.048)	(0.062)

Note: * significant at 10% level.

IV. CONCLUSIONS

In this paper we have studied Asian business cycle synchronization in the framework of a multi-level factor model. Using quarterly data of sixteen economies' real GDP growth, we identified a global factor and two regional factors. We find that the effects of these factors on output fluctuations in individual Asian economies have been rather heterogeneous. While the role of the global common factor has intensified over the past fifteen years for most of the economies, output fluctuations in Asia have remained less synchronised with the global common factor than the industrial countries. The Asian regional factor has become increasingly important in tightening the interdependence within the region over time, while the co-movement among the G-7 economies has been mainly driven by the global factor.

Through a further investigation of the co-movement of underlying structural shocks, we find that synchronised supply shocks contributed more to the observed synchronization in output fluctuations among the Asian economies than demand shocks. This points to the role of productivity enhancement through vertical trade integration, rather than dependence on external demand, as the primary source of business cycle synchronisation in Asia.

While these findings are fresh, interesting and have rich policy implications, they also leave many questions remaining to be answered. In particular, we need to understand better the transmission mechanisms through which the global factor and the regional factor drive output fluctuations in individual economies. How important were oil price shocks in driving output fluctuations in Asia? Were such shocks demand shocks or supply shocks? What is the relative importance of trade linkages as compared to financial market linkages in driving business cycle synchronisation in the region? Has China become an independent growth engine for the Asia region? These are important questions for future research.

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