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A Bayesian Approach to Optimum Currency Areas in East Asia

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Abstract

This paper assesses the empirical desirability of the East Asian economies to an alternative exchange rate arrangement (a monetary union) that can potentially enhance the exchange rate stability and credibility in the region. Specifically, the symmetry in macroeconomic disturbances of the East Asian economies is examined as satisfying one of the preconditions for forming an Optimum Currency Area (OCA). We extend the existing literature by improving the methodology of assessing the symmetry shocks in evaluating the suitability of a common currency area in the East Asian economies employing the Bayesian State-Space Based approach. We consider a model of an economy in which the output is influenced by global, regional and country-specific shocks. The importance of a common regional shock would provide a case for a regional common currency. This model allows us to examine regional and country-specific cycles simultaneously with the world business cycle. The importance of the shocks decomposition is that studying a subset of countries can lead one to believe that observed co-movement is particular to that subset of countries when it in fact is common to a much larger group of countries. In addition, the understanding of the sources of international economic fluctuations is important for making policy decisions. Our findings also indicate that regional factors play a minor role in explaining output variation in both East Asian and the European economies. This implies that while East Asia does not satisfy the OCA criteria (based on the insignificant share of regional common factor), neither does Europe.

Keywords: Optimum Currency Area; Business Cycle Synchronisation, Monetary Integration; East Asia
JEL codes: E3, F1, F4

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1. Introduction

East Asia was late in jumping onto the regionalism bandwagon in comparison with the European and North American countries. The first Regional Trade Arrangements in East Asia only existed in 1977 when Association of Southeast Asian Nations (ASEAN)[2] reached an agreement on its Preferential Trading Arrangements. Several further attempts to forge closer economic integration amongst the East Asian countries during the 1990s were unsuccessful. Most researchers identified three major reasons for the sudden interest in East Asia for greater economic integration: (1) the failure of the World Trade Organisation (WTO) and Asia-Pacific Economic Cooperation (APEC) to make any significant headway on trade liberalisation. (2) the widening and deepening economic integration in Europe and North America; and (3) the Asian Financial crisis.

East Asian countries have reassessed their strategies towards further trade liberalisation after the failure to launch a new round of trade negotiations during the WTO Ministerial Meeting in Seattle. If the global trading system does not continue to liberalise, the region may be affected negatively as many of the East Asian countries depend on export to sustain their economic growth.[3] Hence, the perception that a new round of WTO trade negotiations had failed to materialise due to a lack of enthusiasm and political will in both the US and Europe has fueled concerns among the East Asian countries about the direction that the global trading system is heading. In Europe, the European Union (EU) has expanded into Central and Eastern Europe and will be progressing into greater monetary union. In the United States (US), North American Free Trade Area (NAFTA) and Latin American countries are heading towards greater economic integration.

[2] Comprising only the founding members: Indonesia, Malaysia, the Philippines, Singapore and Thailand.
[3] Bergsten (2000).

On the monetary side, the single greatest push for East Asian regionalism was Asian crisis, sparked in mid-1997 by the devaluation of the Thai baht, and the related global financial crisis, triggered by the Russian debt default in August 1998, shook the foundations of the international monetary system. Many East Asian countries felt that they were let down by the West during the crisis. In their view, western banks and other financial institutions had created and exacerbated the crisis by pulling out their funds from the region. The leading financial powers then either declined to take part in the rescue operations (as was the case of US with Thailand) or built in excessively stringent demands into their financial assistance programs. At the same time, there was a negative perception among East Asian countries that the International Monetary Fund (IMF) and the US were dictating their policy responses to the crisis by controlling their access to funds and private capital markets (Yip, 2001). This resentment was further fuelled by the widespread view that the IMF's rescue programs had worsened the situation for the East Asian economies by pushing them into a deeper economic recession than was necessary to begin with (Bergsten, 2000). Whether these views were justified, the East Asian countries have decided that they do not want to be beholden to the West should a crisis recur in the future (Yip, 2001). The idea of a common currency for APT became popular after the Asian Financial Crisis 1997. Currency stability was identified as important to avoiding future financial crises and greater monetary and exchange rate cooperation is called for in the Chiang Mai Initiative 2000 in Thailand.

After the Chiang Mai Initiative in 2000 that established a regional currency-swap facility, the idea of a single currency for East Asia was created. There are also efforts beyond the Chiang Mai Initiative to coordinate macroeconomic and exchange rate policies. An ASEAN Task Force on ASEAN Currency an Exchange Rate Mechanism was established in March 2001.[4]

[4] The Task Force completed the study in September 2002 and it was presented at the meeting of the ASEAN Central Bank and Finance Deputies in Myanmar in October 2002.

In addition, the Kobe Research Project is conducted to provide stimulus to this work through studies exploring ways and means to improve regional monetary and financial cooperation. Although the progress and commitment in monetary cooperation in East Asia has been encouraging, much remains to be accomplished.

Robert Mundell's OCA theory has been widely used to assess the suitability of the EU to form a monetary union. Although there has been increasing interest among the researchers to examine the suitability of East Asian countries for a common regional currency, most of the related studies have been based primarily on inappropriate econometrics techniques. Simple correlation between countries is mainly used to measure the degree of shock symmetry in the OCA literature. The correlation is usually calculated between a country and a chosen anchor country. Lee *et al*. (2002) provided some disadvantages of bilateral measures in the following reasons: (1) the degree of region-wide co-movements, rather than bilateral ones provides a more appropriate measure since we are interested in the net benefits of adopting a common monetary policy across economies in the region; (2) the simple correlation does not offer the sources of the shocks, there may be the third factor such as the world common shocks that induce a high correlation between countries; (3) there is no single country plausibly offers a regional anchor.[5]

Another celebrated technique in OCA literature is Bayoumi's structural VAR technique. The first stage of this technique consists of running a national VAR of changes of output and prices. To identify the coefficients of the structural form, Bayoumi assumed the orthogonality of supply and demand shocks that only supply shocks are able to affect the level of output, and that demand shocks are temporary. This approach comes with several

[5] In Europe, Germany is generally perceived as the regional anchor. In East Asia, however, there is no country which can play such similar role.

caveats. First of all, if the logs of output and prices in quarterly format are cointegrated in several of the countries of the sample, the coefficients of the VAR are asymptomatically biased. In addition, as Bayoumi recognises, neither the orthogonality of supply and demand shocks nor the short duration of demand shocks are uncontestable assumptions. A shock to terms of trade would affect both aggregate supply and demand. In economies with high unemployment rates, demand shocks can be expected to have effects that are highly persistent, if not permanent. Bayoumi and Eichengreen (1994) argued that only supply shocks are crucial disturbances to which independent monetary policy wishes to respond. Many researchers see little justification that only supply shocks matter.[6] They argue that there may not be much room left for the policy makers to react to if supply shocks are permanent shocks. In addition, if demand shocks do not originate from policy implementations, the monetary policy authority may wish to counteract to these disturbances. The existing methodologies also fail to recognise the sources of the shocks. For instance, one does not know whether the economic fluctuations of a country are accounted by the country specific, regional or the world common factors.

In the business cycle literature, there exists a new strand of methodology that allows the analysis at a disaggregated level using the Bayesian State-Space Model. However, such methodology is mainly used to analyse the business cycles in the Western countries. Very few, to our knowledge, have applied it in the OCA context. We propose to employ this model which allows us to decompose aggregate shocks into country-specific, regional and world common business cycles. The importance of studying all three in one model is that studying a subset of countries can lead one to believe that observed co-movement is particular to that subset of countries when it in fact is common to a much larger group of countries. For example, Kose *et al.* (2003) find that the distinct "European" business cycle in

[6] Among others, see Lee *et al*. (2002).

the European countries is due to co-movement common to all countries in the world. Understanding the sources of international economic fluctuations is important for making policy decisions. For example, if a country exhibits a large value of the share accounted by the region common factor, then its business cycle movement is largely synchronised to the region, indicating that a regional common monetary policy is more effective to respond to the disturbances. However, if a country possesses a smaller value of the share accounted for by the region common factor and a larger value of that accounted for by the country-specific factor, it needs to rely more heavily on its own independent counter-cyclical monetary policy. Unlike previous studies that examine only the degree of correlations of business cycle among countries, our study enables us to identify the sources of the economic fluctuations for each country. As a result, composition of the shocks in East Asia will be identified and appropriate policy actions can be undertaken accordingly.

2. The Suitability of East Asian Countries for A Common Currency – A Literature Review

The symmetry of underlying shocks among the East Asian countries provides one of the preliminary guides in identifying potential members for monetary union. The rationale is that countries experiencing similar disturbances are likely to respond with similar policies, thus making them better candidates for forming a monetary union. The estimation of the incidences of macroeconomic disturbances is inherently empirical. One of the first empirical papers to have dealt with the issue of macroeconomic disturbances through a statistical approach is by Bayoumi and Eichengreen (1993, 1994). Applying a variant of the VAR methodology proposed by Blanchard and Quah (1989), Bayoumi and Eichengreen (1993) assessed the nature of macroeconomic disturbances among different groups of countries. Bayoumi and Eichengreen (1994) showed that supply shocks are symmetrical among (1) Japan, South Korea and Taiwan and (2) Hong Kong, Indonesia, Malaysia and Singapore.[7] Demand shocks are found to be highly symmetrical for the latter group of countries. Based on the OCA criterion of symmetry in underlying disturbances, they conclude that these two groups of countries are likely to form separate OCAs. Their results on the correlation, size and speed of adjustment to underlying disturbances for Asia are updated in Bayoumi, and Mauro (1999).[8] It is concluded that aggregate supply disturbances affecting Indonesia, Malaysia and Singapore are reasonably correlated, while the Philippines and Thailand experience more idiosyncratic shocks.[9] Their study also reports that, (1) size of the disturbances experienced by the Asian economies is considerably larger than that of the equivalent shocks for Europe[10]; (2) the speed of adjustment in Asia (and ASEAN in particular) is much more rapid than in Europe. Based on economic criteria, the authors conclude that ASEAN is less suitable for a currency union than the continental European countries were in 1987 (a few years before the Maastricht treaty providing a road map for EMU was signed), although the difference is not very large.[11]

Using a different methodology from Bayoumi and Eichengreen (1994), Wyplosz (2001) identifies shocks as the residuals from simple AR(2) regressions of real GDP for the Asian, European, Australia and New Zealand countries using annual data over the period 1961-1998.[12] He finds that shocks in European countries are significantly more correlated

[7] Bayoumi and Mauro (1999) argue that aggregate supply disturbances are generally more relevant than aggregate demand disturbances, because aggregate supply disturbances are more related to private sector behaviour rather than the impact of macroeconomic policies.
[8] The updated Asian results use data from 1968 to 1998, compared to a sample period of 1969-1989 used in the European results reported.
[9] The authors claim that there are parallels with Europe, where the shocks experienced by France and Germany are relatively highly correlated, while those affecting Italy and Spain were more idiosyncratic.
[10] This also occurs when the sample period excludes the Asian crisis (1997 and 1998).
[11] The authors view firm political commitment as vital in forming a regional currency arrangement.
[12] The Asian countries under study include: China, Hong Kong, Indonesia, Japan, Korea, Malaysia, the Philippines, Singapore, Taiwan and Thailand.

than shocks in Asian countries.[13] It is reported that Korea, Malaysia and Thailand seem to be more correlated with Japan. As recognized by the author, the difference between his results and Bayoumi-Eichengreen's (1994) results can be due to the different methodology or to the sample period (Bayoumi and Eichengreen's sample covers from 1972 to 1989).[14] Most empirical analyses based on the theory of optimum currency areas, including those of Taguchi, and Bayoumi and Eichengreen (1994) and Wyplosz (2001) cited above, have focused on the costs of monetary integration and studied the correlation of various macroeconomic variables among the Asian countries. In an effort to combine the various criteria for a monetary union, Bayoumi and Eichengreen (1999) developed an "OCA index" that predicts the expected level of exchange rate variability for various Asian countries.[15] They derive the index from the results of a cross-sectional regression covering advanced and East Asian economies that relates observed exchange rate variability to four optimum currency indicators. The independent variables are: (i) the standard deviation of the difference in growth rates across the two economies; (ii) the dissimilarity of the composition of trade; (iii) the level of bilateral trade; and (iv) the size of the two economies. The first two indicators are proxies for the costs associated with asymmetric shocks, the second two for the benefits from stabilizing exchange rates with close trading partners and across larger groupings. Based on the OCA index, the authors report that the following country pairs achieve scores comparable to those in Western Europe: Singapore-Malaysia, Singapore-Thailand, Singapore-Hong Kong, Singapore-Taiwan, and Hong Kong-Taiwan.[16] However, Indonesia, South Korea and the Philippines do not rank well, and the Malaysia-Thailand pair displays a very weak score.

[13] Since the author also find that trade integration is deeper in Asia than it is in Europe, it can be concluded that a high degree of trade integration does not translate into strong output correlations.
[14] Bayoumi and Eichengreen (1994) find little difference between Europe and Asia for both supply and demand shocks. Besides, different country groupings are identified.
[15] The East Asian countries are Japan, Hong Kong, Korea, Singapore, Taiwan, Indonesia, Malaysia, the Philippines and Thailand (covering the sample period from 1976 to 1995).
[16] These are the cases where the value of the OCA index approaches Western European levels.

These studies are based on historical data before monetary integration. However, the correlation relations may change after monetary integration as exchange rate fluctuations among member countries are eliminated.[17] The behaviour of economic agents and the government will be altered. In a study to examine the possibility of forming a Yen bloc in Asia, Kwan (1998) stresses the importance of using correlation of economic structures and of policy objectives as OCA criteria since they are less dependent on the exchange-rate system. He quantifies the degree of similarity in the economic structures of two countries in terms of the correlation coefficient between vectors showing their respective share composition of trade (imports and exports) classified by product[18]. Such correlation coefficient can also be used as an indicator of the degree of competition (or complementarity) in the trade structures of two countries. It is found that countries with similar per capita incomes tend to have similar trade structures since the latter is closely related to the level of economic development. Kwan finds that trade structures in Asian countries are less similar than the trade structures of West European countries.[19] By comparing inflation rates (to examine the similarity of policy objectives among nations), the author finds that East Asia qualifies as an optimum currency area as much as West Europe[20,21]. Therefore, by the "similarity in inflation rate" criterion, low-inflation countries such as Singapore, Taiwan, Malaysia, Thailand, and South Korea, which also belong to the higher income group, are more appropriate candidates for forming a yen bloc.

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[17] Kwan (1998) illustrates this by noting the relations between Japan and South Korea. With South Korea belonging to the dollar bloc, fluctuations in the yen-dollar rate affect Korea and Japan asymmetrically. An appreciation of the yen, for example, will increase the inflation and economic growth for South Korea but reducing the inflation and economic growth for Japan. If Japan and South Korea form a monetary union, however, such asymmetric shock would be eliminated and the correlation of economic growth rates and of inflation rates between the two countries would increase.

[18] The bilateral correlation coefficients are calculated based on the three-category classification for exports and imports, namely primary commodities, machinery, other manufacturers.

[19] The 45 correlation coefficients for the 10 Asian countries (Korea, Taiwan, HK, Singapore, Indonesia, Malaysia, Philippines, Thailand, China and Japan) averaged 0.28 while the 55 correlation coefficients for the 11 West European countries (U.K., France, Italy, Belgium, Netherlands, Denmark, Ireland, Spain, Portugal and Greece) averaged 0.52.

[20] Kwan (1998) reports that between 1982 and 1996, the inflation rate of the Asian countries averaged 5.8% a year, marginally lower than the 6.1% annual average for the West European countries. The standard deviation showing the dispersion of inflation rates among countries is also smaller for East Asia than for West Europe.

[21] The author also notes that inflation rates among the West European countries have shown signs of convergence in recent years as they move closer to a monetary union.

3. Methodology

The econometric model employed here follows the dynamic unobserved factor model in Kose *et al.* 2003), which is an extension of the single dynamic unobserved factor model in Otrok and Whiteman (1998). The world economy consists of many different regions and each region consists of many different countries. The movement of an aggregate output in each country *i* is decomposed into three different components: (i) the world common component, (ii) the region common component and (iii) the country-specific component. Every country in the world is influenced by the world common, while the region common component influences only the countries belonging to the same region. The influence of country-specific component is restricted to the specific country. For example, the output of Malaysia fluctuates due to shocks to the world economy, shocks to the East Asian region or Malaysia-specific shocks.

We should recognise that it is not a threshold question that East Asia's business cycle synchronisation must pass a certain value in order to satisfy the OCA criteria. In fact, there are no exact empirical standards set for the OCA criteria and researchers can only make their own judgments based on the empirical results. The Euro Area, the first region in the world to adopt a single currency, should be used as the benchmark for any regions who are interested to form a monetary union. In this paper, the benchmarks of the comparison are the European Union and the North American countries.[22]

In our model, there are *K* dynamic, unobserved factors thought to characterise the temporal comovement in the cross-country panel of economic time series. Let $Y_{i,t}$ denote a

[22] Refer to Appendix for a list of the countries in these regions.

measure of observable aggregate output at time t for country i, N denote the number of countries, M the number of time series per country, and T the length of the time series.

The output series for each country is decomposed into three separate components:

$$Y_{i,t} = a_i + b_{wi} Y_t^W + b_{ri} Y_t^R + b_{ni} Y_t^N + \varepsilon_{i,t} \quad (1)$$

$$E\, \varepsilon_{i,t}\, \varepsilon_{j,t-s} = 0 \text{ for } i \neq j$$

Let Y_t^W (world common factor) be an unobservable component of world economic activity common to all the countries; Y_t^R (region common factor) be an unobservable component common to each country belonging to the same region R and Y_t^N be an unobservable component of country specific factors. There are three regions considered: East Asia, Europe and North America areas. If R = 1, that country belongs to East Asia, if R = 2, it belongs to the Europe, and if R = 3, it belongs to North America.

The coefficients, b_{wi}, b_{ri} *and* b_{ni} are the impact coefficients on factors Y_t^W, Y_t^R and Y_t^N, reflecting the degree to which variation in y_i can be explained by each factor. The impact coefficients are allowed to differ across countries since the world common and the region common factors have different influences on each country. There are $M \times N$ time series to be "explained" by the (many fewer) $N+R+1$ factors. The "unexplained" idiosyncratic errors $\varepsilon_{i,t}$ are assumed to be normally distributed, but may be serially correlated and are modeled as p_i - order autoregressions:

$$\text{ø}_i(L)\varepsilon_{i,t} = u_{i,t} \quad (2)$$

or $\text{ø}_i(L) = 1 - \text{ø}_{i,1} L - \text{ø}_{i,2} L - \ldots - \text{ø}_{i,p_i} L^{p_i}$

is a polynomial in the lag operator L; $Eu_{i,t}\, u_{j,t-s} = \sigma^2_i$ for $i = j$ and s = 0, 0 otherwise.

The evolution of the unobserved factors is likewise governed by an autoregression of q_i - order with normal errors:

$$f_{k,t} = \varepsilon_{f_k,t} \tag{3}$$

$$\varepsilon_{f_k,t} = \o_{f_k,1}\,\varepsilon_{f_k,t\text{-}1} + \o_{f_k,2}\,\varepsilon_{f_k,t\text{-}2} + \ldots + \o_{f_k,\mathrm{q}_k}\,\varepsilon_{f_k,t\text{-}\mathrm{q}_k} + \mathrm{u}_{f_k,t} \tag{4}$$

$E\,u_{f_k,t}\,u_{f_k,t\text{-s}} = \sigma^2_{f_k}$ for $s = 0;\ 0$ otherwise

$E\,u_{f_k,t}\,u_{i,t\text{-s}} = 0$ for all $k,\ i$ *and* s.

As in Otrok and Whiteman (1998), all the innovations, $u_{i,t}$, $i = 0, \ldots, M\times N$ and $u_{fk,t}$, $k = 1,\ldots,K$ are assumed to be zero mean, contemporaneously uncorrelated normal random variables; that is $u_{i,t} \sim N(0, \sigma^2_i)$ and $u_{f_k,t} \sim \mathrm{N}(0, \sigma^2_{f_k})$. Thus all comovement is mediated by the factors, which in turn all have autoregressive representations (of possibly different orders).

There are two related identification problems arise for the model[23] (1)-(4): the signs and the scales of the dynamic factors (Y_t^W, Y_t^R and Y_t^N) and the impact coefficients (b_{wi}, b_{ri} *and* b_{ni}) cannot be separately identified. Following Otrok and Whiteman (1998), signs are identified by requiring one of the impact coefficients to be positive for each of the factors. In particular, b_{wi} (impact coefficient for the world factor) for the US output; country factors are identified by positive impact coefficients for output for each country, and the regional factors are identified by positive coefficients for the output of US for the North America region; Germany for the Europe region; and Singapore for the East Asian region.[24] Scales are identified following Sargent and Sims (1977) and Stock and Watson (1989, 1992, and 1993) by assuming that each $\sigma^2_{f_k}$ is equal to a constant.

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[23] These problems are also recognised by Otrok and Whiteman (1998) and Kose *et al.* (2003).

[24] In Kose *et al.* (2003), regional factors are identified by positive coefficients for the output of US for the North America region; Cameroon for the Africa region; Costa Rica for the South America region; France for the Europe region, Bangladesh for the Asia (poor) region; Hong Kong for the Asia (rich) region and Australia for the Oceania region.

However, the dynamic factors (Y_t^W , Y_t^R and Y_t^N) are unobservable, traditional methods cannot be employed and special methods must be used to estimate the model. Gregory *et al.* (1997) follow Stock and Watson (1989, 1992 and 1993), using classical statistical techniques employing the Kalman filter for estimation of the model parameters, and the Kalman smoother to extract an estimate of the unobserved factor. They treat a related model as an observer system. Otrok and Whiteman (1998) used an alternative model based on a recent development in the Bayesian literature on missing data problems called "data augmentation" (Tanner and Wong, 1987).

Under a conjugate prior, the model (1)-(4) would be a simple set of regressions with Gaussian autoregressive errors if the factors were observable. This structure can be used to determine the conditional (normal) distribution of the factors given the data and the parameters of the model. It is then straightforward to generate random samples from this conditional distribution. These samples will then be used as stand-ins for the unobserved factors. The essential idea is to determine posterior distributions of all unknown parameters conditional on the latent factor, and then if the conditional distribution of the latent factor given the observables and the other parameters is available, the joint posterior distribution of the unknown parameters and the unobserved factor can be sampled using a Markov Chain Monte Carlo procedure on the full set of conditional distributions.

We start sampling by taking starting values of the parameters and factors as given and follow the following steps:

(i) Sample from the posterior distribution of the parameters conditional on the factors;

(ii) Sample from the distribution of the world factor conditional on the parameters and the country and regional factors;

(iii) Sample each regional factor conditional on the world factor and the country factors in that region;

(iv) One step of the Markov Chain is completed by sampling each country factor conditioning on the world factor and the appropriate regional factor.[25]

This sequential sampling of the full set of conditional distributions is known as "Gibbs sampling" (See Chib and Greenberg, 1996; Geweke, 1997). Technically, our procedure is "Metropolis within Gibbs" (Kose *et al.*, 2003), as one of the conditional distributions – for the autoregressive parameters given everything else – cannot be sampled from directly. As in Otrok and Whiteman (1998) and Kose *et al.* (2003), we follow Chib and Greenberg (1996) in employing a "Metropolis-Hastings" procedure for that block. Given the bounded likelihood and proper priors that are used in the model, the joint posterior is well behaved, and thus the regularity conditions of Geweke (1997), Tierney (1994), and Chib and Greenberg (1996) apply, and the procedure produces a realisation of a Markov chain whose invariant distribution is the joint posterior of interest.

Let φ denote the set of parameters $(a_i, b_{wi}, b_{ri}, b_{ni}, \sigma_i^2, ø_{ij,})$ $i = 1,\ldots,n$. We then proceed in the following two steps:

(i) Describe analysis of the posterior of φ conditional on the dynamic factors by applying Chib and Greenberg's (1994) procedure in estimating regression models with AR errors.

(ii) Determination and analysis of the conditional distribution of the factors given φ using Otrok and Whiteman's (1998) procedure.

Following Kose *et al.* (2003), we measure the relative contributions of the world, region, and country factors to variations in aggregate output in each country by estimating

[25] Note that the sampling order within each step is irrelevant. Kose *et al.* (2003) experimented with changing the order, and the results obtained were indifferent.

the share of the variance of the output aggregate due to each factor. Since the world common, the region common, and the country-specific factors are orthogonal, the variance of aggregate output for country *i* can be decomposed into:

$$Var\left(Y_{i,t}\right)=\left(b_{wi}\right)^2 Var\left(Y_t^W\right)+\left(b_{ri}\right)^2 Var\left(Y_t^R\right)+\left(b_{ni}\right)^2 Var\left(Y_t^N\right)+Var\left(\varepsilon_{i,t}\right)$$

Let S_i^f denote the share of the variance of aggregate output for country *i* accounted for by variation in the factor $f = W, R, N$.

$$S_i^f=\frac{\left(b_{fi}\right)^2 Var\left(Y_t^f\right)}{Var\left(Y_{i,t}\right)}$$

These measures can be calculated at each pass of the Markov chain. The estimates of the shares accounted for by the world common, the region common and the country-specific factors will play a crucial role in evaluating if countries belonging to the same region are eligible to form a regional currency arrangement. Especially a large value of the share accounted for by the region common factor – capturing how symmetric shocks are within a region – constitutes a *prima facie* case for a currency union.

4. Markov Chain Monte Carlo (*MCMC*) Diagnostics and the Test for Heteroskedasticity

The fact that the state of the Gibbs sampler at draw '*s*' (i.e. $\theta^{(s)}$) depends on its state at draw '*s*-1' (i.e. $\theta^{(s-1)}$) means that the sequence is a Markov chain. Such posterior simulators have the general name of *MCMC* algorithms. Associated with these are numerous measures of the approximation error in the *MCMC* algorithm and various other diagnostics to see whether the estimated results are reliable. These are called the *MCMC* diagnostics. We employ such commonly used diagnostics as the numerical standard error (*NSE*), convergence diagnostic

(*CD*), estimated potential scale reduction and the highest potential density intervals (*HPDI*). In practice, there are numerous computer programs for these diagnostics available over the web. We employ James LeSage's Econometrics Toolbox (LeSage, 1999) using *MATLAB*.[26] We have passed all the above mentioned convergence diagnostics, confirming that the posterior simulators are working well and the number of draws is sufficient to achieve the desired degree of accuracy.[27] The results of these MCMC diagnostics are reported from Table 1 to Table 7.

4.1 Numerical Standard Error (NSE)

The *NSE*s columns presented in Table 4.1, 4.2 and 4.3 represent the approximation of $E(\beta_i | y)$, $E(\sigma_i^2 | y)$ and $E(\phi_i | y)$ for i =1, 2,…, 28 (denoting the number of countries in this study).

[Insert Table 1 here]

[Insert Table 2 here]

[Insert Table 3 here]

These tables present the results of posterior means, standard deviation and the *NSE*s based on the assumptions of no serial correlation, 4% autocovariance taper, 8% autocovariance taper and 15% autocovariance taper. For instance, the *NSE* relating to the estimation of $E(\beta_1 | y)$ is 4.80×10^{-4}, $E(\sigma_1^2 | y)$ is 8.09×10^{-8} and $E(\phi_1 | y)$ is 9.19×10^{-4}. The results indicate that we are achieving reasonably precise estimates.

[26] Other available programs for the same purpose include *BUGS* and *BACC*.
[27] The MCMC results are available upon request.

4.2 Convergence Diagnostic (CD)

As pointed out by Koop (2003), the Gibbs sampler may yield misleading results if the initial replication is extremely far away from the region of the parameter space where most of the posterior probability lies. The *CD* will detect this problem as the draws are divided into 3 sets and the estimation based on the first half of the draws should be essentially the same as the estimate based on the last half. We follow the standard practice of setting S_A = 0.1S_1, S_B = 0.5S_1 and S_C = 0.4S_1. The reported results are based on S_1=100,000; therefore S_A=10,000, S_B=50,000 and S_c=40,000. Since *CD* is asymptotically standard Normal, a common rule is that if *CD* is less than 1.96 in absolute value for all parameters, we can conclude that convergence of the *MCMC* algorithm has occurred.

[Insert Table 4 here]

Table 4 shows the Geweke's *CD* for all the parameters β_i, σ_i^2 and ϕ_i. The figures shown in the table compares the estimation based on the first 10,000 replications (after the burn-in replications) to that based on the last 40,000 replications. It is evident that *CD* is less than 1.96 in absolute value for all parameters in Table 4. We can therefore conclude that the initial condition has vanished and an adequate number of draws have been taken. In other words, the *MCMC* algorithm has converged.

4.3 Highest Posterior Density Intervals (HPDI)

This section reports the posterior mean and the 95% *HPDI* of β_i, σ_i^2 and ϕ_i in Table 5, 6 and 7 respectively.

[Insert Table 5 here]

[Insert Table 6 here]

[Insert Table 7 here]

According to the reported figures in Table 5, 6 and 7, we are 95% certain that all the parameters in the model (β_i, σ_i^2 and ϕ_i) lies within the *HPDI.* For instance, the mean for β_I is 0.31 which lies between the 95% highest posterior density intervals of 0.074 and 0.58.

4.4 Test for Heteroscedasticity

The test for heteroscedasticity is being conducted to examine if the error variances differ across observations. The results presented in Table 8 show that the presence of heteroscedasticity is not detected in the model.[28]

[Insert Table 8 here]

5. Results and Estimation

This study examines eight East Asian countries, namely ASEAN 5 – Indonesia, Malaysia, the Philippines, Singapore and Thailand – and China, Japan and Korea.[29] The list

[28] Among others, the Bayesian model with heteroscedasticity can be estimated using the *GAUSS* program. The *Gauss* codes are provided in Luc Bauwens' website that accompanied the book Bauwens *et al.* (1999).

of 17 European and 3 North American countries included in the study is provided in the Appendix (Table 9).

[Insert Table 9 here]

The data used in this paper are drawn from the Penn World Table, the sample period is from 1970 to 2000.[30] Output is measured by the log of real GDP growth. Gauss program is used in the estimation. It can be shown that the accuracy of the model estimation gets better and better as the number of replications is increased. In order to get highly accurate estimates, we set S = 100,000 and discard an initial 10,000 burn-in replications.

We report the variance shares (medians, 33% and 67% quantiles of posterior) attributable to the world, regional and country factors for East Asia, Europe and North America in Tables 10.[31]

[Insert Table 10 here]

5.1 East Asia

[Insert Table 11 here]

Table 11 demonstrates variance decompositions for the East Asian countries. The country-specific factors capture the greatest share of output fluctuations in the region, explaining about 65% of output volatility. However, the country-specific factors share of

[29] The new ASEAN members include Cambodia, Laos, Myanmar and Vietnam are excluded in the study as the stages of development in these countries are very much different from the rest of the East Asian countries. Williamson (1999), for example, omits the new members of ASEAN, limiting the heterogeneity of the countries adopting a common basket peg. We lack data on Brunei.
[30] It is our intention to examine the business cycle synchronisation for the European countries before the adoption of Euro.
[31] Figures for idiosyncratic factors are not reported here. Since there are only 28 countries in our model, the unexplained output movement (which falls under idiosyncratic factors) is expected to be large. Another explanation for the large role of the idiosyncratic factor is measurement error and this is especially true for developing or less developed economies.

output volatility ranges widely across the East Asian region, from a low of 43.62% in Japan to a high of 81.61% and 81.66% in Korea and Thailand respectively using the median quantile.

The world and region factors, on the other hand, play a relatively modest role in accounting for the economic activities in these countries. For the median country, only 8% of the output variation is due to the world factor and only about 3% of the output variation is due to the East Asian regional factor. The region factor is largest for the most developed economies in the region, namely, Japan, Korea and Singapore. The region factor accounts for about 7% of output variation in these countries. In fact, the world factor share of output volatility also ranges widely across the region from a low of less than 1% in Indonesia to a high of more than 36% in Japan. This result is consistent with that of Kose *et al.* (2003) who found Japan's world factor to be important.

5.2 Europe

[Insert Table 12 here]

Table 12 demonstrates variance decompositions for the European countries. The world factor explains more than 28% of the output fluctuations in these economies. However, the world factor share of output fluctuations varies widely across these countries, ranging from a low of less than 2.5% in Ireland and Norway to a high of 77% in Belgium.

Though less important than in East Asia, the country-specific factor explains a noticeable 23% of output volatility in Europe. The country-specific factors, however, are more important for some countries in the region than others. For instance, country-specific factor account for more than 50% of output volatility in Denmark and Norway and it accounts for more than 40% of output volatility in Finland, France, Ireland and Spain. However, the country-specific factor only accounts for less than 5% of output volatility in Belgium, Netherlands, Portugal, Sweden and Luxembourg.

The European regional factor, however, plays a relatively minor role in accounting for the economic activity in these countries: it accounts for about 5% of output volatility in Austria and Luxembourg, and about 9% of output volatility in Norway. The regional factors in the rest of the European countries are insignificant.

5.3 North America

[Insert Table 13 here]

Table 13 presents the variance decompositions for the North America. It is evident that the regional factor explains the majority of volatility in output, accounting for about 50% of output volatility in US and Canada. The results for Mexico however, show a different trend with the country factor explaining the majority of the output fluctuation, the regional factor only explains less than 1% of output fluctuation.

6. Conclusion

The empirical results suggest that the country-specific factors explain the majority of output volatility in the East Asian economies. Most of the East Asian economies exhibit little co- movement with the rest of the world compared with Europe and North America. The world factor explains a noticeable fraction of aggregate output volatility in the Europe and North American economies. Our findings also indicate that regional factors play a minor role in explaining output variation in both East Asia and the European economies. This implies that while East Asia does not satisfy the OCA criteria (based on the insignificant share of regional common factor), neither does Europe. The regional factor seems to be playing its most important role in the North American region.

In economic discussions, the loss of the exchange rate instrument was often put forward as the main argument against monetary union. Our results imply that it could be costly to renounce individual currencies to advance into a currency union in East Asia as the output variations explained by country-specific factors is significant. For the time being, there may not exist scope for East Asia to form a monetary union. Although we do not find the evidence of a European cycle which provides a case for a regional common currency, the output in most European countries fluctuates due to shocks to the world economy.

Critics may rightly charge that East Asia lacks the fundamental conditions necessary for monetary union. However, it is important to note that the perspective of those interested in pursuing the idea. Proponents acknowledge that monetary union is impossible in the short term but consider it feasible in the long term. To realise the goal in the future, leaders must begin laying the groundwork today. More studies need to be done to shed light on the prospect of a single currency for East Asia. Policy makers who are interested to pursue the idea of a single currency for East Asia must conduct every possible study related to this issue.

7. Limitation of the Study and Future Studies

The results of our study will only shed light on suitability of East Asia to form a single currency based on how far we are compared to the Euro Area in terms of the business cycle synchronisation. Of course, many more studies that are outside the scope of this paper need to be done to examine the suitability of East Asia to form a single currency. Political will, for instance, is one of the key determinants of whether or not a country would join the monetary union.

A country's suitability to form a monetary union depends, inter alia, on their trade integration and the extent to which its business cycles are correlated. However, studies have shown that both international trade patterns and international business cycle correlations are endogenous. A region's business cycle may become more synchronised after a monetary union is formed. This can be explained by the increased intra-regional trade (after the elimination of exchange fluctuations among the countries in the region) that potentially increases the business cycle synchronisation. It follows that countries are more likely to satisfy the criteria for entry into a currency union after taking steps toward economic integration than before. If such hypothesis is empirically verified, policy makers have little to worry about the region being unsynchronised in their business cycles as the business cycles will become more synchronised after the monetary union is formed. From a theoretical viewpoint, the effect of increased trade integration on the cross-country correlation of business cycle activity is ambiguous. Empirical evidence has shown mixed results. Therefore, it is imperative to investigate the relationship between business cycle synchronisation and trade integration while examining the suitability of a region to form an OCA.

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Table 1: MCMC Diagnostics - Numerical Standard Error (Posterior Results for β_i)

Country	Standard Deviation	*NSE*	*NSE*1	*NSE*2	*NSE*3
US	0.15	4.80×10^{-4}	3.71×10^{-3}	4.40×10^{-3}	4.10×10^{-3}
Canada	0.14	4.51×10^{-4}	2.56×10^{-3}	2.90×10^{-3}	2.63×10^{-3}
Mexico	0.60	1.89×10^{-3}	1.29×10^{-2}	1.53×10^{-2}	1.42×10^{-2}
Singapore	0.18	5.55×10^{-4}	4.53×10^{-3}	4.99×10^{-3}	4.23×10^{-3}
Japan	0.17	5.53×10^{-4}	3.60×10^{-3}	4.07×10^{-3}	3.56×10^{-3}
Korea	0.63	2.00×10^{-3}	1.25×10^{-2}	1.32×10^{-2}	1.11×10^{-2}
Malaysia	0.24	7.61×10^{-4}	3.05×10^{-3}	2.44×10^{-3}	1.68×10^{-3}
Thailand	0.26	8.17×10^{-4}	2.58×10^{-3}	2.08×10^{-3}	1.21×10^{-3}
China	0.76	2.41×10^{-3}	5.93×10^{-3}	4.88×10^{-3}	4.14×10^{-3}
Indonesia	0.53	1.66×10^{-3}	1.12×10^{-2}	1.03×10^{-2}	8.00×10^{-3}
Philippines	0.71	2.24×10^{-3}	1.28×10^{-2}	1.19×10^{-2}	9.94×10^{-3}
France	0.77	2.43×10^{-3}	3.30×10^{-3}	2.97×10^{-3}	2.54×10^{-3}
Austria	0.27	8.55×10^{-4}	4.75×10^{-3}	4.63×10^{-3}	3.68×10^{-3}
Belgium	0.26	8.21×10^{-4}	4.21×10^{-3}	4.02×10^{-3}	3.27×10^{-3}
Denmark	0.52	1.66×10^{-3}	8.76×10^{-3}	8.55×10^{-3}	6.86×10^{-3}
Finland	0.30	9.39×10^{-4}	2.88×10^{-3}	2.70×10^{-3}	2.48×10^{-3}
Germany	0.32	1.02×10^{-3}	3.05×10^{-3}	2.93×10^{-3}	2.76×10^{-3}
Greece	0.82	2.60×10^{-3}	2.90×10^{-3}	2.11×10^{-3}	1.61×10^{-3}
Ireland	0.21	6.69×10^{-4}	2.01×10^{-3}	2.17×10^{-3}	2.06×10^{-3}
Italy	0.46	1.47×10^{-3}	3.32×10^{-3}	3.12×10^{-3}	2.60×10^{-3}
Netherlands	0.80	2.53×10^{-3}	3.78×10^{-3}	2.60×10^{-3}	1.84×10^{-3}
Norway	0.24	7.48×10^{-4}	1.96×10^{-3}	2.00×10^{-3}	1.74×10^{-3}
Portugal	0.28	8.85×10^{-4}	2.60×10^{-3}	2.93×10^{-3}	2.75×10^{-3}
Spain	0.82	2.61×10^{-3}	6.17×10^{-3}	5.84×10^{-3}	4.25×10^{-3}
Sweden	0.36	1.14×10^{-3}	2.04×10^{-3}	1.76×10^{-3}	1.12×10^{-3}
Switzerland	0.40	1.27×10^{-3}	3.15×10^{-3}	2.96×10^{-3}	2.48×10^{-3}
UK	0.74	2.35×10^{-3}	4.31×10^{-3}	3.98×10^{-3}	3.54×10^{-3}
Luxembourg	0.25	8.05×10^{-4}	2.93×10^{-3}	2.69×10^{-3}	2.46×10^{-3}

Notes: *NSE* is calculated using the assumption of no serial correlation; *NSE*1 is calculated using the assumption of 4% autocovariance taper; *NSE*2 is calculated using the assumption of 8% autocovariance taper and *NSE*3 is calculated using the assumption of 15% autocovariance taper.

Table 2: MCMC Diagnostics - Numerical Standard Error (Posterior Results for σ_i^2)

Country	Standard Deviation	*NSE*	*NSE*1	*NSE*2	*NSE*3
US	2.56×10^{-5}	8.09×10^{-8}	1.81×10^{-7}	1.36×10^{-7}	1.02×10^{-7}
Canada	3.31×10^{-5}	1.05×10^{-7}	2.35×10^{-7}	1.49×10^{-7}	1.30×10^{-7}
Mexico	1.24×10^{-4}	3.91×10^{-7}	3.49×10^{-7}	2.70×10^{-7}	2.40×10^{-7}
Singapore	2.21×10^{-4}	6.98×10^{-7}	1.07×10^{-6}	9.52×10^{-7}	7.69×10^{-7}
Japan	4.94×10^{-5}	1.56×10^{-7}	2.51×10^{-7}	2.63×10^{-7}	2.51×10^{-7}
Korea	6.22×10^{-5}	1.97×10^{-7}	3.90×10^{-7}	2.96×10^{-7}	1.95×10^{-7}
Malaysia	1.05×10^{-4}	3.32×10^{-7}	4.06×10^{-7}	2.64×10^{-7}	2.42×10^{-7}
Thailand	9.20×10^{-5}	2.91×10^{-7}	5.39×10^{-7}	4.73×10^{-7}	2.84×10^{-7}
China	1.57×10^{-4}	4.98×10^{-7}	8.04×10^{-7}	6.30×10^{-7}	4.20×10^{-7}
Indonesia	1.48×10^{-4}	4.67×10^{-7}	9.57×10^{-7}	9.44×10^{-7}	8.61×10^{-7}
Philippines	1.17×10^{-4}	3.70×10^{-7}	1.00×10^{-6}	9.11×10^{-7}	6.26×10^{-7}
France	7.50×10^{-5}	2.37×10^{-7}	3.46×10^{-7}	3.77×10^{-7}	3.23×10^{-7}
Austria	4.57×10^{-5}	1.45×10^{-7}	5.93×10^{-7}	3.32×10^{-7}	2.93×10^{-7}
Belgium	3.00×10^{-5}	9.47×10^{-8}	2.06×10^{-7}	1.61×10^{-7}	1.21×10^{-7}
Denmark	2.77×10^{-5}	8.75×10^{-8}	1.05×10^{-7}	7.09×10^{-8}	5.35×10^{-8}
Finland	7.49×10^{-5}	2.37×10^{-7}	4.01×10^{-7}	3.85×10^{-7}	3.64×10^{-7}
Germany	2.99×10^{-5}	9.45×10^{-8}	2.55×10^{-7}	2.66×10^{-7}	2.15×10^{-7}
Greece	1.65×10^{-4}	5.20×10^{-7}	9.34×10^{-7}	8.63×10^{-7}	5.61×10^{-7}
Ireland	1.19×10^{-4}	3.75×10^{-7}	2.10×10^{-6}	2.15×10^{-6}	2.16×10^{-6}
Italy	4.39×10^{-5}	1.39×10^{-7}	2.80×10^{-7}	2.10×10^{-7}	1.74×10^{-7}
Netherlands	3.22×10^{-5}	1.02×10^{-7}	1.97×10^{-7}	1.64×10^{-7}	1.23×10^{-7}
Norway	4.20×10^{-5}	1.33×10^{-7}	1.62×10^{-7}	1.42×10^{-7}	1.43×10^{-7}
Portugal	1.06×10^{-4}	3.34×10^{-7}	2.74×10^{-6}	2.44×10^{-6}	2.31×10^{-6}
Spain	3.15×10^{-5}	9.96×10^{-8}	1.59×10^{-7}	1.22×10^{-7}	7.95×10^{-8}
Sweden	7.62×10^{-5}	2.41×10^{-7}	2.33×10^{-6}	2.14×10^{-6}	2.18×10^{-6}
Switzerland	1.03×10^{-4}	3.25×10^{-7}	4.99×10^{-7}	4.62×10^{-7}	3.65×10^{-7}
UK	4.97×10^{-5}	1.57×10^{-7}	8.38×10^{-8}	5.95×10^{-8}	4.85×10^{-8}
Luxembourg	2.68×10^{-4}	8.46×10^{-7}	3.43×10^{-6}	2.83×10^{-6}	2.71×10^{-6}

Notes: *NSE* is calculated using the assumption of no serial correlation; *NSE*1 is calculated using the assumption of 4% autocovariance taper; *NSE*2 is calculated using the assumption of 8% autocovariance taper and *NSE*3 is calculated using the assumption of 15% autocovariance taper.

Table 3: MCMC Diagnostics - Numerical Standard Error (Posterior Results for ϕ_i)

Country	Standard Deviation	*NSE*	*NSE*1	*NSE*2	*NSE*3
US	0.29	9.19×10^{-4}	8.95×10^{-4}	8.78×10^{-4}	7.50×10^{-4}
Canada	0.25	7.94×10^{-4}	1.32×10^{-3}	1.34×10^{-3}	1.34×10^{-3}
Mexico	0.31	9.76×10^{-4}	8.13×10^{-4}	6.78×10^{-4}	6.12×10^{-4}
Singapore	0.29	9.09×10^{-4}	1.37×10^{-3}	1.40×10^{-3}	1.02×10^{-3}
Japan	0.29	9.20×10^{-4}	1.77×10^{-3}	1.31×10^{-3}	1.14×10^{-3}
Korea	0.28	8.81×10^{-4}	1.36×10^{-3}	8.65×10^{-4}	7.05×10^{-4}
Malaysia	0.23	7.14×10^{-4}	7.74×10^{-4}	8.14×10^{-4}	7.14×10^{-4}
Thailand	0.28	8.96×10^{-4}	1.40×10^{-3}	1.06×10^{-3}	8.07×10^{-4}
China	0.25	7.89×10^{-4}	5.34×10^{-4}	4.46×10^{-4}	4.18×10^{-4}
Indonesia	0.30	9.35×10^{-4}	8.46×10^{-4}	7.10×10^{-4}	5.83×10^{-4}
Philippines	0.21	6.76×10^{-4}	8.85×10^{-4}	6.97×10^{-4}	4.20×10^{-4}
France	0.26	8.36×10^{-4}	1.59×10^{-3}	1.75×10^{-3}	1.76×10^{-3}
Austria	0.28	8.96×10^{-4}	8.88×10^{-4}	9.09×10^{-4}	7.82×10^{-4}
Belgium	0.19	6.14×10^{-4}	8.39×10^{-4}	8.95×10^{-4}	7.42×10^{-4}
Denmark	0.28	8.78×10^{-4}	7.47×10^{-4}	6.25×10^{-4}	4.27×10^{-4}
Finland	0.28	8.88×10^{-4}	8.40×10^{-4}	6.64×10^{-4}	5.65×10^{-4}
Germany	0.24	7.55×10^{-4}	9.92×10^{-4}	7.38×10^{-4}	4.46×10^{-4}
Greece	0.28	8.79×10^{-4}	1.01×10^{-3}	9.76×10^{-4}	7.95×10^{-4}
Ireland	0.31	9.65×10^{-4}	1.98×10^{-3}	1.61×10^{-3}	1.60×10^{-3}
Italy	0.30	9.47×10^{-4}	2.17×10^{-3}	1.72×10^{-3}	1.59×10^{-3}
Netherlands	0.30	9.38×10^{-4}	1.42×10^{-3}	1.37×10^{-3}	1.13×10^{-3}
Norway	0.28	8.72×10^{-4}	9.89×10^{-4}	8.75×10^{-4}	6.54×10^{-4}
Portugal	0.21	6.67×10^{-4}	1.40×10^{-3}	1.41×10^{-3}	9.97×10^{-4}
Spain	0.30	9.36×10^{-4}	8.21×10^{-4}	7.52×10^{-4}	5.31×10^{-4}
Sweden	0.28	8.89×10^{-4}	6.41×10^{-4}	5.82×10^{-4}	3.68×10^{-4}
Switzerland	0.29	9.14×10^{-4}	9.29×10^{-4}	9.45×10^{-4}	6.21×10^{-4}
UK	0.23	7.25×10^{-4}	1.51×10^{-3}	1.07×10^{-3}	7.96×10^{-4}
Luxembourg	0.31	9.71×10^{-4}	8.72×10^{-4}	7.32×10^{-4}	6.25×10^{-4}

Notes: *NSE* is calculated using the assumption of no serial correlation; *NSE*1 is calculated using the assumption of 4% autocovariance taper; *NSE*2 is calculated using the assumption of 8% autocovariance taper and *NSE*3 is calculated using the assumption of 15% autocovariance taper.

Table 4: MCMC Diagnostics - Geweke's CD for β_i, σ_i^2 and ϕ_i

Country	β_i	σ_i^2	ϕ_i
US	1.49	-0.79	-0.57
Canada	1.87	-1.23	-1.47
Mexico	0.99	-0.22	-1.17
Singapore	1.09	0.55	1.09
Japan	1.49	-0.61	0.42
Korea	0.41	-1.21	-0.92
Malaysia	1.51	0.39	-1.90
Thailand	0.89	0.08	-1.53
China	0.83	-0.68	1.02
Indonesia	-1.20	-1.04	0.61
Philippines	-1.57	-0.86	0.52
France	0.94	-0.99	1.08
Austria	0.07	1.73	0.27
Belgium	-0.33	0.02	-0.32
Denmark	0.10	0.32	0.26
Finland	1.13	-0.68	0.52
Germany	1.93	-0.56	0.81
Greece	0.34	-0.45	-0.31
Ireland	1.47	-1.56	0.03
Italy	0.05	0.13	0.89
Netherlands	0.03	0.48	1.03
Norway	0.16	0.99	0.50
Portugal	0.69	1.92	-0.24
Spain	-0.48	-0.51	-0.03
Sweden	-0.13	-1.08	-0.61
Switzerland	-1.02	-0.89	0.17
UK	-0.83	-0.16	0.92
Luxembourg	-0.28	1.21	-0.52

Notes: Since *CD* is asymptotically standard Normal, a common rule is that if *CD* is less than 1.96 in absolute value for all parameters. We can conclude that convergence of the *MCMC* algorithm has occurred.

Table 5: MCMC Diagnostics - Posterior Mean and 95% *HPDI* for β_i

Country	Mean	95% HPDI	Pass (Yes/ No)
US	0.31	[0.074, 0.58]	Yes
Canada	0.20	[-0.028, 0.44]	Yes
Mexico	0.77	[-0.185, 1.76]	Yes
Singapore	0.41	[0.127, 0.70]	Yes
Japan	0.19	[-0.095, 0.48]	Yes
Korea	0.55	[-0.472, 1.61]	Yes
Malaysia	0.20	[-0.195, 0.60]	Yes
Thailand	0.42	[0.001, 0.84]	Yes
China	-0.01	[-1.249, 1.25]	Yes
Indonesia	0.97	[0.106, 1.82]	Yes
Philippines	0.66	[-0.518, 1.81]	Yes
France	1.34	[0.065, 2.57]	Yes
Austria	1.05	[0.654, 1.49]	Yes
Belgium	0.84	[0.445, 1.27]	Yes
Denmark	2.21	[1.436, 3.05]	Yes
Finland	0.30	[-0.183, 0.79]	Yes
Germany	0.45	[-0.064, 0.99]	Yes
Greece	0.60	[-0.777, 1.93]	Yes
Ireland	0.28	[-0.059, 0.63]	Yes
Italy	0.55	[-0.216, 1.31]	Yes
Netherlands	0.76	[-0.572, 2.07]	Yes
Norway	0.15	[-0.238, 0.54]	Yes
Portugal	0.14	[-0.315, 0.60]	Yes
Spain	0.47	[-0.903, 1.80]	Yes
Sweden	-0.74	[-1.327, -0.16]	Yes
Switzerland	-0.45	[-1.111, 0.21]	Yes
UK	-0.73	[-1.945, 0.50]	Yes
Luxembourg	-0.17	[-0.592, 0.24]	Yes

Notes: According to the reported figures above, we are 95% certain that all the parameters in the model lies within the *HPDI*. For instance, the mean for US is 0.31 which lies between the 95% highest posterior density intervals of 0.074 and 0.58.

Table 6: MCMC Diagnostics - Posterior Mean and 95% *HPDI* for σ_i^2

Country	Mean	95% HPDI	Pass (Yes/ No)
US	7.41×10^{-5}	$[4.25 \times 10^{-5}, 1.21 \times 10^{-4}]$	Yes
Canada	9.17×10^{-5}	$[5.09 \times 10^{-5}, 1.53 \times 10^{-4}]$	Yes
Mexico	3.84×10^{-4}	$[2.20 \times 10^{-4}, 6.12 \times 10^{-4}]$	Yes
Singapore	4.01×10^{-4}	$[1.36 \times 10^{-4}, 8.22 \times 10^{-4}]$	Yes
Japan	1.12×10^{-4}	$[5.68 \times 10^{-5}, 2.02 \times 10^{-4}]$	Yes
Korea	1.55×10^{-4}	$[7.90 \times 10^{-5}, 2.69 \times 10^{-4}]$	Yes
Malaysia	2.65×10^{-4}	$[1.26 \times 10^{-4}, 4.58 \times 10^{-4}]$	Yes
Thailand	2.13×10^{-4}	$[1.06 \times 10^{-4}, 3.76 \times 10^{-4}]$	Yes
China	3.17×10^{-4}	$[1.27 \times 10^{-4}, 6.03 \times 10^{-4}]$	Yes
Indonesia	2.56×10^{-4}	$[9.73 \times 10^{-5}, 5.27 \times 10^{-4}]$	Yes
Philippines	2.25×10^{-4}	$[9.25 \times 10^{-5}, 4.48 \times 10^{-4}]$	Yes
France	2.30×10^{-4}	$[1.32 \times 10^{-4}, 3.69 \times 10^{-4}]$	Yes
Austria	1.52×10^{-4}	$[9.19 \times 10^{-5}, 2.36 \times 10^{-4}]$	Yes
Belgium	9.77×10^{-5}	$[5.84 \times 10^{-5}, 1.53 \times 10^{-4}]$	Yes
Denmark	8.09×10^{-5}	$[4.73 \times 10^{-5}, 1.30 \times 10^{-4}]$	Yes
Finland	2.31×10^{-4}	$[1.32 \times 10^{-4}, 3.69 \times 10^{-4}]$	Yes
Germany	9.92×10^{-5}	$[5.97 \times 10^{-5}, 1.54 \times 10^{-4}]$	Yes
Greece	5.80×10^{-4}	$[3.63 \times 10^{-4}, 8.86 \times 10^{-4}]$	Yes
Ireland	4.26×10^{-4}	$[2.69 \times 10^{-4}, 6.44 \times 10^{-4}]$	Yes
Italy	1.48×10^{-4}	$[8.99 \times 10^{-5}, 2.29 \times 10^{-4}]$	Yes
Netherlands	1.08×10^{-4}	$[6.60 \times 10^{-5}, 1.68 \times 10^{-4}]$	Yes
Norway	1.48×10^{-4}	$[9.30 \times 10^{-5}, 2.26 \times 10^{-4}]$	Yes
Portugal	2.91×10^{-4}	$[1.54 \times 10^{-4}, 4.88 \times 10^{-4}]$	Yes
Spain	1.05×10^{-4}	$[6.50 \times 10^{-5}, 1.62 \times 10^{-4}]$	Yes
Sweden	2.57×10^{-4}	$[1.55 \times 10^{-4}, 3.97 \times 10^{-4}]$	Yes
Switzerland	2.93×10^{-4}	$[1.52 \times 10^{-4}, 4.81 \times 10^{-4}]$	Yes
UK	1.67×10^{-4}	$[1.01 \times 10^{-4}, 2.59 \times 10^{-4}]$	Yes
Luxembourg	9.15×10^{-4}	$[5.63 \times 10^{-4}, 1.41 \times 10^{-3}]$	Yes

Notes: According to the reported figures above, we are 95% certain that all the parameters in the model lies within the *HPDI*.

Table 7: MCMC Diagnostics - Posterior Mean and 95% *HPDI* for ϕ_i

Country	Mean	95% HPDI	Pass (Yes/ No)
US	0.05	[-0.43, 0.52]	Yes
Canada	0.16	[-0.25, 0.57]	Yes
Mexico	-0.04	[-0.54, 0.47]	Yes
Singapore	0.13	[-0.34, 0.61]	Yes
Japan	0.24	[-0.24, 0.72]	Yes
Korea	-0.01	[-0.46, 0.45]	Yes
Malaysia	0.21	[-0.16, 0.57]	Yes
Thailand	0.09	[-0.38, 0.55]	Yes
China	0.18	[-0.23, 0.59]	Yes
Indonesia	0.05	[-0.44, 0.53]	Yes
Philippines	0.13	[-0.22, 0.48]	Yes
France	-0.01	[-0.45, 0.42]	Yes
Austria	0.15	[-0.32, 0.61]	Yes
Belgium	0.07	[-0.25, 0.39]	Yes
Denmark	0.12	[-0.34, 0.57]	Yes
Finland	0.05	[-0.41, 0.51]	Yes
Germany	0.10	[-0.29, 0.50]	Yes
Greece	0.09	[-0.38, 0.54]	Yes
Ireland	0.16	[-0.35, 0.65]	Yes
Italy	0.73	[0.19, 1.17]	Yes
Netherlands	-0.15	[-0.62, 0.35]	Yes
Norway	0.15	[-0.31, 0.60]	Yes
Portugal	-0.30	[-0.64, 0.05]	Yes
Spain	-0.04	[-0.53, 0.45]	Yes
Sweden	-0.01	[-0.47, 0.45]	Yes
Switzerland	0.00	[-0.47, 0.48]	Yes
UK	0.25	[-0.14, 0.61]	Yes
Luxembourg	-0.04	[-0.54, 0.47]	Yes

Notes: According to the reported figures above, we are 95% certain that all the parameters in the model lies within the *HPDI*.

Table 8: Test for Heteroskedasticity

Country	*F*-statistics *F*(4,23)	Probability of *F*
US	0.42	0.80
Canada	0.61	0.66
Mexico	0.86	0.50
Singapore	1.68	0.19
Japan	1.29	0.30
Korea	0.14	0.97
Malaysia	2.68	0.06
Thailand	0.13	0.97
China	0.69	0.61
Indonesia	1.29	0.30
Philippines	0.65	0.64
France	1.46	0.25
Austria	1.07	0.40
Belgium	2.62	0.06
Denmark	0.49	0.74
Finland	1.46	0.25
Germany	0.93	0.46
Greece	1.63	0.20
Ireland	1.57	0.22
Italy	0.13	0.97
Netherlands	2.05	0.12
Norway	0.47	0.76
Portugal	0.33	0.72
Spain	1.45	0.25
Sweden	1.65	0.20
Switzerland	2.40	0.08
UK	1.26	0.32
Luxembourg	1.13	0.37

Notes: The critical value of 95th percentiles of the *F* Distribution for *F* (4, 23) is 2.80. The *F*-Statistics for all countries are less than the critical value; therefore the null hypothesis of homoskedasticity cannot be rejected. The presence of heteroskedasticity is not detected in the model.

Table 9: Regional Definitions

East Asia	Europe		North America
China	Austria	Luxembourg	Canada
Indonesia	Belgium	Netherland	Mexico
Japan	Denmark	Norway	US
Korea	Finland	Portugal	
Malaysia	France	Spain	
Philippines	Germany	Sweden	
Singapore	Greece	Switzerland	
Thailand	Ireland	UK	
	Italy		

Table 10: Variance Decompositions (Regional Average)

East Asia			
	1/3	**Med**	**2/3**
World	6.86	8.07	9.39
Country	60.97	64.83	68.40
Region	1.28	3.11	6.31

Europe			
	1/3	**Med**	**2/3**
World	26.53	28.80	31.11
Country	18.80	23.04	27.44
Region	1.31	2.61	4.69

North America			
	1/3	**Med**	**2/3**
World	16.29	18.69	21.23
Country	15.07	22.37	29.12
Region	42.60	49.28	55.84

Notes: Figures are expressed in percentage terms.

Table 11: Variance Decompositions for East Asia

Country	Factor	1/3	Median	2/3
China	World	11.11	12.47	13.87
	Country	59.73	63.58	67.21
	Region	1.01	2.20	4.01
	Idiosyncratic	16.88	20.04	23.30
Indonesia	World	0.10	0.23	0.46
	Country	74.17	78.82	82.80
	Region	1.13	2.73	5.53
	Idiosyncratic	12.52	15.49	19.03
Japan	World	33.11	35.99	38.85
	Country	38.79	43.62	48.09
	Region	4.08	7.05	10.69
	Idiosyncratic	9.92	11.53	13.34
Korea	World	1.97	2.65	3.44
	Country	75.30	81.61	85.54
	Region	2.99	6.98	13.45
	Idiosyncratic	6.72	7.72	8.77
Malaysia	World	8.78	10.19	11.70
	Country	53.55	58.04	62.35
	Region	0.43	1.05	2.16
	Idiosyncratic	25.43	29.34	33.34
Philippines	World	11.98	13.60	15.31
	Country	62.21	66.09	69.58
	Region	0.54	1.30	2.64
	Idiosyncratic	14.26	17.11	20.39
Singapore	World	4.94	5.95	7.08
	Country	51.06	58.02	64.50
	Region	3.51	6.69	10.81
	Idiosyncratic	20.78	26.07	32.11
Thailand	World	2.21	3.00	3.90
	Country	77.86	81.66	84.47
	Region	1.44	3.49	7.09
	Idiosyncratic	8.86	10.10	11.46
Regional Median	World	6.86	8.07	9.39
	Country	60.97	64.83	68.40
	Region	1.28	3.11	6.31
	Idiosyncratic	13.39	16.30	19.71

Notes: Figures are expressed in percentage terms.

Table 12: Variance Decompositions for Europe

Country	Factor	1/3	Median	2/3
Austria	World	52.47	55.49	58.49
	Country	4.88	6.84	9.02
	Region	2.68	4.74	7.16
	Idiosyncratic	29.23	31.36	33.51
Belgium	World	74.53	76.84	79.03
	Country	1.03	1.96	3.20
	Region	0.19	0.46	0.94
	Idiosyncratic	17.83	19.57	21.35
Denmark	World	26.53	28.80	31.11
	Country	51.71	55.05	58.15
	Region	2.10	4.10	6.87
	Idiosyncratic	9.17	10.26	11.42
Finland	World	22.16	24.51	27.12
	Country	43.10	47.64	51.44
	Region	1.49	3.64	7.35
	Idiosyncratic	20.51	22.27	24.00
France	World	52.71	55.27	57.75
	Country	18.46	20.63	22.86
	Region	0.60	1.48	3.07
	Idiosyncratic	19.32	21.05	22.77
Germany	World	52.71	55.27	57.75
	Country	18.46	20.63	22.86
	Region	0.60	1.48	3.07
	Idiosyncratic	19.32	21.05	22.77
Greece	World	26.19	28.44	30.72
	Country	24.55	26.52	28.52
	Region	0.24	0.59	1.22
	Idiosyncratic	41.94	43.64	45.33
Ireland	World	1.57	2.19	2.93
	Country	43.40	45.36	47.30
	Region	1.04	2.16	3.68
	Idiosyncratic	47.93	49.43	50.77
Italy	World	60.90	63.23	65.52
	Country	8.26	9.64	11.11
	Region	0.21	0.51	1.03

	Idiosyncratic	24.09	25.79	27.56

Table 12: Variance Decompositions for Europe (continued)

Country	Factor	1/3	Median	2/3
Netherlands	World	55.50	58.13	60.68
	Country	2.90	3.58	4.33
	Region	1.31	2.61	4.31
	Idiosyncratic	32.39	34.58	36.82
Norway	World	0.07	0.16	0.33
	Country	48.55	51.87	55.08
	Region	6.22	9.28	12.44
	Idiosyncratic	36.21	38.18	40.13
Portugal	World	63.45	66.62	69.67
	Country	0.13	0.32	0.65
	Region	0.83	1.71	2.96
	Idiosyncratic	27.10	30.04	33.10
Spain	World	34.31	36.78	39.25
	Country	44.72	48.22	51.35
	Region	1.65	3.77	7.00
	Idiosyncratic	9.05	9.66	10.28
Sweden	World	18.45	20.77	23.32
	Country	0.06	0.12	0.23
	Region	0.99	2.38	4.69
	Idiosyncratic	72.21	75.48	78.26
Switzerland	World	38.19	40.54	42.94
	Country	18.80	23.04	27.44
	Region	0.22	0.54	1.10
	Idiosyncratic	31.40	35.12	38.58
United Kingdom	World	23.56	25.90	28.34
	Country	33.61	36.71	39.81
	Region	1.41	3.19	5.91
	Idiosyncratic	29.82	31.99	34.14
Luxembourg	World	14.40	16.34	18.41
	Country	0.49	1.00	1.71
	Region	2.67	4.82	7.53
	Idiosyncratic	73.15	76.22	78.95
Regional Median	World	26.53	28.80	31.11
	Country	18.80	23.04	27.44
	Region	1.31	2.61	4.69
	Idiosyncratic	29.23	31.36	33.51

Notes: Figures are expressed in percentage terms.

Table 13: Variance Decompositions for North America

Country	Factor	1/3	Median	2/3
US	World	16.29	18.69	21.23
	Country	15.07	22.37	29.12
	Region	42.45	49.58	57.30
	Idiosyncratic	6.88	7.94	9.10
Canada	World	19.82	22.40	25.04
	Country	11.27	17.96	24.12
	Region	42.60	49.28	55.84
	Idiosyncratic	8.31	9.52	10.85
Mexico	World	2.00	2.78	3.67
	Country	55.67	58.91	62.20
	Region	0.30	0.72	1.46
	Idiosyncratic	33.44	36.54	39.54
Regional	World	16.29	18.69	21.23
	Country	15.07	22.37	29.12
	Region	42.60	49.28	55.84
	Idiosyncratic	8.31	9.52	10.85

Notes: Figures are expressed in percentage terms.