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Christian **Urom**[1] , Khaled **Guesmi**[2] , Ilyes **Abid**[3] and Leila **Dagher**[4]

[1] Paris School of Business, 54 Rue Nationale, Paris, France
[2] Paris School of Business, 54 Rue Nationale, Paris, France
[3] ISC Paris School of Business, Paris, France
[4] Institute of Financial Economics, American University of Beirut, Beirut, Lebanon

Abstract

This paper examines the short term dynamic integration among oil price shocks and interest rates for the U.S.A, Euro area and twelve Asian economies from August 1999 to January 2018 using a Time-Varying Parameter Vector Autoregression (TVP-VAR) with stochastic volatility. First, we found convincing evidence of time variation in the co-movement of interest rates and oil shocks and that the integration levels were highest towards the 2001 financial crisis whereas there is an evidence of decoupling as shown by notable drop in the the level of integration during the 2007-2009 economic and Euro-debt crises. In descending order, Singapore, crude oil, Hong Kong, Philippines and the United States are the net-transmitters of shocks while India, Japan and Vietnam are net-receivers. Results from a sub-sample containing highly industrializing economies in Asia, the United States, Euro area and crude oil market suggest that Singapore, Hong Kong and the United States remained top transmitters of shocks whereas the Euro-area, Taiwan, Korea and crude oil market become net receivers of shocks. Results from the analysis of transmission channels suggest that higher integration for the full sample tend to be driven by increasing levels of external exposure through trade and financial linkages, information asymmetry and political stability while financial crisis reduces the level of integration. Lastly, among the highly industrialized markets, time varying integration is also driven by the degree of external exposure as well as both political and financial stability. We also document important policy implications of our findings.

Introduction

In recent years, more specifically following the global financial crisis, a deep understanding of the nature and evolution of interdependence between economies, both in terms of business and financial cycle synchronization, has received great attention. Special emphasis has been placed on examining the increasing volatility spillover from one economy to another especially through financial linkages for several reasons. For instance, financial flows and other forms of economic interactions are key drivers intensifying regional and global financial integration. Due to the strengthening of financial linkages and the resulting increased flow of financial resources across countries, shocks are more prone to easily spread between countries. Given liquidity constraints and information asymmetries, Kim, Lee and Park (2011) argue that investors' hedging behaviour amplifies small shocks causing strong impacts across many economies in a region as observed during the 1997/1998 Asian financial crisis. In a recent study, Goetz and Gozzi (2020) find evidence that this applies even within states in the U.S.; financial integration contributed to the transmission of financial shocks across states, making state economic fluctuations more alike.

The study of integration is important in the present era of globalization for several reasons. For instance, it enables the understanding of co-movement, contagion and volatility spillover which is very crucial in guiding macroeconomic policies. Researchers have examined linkages across countries for exchange rates (Huynh, Nasir, and Nguyen, 2020; Nasir et al., 2020; Pham et al., 2020) and among cryptocurrencies (Huynh, 2019; Huynh et al., 2020). Loayza, Lopez and Ubide (1999) note that international co-movement or contagion may arise through the following channels. First, co-movement may arise from country-specific shocks that get amplified and speedily spills over to other countries. Secondly, co-movements may arise from the existence of shocks that impacts on all the countries alike especially from developments in the market of globally crucial commodities such as the energy market. International co-movements may also arise from shocks specific to an important sector of a country such as the sub-prime crisis that began in the housing sector of the U.S.A before spreading to the entire economy and globally. Moneta and Rüffer (2009) argue that in the case of Asia, international co-movements may arise as a result of increased exposure to the USA and Europe as well as spillovers due to strong intra-regional linkages transmitted mostly through current account transactions and the capital markets.

Following the Asian 1997/1998 financial crisis and the contagion effect, a significant interest was devoted towards studying the evolution of business cycle synchronization among the East Asian region (see e.g. Crosby 2003; Shin and Wang 2003; Shin and Solin 2006; Rana 2006; Sato and Zhang 2006; Rana 2007; Park and Shin 2009; Moneta and Rüffer 2009; Kim, Lee and Park 2009; He and Liao 2012; Kim and Kim 2013; Duval et al. 2014). Specifically, Moneta and Rüffer (2009) document that the degree of business cycle synchronization has increased significantly especially among the newly industrialized economies in East Asia and that synchronisation has mainly reflected increased trade ties than investment dynamics. Also, they found a significant spillover of shocks within the region and that crude oil prices may have significantly influenced the degree of synchronization whereas the state of the global economic activities as well as financial conditions did not matter so much.

It has also become interesting to study the linkages of South-East Asian capital markets with increasing evidence of cross-country linkages as demonstrated by stock market returns and volatility correlations (See e.g. Sheng and Tu 2000; Hee 2002; Narayan, Smyth and Nandha 2004; Click and Plummer 2005; Lee, Wu and Wang 2007; Chuang, Lu and Tswei 2007; Gebka and Serwa 2007; Chiang, Jeon and Li 2007; Mukherjee and Bose 2008; Lim 2009; Khan and Park 2009; Huyghebaert and Wang 2010; Perera and Wickramanayake 2012; Jiang, Nie and Monginsidi 2017). These studies have offered sufficient evidence of increasing stock markets co-movement and a support for a contagion effect spreading from crisis hit countries such as Thailand during the Asian financial crisis. There is also an increasing literature on the regional leaders especially the most rapidly industrializing such as South Korea, Singapore, Hung Kong, Taiwan, Japan and China (see e.g. Worthington and Higgs 2004; Jayasuriya 2011; Chien et al 2015).

Further, given the increasing internationalization of capital markets and the huge inflow of funds following the tremendous success of emerging Asian countries, the influence of global factors such as developments in the U.S.A and European capital markets, and crude oil prices have attracted huge empirical exposition especially given the effect of the global financial crisis in 2007. Among others, these studies include Jeon, Oh and Yang (2006), Chancharoenchai and Dibooglu (2006), Hyde, bredin and Nguyen (2007), Singh, Kumar and Pandey (2010), Johansson (2011), Loh (2013) and Wang (2014). Particularly, Chancharoenchai and Dibooglu (2006) document strong evidence of increasing comovement among stock markets in South East Asia but that the influence of the U.S.A stock market is greater that of any single country within the regime. Yet, others have considered the comovement between energy markets and Asian stock markets (see. e.g. Asmar and Brahmana 2013; Abdullah, Saiti and Masih 2016; Noor and Dutta, 2017; Batten et al. 2017; Maneejuk, Yamaka and Sriboonchitta 2018; Jiang et al. 2019).

Edwards (1998) argues that movements in the monetary policy rate such as the federal funds rates are perhaps, one of the key macroeconomic variables that serve as transmission channels through which shocks are amplified and propagated through the economy, thus playing a central role in asset pricing. Surprisingly, little attention has been devoted towards understanding the co-movement among interest rates in the Asian region. The rationale for investigating countries in the same region is based on the finding that the most important factors affecting the extent of spillover are geographical proximity and trade (Sowmya, Prasanna, and Bhaduri, 2016). Furthermore, given the increasing liberalization of Asian capital markets and the resulting international linkages of its financial markets, significant interaction is expected among monetary policy rates in the Asian region as well as the rest of the world. However, interest rate linkages within Asia and the effect of developments in leading global economies and other key indicators of global economic conditions on Asian interest rates has so far received very limited attention.

After the Asian Financial Crisis of the late 1990s, Asian countries started thinking of ways to reduce their reliance on the USD. Several proposals have been discussed; internationalization of regional currencies, regional exchange policy coordination, regional currency arrangement, etc. Recently, Malaysian Prime Minister Dr Mahathir Mohamad suggested that East Asia should adopt a common trading currency. Hence, the study of interest rates linkages among Asian countries is very crucial and timely given the increasing prospects for monetary cooperation and integration in the region.

In this paper, we address two key issues. First, we investigate the co-movement and volatility transmission of interest rates among twelve Asian countries. We account for the influence of global economic factors by introducing interest rates of the USA and the Euro area as well as innovations in the market for crude oil. We rely on the refined dynamic connectedness measure of Antonakakis and Gabauer (2017), which refines and extends the connectedness measures of Diebold and Yilmaz (2009, 2012 and 2014) by introducing a Time-Varying Parameter Vector Autoregression (TVP-VAR) in place of the rolling window VAR. This methodology has found increasing applications in the literature given its improvement on the previous measures of connectedness in the following ways: First, it adjusts automatically to events and is therefore not sensitive to outliers. Second, it does not involve an arbitrary selection of rolling widow sizes and there is no loss of observations, while also been suitable for lower frequency data. Third, we use regression models to identify key determinant factors that drive dynamic integration of interest rates. In this aspect, we rely on the six shock transmission channels proposed by Bakaert et al. (2014). These channels capture shocks transmission through external exposures via financial and trade linkages, cross-border capital flows, information asymmetry, financial and political stability while controlling the effects of the now infamous global financial crisis of 2007-2008.

To preview our key findings, we document some convincing evidence of time variation in the integration of interest rates among these markets and crude oil. We found that volatility linkages was highest towards the 2001 financial crisis whereas there is convincing evidence of decoupling as shown by a notable drop in connectedness during the 2008 GFC and the euro-debt crises. In descending order, Singapore, Brent crude oil, Hong Kong, Philippines and U.S.A are the net-givers of spillover whereas India, Japan and Vietnam are net-receivers of spillover. In a sub sample containing highly industrializing economies in Asia, the U.S.A, Euro area and crude oil prices, Singapore, Hong Kong and the U.S.A remained top givers of spillover whereas the Euro area, Taiwan, Korea and the market for crude oil become net receivers of volatility spillover. Results from our regression model suggest that higher integration of the full sample tend to be driven by increasing levels of external exposure through trade and financial linkages, information asymmetry and political stability whereas economic crisis times reduces the level of integration. Lastly, we found that among the highly industrialized markets, dynamic integration is driven by the degree of external exposure as well as both political and financial stability.

The rest of this paper proceeds as follows. Section 2 provides an overview of the existing related literature}. Section 3 presents the empirical strategy which details the build-up to the models for this paper as well as offers a description of the data and preliminary analysis. Section 4 presents the empirical results and discussion, while Section 5 concludes.

2 Literature Review

2.1 Theoretical background

Theoretically, there are interesting transmission mechanisms that have the potential to facilitate the integration of monetary policy and the cross-border spillover of crisis from one market to another. In particular, many studies identify three distinct transmission channels through which changes in policy rates in one country may have spillover effects on other countries (see e.g. Ammer et al. 2016; Pham and Nguyen, 2019). First, the Mundell (1963) and Fleming (1962) monetary policy theoretical models of exchange rate determination (or the IS-LM-BP model) demonstrates that an expansionary shock on monetary policy in one country would cause a relatively lower interest rate in the source country when compared to that of its trade partners and a depreciation of the source country's currency. The result would be a boost in the source country's trade balance, gross domestic product and ultimately, a shift in expenditure from partners to the source country following a reverse effect in partner countries. The expenditure-shifting effect has the potential of distorting the balance sheet, leading to increased foreign debt and a decrease in demand (Blanchard et al., 2010).

Secondly, the domestic demand channel may lead to an opposite effect in partner countries following the conditions set by the exchange rate channel. Here, given that the domestic monetary easing may promote consumption and investment in the source country, causing an increase in imports by the source country while increasing exports from partner countries. Therefore, the domestic demand channel may lead to growth in the GDP of partner countries. Put differently, the domestic demand channel may cause expenditure-increasing effects in partner countries. Lastly, the third channel may be described as the financial spillovers channel. Pham and Nguyen (2019) note that the mechanism of this channel relates to economies that are at a significant level of financial integration. As the source country eases its monetary policy, decreasing long-term interest rates would give rise to increases in asset prices. This has the tendency to cause international investors to adjust their portfolio balances by channeling their capital from the source country to other countries. This would lower interest rates in partner countries, leading to increases in assets prices. As a result, both investment and consumption would be boosted, leading to expenditure-increasing effects on partner countries.

However, it has been argued that effects may be constrained by the size of foreign debt in the partner countries if international investors fail to channel their capital to the partner countries with high levels of foreign debt (see e.g. Blanchard et al., 2010; Pham and Nguyen, 2019). Hence, a decrease in interest rates may not be achieved in these countries. Consequent upon the inadequacy of these theoretical points of view to offer clear-cut answers to whether positive monetary policy shocks in a source country leads to positive or negative spillover effects (expenditure-increasing or expenditure-shifting effects) on real economic activities in partner countries, the resulting effect has been thought to depend on the relative strengths of the exchange rate channel as well as the joint strength of the domestic demand and financial spillovers channels. Hence, empirical studies have evolved with the aim of shading light on the effects of many potential transmission mechanisms including international trade links, financial links and other business cycle-related factors such as financial stability, information asymmetry, capital flows and developments in the market for crucial commodity markets such as crude oil market.

2.2 Empirical literature review

Investigating the extent and magnitude of interest rate cross-border spillovers is critical to better understanding how foreign monetary policy (and foreign interest rates) can potentially influence the domestic interest rates. Of particular interest to developing and emerging countries is to examine how changes in the advanced countries' policy interest rates are transmitted to them. This information helps determine the ability to conduct independent monetary policy. According to Hegerty (2014) there are two channels for interest rate linkages across countries. The first is through capital flows and exchange rates such that the country that experienced a capital outflow might raise interest rates to avoid currency depreciation. The second is due to investor psychology where an increase in money demand, even if not based on changes in underlying fundamentals, will lead investors in other countries to expect higher interest rates. Moreover, the interest rate channel is considered to be an important transmission channel facilitating the understanding of linkages in other financial assets and economic activity (Jotikasthira et al., 2015).

The literature investigating interest rate linkages is not new and can be traced back to the 1960s (e.g. Henderschott, 1967). However, most of these studies examined interest rates of developed economies around the world. We will focus in this section on the recent wave of studies emerging after the Global Financial Crisis and investigating developing or emerging countries. Hegerty (2014) examines interest rate volatility and its potential for contagion among nine Latin American countries. Using GARCH methods and short-term nominal interest rate volatility, he finds intra-regional contagion to be limited, a finding which he attributes to controls on capital movements.

Furthermore, Sowmya, Prasanna, and Bhaduri (2016) investigate the degree of integration and transmission of shocks between countries at various maturity horizons of the term structures of interest rates. Net spillover for long-term interest rates among the US, UK, Germany and Australia, and the Asian countries of China, Japan, Hong Kong, Malaysia, India, Singapore and Korea was found to be above 20% for the U.K., Australia, Malaysia, South Korea, and India, while for short-term interest rates net spillover was much lower; the highest was 18% for South Korea. Evidence also suggested that the linkages are especially high during crisis periods.

Recently, Rout and Mallick (2020) examined cross-country spillover of the real overnight short and long-term interest rates of US, Japan, Germany, China, India, and Russia. Their findings indicate that the net spillover is at least 37%, with long-term interest rate marginally higher compared to overnight and short-term interest rates. While also investigating a mix of developed and developing economies (Brazil, Chile, Colombia, Mexico, Indonesia, Korea, Malaysia, Philippines, and the US), Edwards (2010) adds the spot price of oil as an additional possible global shock that might affect interest rates. The pass-through coefficient from the US to East Asian and Latin American countries was found to be −0.5 but with a differing dynamic adjustment process, while oil prices were not found to have any significant effect. Feldkircher et al. (2017) examine the impact of a positive euro area monetary policy shock (impulse response) on Asian countries.

Short-term and long-term interest rates show a significant decrease lasting for at least 15 months in China, India, Indonesia, Korea, Philippines, Malaysia, and Thailand.

3 Data and empirical methodology

3.1 Data

The dataset for this study includes fourteen short term interest rates and crude oil prices. The interest rates are for twelve developed and developing economies from the Asian region including Japan (JAP), Philippines (PHI), Singapore (SING), Thailand (THAI), Malaysia (MYL), Indonesia (INDO), China (CHIN), India (INDI), Taiwan (TAI), South Korea (KOR), Hung Kong (HNGKNG) and Vietnam (VIET). It also includes an aggregate policy rate for the Euro area and the USA. To have a better coverage of the oil market, we use the average of West Texas Intermediate (WTI) and Brent crude oil prices as the benchmark for global crude oil prices in US dollars. The monthly data series cover the period from August 1999 to January 2018. All the monetary policy data series were extracted from Thomson Datastream International except for the Euro area which was retrieved from the U.S. Federal Reserve Economic Database (FRED). Concerning crude oil prices, we rely on WTI and the Europe Brent spot prices from the U.S Energy Information Administration.

Regarding the identification of driving factors of dynamic integration, we rely mainly on Bekaert et al. (2014) which analyzes the channels of shocks transmission between domestic markets and the global financial sector. Following this, we construct six factors including Financial integration (FININT), Trade integration (TRDINT), Capital flows (CAPFLW), Information asymmetry (INFASY), Financial stability (FINSTAB) and Political stability (POLSTAB). We also created a dummy variable to capture the effect of the past 2007-2008 economic and financial crisis. Specifically, the first three factors namely FININT, TRDINT and CAPFLW measure the degree of external exposure of each market. FININT is the stock of portfolio assets and liabilities overseas whereas TRDINT is the sum of exports and imports all scaled by GDP. Likewise, CAPFLW is the net sales of long term securities by domestic residents and of foreign residents scaled by GDP. A positive value shows a net inflow of capital whereas a negative value shows a net out flow of capital. Information asymmetry is captured by net imports of newspaper and periodicals from the U.S.A and is expected to increase correlation and integration especially during crisis period during which investors' decision are guided by easily available public information.

We attempt to capture existing domestic economic and political conditions using FINSTAB and POLSTAB. We use each country's domestic bank Z-score which measures the probability of default of a banking system. This score compares the banking system capitalization and returns with the volatility of these returns. The higher the score, the higher the probability of default of the banking system and the higher the volatility of returns. A higher probability of default implies that the banking sector seems more vulnerable to higher volatility spillover from both regional and global financial systems, hence higher connectedness. POLSTAB is measured as the sum of the index for government support and legislative strength. Regarding data sources for these factors, FININT and TRDINT were collected from the Coordinated Portfolio Investment Survey (CPIS) and IMF databases. CAPFLW was retrieved from the U.S. Treasury International Capital (TIC) database whereas INFASY was gotten from the U.N Comtrade database, exports of items 8922 SITC. lastly, FINSTAB was sourced from IMF, Bank scope and Orbis Bank Focus, Bureau Van Dijk (BVD) whereas POLSTAB is from the Risk Guide (ICRG) researchers dataset by PRS group Inc, Harvard Dataverse.

Table 1 reports the descriptive analysis of interest rates for all the countries, Euro area and crude oil prices. We find that among all the countries and the Euro area, the mean policy rate is highest in Indonesia with about 10% followed by the Philippines and Vietnam with about 8.5% respectively. However, the mean policy rate is least in Japan with about 0.09%. Similarly, the minimum policy rates are found in the Euro area followed by Japan with about -0.39% and -0.21% respectively. Also, the maximum policy rates during this period are found in the Philippines followed by Indonesia with about 15.4% and 13.6% respectively. The standard deviation is highest in the Philippines followed by Japan with about 3.97 and 0.15 respectively. lastly, concerning Brent crude oil prices, the mean spot price of crude oil is about 63.3 U.S dollars, the maximum value is 132.7 dollars whereas the least price is 18.7 dollars with a standard deviation of 31.6.

Table 1: **Descriptive statistics**

	Descriptive statistics					
	Obs.	Mean	Min	Max	Std. Dev	ADF
JAP	222	0.0972	-0.2141	0.4243	0.1479	-10.39***
PHI	222	8.5198	3.7778	15.434	3.967	-9.192***
SING	222	2.7582	1.8353	4.6808	0.7022	-8.822***
THAI	222	4.202	2.3727	7.6172	1.1331	-2.814*
MYL	222	4.2244	3.702	6.5736	0.5607	-6.322***
INDO	222	10.03	6.6042	13.571	2.3463	-6.337***
CHIN	222	3.2974	2.3659	4.7604	0.8464	-4.858***
INDI	222	7.0866	5.5128	9.6905	1.1667	-13.16***
TAI	222	1.5271	0.6068	5.0606	1.0529	-7.90***
KOR	222	3.7287	1.2712	7.5979	1.4712	-2.643*
HNGKNG	222	1.3922	0.0513	6.4699	1.585	-8.311***
VIET	222	8.529	5.0568	11.409	1.6904	-12.42***
GER	222	1.9161	-0.3992	4.1717	1.5508	-6.716***
US	222	1.6608	-0.0541	6.0723	1.6707	-9.253***
BRENT	222	63.296	18.71	132.72	31.683	-9.980***
Drivers of dynamic connectedness						
FININT	222	69.988	60.808	78.12	5.4855	-10.728***
INFASY	222	14.667	13.419	16.615	0.6654	-10.540***
TRDINT	222	82.14	56.874	118.07	19.799	-10.332***

CAPFLW	222	200.2	-1265.8	1586.9	418.79	-8.839***
FINSTAB	222	13.569	11.693	15.149	1.1875	-8.824***
POLSTAB	222	10.991	8.954	13.273	1.1583	-15.690***
CRISIS	222	0.1801	0	1	0.3852	-2.625*

Table 2 presents the correlation coefficients among policy rates and crude oil prices with their associated levels of significance. We can deduce from the results that the correlations among policy rates are in most cases positive and strong with coefficients of 0.5 and above. However, this is not the case for Japan where correlation coefficients are mostly less than 0.5 except with Thailand, Korea, Vietnam and the Euro area. Perhaps, the key takeaway from these are as follows: First, we find that among the Asian economies, policy rates in India is not significantly correlated with other policy rates and crude oil prices except with Taiwan and Korea. On the other hand, we find that the correlation between policy rates in China is negatively correlated with those of other markets except India, Vietnam and Crude oil. Similarly, crude oil prices is negatively correlated with policy rates in all markets except in Japan, china and Hung Kong.

Table 2: Correlation matrix

	JAP	PHI	SING	THAI	MYL	INDO	CHIN	INDI	TAI	KOR	HNGKNG	VIET	Euro Area	USA
JAP	1.00													
PHI	0.309***	1.00												
SING	0.141**	0.876***	1.00											
THAI	0.554***	0.913***	0.831***	1.00										
MYL	0.116*	0.861***	0.964***	0.817***	1.00									
INDO	0.131**	0.856***	0.935***	0.783***	0.888***	1.00								
CHIN	-0.10	-0.833***	-0.884***	-0.752***	-0.898***	-0.939***	1.00							
INDI	-0.04	-0.041	-0.036	0.05	-0.150**	-0.188***	0.365***	1.00						
TAI	0.404***	0.832***	0.849***	0.891***	0.766***	0.777***	-0.660***	0.258***	1.00					
KOR	0.561***	0.915***	0.832***	0.956***	0.768***	0.789***	-0.707***	0.111*	0.928***	1.00				
HNGKNG	0.297***	0.808***	0.875***	0.851***	0.891***	0.771***	-0.745***	-0.031	0.833***	0.821***	1.00			
VIET	0.821***	0.01	-0.284***	0.177***	-0.305***	-0.223***	0.231***	0.01	-0.006	0.190***	-0.227***	1.00		
Euro Area	0.629***	0.889***	0.806***	0.961***	0.752***	0.762***	-0.680***	0.09	0.916***	0.991***	0.827***	0.240***	1.00	
USA	0.305***	0.773***	0.868***	0.836***	0.888***	0.758***	-0.735***	-0.064	0.813***	0.794***	0.988***	-0.237***	0.807***	1.00
BRENT	0.335***	-0.602***	-0.791***	-0.434***	-0.797***	-0.710***	0.707***	0.01	-0.505***	-0.450***	-0.646***	0.632***	-0.399***	-0.616***

Empirical methodology

The methodological framework for this paper unfolds as follows; first, we derive the time-varying integration among crude oil price shocks and interest rates using a network-based spillover index. Secondly, we use regression models to identify the drivers of the degree of integration among oil shocks and monetary policy. To examine the dynamic integration among crude oil price shocks and interest rates, this paper relys on the Time-Varying Paremeter VAR (TVP-VAR) with stochastic volatility proposed by Antonakakis and Gabauer (2017). This network-based spillover framework extends the spillover approach of Diebold and Yilmaz (2009, 2012, 2014) by incorporating changes in the variances using the stochastic volatility Kalman Filter estimation of Koop and Korobilis (2014). This methodology has proven to be useful in exploring network-based time-varying spillovers and has been employed by previous studies (see e.g. Dahir et al., 2019; Ji at al., 2019; Urom et al., 2020; Urom et al., 2021a; Bouri et al., 2021; Urom et al., 2021b; Li et al., 2021).

Basically, the stationary covariance *x*-variable VAR(p) model may be written as follows:

$$x_t = \emptyset + \beta_i x_{t-1} + \beta_2 x_{t-2} + \cdots + \beta_p x_t + v_t \quad (1)$$

Where x_t is an $N \times 1$ vector of conditional volatilities, x_{t-1} is an $N_p \times 1$ conditional vector while β_t is an $N \times N_p$ dimensional time-varying coefficient matrix and v_t denotes an $N \times 1$ vector of error terms. The parameters x_t depend on their past values x_{t-1} up to x_{t-P}.

Following the Wold representation theorem, the Generalized Impulse Response Functions (GIRF) and Generalized Forecast Error Variance Decomposition (GFEVD) are derived by transforming Equation 1 into a vector of moving average $x_t = \sum_{i=0}^{\infty} A_i \, v_{t-1}$. The vector of coefficient matrix A_1 follows a recursion of the form: $A_j = \beta_i A_{j-1} + \beta_2 A_{j-2} + \cdots \ \beta_P A_{j-p}$, where A_j is the $n \times n$ identity matrix and $A_j = 0$ for *j < 0*. Therefore, the GFEVD is estimated and normalized, allowing it to be interpreted as the share of variance that a variable has on the system. Therefore, each roll of the normalized variance share adds up to one, implying that all the variables in the system jointly explain 100% of variable *i*'s forecast error variance. This is given as:

$$\tilde{\gamma}_{ij,t}^{g}(J) = \frac{\sum_{t=1}^{j-1} \Psi_{ij,t}^{2,g}}{\sum_{j=1}^{N} \sum_{t=1}^{J-1} \Psi_{ij,t}^{2,g}} \quad (2)$$

where $\sum_{j=1}^{N} \tilde{\gamma}_{ij}^{N}(J) = 1$ while $\sum_{ij,t}^{N}(J) = N$

Connectedness measures

(a) Total directional connectedness "To" and "From"

The total directional connectedness measures how a shock in one of the variables spills over to others. Assuming a variable \$i\$ transmits its shock to all other variables \$j\$, the total directional connectedness may be computed as follows:

$$TDC^{g}_{i\to j,t}(J) = \frac{\sum_{j=1,}^{N} i \neq j\, \tilde{\gamma}^{g}_{ji,t}(J)}{\sum_{j=1}^{N} \tilde{\gamma}^{g}_{ji,t}(J)} \times 100 \qquad (3)$$

where *TDC* represents total directional connectedness. Similarly, the total directional connectedness variable *i* receives from other variables *j* is regarded as total directional connectedness from others. This may be measured as follows:

$$TDC^{g}_{i\leftarrow j,t}(J) = \frac{\sum_{j=1,}^{N} i \neq j\, \tilde{\gamma}^{g}_{ij,t}(J)}{\sum_{j=1}^{N} \tilde{\gamma}^{g}_{ij,t}(J)} \times 100 \qquad (4)$$

(b) Net pairwise connectedness

Given the above values, the net directional connectedness may be derived from subtracting the total directional connectedness to others from the total directional connectedness from others. Ideally, this may be interpreted as the strength or influence of variable i on other variables within the system. This is defined as follows:

$$NTDC^{g}_{i,t} = TDC^{g}_{i\to j,t}\,(J) - TDC^{g}_{i\leftarrow j,t}\,(J) \qquad (5)$$

where *NDC* represents net total directional connectedness. By the above expression, a positive NDC implies that the influence of variable *i* over the network is less than the influence of the network on variable *i*. Contrarily, a negative NDC implies that the influence from the network on variable *i* is greater than the influence from variable *i* on the network.

(c) Total connectedness index

Finally, the total connectedness index (*TCI*) which uses the total spillover to capture the level of integration or connectedness in the system may be written as:

$$TCI^{g}_{t}\,(J) = \frac{\sum_{i,j=1,}^{N} i \neq j\, \tilde{\gamma}^{g}_{ji,t}(J)}{\sum_{i,j=1}^{N} \tilde{\gamma}^{g}_{ij,t}(J)} \times 100 \qquad (6)$$

Drivers of dynamic integration

In this subsection, we follow previous studies (see e.g. Ji et al., 2019; Urom et al., 2019) to assess how the dynamic integration vary over some chosen factors. To do this, we fit two regression models which enables us to regress all the chosen factors on the realized total connectedness series for both the full and sub samples. This may be expressed as follows:

$$TCI^{g}_{t}\,(J) = x_{ij} + \sum_{k}\sum_{l} x^{kl}_{ij}\, f_{k,t-1} + v_{ij,t} \qquad \forall_{t} \neq j \qquad (7)$$

where $TCI_t^g\ (J)$ is the total connectedness series for both the full sample and a sub sample to be realized based on Equation 6. $f_{k,t-1}$ represent each of the factors. Therefore, *k* refers to each of the factors namely financial integration (*FININT*), trade integration (*TRDINT*), capital flows (*CAPFLW*), information asymmetry (*INFASY*), financial stability (*FINSTAB*), political stability (*POLSTAB*) and a financial and economic crisis dummy used to assess the effect of past global crises on dynamic connectedness. Consequently, in connection with the theoretical background presented in the literature review section, Equation 7 enables us to demonstrate how the level of integration intensifies or decreases over each of the chosen transmission channels. Put differently, a positive coefficient implies that the level of integration intensifies over the concerned factor while a negative coefficient suggests that the level of integration decreases over the concerned factor.

Results and discussion

Full-sample results

The results of time-varying integration among interest rates in all the markets in our sample and crude oil shocks is presented in Table 3 and Figures 1-3. Following the methodology we described earlier, we first estimated a 15-variable TVP-VAR system containing crude oil prices, interest rates for the USA, Euro area and twelve Asian economies for the full sample period. Here, we investigate and quantify the total connectedness index as well as the total directional connectedness among the system. Indeed, we derive three outcomes. First, we examine the evolution of the total connectedness of the 15 variables over the entire sample period. Second, we explore the direction of connectedness by studying the contribution of each variable *TO* the system as well as the contribution *FROM* the system to the volatility of each market. This permits us to retrieve the net directional connectedness of each market. Lastly, we generate and plot net pairwise connectedness among different possible combinations of the fifteen markets in the system.

				Dynamic connectedness											
	JAP	PHI	SING	THAI	MYL	INDO	CHIN	INDI	TAI	KOR	HNGKNG	VIET	GER	US	BRENT	FROM
JAP	30.43	1.71	1.85	6.74	0.49	4.22	3.88	1.14	1.51	7.74	3.15	15.75	11.37	4.94	5.10	69.57
PHI	0.39	10.77	10.23	7.00	7.36	9.01	8.65	0.06	7.20	7.44	7.07	2.00	7.30	6.80	8.74	89.23
SING	0.39	8.86	10.59	7.02	8.81	7.32	7.22	0.22	8.08	6.89	8.63	2.75	6.54	8.38	8.32	89.41
THAI	1.42	8.05	9.70	9.09	8.71	5.97	5.79	0.65	8.55	8.57	9.55	1.92	7.54	9.21	5.27	90.91
MYL	0.78	7.49	10.50	7.37	12.92	3.99	4.49	1.40	10.16	6.50	10.09	3.55	4.40	8.53	7.84	87.08
INDO	0.98	10.33	9.66	5.94	4.79	12.23	11.80	0.65	4.88	6.64	5.65	1.90	8.68	6.61	9.27	87.77
CHIN	1.12	9.69	9.36	5.30	5.05	11.82	13.22	1.87	3.98	5.61	5.31	2.78	7.84	6.54	10.52	86.78
INDI	2.35	2.83	3.27	4.78	5.38	5.76	9.46	32.99	9.36	4.60	5.16	3.04	2.99	2.77	5.27	67.01
TAI	0.48	7.88	9.91	8.81	10.18	4.57	3.97	2.95	11.22	8.66	10.31	1.23	6.36	8.52	4.95	88.79
KOR	1.78	8.54	9.57	8.85	7.85	6.60	5.94	0.70	8.65	9.01	8.91	1.75	8.16	8.42	5.27	90.99
HNGKNG	0.62	7.20	10.04	8.55	9.56	5.07	4.93	1.15	9.60	7.82	11.09	1.81	6.78	10.61	5.18	88.91
VIET	16.05	3.37	5.24	1.60	4.06	3.65	3.80	0.70	2.03	1.96	2.59	33.06	2.07	3.01	16.82	66.94
GER	2.60	8.81	9.26	8.24	5.77	8.90	8.23	0.08	6.80	8.73	7.96	1.08	9.79	8.60	5.17	90.21
US	0.90	7.12	9.96	8.07	8.34	6.18	6.25	0.39	8.07	7.34	10.71	2.26	7.48	11.39	5.55	88.61
BRENT	1.88	8.70	9.94	2.87	7.26	8.67	9.66	0.22	5.21	3.07	5.21	7.68	3.63	5.21	20.80	79.20
Contribution to others	31.72	100.56	118.49	91.13	93.61	91.72	94.06	12.18	94.06	91.58	100.30	49.49	91.12	98.15	103.25	1261.41
Contribution including own	62.15	111.33	129.08	100.22	106.53	103.95	107.27	45.17	105.27	100.59	111.39	82.55	100.91	109.53	124.05	TCI = 84.1%
Net spillovers	-37.85	11.33	29.08	0.22	6.53	3.95	7.27	-54.84	5.27	0.59	11.39	-17.45	0.91	9.53	24.05	

Understanding the connectedness dynamics among different economies can help the monetary policy makers in a region to coordinate their monetary policies and to understand which economy is worst hit by spillover from other economies as well as how much volatility come into the region through global factors. Table 3 contains estimates of total connectedness index (TCI) for the system as well as the directions and net connectedness for each market. The results suggest that the TCI is 84.1% which reflects the degree of integration among policy rates in Asia, developed markets and global oil prices. Put differently, this implies that the spillover effects within the system is about 84.1%. This finding is consistent with the conclusion of previous studies including Hofmann and Takáts (2015) who found that interest rates have moved closely together internationally in recent years. Concerning the directions of connectedness, results show that Singapore (118.5%), oil price (103.3%), Philippines (100.6%), Hong Kong (100.3%) and the U.S.A (98.2%) are the highest contributors of spillover to the system where as the least contributors are Vietnam (49.5%), Japan (31.7%) and India (12.2%). Contrarily, the top receivers of spillovers from the entire system include Korea (90.9%), Thailand (90.9%), Euro area (90.2%) and Singapore (89.4%) whereas the least receivers of spillover from the system include Vietnam (66.9%), India (67.0%), Japan (69.6%) and oil prices (79.2%).

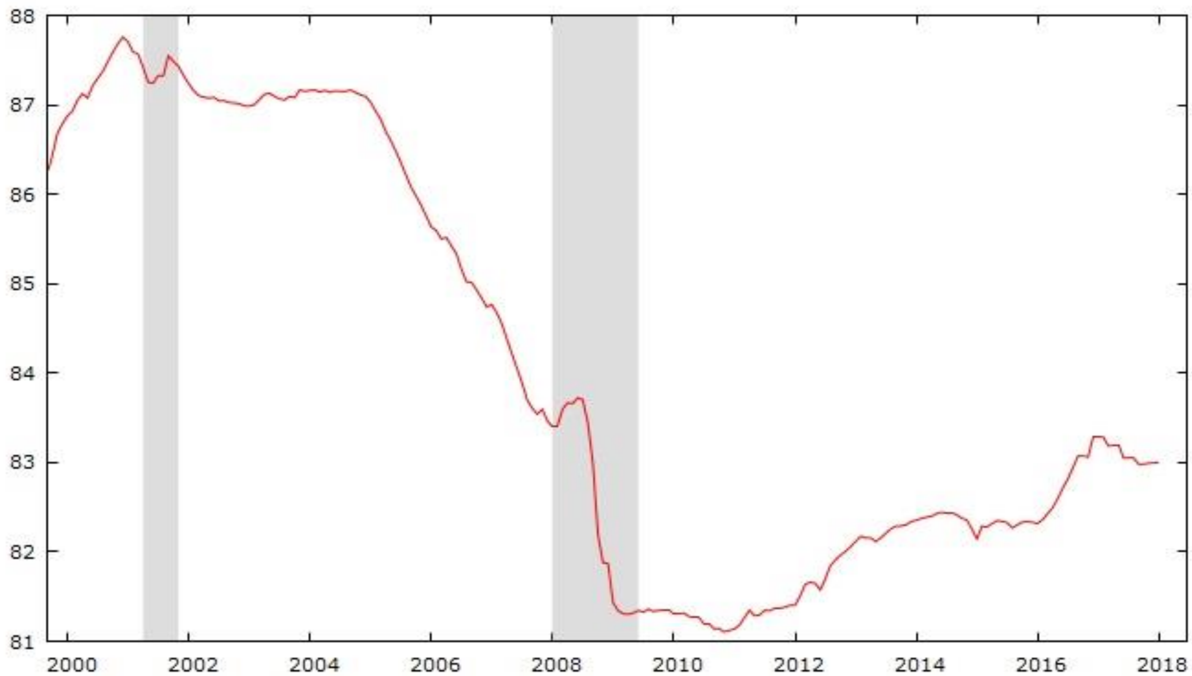
The last row of Table 3 shows the estimates of net connectedness which denotes the difference between each market's contribution of spillover to other markets in the system and the spillover it receives from them. The net connectedness enables us to distinguish between net-transmitters (positive net connectedness) and net-receivers (negative net connectedness) of spillover within the system. Results show that the net-transmitters of spillover are Singapore (29.1%), oil prices (24.1%), Hong Kong (11.4%), Philippines (11.3%), U.S.A (9.5%), China (7.3%), Malaysia (6.5%), Taiwan (5.3%), Indonesia (3.9%), Euro area (0.91%), Korea (0.59%) and Thailand (0.22%). Contrarily, the net-receivers of spillover include India (-54.8%), Japan (-37.8%) and Vietnam (-17.5%). Essentially, net-transmitters are countries that contribute more spillovers to the system than they receive from the system whereas the reverse is the case for net-receivers. These results imply that among the Asian countries, volatility from Singapore, Hong Kong and Philippines spills over more rapidly into other countries than the volatility spill from other countries into them. Concerning external factors, results show also that spillover of crude oil prices, policy rates in the U.S.A rapidly spillover into the Asian markets.

These results also suggest that India, Japan and Vietnam are the major receiver of volatility spillover from the system. This implies that monetary policy rates in these countries seem to be more sensitive to innovations in the policy rates of other countries within the region as well as the global factors. For instance, except spillover from Vietnam, policy rates in Japan seem to be highly sensitive to policy rates in the Euro area (11.4%) followed by Korea (7.7%) and Thailand (6.7%). However, concerning the entire Asia, the Euro area is also a net-giver of spillover, results but the degree of spillover of policy rates from Europe into the Asian market is very weak. This result appears not to support that of Apostolou and Beirne (2019) which reports that the magnitude of volatility spillover from monetary policy shocks in the European Central Bank to emerging markets including China and India appear to be stronger than that of the Federal reserves of the United States.

Figure 1 presents the full sample's time-varying integration with indications of periods of major global financial and economic crises during the study period as identified by National Bureau of Economic Research (NBER). The plot shows clear evidence in support of time variation in total connectedness in the system ranging from about 81.1% to 87.8%. Apart from movements around the crisis periods, some notable conclusions may be distilled from the evolution of total connectedness. First, from 1999 up till around 2005, total connectedness was fairly stable ranging between 86% and 87.8%. This period also marks the era of highest market integration which occurred around 2001. This period is however, preceded by a sharp fall in integration notably between 2005 and late 2007. The 2007-2010 financial crisis as well as the euro-debt crisis seems to have caused a very sharp reduction in integration, reaching its lowest level of 81.1% around late 2010. During the last portion of the sample period which ranges from 2011 to 2018, integration level has risen albeit gradually ranging from 81.1% to 83%.

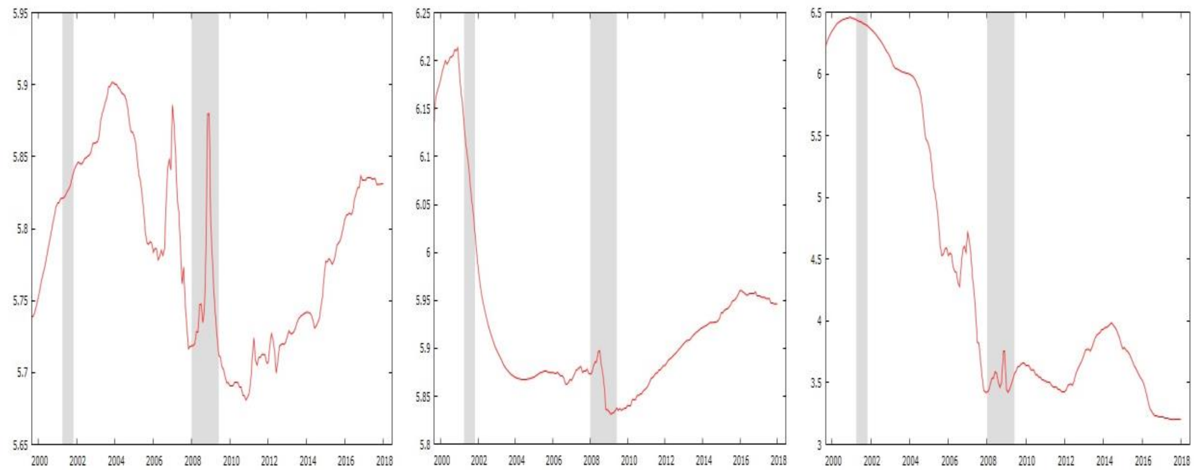
Figure 2 presents plots of contributions of spillover from each market as well as oil prices to the system. From these plots, the key takeaways are as follows: First, we find that in all the countries and crude oil market, there is a significant time variation in the level of contribution of spillover to the system. Also, as indicated by the shaded grey areas in the plots, we find a substantial effect of the immediate past global economic crisis and the euro area debt crisis especially in frontline economies in Asia. This is demonstrated by a sharp drop in the level of spillover contribution in economies such as China, Philippines, Singapore, Indonesia and Vietnam. Concerning the evolution of spillover contributions, the plots suggest that in most of the markets, spillover contribution is on the decrease except in Malaysia, Philippines, Singapore and crude oil market where it is sloping upwards towards the end of our sample period. The highest levels of spillover contribution of about 6.4% and 6.35% may be seen in India and Thailand around 2001 and 2000 respectively. On the contrary, the lowest levels may be found in India and Vietnam with about 3.25% and 3.5% in 2018 and 2009 respectively.

Figure 1: Plot of dynamic total connectedness for the full sample

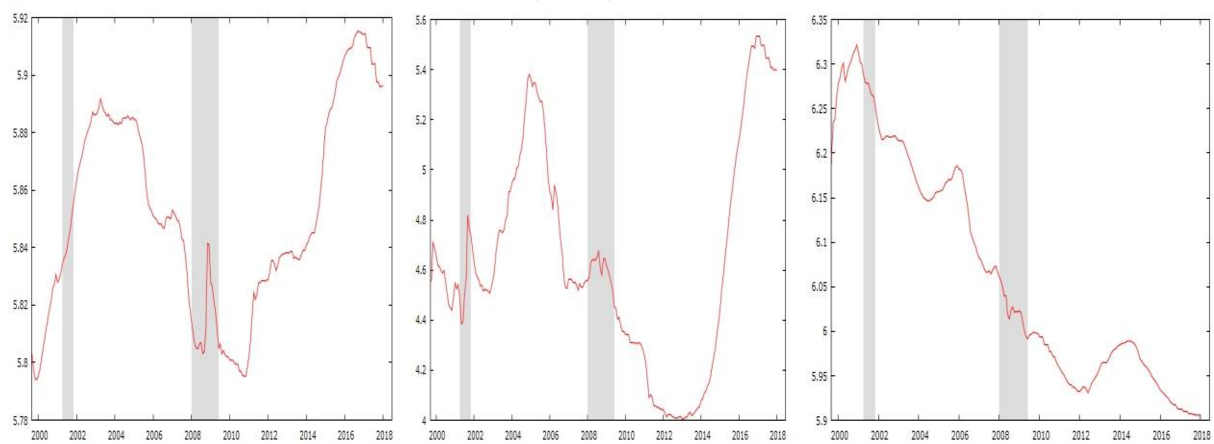


In Figure 2, we show plots of spillover received from the system by each of the markets over the entire sample period. Similarly, we can distill the following points. First, we can find significant time variation in the spillover from the system to each market. The effects of the 2007-2009 financial crisis and euro area debt crisis are also very noticeable in markets such as China, Indonesia, Japan, Philippines, Singapore, Vietnam, the Euro area and U.S.A. Regarding the evolution of the spillover received from the system by each of the market, we find that crude oil market received the highest spillover of about 13% during the economic crisis of 2001-2002. This is followed by Singapore that received about 8.5% around this same period. The implication is that the effects of the crisis on these economies spilled over sharply into the market for crude oil and that of Singapore. On the other hand, the spillover received by India and Japan were the least with about 0.3% and 1.3% respectively. The least spillover was recorded in India during the 2001-2002 economic crisis whereas that of Japan coincides with the 2007-2009 economic crisis and debt crisis in Euro area. Lastly, we note that towards the end of the study period, the spillover received from the system has been trending upwards in seven markets including China, Indonesia, Malaysia, Philippines, Singapore, Vietnam, the U.S.A and crude oil market. However, it is on the increase in the remaining eight markets.

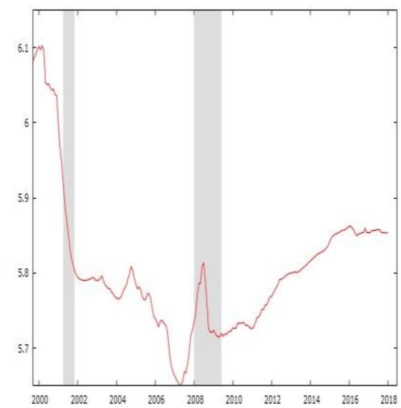
The evolution of net connectedness over the entire period for each market is presented in Figure 3 Recall that net connectedness measures the difference between contributions to the system and the contribution from the system for each market. The striking feature of the plots are as follows: First, we find that the net directional connectedness for India and Japan is negative throughout the study period. On the contrary, it is positive for Singapore throughout the period whereas for the Philippines, a short-lived sharp drop during the period of 2007-2009 economic crisis led it into the negative horizon. This implies that India and Japan are net-receivers of volatility spillover in policy rates throughout the study period whereas Singapore and the Philippines are net-transmitters of spillover over the same period. Another noticeable feature in the plots is the switch in net connectedness for key countries after the past economic crises. For instance, after the 2001/2002 crisis, Hong Kong, Taiwan and the U.S.A switched from being net-receivers of spillover to become net-transmitters for the rest of the sample period. Similarly, after the 2007-2009 economic and the Euro area debt crises, Korea, Thailand and the Euro area switched from being net-receivers to net-transmitters of spillover till the rest of the period under study. This implies that the crises may have altered the nature of dependence among these economies following changes in macroeconomic policies taken during and after the crises.



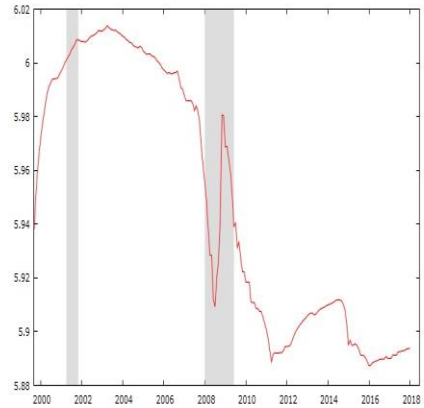
a. China b. Hong Kong c. India



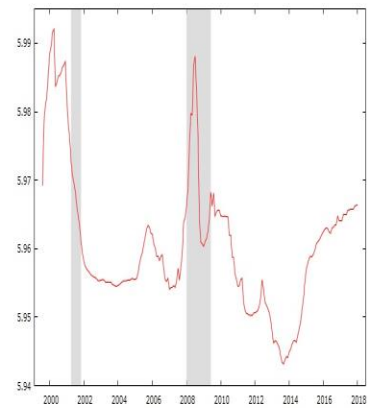
d. Indonesia e. Japan f. Korea



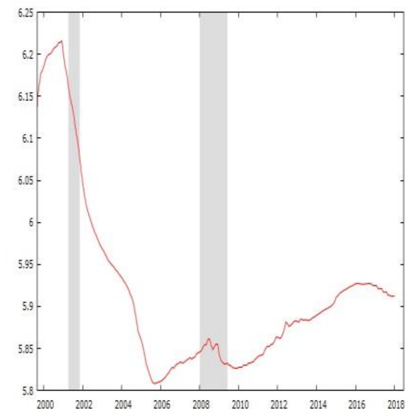
g. Malaysia



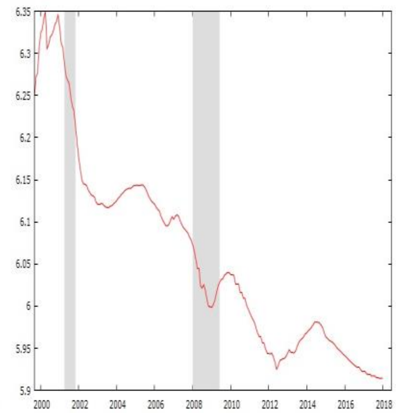
h. Philippines



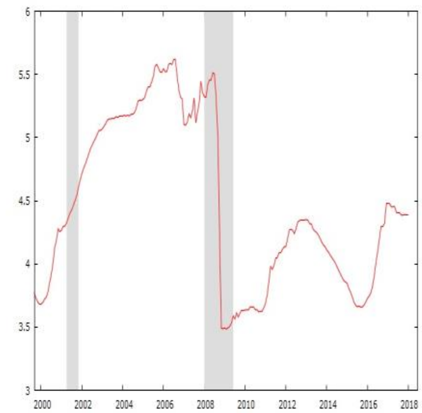
i. Singapore



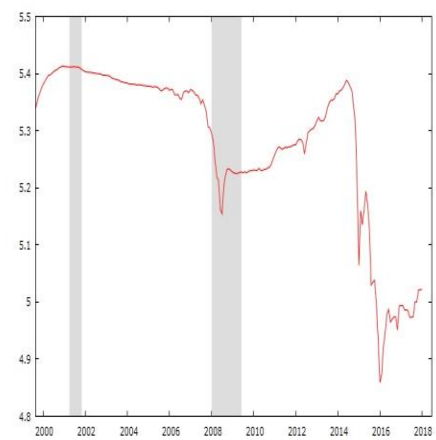
j. Taiwan



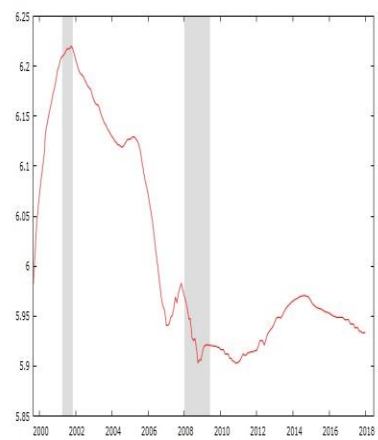
k. Thailand



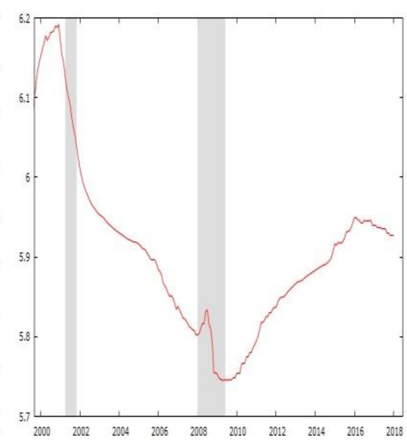
l. Vietnam



m. Oil

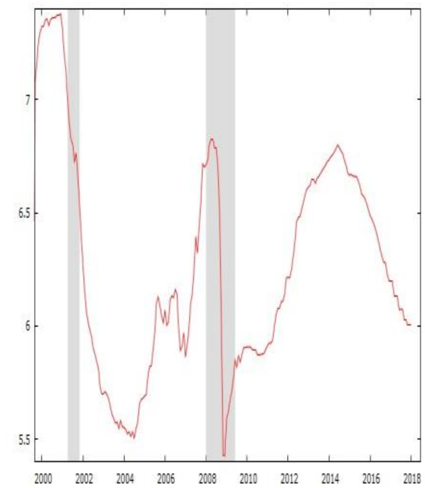


n. Euro Area

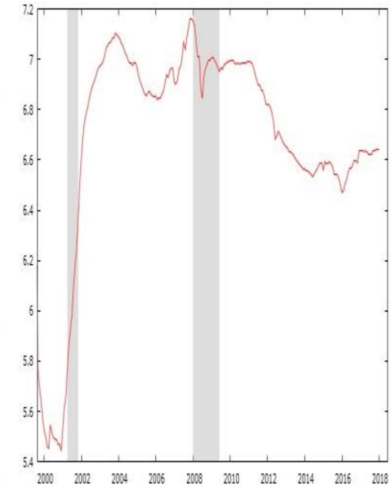


o. USA

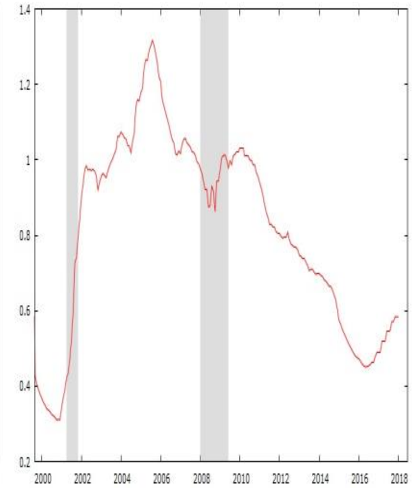
Figure 2: Plots of contribution **FROM** each country to the system



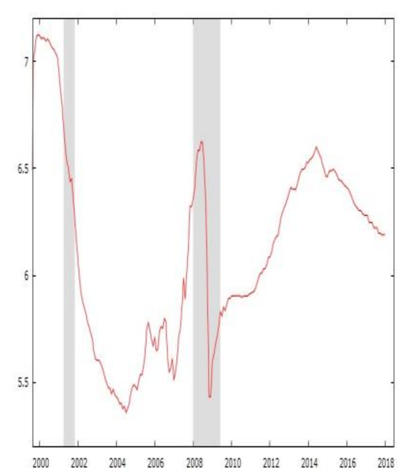
a. China



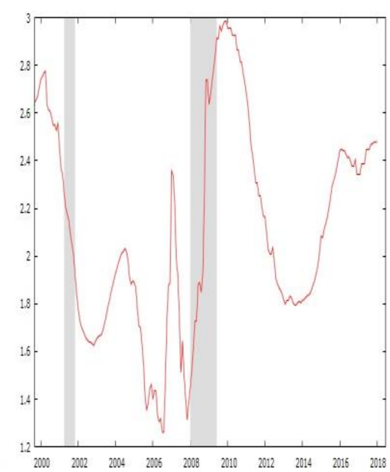
b. Hong Kong



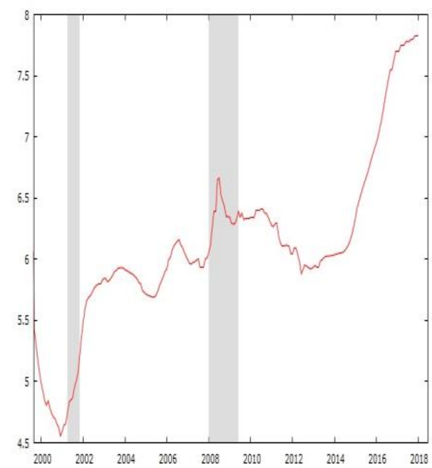
c. India



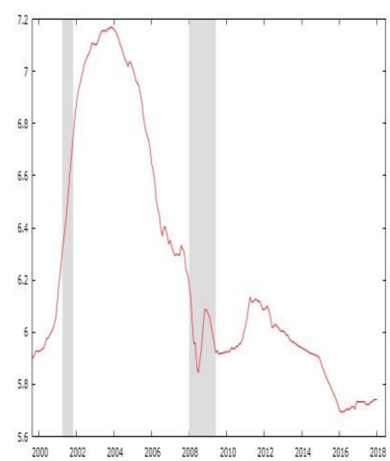
d. Indonesia



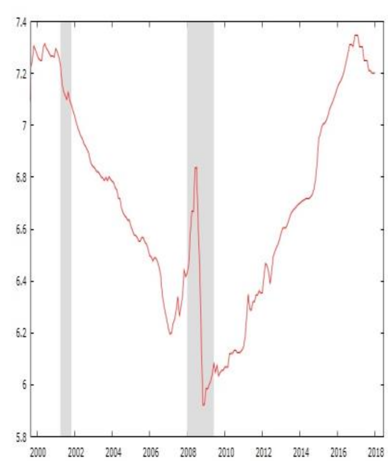
e. Japan



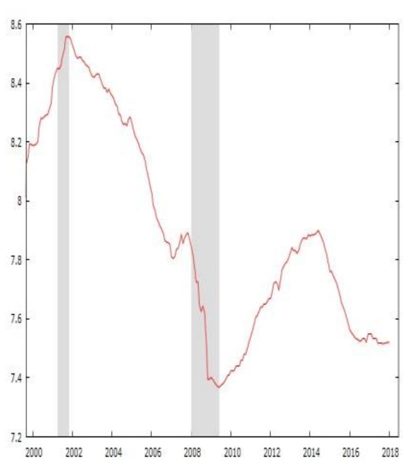
f. Korea



g. Malaysia



h. Philippines



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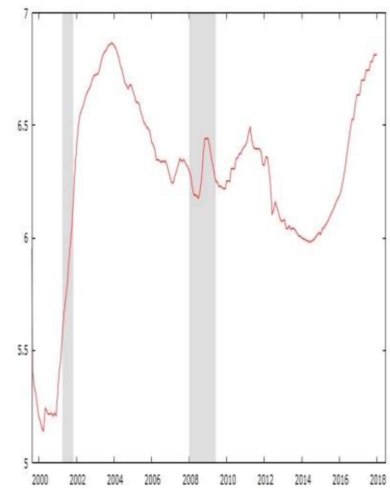
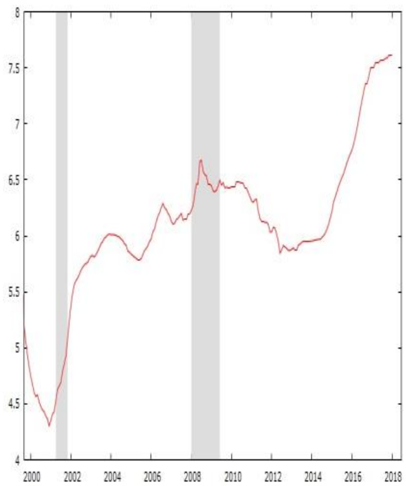
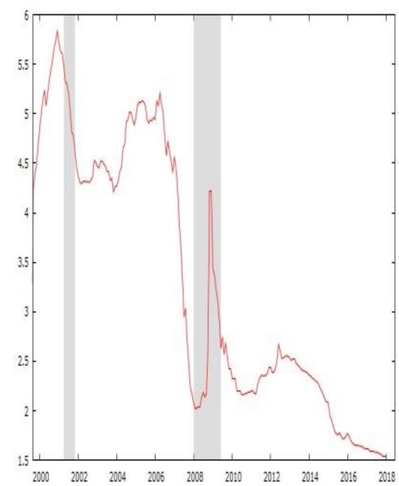


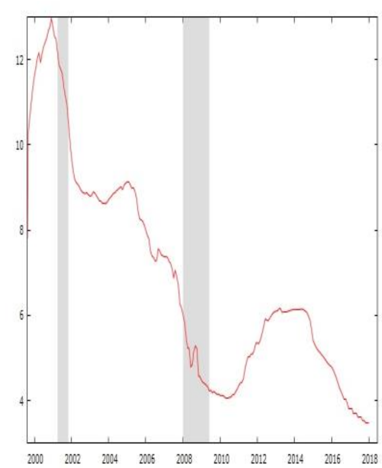
j. Taiwan



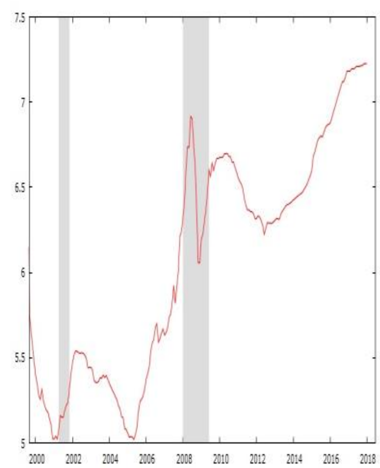
k. Thailand



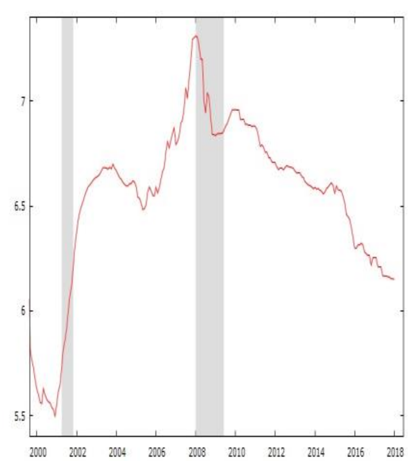
l. Vietnam



n. Oil

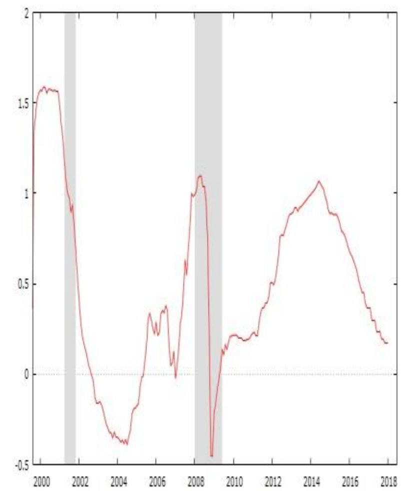


n. Euro Area

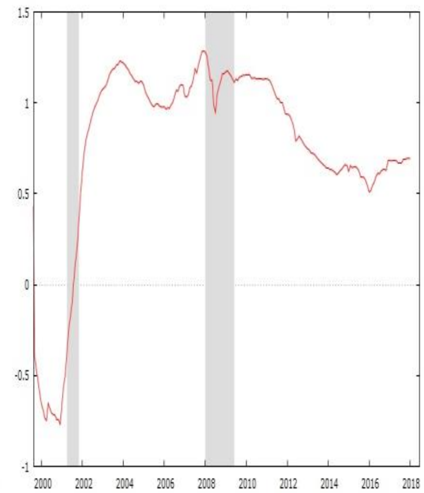


o. USA

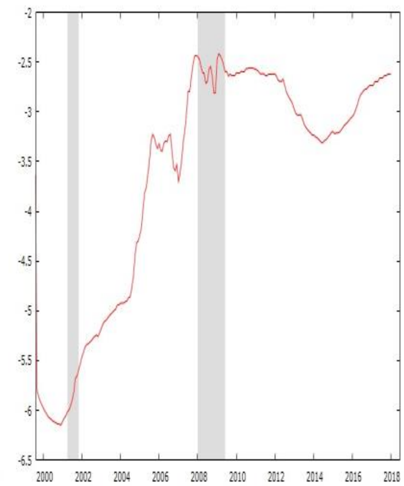
Figure 3: Plots of contribution from the system **TO** each country



a. China



b. Hong Kong



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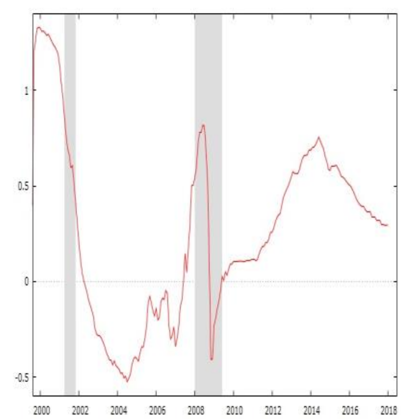
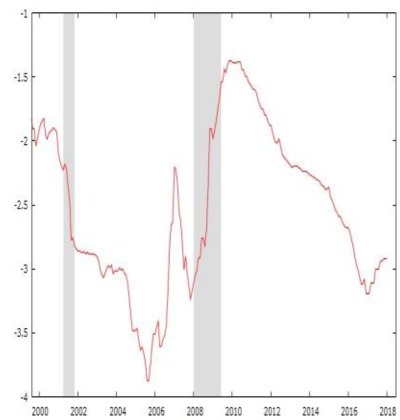


d. Indonesia



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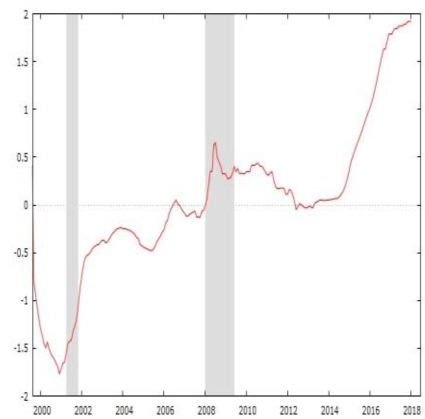

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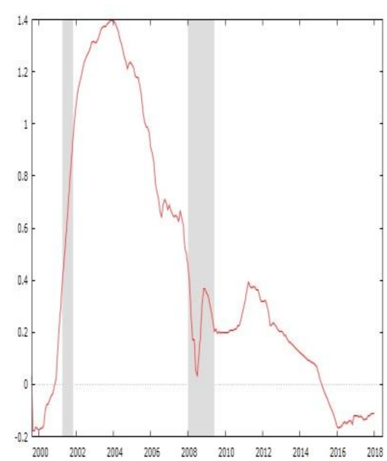
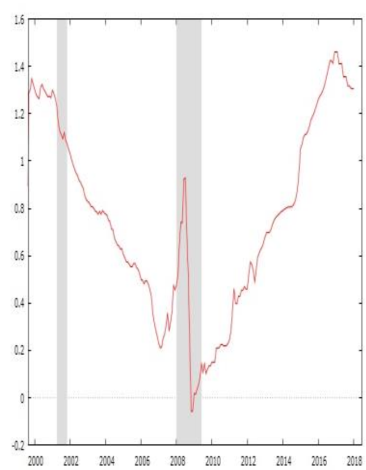
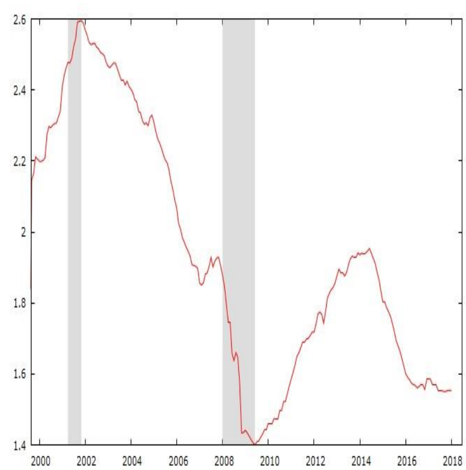


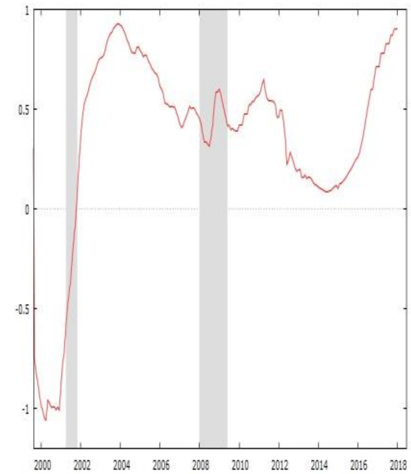
g. Malaysia



h. Philippines

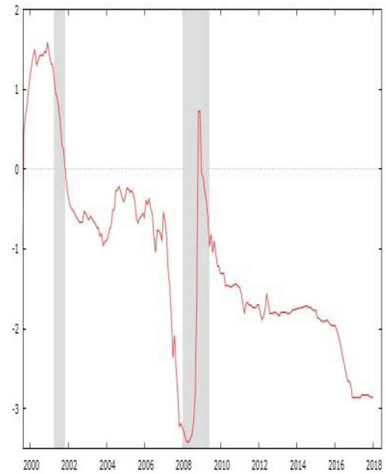


i. Singapore

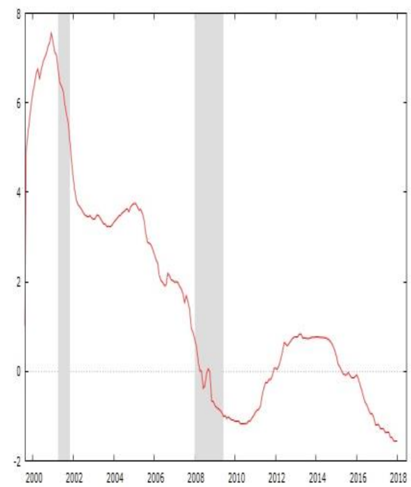


j. Taiwan

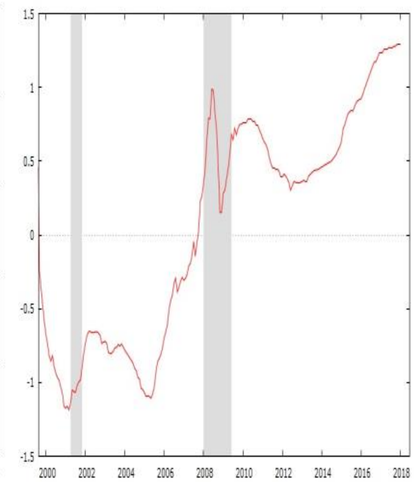
k. Thailand



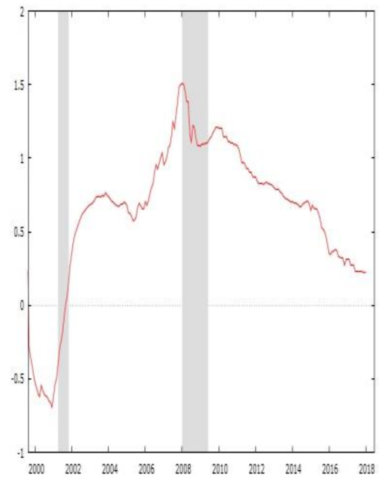
l. Vietnam



o. Oil



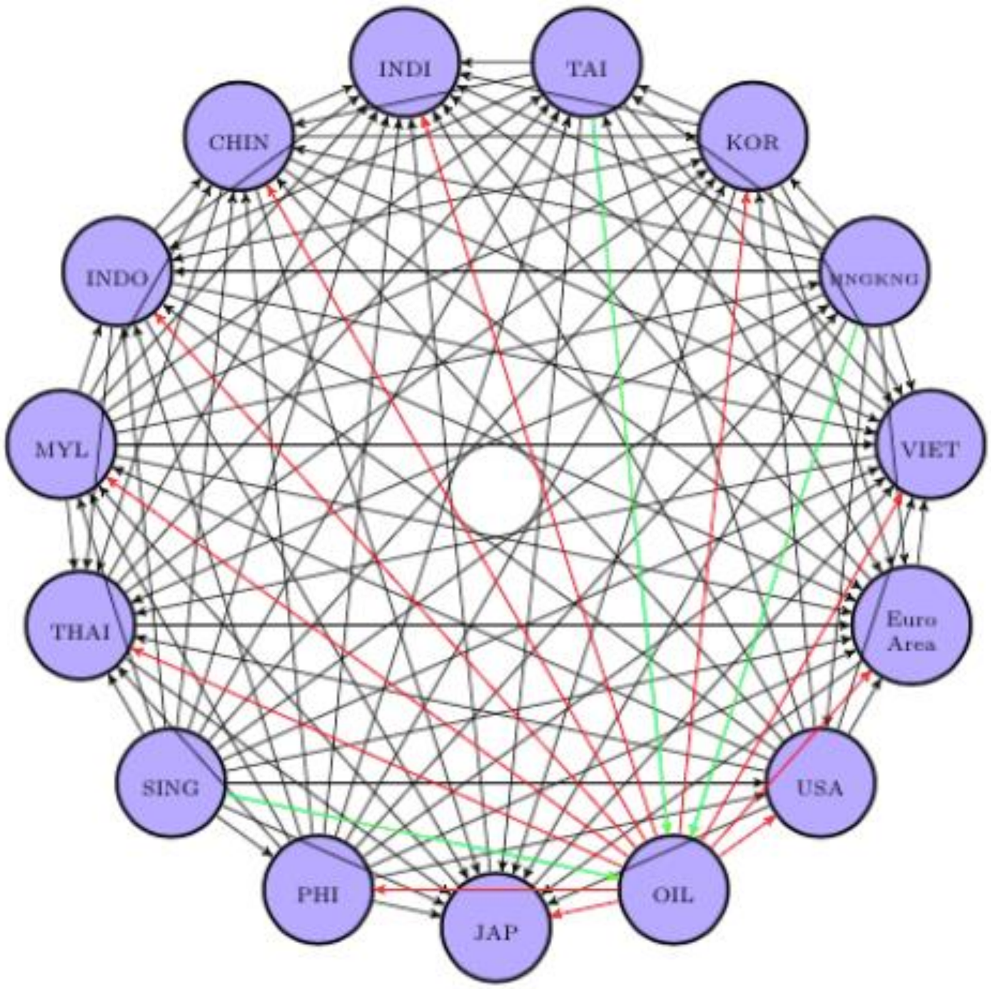
n. Euro Area



o. USA

Figure 4: Plots of **Net** connectedness for each country

Figure 5: Pairwise net directional connectedness for the full sample



In Figure \ref{Fig5}, we present the pairwise net directional connectedness for the full sample. This describes the nature of relations among constitute markets and enables us to rank the markets according to positive pairwise net connectedness. There are a total of 15 nodes with 105 arrows. Each node represents a market and each arrow represents the direction of pairwise net connectedness. Put differently, an arrow from node A to B denotes that market A is a net-transmitter of spillover to market B or that B is a net-receiver of spillover from A. We different arrows to and from the crude oil market with red and green colours. A red arrow indicates that the oil market is a net-transmitter of spillover to the relevant market while a green arrow shows otherwise. According to the diagram, some key results can easily be identified. For instance, Singapore and India are two opposing extreme cases. Singapore is a net-giver of spillover to all the countries including the U.S.A, Euro area and Brent crude oil. Contrarily, India seems to be a net-receiver of spillover from all the markets in the sample. Ranking the markets according to pairwise net connectedness, we find that Philippines and Hung Kong rank next to Singapore. Philippines is a net-giver of spillover to all other markets except for Singapore and crude oil market whereas Hong Kong is a net receiver of spillover only from Malaysia, Singapore and Philippines.

Following India, the highest net receivers of pairwise net connectedness are Vietnam and Japan. The diagram suggest that Vietnam is a net-receiver of spillover from all other markets but only a net-giver of spillover to Thailand and India. Similarly, Japan appear to be a net-receiver of spillover from all the markets except for India, Malaysia and Vietnam. Concerning the three global markets, we find that the oil market leads the U.S.A and Euro area as net-transmitter of pairwise net directional connectedness. Shocks on crude oil price sends higher volatility to all the markets except to Singapore, Taiwan and Hong Kong whereas the U.S.A is a net-receiver of spillover only from Singapore, Philippines, Hong Kong and the oil market. Contrarily, we find that the Euro area is a net receiver of spillover from most countries in the sample except for Japan, India and Vietnam. We may infer from these findings that although changes in the global price of crude oil has significant implications on policy rates among the Asian markets, the economic conditions within highly industrialized economies such as Singapore, Taiwan and Hong Kong send sufficient spillover to the market for crude oil. This also holds for the U.S.A given that developments in the strong economies of Singapore, Philippines and Hong Kong seems to send superior spillover that influences policy rates in the U.S.A.

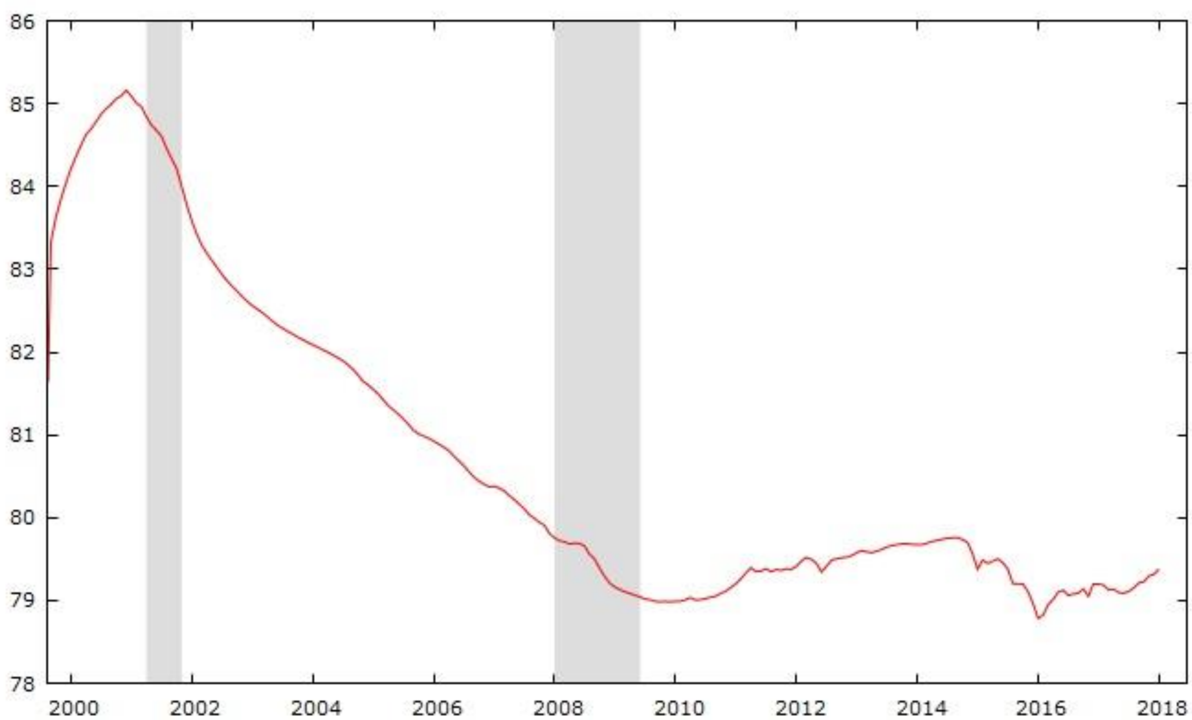
Sub-sample results

In this section, we take a closer analysis by studying a sub sample comprising of the highly industrializing economies in the Asian region with the U.S.A, Euro area and the oil market. Indeed, we aim to characterize the dynamic integration among the so-called Asian tigers plus China and the global markets to enable us understand the nature of integration among the industrialized markets.

Table 4 presents estimates of dynamic connectedness for the sub sample. The results suggest that total connectedness index for the sub sample is about 80.7%. This implies that the connectedness among the high industrializing Asian economies with the U.S.A, Euro area and oil prices is about 80.7%. This suggests that the level of integration among the sub sample is less than the integration among our entire sample. When we take a closer look at the net directional connectedness for each of the markets, we find that Singapore stands high with a positive net directional connectedness of about 20.6%. This is followed by the U.S.A and Hong Kong with 5.61% and 5.46% respectively. This implies that among our sub sample, Singapore, the U.S.A and Hong Kong are net-transmitters of volatility to others within the system. This result is consistent with that of Antonakakis et al. (2019) which report a positive net directional connectedness from U.S. monetary policy shocks in a system containing developed economies including the Euro Area and Japan. On the contrary, Korea leads the net-receivers of spillover with a total net directional connectedness of about -8.9%. This is followed by the Euro area, China, Taiwan and the crude oil market with net directional connectedness of -8.8%, -6.7%, -5.7% and -1.36% respectively. This suggests that when placed among high industrializing Asian economies, Korea, Taiwan, China, the Euro area and the market for crude oil become net-receivers of volatility.

In Figure 6, we characterize the evolution of integration over the entire sample period. The plot shows that the peak and trough of total connectedness ranges between 79% and 85.1%. Similar to the full sample, the highest point of integration for the sub sample occurred during the 2001-2002 financial crisis. However, the least point is witnessed in 2016, perhaps suggesting an effect of the highest drop in the prices of crude oil, causing a shock in oil prices. We note that unlike in the full sample in which the total connectedness was on the rise about this same time, for the sub sample, it recorded its lowest levels and has risen albeit reluctantly till the end of the sample period. It is evident also that unlike the full sample, the integration among the sub sample showed no significant reaction during the 2007-2009 economic crisis as well as the Euro debt crisis that followed. This may not be completely unexpected given that the Euro area is a net-receiver of volatility from the sub sample.

Figure 6: Plot of dynamic total connectedness for the sub sample



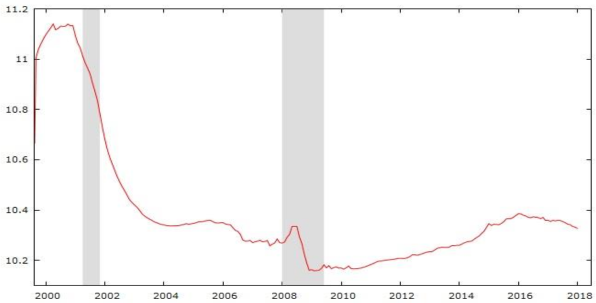
Looking at the contribution of spillover from each market into the sub-sample network as represented by the plots in Figure 7, the following observations may be made. First, we find that seem to be no major impact of past economic and the euro area debt crises except in the case of

Singapore and China where contributions of spillover dropped significantly during the crises periods. Another key finding is that the highest point of spillover contribution of about 11.5% is found in Korea around 2001 followed by 11.3% from the Euro area at the same period. The least contribution of about 7% comes from crude oil market around the period of significant drop in crude oil prices in 2016. Lastly, the plots suggest that towards the end of our sample period, contributions of spillover from Singapore, China and crude oil are on the rise whereas contributions from Hong Kong, Taiwan, Euro area and the U.S.A have been on decline.

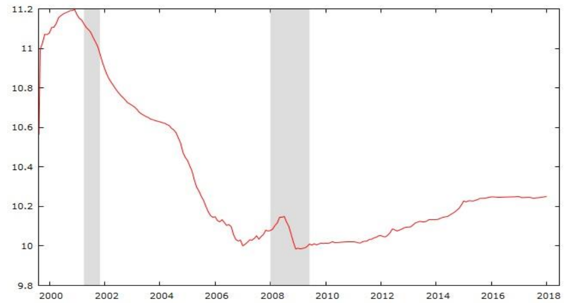
		Dynamic connectedness							
	SING	TAI	KOR	HNGKNG	CHIN	GER	US	BRENT	FROM
SING	16.38	12.66	11.20	13.48	11.07	10.56	13.09	11.56	83.63
TAI	15.36	17.29	13.61	16.26	6.31	10.47	13.80	6.91	82.71
KOR	14.70	13.42	14.87	13.89	9.51	13.58	13.20	6.84	85.13
HNGKNG	14.97	14.26	12.35	16.84	7.57	10.94	16.34	6.73	83.16
CHIN	14.74	6.09	8.99	8.17	21.46	12.68	10.16	17.72	78.54
GER	14.03	10.36	13.75	12.42	12.79	15.62	13.55	7.49	84.38
US	14.73	11.99	11.62	16.26	9.25	11.82	17.41	6.93	82.60
BRENT	15.71	8.21	4.65	8.14	15.30	5.45	8.08	34.47	65.53
Contribution TO others	104.22	76.99	76.18	88.62	71.79	75.49	88.21	64.18	645.66
Contribution including own	120.59	94.28	91.05	105.46	93.25	91.11	105.61	98.64	T.C.I = 80.7
Net spillovers	20.59	-5.72	-8.95	5.46	-6.75	-8.89	5.61	-1.36	

In Figure 8, we present plots of spillover from the system to each of the markets in our sub sample. The plots show a significant decrease in contribution of spillover sent from the system only to the Euro area and then, Korea during the 2007 - 2009 economic and euro area crises. The market for crude oil and Hong Kong appear to be the highest receivers of spillover from the system with about 20% and 12.2% respectively. We note that whereas this occurs during the 2001 crisis for crude oil market, it occurred during the 2007 - 2009 crisis for Hong Kong. On the contrary, the crude oil market also doubles as the least receiver of spillover of about 5% during the 2007 - 2009 economic crisis. This is followed by Korea with about 6.5%. Lastly, towards the end of our sample, the contribution of spillover from the system to Hong Kong, Taiwan, Korea and the U.S.A has been on the rise whereas this is not the case for the remaining markets in our sub sample.

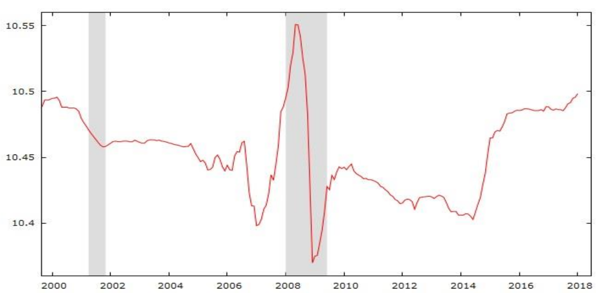
The plots of net directional conneectedness for each of the markets in the sub sample is presented in Figure 9. The key finding are as follows: First, we can observe that Taiwan and Singapore stand out, representing the two extreme scenarios. Throughout the sample period, Singapore remained a net-transmitter of spillover with the plot lying above the zero line. On the contrary, Taiwan remained a net-receiver of spillover throughout the sample period. Hong Kong and the U.S.A represent a similar scenario with both countries starting off as net receivers of spillover up till the 2001 - 2002 crisis, after which they became net-transmitters of spillover for the rest of the sample period. China and the oil market offer an opposing situation, starting off as net-transmitters of spillover but switching to become net-receivers around 2002 for China but beginning with the 2007 economic crisis for the case of the market for crude oil. Lastly, a similar pattern may also be found between Korea and the Euro area. Both markets were net-receivers of spillover up till 2014 after which they have become net-transmitters till the rest of the sample period. However, at the wake of the 2007 economic crisis, both markets rose sharply to become net-transmitters of spillover but slipped to remain below the zero line before the end of the crisis period.



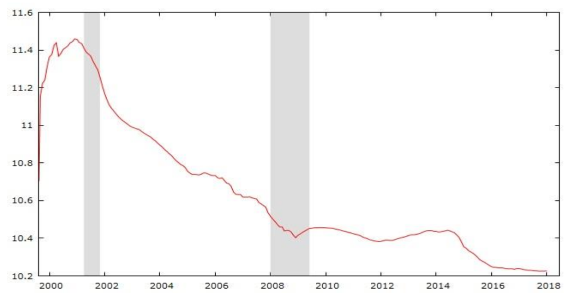
a. Hong Kong.



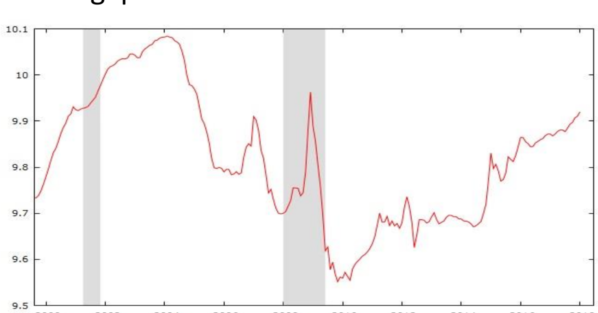
b. Taiwan



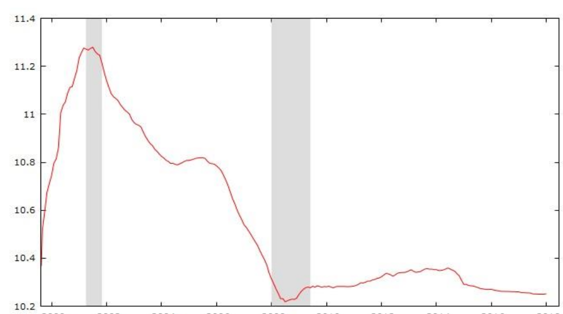
c. Singapore



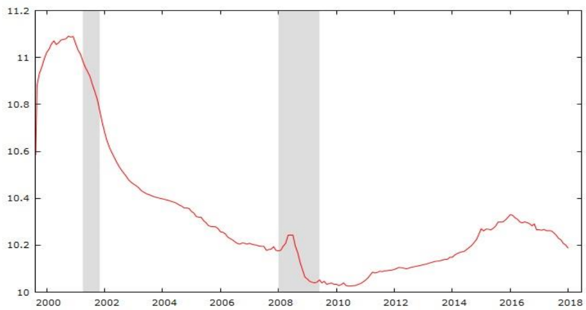
d. Korea

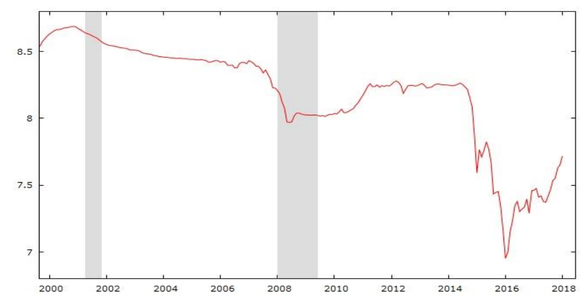


e. China



f. Euro Area

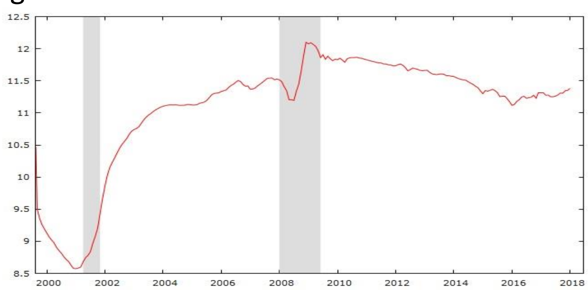




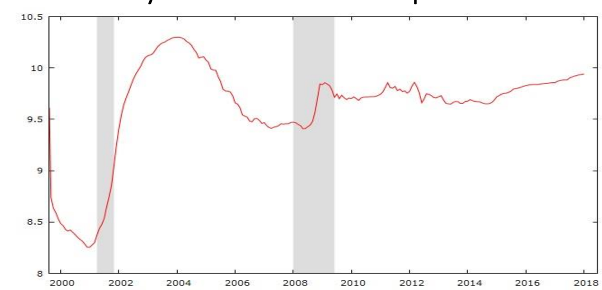
g. USA

h. Oil

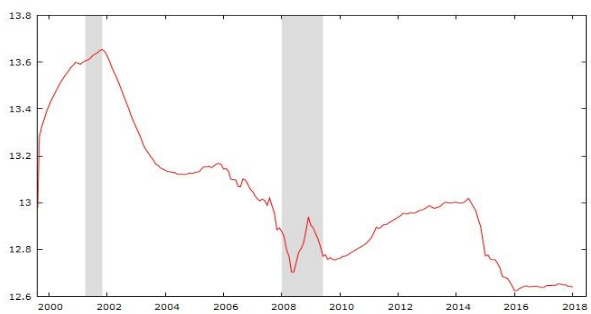
Figure 7 : Plots of contribution FROM each market to the system in the subsample



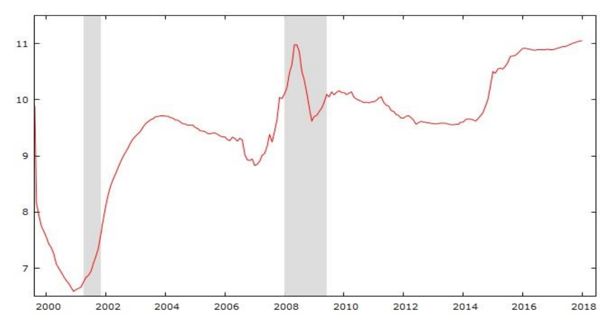
a. Hong Kong.



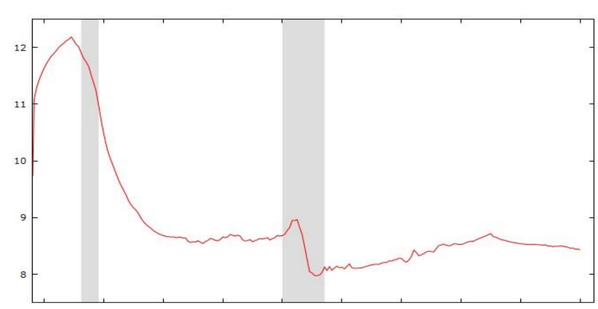
b. Taiwan



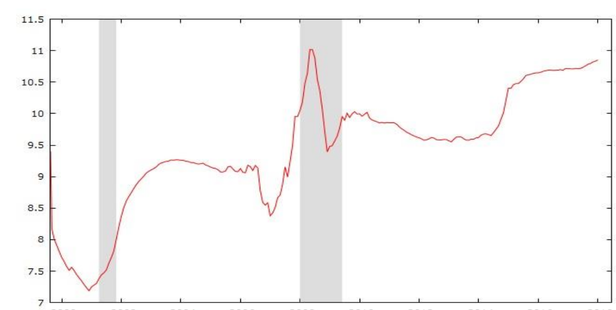
c. Singapore



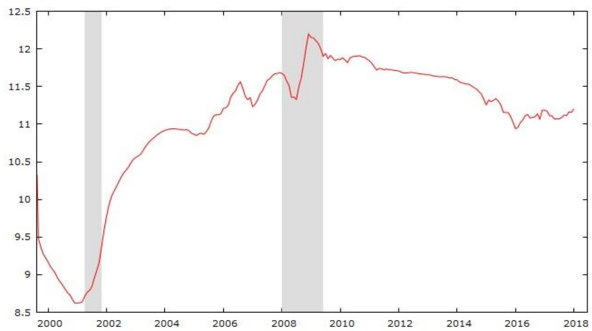
d. Korea



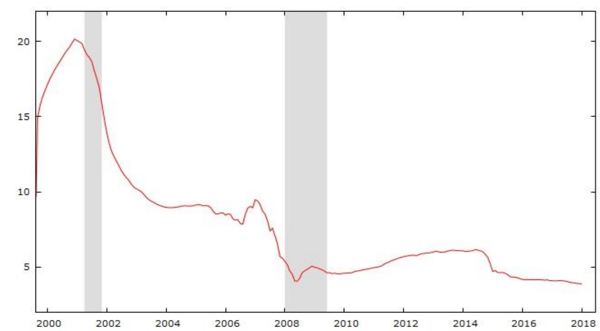
e. China



f. Euro Area

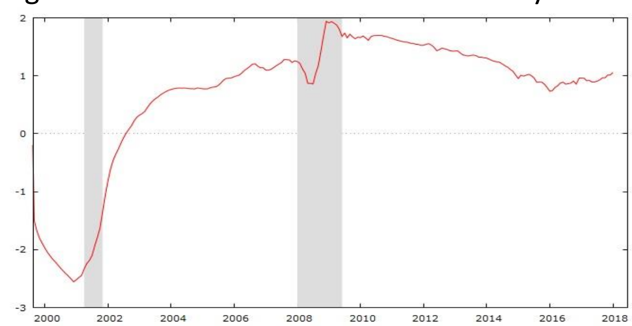


g. USA

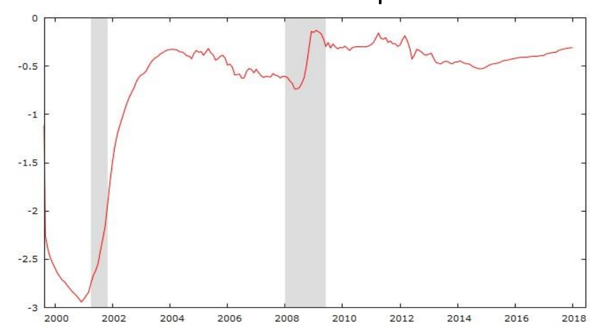


h. Oil

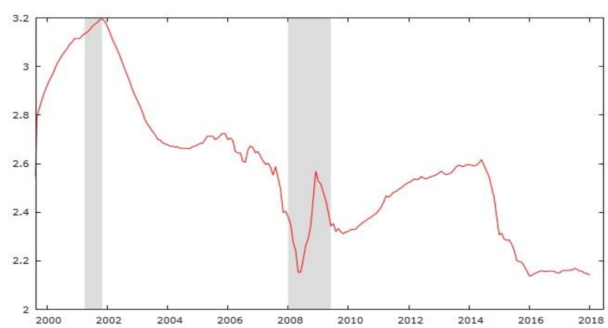
Figure 8: Plots of contribution from the system TO each market in the sub sample



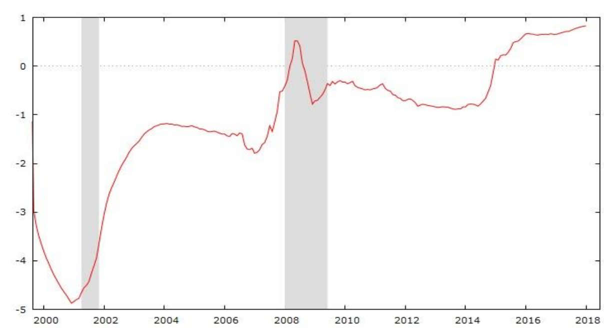
a. Hong Kong.



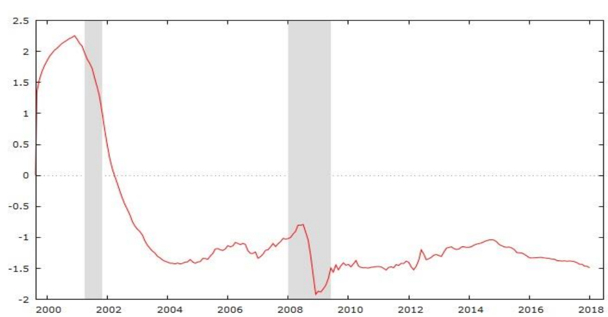
b. Taiwan



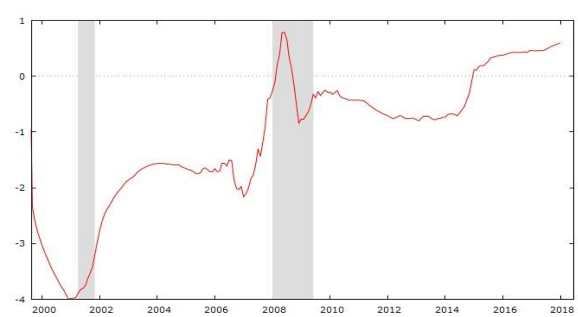
c. Singapore



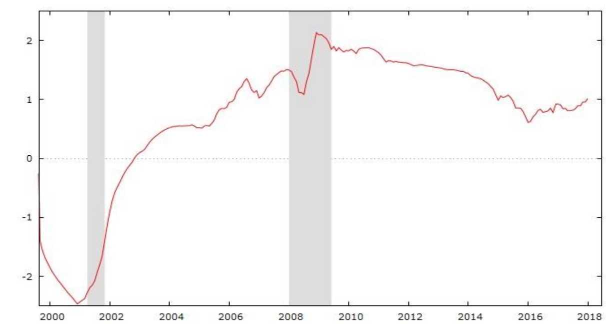
d. Korea



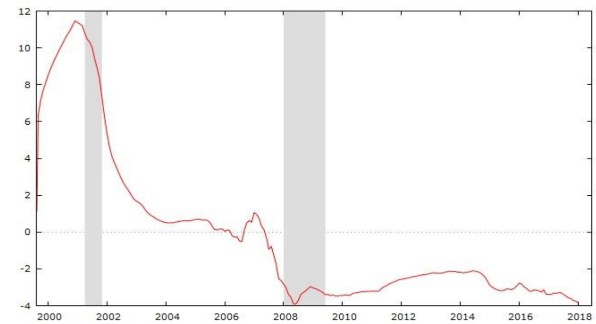
e. China



f. Euro Area



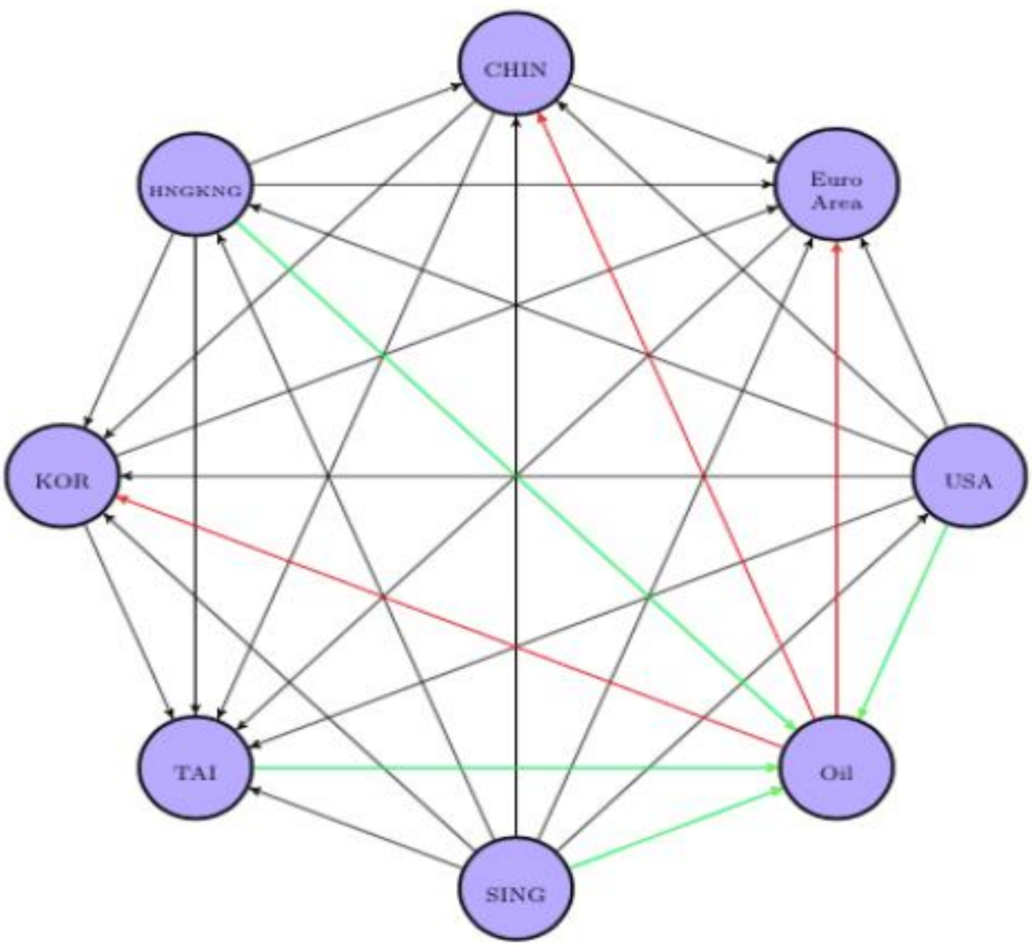
g. USA



h. Oil

Figure 9: Plots of net contribution from each market in the sub sample

Figure 10: Pairwise net directional connectedness for the sub-sample



In Figure 10 we present the pairwise net directional connectedness for the sub sample. Similar to the full sample, this enables us to rank the markets according to positive and negative pairwise net connectedness. There are a total of 8 nodes with 28 arrows. Similarly, we differentiate interactions with the crude oil market using the red and green colored arrows. According to the diagram, we can distill the following outcomes. For instance, we find that Singapore maintains its position as a net-transmitter of spillover to all other markets including the U.S.A, Euro area and crude oil market. This is followed by the U.S.A which is only a net-receiver of spillover from Singapore. On the contrary, the Euro area is a net-receiver of spillover from every other market in the sub sample except Taiwan. Following the Euro area is Taiwan and Korea. Taiwan is a net-receiver of spillover except from crude oil market whereas Korea is only a net-transmitter of spillover to the Euro area and Taiwan. These results imply that among the highly industrializing Asian markets, the U.S.A, Euro area and crude oil market, Singapore remains a key propagator of shocks within the system followed by the U.S.A and Hong Kong. Within the system, those that are hardly hit by spillover of shocks from these three markets are Taiwan, the Euro area and Korea.

Drivers of dynamic connectedness

In Table 5 above, we present the results of our estimation of the drivers of dynamic integration for both the full sample (Panel A) and the sub sample (Panel B). According to results for the full sample, we can infer that capital flows and financial stability are not statistically significant factors that drive integration among interest rates in the Asian economies, the Euro area, U.S.A and crude oil market. However, the remaining factors are significant at various degrees. Specifically, we note that the level of economic openness in terms of both financial and trade integration are important driving factors of dynamic integration as shown by their statistically significant positive coefficients of about 0.05% each. Also, political stability and information asymmetry are important drivers of integration with coefficients of about 0.11% and 0.03% respectively. However, the coefficient of information asymmetry is only significant at 10%. Contrarily, the results show that the crisis dummy is the only factor that negatively affects the degree of dynamic integration among these markets and this is significant at 1%. Lastly, the value of the R-squared is 0.88 implying that the factors included in our model explain about 88% of the behaviour of dynamic integration in the entire sample. Also, the value of the Durbin Watson test for autocorrelation in the residuals from our regression analysis is 2.31. This permits us to reject the presence of residual autocorrelation.

Panel A					**Panel B**			
Variables	Coef.	Std. error	t-ratio	p-value	Coef.	Std. error	t-ratio	p-value
Constant	4.063	0.105	38.54	(0.0000)***	4.137	0.181	22.77	(0.0000)***
FININT	0.055	0.016	3.464	(0.0007)***	0.065	0.026	2.435	(0.0163)**
INFASY	0.031	0.018	1.664	(0.0983)*	–0.017	0.016	–1.027	(0.3065)

TRDINT	0.051	0.007	7.011	(0.0000)***	0.088	0.012	6.858	(0.0000)***
CAPFLOWS	0.0003	0.0007	0.372	(0.7103)	0.001	0.0007	1.478	(0.1420)
FINSTAB	0.016	0.012	1.314	(0.1909)	0.071	0.012	5.646	(0.0000)***
POLSTAB	0.107	0.015	6.956	(0.0000)***	0.042	0.013	3.2	(0.0017)***
CRISIS	−0.011	0.0026	−4.379	(0.0000)***	0.003	0.002	1.348	(0.1802)
Ω Mean	84.09				80.7			
Ω Max	87.75				85.16			
Ω Min	81.1				78.78			
Ω Std Dev	2.34				1.87			
R-squared	0.88				0.81			
D-W	2.31				2.23			

Note: ***,** and * denote significance at 1%, 5% and 10% respectively whereas Ω Mean, Ω Max and Ω Min refer to the mean, maximum and minimum values of levels of dynamic connectedness. Lastly, D-W is the Durbin Watson test for autocorrelation.

Regarding the results for the sub-sample as presented in Panel B, we may infer that the dynamic integration among interest rates for the markets in the sub sample is driven by the degree of market integration as represented by financial and trade integration as well as financial and political stability. Specifically, the coefficients for the market integration factors are about 0.06% and 0.08% respectively. The coefficients for financial and political stability are about 0.07% and 0.04% respectively. The coefficients for the remaining factors including information asymmetry, capital flows and the economic crisis dummy is found not to be statistically significant at all levels. The implication is that unlike the full sample analysis, information asymmetry and global economic crisis are not statistically significant factors that drive the dynamic integration of interest rates in highly industrializing Asian economies and the global factors. Also, similar to the full sample, capital flows appear not to be a significant factor driving dynamic integration. The result about capital flows is not in consonance with the finding of Sugimoto and Matsuki (2019) who found that restrictions on capital flow could be an effective mitigating factor on external financial shocks in the Asian region. In terms of the model performance, these factors explain about 81% of the behaviour of total dynamic integration for the markets in the sub sample and the value of the Durbin Watson test for residual autocorrelation of 2.23 is within the acceptable range.

Taken together, based on the transmission mechanism discussed in the theoretical background in section 2, these findings suggest that the key channels of crisis transmission that justify the integration of monetary policy or contagion due to interest rate shocks are external exposures through trade and financial linkages as well as information asymmetry and political stability. These transmission channels have also been identified by previous studies such as Fratzscher et al. (2018), Georgiadis (2016), Tong (2017) and Pham and Nguyen (2019). Specifically, Tong (2017) demonstrates how the impact of US monetary policy shock is transmitted through the capital flow channel, rendering cross-border financial systems vulnerable. However, most emerging markets with significant levels of capital control tend to be less susceptible to the effects of this shock thank those with without capital control.

Lastly, we conduct some additional estimations to confirm the robustness of the results presented in Table 5. Particularly, first, we add the independent variables sequentially to predict the likelihood of connectedness across the chosen independent variables. Second, we use Principal Component Analysis (PCA) to reconstruct the stability factor so as to check how our estimates remain robust in the presence of a single stability factor. As shown in Table 5, estimates in Panel I are the estimates from the sequential inclusion of each independent variable both for the full sample and the sub-sample for the highly industrialized Asian markets. Similarly, Panel II presents the estimates for the full and sub-samples using a single factor to capture stability.

Results from Table 6 Panel I for both the full and sub-sample indicate that although there are slight differences in the size of the coefficients, the effects of the independent variables remain the same when added sequentially. This is, however, not the case with information asymmetry (INFASY) which becomes statistically insignificant in the full sample. Regarding the estimation with the single stability factor, result in Table 6 Panel II shows that the effects of the independent variables on total connectedness remains similar across both samples. The single stability factor is statistically significant in both samples with values of about 0.09% and 0.03% for the full and sub-samples, respectively. This implies that the single stability factor is stronger for the full sample. These results suggest that the combined effects of both political and financial stability drive the level of connectedness among the 12 Asian countries with the U.S., EU and crude oil markets than among the highly industrialized markets.

Conclusion

This paper empirically investigates the dynamic integration and volatility transmission channels of short-term interest rates among twelve Asian countries. We control for the influence of global economic factors by introducing policy rates of the U.S.A and the Euro area as well as innovations in the market for crude oil. The study period spans through August 1999 to January 2018. The empirical strategy relies on the refined dynamic connectedness measure proposed in Antonakakis and Gabauer (2017) which refines and extends the connectedness measures of Diebold and Yilmaz (2009, 2012 and 2014) by introducing a TVP-VAR in place of the rolling window VAR. After retrieving the time varying total connectednss for the full and a sub sample, we further our analysis by using regression models to identify key factors that drive dynamic integration using six shock transmission channels following Bakaert et al (2014).

Our key finding offer convincing evidence of time variation in the level of integration of interest rates in these markets. We found that integration levels were highest towards the 2001 financial crisis whereas there seem to be a decoupling as shown by notable drop in connectedness during the 2007-2009 economic and the euro-debt crises. In descending order, Singapore, crude oil market, Hong Kong, Philippines and the U.S.A are the net-transmitters of spillover whereas India, Japan and Vietnam are net-receivers of spillover. In a sub-sample containing highly industrializing economies in Asia, the U.S.A, Euro area and crude oil market, Singapore, Hong Kong and the U.S.A remained top transmitters of spillover whereas the Euro area, Taiwan, Korea and the market for crude oil become net-receivers of spillover. Results from our regression models suggest that higher integration for the full sample tend to be driven by increasing levels of external exposure through trade and financial linkages, information asymmetry and political stability whereas economic crisis reduces the level of integration. Lastly, we found that among the highly industrialized markets, dynamic integration is driven by the degree of external exposure as well as both political and financial stability.

Understanding the degree of integration both in terms of economic and financial factors within a region and globally is very crucial for several reasons. For instance, given the increasing potential of a regional monetary system in the Asian region, the knowledge of shock spillovers among these economies as well as the various factors that drive the level of co-movement is very important for the policy makers and other economic agents within the region. Even more, the knowledge of the extent of volatility spillover from the global financial system and the market for a very crucial global commodity such as crude oil is very valuable given the increasing integration of the global economies with which comes both beneficial and adverse economic consequences. For instance, whereas results from this study reveal high levels of interest rates co-movement among the economies of Asia with spillover running from the big economies such as Singapore, Hong Kong, Taiwan to the less strong economies like Vietnam, there is also evidence of significant level of interest rates shocks spillover into the region from global markets such as the U.S.A and from the oil market given the importance of oil in the process of economic production.

Based on the conclusions aforementioned, this study offers fresh insights to propose significant implications for both policy makers as well as investors. Given that monetary policy from within and outside the Asian region has the potential to destabilize monetary policy stance, especially in industrializing markets in the region, policy makers should take into account the responses of interest rates to policy uncertainty in these front-line markets when formulating economic policies. Moreover, the level of shocks spillover into the oil market is very relevant to both policy makers and international investors in understanding the implications of monetary policy shocks on oil price stabilization. Put differently, with regards to investors, our findings suggest that they should be more cautious when making investment decisions and strategies regarding crude oil especially during periods of relatively turbulent policy rates uncertainty. Furthermore, equally important are results from the analysis on the transmission mechanism of monetary policy integration. For instance, based on the conclusions from this section, understanding the heterogeneity of the strengths of the transmission channels is also important for both policy makers and investors as it indicates the particular channels that policy makers and investors should pay more attention to during periods of policy uncertainty instead of other channels. When spikes occur in some certain areas, investors could take some measures in advance and revise their portfolio strategies accordingly, depending on the relative strength of the potential channel.

Lastly, the knowledge of the factors that drive integration would act as a barometer for policy makers as it would signify 'ex ante' how existing levels of exposure and domestic conditions would reflect the vulnerability of a particular economy to the spillover of distress from other economies both within the region and globally. As an empirical study, we acknowledge some limitations in regard to our empirical analysis and therefore make some recommendations for future research. First, unlike the analysis of the drivers of the level of connectedness, we acknowledge the limitation of not offering some robustness analysis on the measure of connectedness. Also, future research should focus on the monetary policy of Asian countries with consideration of country-specific characteristics: economic development, exchange rate regimes, and more measures of stability. Moreover future research should also consider the effects of the difficult times created by the COVID-19 pandemic on the level of connectedness among these markets.

Table 6: Robustness test results

	Panel A				**Panel B**			
Panel I: Sequential inclusion of independent variables								
Variables	Coef.	Std. error	t-ratio	p-value	Coef.	Std. error	t-ratio	p-value
Constant	8.017	1.928	4.17	0.0000***	5.858	1.309	4.473	0.0000***
FININT	0.029	0.008	3.917	0.0001***	0.01	0.002	4.657	0.0000***
TCI(-1)	0.929	0.017	53.29	0.0000***	0.945	0.0129	72.86	0.0000***
R-squared	0.98				0.98			
D-W	2.59				2.16			
Constant	1.003	0.899	1.115	0.2662	0.267	0.719	0.371	0.7108
INFASY	0.031	0.038	0.8129	0.4171	0.011	0.013	0.8753	0.3824
TCI(-1)	0.982	0.011	91.53	0.0000***	0.995	0.008	120.4	0.0000***
R-squared	0.97				0.98			
D-W	1.57				2.37			
Constant	9.921	1.596	6.215	0.0000***	1.639	0.923	1.775	0.0773*
TRDINT	0.016	0.003	6.272	0.0000***	0.007	0.004	1.733	0.0845*
TCI(-1)	0.867	0.021	40.98	0.0000***	0.976	0.013	75.76	0.0000***
R-squared	0.98				0.98			
D-W	2.55				2.27			
Constant	1.239	0.862	1.437	0.1522	0.601	0.672	0.895	0.372
CAPFLOWS	0.0001	0.0005	0.187	0.8515	0.0002	0.00005	0.7199	0.472
TCI(-1)	0.985	0.01	95.99	0.0000***	0.992	0.008	119	0.0000***
R-squared	0.97				0.98			
D-W	1.54				2.46			
Constant	1.061	0.981	1.081	0.2809	0.328	0.654	0.501	0.6171
FINSTAB	0.007	0.021	0.3451	0.7304	0.023	0.008	2.772	0.0061***
TCI(-1)	0.986	0.01	94.27	0.0000***	0.992	0.008	122.6	0.0000***
R-squared	0.98				0.99			
D-W	1.47				2.17			
Constant	6.246	1.283	4.868	0.0000***	0.875	0.737	1.187	0.2365
POLSTAB	0.201	0.039	5.058	0.0000***	0.091	0.012	7.583	0.0000***
TCI(-1)	0.899	0.019	46.02	0.0000***	0.987	0.01	95.01	0.0000***

R-squared	0.98				0.98			
D-W	2.07				2.58			
Constant	1.17	0.854	1.369	0.1723	0.344	0.662	0.52	0.6035
CRISIS	-0.101	0.062	-1.645	0.1014	-0.080	0.039	-2.016	0.0450**
TCI(-1)	0.986	0.01	97.07	0.0000***	0.996	0.008	121.3	0.0000***
R-squared	0.97				0.99			
D-W	1.49				2.22			
Constant	2.699	1.182	2.283	0.0234**	0.249	0.697	0.359	0.7203
STBFPC	0.054	0.029	1.801	0.0731*	0.016	0.009	1.778	0.0683*
TCI(-1)	0.968***	0.014	68.88	0.0000***	0.997	0.009	115.5	0.0000***
R-squared	0.99				0.98			
D-W	1.98				2.28			
Panel II: Combined effect of stability factors								
Constant	4.875	2.023	41.94	0.0000***	6.055	1.572	53.88	0.0000***
FININT	0.149	0.017	8.978	0.0000***	0.093	0.009	9.877	0.0000***
INFASY	0.242	0.097	2.502	0.013**	0.017	0.065	0.262	0.6051
TRDINT	0.075	0.007	11.29	0.0000***	0.163	0.021	7.739	0.0000***
CAPFLOWS	0.0002	0.0002	1.539	0.1252	0.0002	0.00005	2.247	0.0257**
STBFPC	0.091	0.035	2.601	0.0212**	0.033	0.008	4.125	0.0000***
CRISIS	-0.517	0.183	-2.830	0.0051***	0.087	0.018	4.833	0.0000***
Mean	84.09				80.7			
Max	87.75				85.16			
Min	81.1				78.78			
Std Dev	2.34				1.87			
R-squared	0.86				0.79			
D-W Stat.	2.02				2.14			

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