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Fragmentation of International Production and Business Cycle Synchronization: New Evidence pre and during Global Financial Crises

Norrana Khidil, Mohd Azlan Shah Zaidi and Zulkefly Abdul Karim *

Center for Sustainable and Inclusive Development Studies (SID), Faculty of Economics and Management, National University of Malaysia (UKM), Bangi 43600, Selangor, Malaysia; nor_jamil64@yahoo.com (N.K.); azlan@ukm.edu.my (M.A.S.Z.)
* Correspondence: zak1972@ukm.edu.my

Abstract: Understanding the link between the fragmentation of international production (FIP) and business cycle synchronization (BCS) is crucial because it affects the world economic stability and hence hampers the sustainability in world trade, world production, and the world supply chain. Following that, this paper investigates the effects of fragmentation in an international production (FIP) on business cycle synchronization (BCS) amongst 38 countries (29 OECD and nine non-OECD countries) for two different periods; pre-crisis (2003–2007) and during the crisis period (2008–2012). This study uses a dynamic panel system GMM estimation in analyzing the effect of FIP on BSC by controlling other explanatory variables, namely, trade linkages and financial openness. Unlike many previous results, the main findings reveal that FIP positively and significantly affects BCS during a crisis period. However, it shows an insignificant effect during the normal period. In other words, FIP would amplify the synchronization of output downfall during the crisis period. Trade linkages have a negative and significant relationship with BCS in both periods, whereas financial openness has a negative and significant relationship with BCS during the normal period. The study suggests that selective measures have to be undertaken in implementing FIP during the crisis period to reduce the negative impact of BCS. Increasing trade and financial activities, on the other hand, would be beneficial for the countries as they would reduce the negative effect of BCS during the crisis period.

Keywords: international trade; fragmentation in international production; synchronization of business cycles; generalized methods of moment (GMM)

1. Introduction

Sustainability in world production and world trade is essential to stabilize the world economy and economic activity across countries. This spirit is also in line with Sustainable Development Goals (SDG) 2030 agenda, mainly to ensure sustainable consumption and production patterns (Goal 12) [1]. Sustainability in the world production and supply chain also reflects how an economy operates sustainably, protecting social and environmental elements [2]. Economic sustainability is very inter-related with world production patterns and how international economic and financial systems work [3,4]. Accordingly, the roles of world production and trade systems could intervene in the goal of economic sustainability. Notably, in the case of an open economic system, the world production pattern is very fragmented. This condition will initiate economic co-movement amongst countries, promoting economic instability and creating a hurdle to maintain economic sustainability.

Various studies have shown that economic growth amongst countries tends to move together, both amongst the industrialized economies [5–7] and amongst the emerging markets. The co-movement of economic growth is known as business cycle synchronization (BCS). The BCS has been extensively highlighted in the discussion of the optimum currency area (OCA) as it is a prerequisite for a new member to join the OCA. However, in the wake of

the global crisis in 2008, BCS amongst countries has created hurdles to economic recoveries. OECD reports that industrialized countries suffered from prolonging depression following the 2008 global crisis. Fink and Schuler [8], and Horvath and Zhong [9] demonstrated that emerging market economies also recorded higher BCS during the global financial crisis. However, by 2010 only emerging countries like India and China had come out from that crisis [10]. G7 has registered negative growth during that particular crisis despite recorded higher growth the year before [11]. Hence, high BCS during crises becomes an issue.

Generally, in open economies, where countries are integrated through trade, shocks can be transmitted through trade linkages. Hence, it is augmented that trade linkages became the shocks transmission channel and inflated BCS [12,13]. However, economic scholars could not ensure a definite relationship between trade linkages and BCS [14,15], not even when specialization in trade intra-industry was taken into account [16,17]. Apart from the unavailability of concrete theories about trade and BCS, there is no specific measurement to represent trade linkages.

One way to overcome this issue is to consider fragmentation in an international production (FIP) in the study. In essence, FIP is slicing down the production process into several parts and allocating each section of the productions worldwide according to their competitiveness [18]. It implies that intermediate goods have to travel across the border more than once to be assembled with other intermediate goods before being re-exported as advanced intermediate goods or as final goods [19–22]. However, there is no specific economic theory regarding FIP and economic co-movement, and there is also no clear and concrete way to identify FIP [23–25]. Given that, FIP should be measured in value-added terms [26–28]. The regular and conventional trade statistics do not have information about value-added trade or the content of export (intermediate goods) being re-exported. Using standard trade statistics will contribute to the double counting problem and misleading results, such as using data on trade statistics to measure trade linkages and competitiveness across countries. The vertical specialization (VS) method, on the other hand, measures value-added trade, provides information regarding re-imported and re-exported, and simultaneously avoids the double counting problem. Hence VS has provided a better measurement for trade linkages. When BCS or co-movement between two countries is concerned, VS is less suitable because it has lacked bilateral trade information [29]. It is more appropriate to ensure consistency in the measurement of the study. Since BCS is measured bilaterally, the other variables in the model have also been constructed bilaterally.

This paper considers a new variable of FIP and investigates whether FIP influences the BCS. Many previous studies have tried to show that FIP amplified the synchronization of output downfall during the financial crisis of 2008–2009 using a simple measure of FIP such as intermediate goods and VS [12,13,16,17,30]. The crisis period of 2008–2012 has been chosen for the study as it was regarded as the most severe crisis that hit the global economy where two-thirds of global GDP in term of purchasing power parity experienced a fall in output within a year after the financial crisis began in late 2008 [31]. This study employs a modified FIP initially developed by Lopez-Gonzales and Holmes [29] as a new variable to examine FIP's effect on BCS during 2007–2012. This study also considers factors like trade intensity and financial market openness as the determinant for BCS [14,32]. The countries included in the study are 29 OECD and nine non-OECD ones (see Appendix A). In general, OECD countries practice special privileges amongst members and have advantages over non-OECD countries in many aspects, especially in trade. Non-OECD countries (for example, Brazil, China, India, and Russia) represent the emerging markets economies that have experiencing high trade volume and have a speedy economic recovery; therefore, it is interesting to include these countries in the study.

Given this background, there are three hypotheses for this study. First, trade linkages, capital market openness, and FIP influences BCS [12,16,17]. Second, these three determinants' impact is more pronounced and significant during the financial crisis (2008–2012). Thirdly, lagged FIP will positively influence BCS during financial crisis [16,17].

This paper contributes to the existing study in international economics in the following ways. First, the study uses a new method to calculate the FIP variable as the determinant of output co-movement. In this case, FIP measures the import content between two countries compared to VS that measures import content in the export of one particular country relative to the world at a specific time. Second, this study revisits the issue by following Abiad et al. [14] work that splits the time into two periods to find the effect of trade and financial linkages on output correlation in two different times. They discovered that trade linkages were not significant during the crisis period. Third, this study considers Duval et al. [16,17], who found that FIP using VS as an indicator was negatively related to output correlation and not significant. This study uses the new measure of FIP instead. The study's findings provide information about FIP's consequences upon output co-movement for formulating strategic trade and industrial policy.

This paper is laid out as follows: Section 2 discusses a literature review on the theoretical framework and empirical studies. Section 3 presents the methodology and data, and Section 4 summarizes the main findings. Finally, Section 5 summarizes and concludes the study.

2. Review of Literature

Generally, trade linkages play an essential role in transmitting shocks and synchronizing the business cycle between countries. The main findings from empirical studies show that paired countries highly integrated through trade channels are more correlated in the business cycle [33]. However, the explanation of the theoretical model is more complicated. According to the international real business cycle model, as proposed by Backus et al. [34], using two-country open economy models with the complete financial market and fully integrated asset market, high trade intensity will reduce business cycle synchronization. The argument is that the looser is the economy, the more specialized in the country. It follows then that each open economy responds to different industries' shock that would cause the asymmetric movement of output. Intuitively, each open economy will become more specialized in a sector where it has a more competitive advantage. In turn, each country is responsive to a sector-specific shock, and therefore, output co-movement or BCS will be less likely to happen.

From another theoretical perspective, trade linkages can increase or reduce business cycle synchronization depending on the nature of trade specialization and type of shocks. Trade linkages via inter-industry specialization under specific-industry shocks will facilitate business cycle synchronization, but trade linkages via intra-industry specialization will do otherwise. Meanwhile, in another opinion, the common shocks will synchronize the business cycle disregard of trade existence [35].

Intuitively, the open economy will drive each economy to specialize. Suppose a country specializes in intra-industry as a result of an open economy. In that case, this kind of trade linkages will increase output synchronization in the business cycle, given that industry-specific shock is dominant. However, if a common shock is dominating, then the open economy will increase output correlation disregarding the type of specialization, either intra-industry or inter-industry.

The financial crisis of 2008–2009 showed some links between trade linkages and business cycle synchronization between paired countries. The report on the financial crisis of 2008–2009 described that the business cycle during the economic fall down was very synchronized and rapidly spread all over Europe in less than a month [13,30,36–38]. For that matter, Abiad et al. [14] found that trade linkages have no significant relationship with the synchronization of economic fall down during the economic crisis of 2008–2009. Meanwhile, Busl and Kappler [32] discovered that trade linkages reduced BCS.

In the meantime, some researchers suggest that a unique trade linkage such as FIP can be a factor that influences the synchronization of output downfall during a crisis [12,16,17]. It was argued that demand shocks had traveled through FIP linkages and caused the synchronization of output collapse between countries. Intuitively, FIP acts like a transmission

channel for a shock. Therefore, the more the FIP between the two countries, the higher the chances of a shock transmitted through this channel, increasing the output movement's synchronization. Intuitively, when the demand for the final goods falls, then intermediate goods' demand also falls. This happens because imported intermediate goods are part of the input for final goods, linked through FIP. Because of that, researchers argue that FIP positively influenced the synchronization of output downfall [13,30,39].

For instance, di Giovanni and Levchencko [12] demonstrated that trade through vertical linkages at the plant level accounts for output synchronization amongst rich countries. They argue that the more correlated the country at the plant level, the more synchronized the two countries' output movement. They show that higher vertical linkages increase output synchronization. However, their studies depend on intermediate goods trade data taken directly from the input-output table. Data taken directly from the input-output table is not in value-added terms; hence it will result in a double-counting problem. Therefore, the result of the study is misleading. Working on the same line, Duval et al. [16,17] split trade variables into four categories, namely trade intensity, intra-industry trade, vertical specialization (VS) trade, and similarity of basket goods for trade. They introduce VS to represent FIP instead of intermediate goods as VS is in a value-added term, which is more sensible than intermediate goods to represent FIP. They found that all categories of trade are positively and significantly related to output correlation as expected, except for VS. This result suggests that FIP, when represented by VS, is not significant to BSC compared to di Giovanni and Levchenko's studies that use intermediate goods as FIP. This indicates that the appropriate measurement of FIP is necessary. Although VS contribution to the field of the study is reputable, the nature of BCS requires some modification of VS. In short, the relationship between FIP and BCS is still indefinite partly because there is no specific model of FIP or how FIP works. Most of the studies about FIP depend on either trade in intermediate goods or simple VS models of Hummel et al. [19], to represent FIP. Both approaches have shortcomings. To measure FIP using intermediate goods trade will result in a double-counting problem because it is not in a value-added term. Whereas the simple VS model, which is in a value-added term, has failed to provide information about FIP in a bilateral form [29]. Hence, both approaches used to measure FIP are insufficient and inadequate for any study related to bilateral relationships, particularly BCS. Therefore, the study about the relationship between FIP and BCS is still opened for exploration.

In line with that, Koopman et al. [26], Lopez-Gonzales and Holmes [29], and Johnson and Noguera [40] have developed an advanced method of FIP calculation with the introduction of vertical specialization indirect (VSI).VSI provides detail about third-party contribution in VS, which give the flow of how countries connect through VS. The difference between them is that Lopez-Gonzales and Holmes have incorporated VSI into FIP in a bilateral form. In contrast, others developed VSI relative to the other world as a whole. VSI in bilateral form is more relevant in the study regarding BCS. Consequently, this study takes into consideration the approach employed by Lopez Gonzales and Holmes.

Apart from the trade linkages in general and FIP, financial linkages are another essential factor in BCS. However, the role of financial linkages is also not very clear. From a theoretical point of view, financial market openness will reduce output synchronization. Under the complete market (where capital moves freely), resources will transfer to productive countries leaving other countries less productive. Hence, the open financial market will reduce output synchronization. On the other hand, alternative views on this motion argue that financial linkages positively influence output synchronization [14,16,17,31,41,42].

The alternative view is that financial linkages between two countries through foreign direct investment (FDI) will increase output synchronization. However, the effect still depends on which factor is dominant. If capital linkages that contribute to financial openness are prevalent, then financial openness will increase output synchronization. If the credit market linkages are dominant, then otherwise [43]. Since there is no specific economic theory supporting the ideas that trade and financial linkages positively influence output co-movement, this study's field rests on the empirical findings proposed by Duval et al. [17].

Furthermore, there is no simple way to track and know the influence of either trade and/or financial linkages to output co-movement, especially in economic downfall during the crisis period. However, trade and financial linkages are essential players in this field of study. Furthermore, these two factors are crucial to globalization policy and economic openness. Therefore, this study focuses on these two factors. Examples of other important factors to business cycle synchronization are similarity in production [44] and sharing the same spoken language [45]. In short, it can be concluded that a study that relates trade linkages, FIP in particular, and financial linkages with output synchronization is still open for investigation.

3. Research Methodology

3.1. Data Descriptions

3.1.1. Business Cycle Synchronization (BCS)

To construct BCS, this study employs GDP per capita at a constant price in USD for the base year 2010. The data is collected from World Bank Data [46]. Following Kalemli-Ozcan et al. [41], BCS is constructed as follows:

$$\text{BCS}_{ij,t} = -\left|(lnY_{i,t} - lnY_{i,t-1}) - (lnY_{j,t} - lnY_{j,t-1})\right| \tag{1}$$

where $\text{BCS}_{ij,tn}$ is a business cycle synchronization of the real GDP per capita growth of country i and country j at time t. $Y_{i,t}$ and $Y_{j,t}$ are real GDP per capita for country i and j at time t, respectively. Hence, BCS measures the difference between the output growth rate of country i and country j. The value of BCS_{ij} is between $-|\infty|$ and 0. The smaller the absolute value (value of the differences in growth between countries i and j), the higher the business cycle synchronization. Therefore, the two countries' outputs become more synchronized as the value of 'absolute value' approaches zero (0) or becomes smaller. In other words, the value of BCS becomes larger. In contrast, the business cycle between the two countries falls apart as the 'absolute value' is getting bigger or the value of BCS becomes smaller. This implies that economic growth for country i and country j are moving in different directions.

3.1.2. Fragmentation in International Production (FIP)

This study utilizes the first and second World Input-Output Data [47–49] in constructing the FIP. The data have transformed into real value using the producer price index. This input-output data has been reduced to three sectors (input-output), namely agriculture, industry, and services, from the previous 35 sectors. The formula proposed by Lopez-Gonzales and Holmes [29] has been used to formulate the FIP as follows:

$$\text{FIP}_{ij} = \mu A^{M_{ij}} \left[I - A^D\right]^{-1} X_j^k, \ \text{FIP}_{ij} \neq \text{FIP}_{ji} \tag{2}$$

where μ is a $1 \times n$ vector used to transform n x n matrix into a $1 \times n$ matrix, A^{Mij} is import coefficient matrix from country j to country i, $(I - A^D)^{-1}$ is Leontief inverse function, Leontief inverse function shows the amount of input needed for one unit production and X_j^k is export to sector k in countries j. Since $FIP_{ij} \neq \text{FIP}_{ji}$, this study adds both FIP together as Equation (3);

$$\text{FIP}_{ij} + \text{FIP}_{ji} = \mu A^{M_{ij}} \left[I - A^D\right]^{-1} X_j^k + \mu A^{M_{ji}} \left[I - A^D\right]^{-1} X_i^k \tag{3}$$

Equation (3) shows FIP's sum from country *i* to country *j* and FIP from country *j* to country *i*. Next, FIP is the sum of FIPs that are weighted by the sum of export of two countries, as stated below:

$$\text{FIP} = \frac{\mu A^{M_{ij}} \left[\mathbf{I} - \mathbf{A}^D \right]^{-1} X_j^k + \mu A^{M_{ji}} \left[\mathbf{I} - \mathbf{A}^D \right]^{-1} X_i^k}{X_{ij} + X_{ji}} \tag{4}$$

Equation (4) shows the value of FIP for two countries, where the total export scalar weights fragmentation in international production for country *i* and *j* ($\text{FIP}_{ij} + \text{FIP}_{ji}$) for country *i* to country *j* (X_{ij}). The value of FIP is between 0 to 1. In other words, $\text{FIP}_{ij} + \text{FIP}_{ji}$ is the sum of the component of imported value from countries *j* in the export component of country *i* and vice versa. It is in monetary value and a percentage form. The closer FIP to 1, the larger the percentage value of the imported component in the export of both county *i* and *j*.

3.1.3. Trade Linkages

Trade linkages have frequently been used to measure the degree of openness of one country. This study uses trade intensity to measure the degree of trade linkages (TRADE_{ij}). Following Nzimande and Ngalawa [50], trade intensity is calculated as a sum of exports and imports between the two countries under consideration, weighted by the sum of their GDPs, as indicated by Equation (5):

$$\text{TRADE}_{ij,t} = \frac{\left(X_{ij,t} + M_{ij,t} \right) + \left(X_{ji,t} + M_{ji,t} \right)}{\left(GDP_{it} + GDP_{jt} \right)} \tag{5}$$

$X_{ij,t}$ is the export country *i* to country *j* at time *t* and $M_{ij,t}$ is import country *i* from country *j* at time *t*. GDP_{it} is income per capita for country *i* at time *t*. TRADE is valued between 0 to 1. The higher the trade intensity between countries *i* and *j*, the stronger the trade linkages' value of TRADE approaches 1. In other words, it implies that GDP is primarily composed of the trade component. If the value of the TRADE approach 0, it indicates almost no trade linkages. This paper calculates the value of trade linkages using data from the Trade Map, International Trade Centre [51] that can be accessed freely from the internet. In contrast, the GDP for the countries is accessed from World Bank data [46].

3.1.4. Financial Market Openness

The financial market openness is another indicator to measure the degree of openness. To measure capital account openness, this study uses Chinn and Ito index (KAOPEN). KAOPEN index is a financial index that measures the level of capital market openness [52,53]. Index KAOPEN is calculated using bilateral capital account indicated in Chinn and Ito's indicators. To construct KAOPEN, this study follows Nguyen [54] as shown in Equation (6):

$$\text{KAOPEN}_{ij,t} = \frac{1}{T} \left(\sum \text{KAOPEN}_{i,t} + \text{KAOPEN}_{j,t} \right) \tag{6}$$

In Equation (6), $\text{KAOPEN}_{ij,t}$ is a bilateral financial linkage between country *i* and *j* in the form of capital such as international bank loans. It measures the restriction and control over monetary transactions crossing borders as recorded by IMF. $\text{KAOPEN}_{ij,t}$ is the average $(1/T)$ sum of $\text{KAOPEN}_{i,t}$ and $\text{KAOPEN}_{j,t}$. Both of $\text{KAOPEN}_{i,t}$ and $\text{KAOPEN}_{j,t}$ are in index form between 0 to 1 while $\text{KAOPEN}_{ij,t}$ is also in an index form between 0 to 2. The more open the country, the closer the $\text{KAOPEN}_{ij,t}$ index to 2.

3.2. Model Specification

Contrary to conventional intertemporal real business cycle (IRBC) theory, some empirical studies demonstrated that open market economies influence BCS and economic

instability among countries [33,37]. The degree of economic openness has some influences over BCS and therefore affects the economic volatility. Thus, this present study has considered both economic openness variables, namely trade intensity (TRADE) and capital market openness (KAOPEN), as a controlling variable in modeling the BCS determinants. Employing these control variables will reduce the regression result's spuriousness due to the omitted variable [55]. The problem related to an omitted variable such as endogeneity can be eliminated or reduced by employing the Generalized Moment Method (GMM) [56]. Thus, in examining the link between FIP and BCS, a dynamic panel GMM is the most appropriate technique in solving the endogeneity issue and considering the dynamic nature of the linkages between economic variables.

The dynamic panel GMM model employs lagged variables as an independent variable to examine whether the previous occurrence influence the present dependence variable. However, using too many lagged variables can create an instrument proliferation problem and reduce the sample size [56]. Therefore, given the nature of the data set with short time series (5 years), this present study has considered one lagged for all variables.

Following that, the baseline model can be written as follows:

$$BCS_{ij,t} = \alpha_0 + \alpha_1 BSC_{ij,t-1} + \alpha_2 KAOPEN_{ij,t} + \alpha_3 KAOPEN_{ij,t-1} + \alpha_4 TRADE_{ij,t} + \alpha_5 TRADE_{ij,t-1} + \alpha_6 FIP_{ij,t} + \alpha_7 FIP_{ij,t-1} + \varepsilon_{ij,t} \quad (7)$$

$BCS_{ij,t}$ is a function of lagged BCS ($BCS_{ij,t-1}$), contemporaneous financial market openness ($KAOPEN_{ij,t}$) and lagged financial market openness ($KAOPEN_{ij,t-1}$), contemporaneous trade linkage ($TRADE_{ij,t}$) and lagged trade linkage ($TRADE_{ij,t-1}$) and contemporaneous FIP ($FIP_{ij,t}$) and lagged FIP ($FIP_{ij,t-1}$). In Equation (7), the dependent variable ($BCS_{ij,t}$) is the business cycle synchronization between country-pair i and j at time t, for $i,j = 1, 2, \ldots$, N and $t = 2, 3, \ldots$,T. The error terms ($\varepsilon_{ij,t} = \upsilon_{ij} + \gamma_t + \rho_{ij,t}$) are followed two ways error component, where υ_{ij} is the country-pair fixed effect, which accounts for fixed factors such as gravity-type variables or other unobservable time-invariant idiosyncratic factors specific to country-pair i and j; γ_t is time specific effect which accounts for time-varying common factors affecting all countries and $\rho_{ij,t}$ is the remainder error term. The error term ($\varepsilon_{ij,t} = \upsilon_{ij} + \gamma_t + \rho_{ij,t}$) has property of $var(\varepsilon_{ij,t}) = var (\upsilon_{ij}) = var(\gamma_t) = 0$ for $i,j = 1, 2,..., N$ and $t = 2, 3, \ldots , T$.

3.3. Dynamic Panel Generalized Method of Moments (GMM)

The baseline model assumes that the BCS of the previous year ($BCS_{ij,t-1}$) influences the present BCS ($BCS_{ij,t}$). Hence, there is a correlation between $BCS_{ij,t-1}$ with another independent variable, or correlation with omitted variable or error term, which violates ordinary least squares(OLS) assumptions. According to Roodman [56], there are a few assumptions regarding the dynamic panel data. First, the dynamic process where the previous occurrence influences the present one (e.g., BCS_{t-1} influence BCS_t). Second, there is a possibility of a specific-individual effect, but it can be eliminated by first differencing. Third, there is an endogeneity problem where there is a dependency between independent variables in the baseline model. Fourth, there is a possibility of heteroscedasticity and serial correlation. The presence of lagged dependent variables in the baseline model (Equation (7)) leads to a biased estimation of using the static panel technique, and therefore the estimation results are inappropriate. [57–60].

Therefore, this study employs a generalized method of moments (GMM) estimation technique in which has advantages to solve the endogeneity issues, heteroscedasticity, and serial correlation problems. Another advantage of using the GMM technique is that it does not need outside instruments to solve for the endogeneity [61]. There are two types of GMM procedures, namely, difference GMM and system GMM. Difference GMM is a regression equation in first-difference where its instrument is the independent variable's lag level. Difference GMM will eliminate country-specific fixed-effects and automatically solve for omitted time-invariant factor country specific which belief to influence the dependent variable. However, the difference GMM approach is not suitable in the case where time series is persistent and the observation period (T) is less than

the number of observations (N) [58]. In such a case, the lag independent variable will contribute to the weak instrument, and the following lag independent variable will produce a biased estimator. Therefore, system GMM is better [58,59]. Bond [60] considered system GMM is better than difference GMM because system GMM can correct unobserved country heterogeneity, omitted variable bias, measurement error, and endogeneity. System GMM combines first differences and level form regression where instruments used for the level form variables are the lag of first differences variables in one equation [61].

In general, this study set up the GMM equation with lag in BCS as the independent variable and chose an instrument from the endogenous variables. The assumption is that some parts are correlated with error and some exogenous variables if the instrument is correct. If the probability statistic of the AR (2) test and Hansen or Jensen test are larger than 0.1 ($p > 0.1$), the chosen parameters are valid and accepted [56].

Following Abiad et al. [14], this study divides data into two parts, namely, the normal period for the year (2003–2007) and the crisis period for the year (2008–2012). For the comparison purpose, the whole sample (2003–2012) has also been estimated. Next, we regress according to the specification above. For robustness, we reduced the number of an instrument in the regression. The finding is robust if the result is consistent in sign and direction after the instrument has decreased. Having mentioned that, it is important to state that this study covers data from the year 2003–2012, considering that crisis last until the year 2012 [14], which is the interest of this paper.

4. Empirical Results

Tables 1 and 2 show the descriptive statistic for the variables in the study for both periods. In general, all the data for both periods show a small standard deviation to indicate that the data is fairly distributed. Both tables show that the degree of output synchronization between countries is equally high for both periods. The average BCS demonstrates this for both periods, which is −0.014 for 2003–2007 and −0.015 for the year 2008–2012.The average value of BCS for both periods indicates that the differences of growth between any two countries almost zero (almost no difference in growth), hence highly synchronized. The value of BCS during 2008–2012 would be higher, if not influenced by the large reduction in BRIC countries' synchronization.

Table 1. Descriptive Statistics for the Years 2003–2007.

	BCS	TRADE	KAOPEN	FIP
Average	−0.014	0.003	1.601	0.002
St. Deviation	0.011	0.005	0.402	0.003
Skewness	−0.917	2.807	−0.772	2.548
Kurtosis	3.085	11.468	2.823	10.477
Min	−0.054	1.09×10^{-6}	0.326	4.41×10^{-7}
Max	$−2.7 \times 10^{-7}$	0.030	2.000	0.019
N	3515	3515	3515	3515

Source: Authors' calculations.

Table 2. Descriptive Statistics for the Years 2008–2012.

	BCS	TRADE	KAOPEN	FIP
Average	−0.015	0.003	1.689	0.002
St. Deviation	0.013	0.005	0.345	0.003
Skewness	−1.045	2.676	−0.973	2.493
Kurtosis	3.499	10.737	3.926	9.965
Min	−0.057	4.5×10^{-6}	0.325	2.35×10^{-6}
Max	-4.4×10^{-6}	0.030	2.00	0.020
N	3515	3515	3515	3515

Source: Authors' calculations.

TRADE's average value is the same (0.003) for both periods indicates no change in the trade linkage patent for both periods. The average value of KAOPEN is a little bit higher during the financial crisis period 2008–2012 is 1.7 as compared to the normal period 2003–2007 is 1.6. This indicates that financial market openness is more relaxed during the crisis period compared to the normal period.

Table 3 summarizes the estimation results using a dynamic panel system-GMM (one step estimation) for Sample 1 (2003–2007), Sample 2 (2008–2012), and Whole Sample (2003–2012) with time-specific effect or year dummy. The regression result shows that lagged BCS influences contemporaneous BCS positively and significantly for both periods and the whole sample.

Table 3. Regression Results of BCS Using System-GMM.

	Sample 1 (2003–2007)	Sample 2 (2008–2012)	Whole Sample (2003–2012)
BCS_{t-1}	0.360 (0.032) ***	0.159 (0.054) ***	0.118 (0.039) ***
$TRADE_t$	−5.227 (2.764) *	−15.894 (4.921) ***	0.500 (0.470)
$TRADE_{t-1}$	4.038 (2.727)	14.741 (6.090) **	0.178 (0.502)
KAOPEN	−0.014 (0.007) *	−0.037 (0.227)	−0.021 (0.020)
$KAOPEN_{t-1}$	0.005 (0.003)	−0.015 (0.018)	0.033 (0.019) *
FIP_t	6.087 (4.052)	0.922 (3.655)	0.397 (0.749)
FIP_{t-1}	−5.245 (4.400)	2.162 (0.692) ***	−1.558 (0.830) *
Constant	0.007 (0.009)	0.336 (0.027)	−0.020 (0.006)
Observation	2812	2812	5619
Instrument	26	15	18
AR(2)	0.860	0.254	0.406
Year Dummy	YES	YES	YES
Hansen T/Sargan T	0.108 (S)	0.210 (H)	0.361 (H)

Note: Number in parentheses is a standard error. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. The dependent variable is business cycle synchronization (BCS) of country i and j, measured by absolute value of the difference between the growth rate of country i and j ($-|(\ln GDP_{it} - \ln GDP_{it-1}) - (\ln GDP_{jt}$-$GDP_{jt-1})|$). Independent variables are lagged BCS(BCS_{t-1}) for country i and j, trade intensity (TRADE), lagged trade intensity ($TRADE_{t-1}$), financial market openness (KAOPEN), lagged financial market openness ($KAOPEN_{t-1}$), fragmentation of international production (FIP) and lagged fragmentation in an international production (FIP_{t-1}). Sources: Writer's calculation.

However, trade as a whole influences' outputs co-movement negatively for both periods significantly. This result is consistent with the traditional international real business cycle theory. According to that theory, the more open the economy, the country tends to specialize in trade, hence respond to specific industry shock, then trade linkages will reduce business cycle synchronization. In other words, trade is not amplifying the synchronization

of output fall. In contrast, TRADE$_{t-1}$ positively influences BCS amongst countries and significantly during the crisis period 2008–2012. This behavior suggests that lagged TRADE could foster co-movement and economic volatility amongst countries. A possible explanation could be, after sometimes, specialization in intra-industry amongst countries started to pick up, where business developed into producing input for final product situated in other countries. As a result, trade-in input escalates in volume, and trade amongst countries expands bilaterally. Such development encourages synchronization of business cycles amongst countries. Trade has a positive relationship with BSC due to the different trade patterns (trade in input) that emerge after some time. Therefore, the finding shows that lagged TRADE positively influences economic movement or BCS and contributes significantly during crisis. Theoretically, when countries specialized in intra-industry, they are in a similar production scope and respond to the same industry-specific shocks, therefore reacting similarly to specific shock [35]. As a result, it further enhances BCS.

Table 3 also shows that KAOPEN is negatively correlated to BCS during both periods but insignificant during the crisis period. This implies that capital market openness is influencing output co-movement negatively during a normal period. This finding is in line with the international real business cycle theory (IRBC). According to IRBC theory, the fund will be reallocated where it gets a higher return. In turn, this fund will be utilized by recipient countries to specialize in the industrial sector. Therefore, the more open the capital market, the more specialized the countries became. They tend to respond to different industrial-specific shocks and reduce the similarity in growth and hence less synchronized. In other words, increasing open capital market will promote perfect specialization amongst countries. As a result, each country will react to different industrial specific shocks and hence reduce similarity in BCS. Abiad et al. [14] and Duval et al. [16,17] also discovered the same findings that capital openness negatively related to output co-movement. This is in line with Dees and Zorell [42], who cannot find a positive and significant relationship between financial linkages and output co-movement. According to Dees and Zorell [42], the financial market could indirectly lead to positive co-movement where financial openness could raise the similarity in sectoral similarity and boost similarity in business cycle output correlation.

Table 3 also demonstrates that FIP as a whole influence BCS positively for both periods. However, the relationship is significant at level $p < 10\%$ during the crisis period only. This result suggests that FIP amplifying the synchronization of output falls during the crisis period. This is in line with the general belief that FIP through plant level relationships has increased output synchronization [12] and hence economic instability.

In summary, while trade and financial market openness negatively influence output synchronization for both periods, FIP influences and amplifies output fall. Although it seems that during the normal period, it transferred positive spillover, but it is insignificant. Whereas during the crisis period, it amplified the synchronization of output fall. For that matter, all the parameters meet the requirement of the AR (2) and Hansen test, hence valid and can be accepted. However, for the whole sample period, lag of trade and lag of FIP have a negative and statistically significant influence on the BCS, indicating that more trade and more international production fragmentation have reduced the BCS.

Robustness Test

The purpose of the robustness test is to determine how reliable the baseline regression model's result is. The reliable parameter will maintain its consistency after the test. For the robustness test, this study has reduced the number of the instrument in the regression. For a valid and reliable parameter, the regression result will be consistent with the prior result when we reduce the instrument's number in the specifications. Table 4 showed the regression result when we decreased the number of instruments. The standard error for FIP$_{t-1}$ very much smaller than the standard error for FIT and TRADE. The standard error is the simplest way to detect abnormality of the data. In this case, possibly there are outliers in the data but have to keep it because we will lose the data set if taken out.

Anyway, perhaps more data set will improve the result of the regression. The result show that all variable is significant and consistent with the direction of the sign. All selected instrument is free from serial correlation (AR2: $p > 10\%$), and valid (Sargent and Hansen test with $p > 0.1\%$) as well as free from endogeneity problem. In short, all parameters are accurate and reliable. The total sample's estimation results also indicated that lagged trade and lagged FIP have a negative and statistically significant influence on BCS. Interestingly, the contemporaneous of KAOPEN has a negative and statistically significant impact on the BCS for the total sample.

Table 4. Robustness Test: Regression Result of BCS Using system GMM.

Variables	Sample 1 (2003–2007)	Sample 2 (2008–2012)	Whole Sample (2003–2012)
BCS_{t-1}	0.354 (0.036) ***	0.163 (0.071) ***	0.172(0.029) ***
$TRADE_t$	−5.913 (3.013) **	−19.685 (7.870) **	−0.860 (0.549)
$TRADE_{t-1}$	5.195 (3.127)	15.517 (7.199) **	−0.325(0.172) *
$KAOPEN_t$	−0.018 (0.008) **	−0.071 (0.060)	−0.074 (0.037) *
$KAOPEN_{t-1}$	0.006 (0.003)	−0.028 (0.037)	0.020 (0.013)
FIP_t	7.157 (4.694)	4.071 (7.737)	−0.394 (0.294)
FIP_{t-1}	−6.879 (5.040)	2.777 (0.013) ***	−0.331 (0.184) *
Constant	0.012 (0.010)	0.077 (0.074)	0.040 (0.024) *
Observation	2812	2812	5619
Instrument	25	13	13
Year Dummy	YES	YES	YES
AR(2)	0.954	0.276	0.412
Hansen T/Sargan T	0.170 (S)	0.563 (H)	0.124/0.167

Note: Number in parentheses is a standard error. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. The dependent variable is business cycle synchronization (BCS) of country i and j, measured by the absolute value of the difference between the growth rate of country i and j ($- | (\ln GDP_{it} - \ln GDP_{it-1}) - (\ln GDP_{jt} - \ln\text{-}GDP_{jt-1}) |$). Independent variables are lagged BCS (BCS_{t-1}) for country i and j, trade intensity (TRADE), lagged trade intensity ($TRADE_{t-1}$), financial market openness (KAOPEN), lagged financial market openness ($KAOPEN_{t-1}$), fragmentation of international production (FIP) and lagged fragmentation in an international production (FIP_{t-1}). Sources: Writer's calculation.

5. Summary and Conclusions

Sustainability in world production and world trade is crucial to stabilize the business cycle and economic activity across countries. However, economic stability and world production pattern are very interconnected. Generally, more and better production and stability in world trade can be translated into better economic sustainability. However, world production recently is very fragmented, and it directly contributes to business cycle synchronization (BCS) and, hence, affects economic instability. When the economy is volatile and BCS amongst countries increases, it will hamper economic sustainability. Thus, the strategic trade policy makers need to understand how fragmentation in production (FIP) is related to BCS. Therefore, this paper examines the effect of FIP on BCS for 703 paired of 38 countries for two different periods; year (2003–2007) and year (2008–2012). This paper considers empirical study by employing a new FIP measure, which is the bilateral vertical specialization.

The study's main finding can be summarized as follows: First, FIP influences output correlation positively for both periods; however, it was significant during the crisis period only. This finding signal that FIP can transfer positive spillover effects during the normal period, but it is not significant. On the other hand, FIP can amplify the synchronization of output fall during the economic crisis. As a result, those countries that engage heavily in FIP during the crisis would endure long-lasting synchronization in recession, as in many G7 countries. Second, lagged BCS ($BCS_{ij,t-1}$) influence BCS positively for both periods

and significant. This finding suggests that lagged BCS have positive spillover during a normal period and negative spillover during the crisis period. Third, trade linkage is negatively related to BCS both during normal and crisis. This implies TRADE reduced BCS both during normal and crisis periods. In other words, TRADE does not have a positive spillover effect during the normal period and does not transfer crisis impact to other countries. Lagged of TRADE influence BCS positively during both periods. Perhaps when a longer time in business, producers tend to trade more intra industry goods, and the trade volume is more of an intra industry, hence translating to positive spillover. Fourth, capital market openness reduces BCS during both periods but only significantly during a normal period. In the case of open capital market, it will promote more specialization during normal period and hence reduce BCS. This can be interpreted that, under an open capital market, no positive spillover effect. However, the result for the capital market during crisis period is insignificant.

As far as policy implication is concerned, the above findings should be interpreted with caution particularly because it mostly refers to some OECD countries and few non-OECD. In general, it suggests that globalization and economic openness regarding increasing trade linkages, financial openness, and FIP are not adequate measures to increase BCS amongst countries, at least during a normal period. Surprisingly, FIP can amplify BCS during the crisis period (2008/2009), while trade linkages and financial linkages are not. For that matter, measures to increase trade linkages, financial openness, and FIP to boost economic development and national welfare can be carried on at least amongst OECD countries during a normal period. However, during crisis period activities, FIP should be reduced, resulting in more deepening BCS and slowing economic growth. FIP is constituted by many economic sectors (agriculture, industry, and services); subsequently, it will be more beneficial to find which sector is more prone to BCS. That is the area that should be explored for future study.

Future study is more interesting to consider a more extensive data set to include earlier periods and periods after a crisis. By doing so, the impact of specific shock and common shock can be taken into account. It is also essential to explore a deeper analysis of BCS at the plant level between economies to identify which economic sector is prone to crisis. Finally, but not least, it is necessary to find out how FIP be attributed to future sustainability and explore more in terms of the relationship of BCS with sustainable development goals (SDG) in terms of production and consumption.

Appendix A

Table A1. OECD Countries.

1	AUS	AUSTRALIA	9	EST	ESTONIA	17	JPN	JAPAN	25	SVK	SLOVAKIA
2	AUT	AUSTRIA	10	FIN	FINLAND	18	KOR	REP. OF KOREA	26	SVN	SLOVANIA
3	BEL	BELGIUM	11	FRA	FRANCE	19	LUX	LUXEMBURG	27	SWE	SWEDEN
4	CAN	CANADA	12	GBR	GREAT BRITAIN	20	LVA	LATVIA	28	TUR	TURKEY
5	CZE	REP. CHECK-OSLAVAKIA	13	GRC	GREECE	21	MEX	MEXICO	29	USA	UNITED STATES OF AMERICA
6	DEU	GERMAN	14	HUN	HUNGARY	22	NDL	NETHERLAND			
7	DNK	DENMARK	15	IDN	INDONESIA	23	POL	POLAND			
8	ESP	SPAIN	16	ITA	ITALY	24	PRT	PORTUGAL			

Sources: Writer's own work based on World Input Output Data [47].

Table A2. NON-OECD Countries.

1	BGR	BULGARIA	8	ROM	ROMANIA
2	BRA	BRAZIL	9	RUS	RUSSIA
3	CHN	CHINA			
4	CYP	CYPRUS			
5	IND	INDIA			
6	LTU	LITUANA			
7	MLT	MALTA			

Sources: Writer's own work based on World Input Output Data [47].

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