VALUE-ADDED TRADE AND BUSINESS CYCLE SYNCHRONIZATION

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Abstract— Ever since Frankel and Rose's (1998) seminal paper, the literature on trade and business cycle synchronization has relied on gross trade data, with weak results in recent papers that carefully address omitted variable bias. This paper re-examines this relationship using new value-added trade data for 63 advanced and emerging economies during 1995–2013. In a panel framework, we identify a significantly positive impact of bilateral (value-added) trade intensity on business cycle synchronization—controlling for global common shocks, country-pair heterogeneity and other covariates—that is absent when gross trade data are used. There is also some evidence that the impact of value-added trade on synchronization increases with the degree of (value-added) intra-industry trade. We provide a theoretical rationale for the role of value-added trade for syncronization using a simple international business cycle model that features cross-country input linkages in production.

I. Introduction

The relationship between trade integration and business cycle synchronization (BCS) has been subject to extensive research, motivated in good part by the optimum currency area literature (OCA) that was pioneered by Mundell (1961) and McKinnon (1963) and given new impetus by Frankel and Rose (1997, 1998). A wide range of empirical papers (e.g., Frankel and Rose, 1997, 1998; Baxter and Kouparitsas, 2005; Imbs, 2004; Inklaar and others, 2008) have found that country pairs that trade more with each other experience higher business cycle synchronization. While these previous studies have adopted a variety of empirical techniques, they have typically not controlled for country-pair factors and common global shocks that could potentially drive the trade-BCS relationship and lead to omitted variable bias. Indeed Kalemi-Ozcan, Papaioannou and Peydro (2013) and Abiad, Furceri, Kalemli-Ozcan and Pescatori (2013) find the relationship between trade integration and BCS to be insignificant when such controls are added in a panel setup.[2] Recent literature has therefore

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[2] Earlier studies that accounted for country-pair heterogeneity also found weaker or no effects of overall trade intensity on BCS (Calderon, Chong and Stein, 2007; Shin and Wang, 2004).

cast serious doubt on the positive impact of trade integration on BCS found in earlier studies using alternative empirical frameworks.

Our paper argues that the measurement of bilateral trade intensity is important for evaluating the trade-BCS relationship. Gross trade data, which have been commonly used in the literature, can misrepresent trade linkages across countries given the growing importance of supply-chain networks across the globe. Once such supply-chain linkages are accounted for and trade integration is measured using *valued added* rather than *gross* trade data—using newly constructed annual data extending the OECD-WTO Trade in Value Added (TiVA) dataset—a positive, highly significant and robust effect of trade intensity on BCS is restored for a sample of 63 countries spanning the last two decades. IV estimates are larger than OLS estimates, suggesting that OLS attenuation bias induced by measurement error—which remains even when valued added trade data are used, as these rely on detailed information on trade flows and input-output matrices—is sizeable. The effect of trade is economically significant: our baseline estimates imply that the increase in (value added) trade intensity observed over the period 1995-2013 has accounted for an increase of close to 0.1 in the correlation of annual growth rates for the median country pair. There is also some evidence that the impact of value-added trade on synchronization increases with the degree of (value-added) intra-industry trade.

The reason why valued-added trade captures the bilateral trade linkages between two countries better than gross trade does is simple (see the detailed discussion in Johnson, 2014a): it is the value added exported by country A to country B, not the gross value of these exports, that contributes to overall value added and therefore to GDP in country A. In a world of growing supply chains and intermediate goods trade (Koopman, Wang and Wei, 2014), countries increasingly specialize in adding value at particular stages of production, and intermediate inputs, passing through these different stages, typically cross borders multiple times. In such a world, gross exports do no longer capture how much value added country A sells to country B, for several reasons. Let us consider for example country A's GDP response to demand shocks originating in country B. First, for each dollar of gross exports from country A to country B, the value added generated in country A is *less than or equal to one* dollar since imported intermediate goods are used in the production of exported goods; the larger the imported foreign content of exports, the more gross exports *overstate* the actual exposure of country A to shocks in country B, all else equal. Second, countries A and B may engage in bilateral intermediate goods trade under which the same good crosses the same border multiple times at different stages of production; here again, gross exports from country A to country B will *over-estimate* the value-added exposure of A to B. Third, and crucially, country A may indirectly export value added to country B without shipping any gross exports, for instance if it exports intermediate goods to a third country C that uses them to produce a final consumption good that is then exported by C to B; in this case, direct gross exports from A to B will *under-estimate* the value added that A exports (indirectly) to B. Focusing on value-added trade addresses these issues because it: i) nets out bilateral trade in intermediate goods—unlike gross trade data which count products multiple times when they cross borders repeatedly for processing purposes; and ii) includes indirect trade linkages via third countries—such as value added exported indirectly by A to B via intermediate inputs exported by A to C that are then used to produce a good exported by C to B.

The iPhone supply chain provides a simple illustration of the importance of the "third country effect" and the broader case for using value-added trade data. Although China exports the product to the US, its domestic firms add only a small fraction of the overall value added, mainly by assembling components sourced from other countries (Xing and Detert, 2010). As a result, China's gross iPhone exports to the US vastly exceed the value added by Chinese producers, and therefore vastly overstate the potential GDP growth impact of demand shocks coming from the US. By contrast, Korea does not export any iPhone to the US. Yet, compared to China, Korea reaps a far bigger share of the total value added from iPhone trade with the US, but it does so indirectly through exports of components to China. In Korea's case, gross trade with the US vastly under-estimates the potential GDP impact of shocks to US iPhone demand—indeed gross trade is zero.

Conventional international real business cycle models (IRBC) in the tradition of Backus, Kehoe and Kydland (1992) do not make a distinction between value-added and gross trade. Traded goods cross borders only once as they are exported either as final consumption goods or as intermediate inputs to produce final goods that are immediately consumed by the importing country. In such models, trade induces cross-country comovement if home-produced and foreign-produced goods are highly complementary.[3] Recently, Johnson (2014b) builds a new type of IRBC model with input-output linkages across sectors within and across countries, introducing another channel through which trade propagates shocks across borders and lead to BCS. Specifically, higher productivity in the home country lowers production costs, and thereby raises production not only in its direct export markets but also in a sequence of countries that indirectly import intermediate inputs from the home country. We present a simplified static version of Johnson (2014b) and show that in our simple model valued-added, rather than gross trade, matters for shock propagation and BCS.

[3] A positive shock in the home country increases its GDP but decreases its export price relative to that of foreign products. The resulting improvement in the terms of trade of the foreign country triggers a positive supply response of production factors, and thereby an increase in GDP. This effect is larger when home-produced goods and foreign-produced goods are more complementary (either as final consumption goods or as intermediate inputs in final production).

Our paper contributes to the burgeoning literature that emphasizes the importance of distinguishing between value-added trade and gross trade in international trade and macroeconomics. Bems (2014), for instance, argues that calibrating a misspecified value-added trade model to gross trade data can generate misleading predictions regarding how relative prices respond to external rebalancing. As supply-side linkages fundamentally alter how relative price changes affect international competitiveness, Bems and Johnson (2012) show that value-added trade weights are the correct weights to attach to each trading partner's final demand when computing real effective exchange rates. This paper adds another dimension to the discussion: we show that BCS bears a robust relationship with value-added trade, while the link with gross trade—which until now has been the focus of both empirical and theoretical literature—is statistically insignificant.

Our paper also adds to an active theoretical and empirical literature on the role of intermediate goods trade for BCS. Theoretically, in a calibrated multi-country multi-sector dynamic IRBC model featuring vertical trade, Johnson (2014b) finds that such a model generates strong positive output comovement but more limited value-added comovement across countries, even with strong complementarity among inputs. This finding is not inconsistent with ours. We do not study the distinction between cross-country output vs. value-added comovement; instead, we show that value-added trade has a statistically and economically significant effect on cross-country GDP comovement, providing empirical confirmation for the claim made by Johnson (2014a). More importantly, Johnson (2014b) is about the inability of the standard IRBC to generate a strong change in bilateral output correlations in response to changes in (gross) trade intensities, a longstanding issue in a literature that has sought to evaluate the performance of IRBC models through the lens of what was thought to be a strong relationship between gross trade and BCS following the seminal papers of Frankel and Rose (e.g. Kose and Yi, 2006; Burstein, Kurz and Tesar, 2008). Our paper is about the importance of the proper measurement of trade linkages in evaluating the empirical trade-BCS relationship.

On the empirical front, using gross trade data at the sector level, Di Giovanni and Levchenko (2010) find a larger positive impact of (gross) trade on comovement between sector pairs that use each other as intermediate inputs. This suggests that vertical trade along the supply chain is likely to generate more comovement than final goods trade. Our paper does not focus on the *type* of trade (intermediate versus final), but rather on how the overall *intensity* of bilateral trade should be computed when thinking about the role of trade for BCS. On this issue, we find that the domestic value added embodied in exports (of final and intermediate goods together) matters, while the overall value of bilateral gross trade does not. It may still be the case that trade in intermediate goods generates greater comovement than trade in final goods—indeed our tentative finding that intra-industry trade generates greater comovement than inter-industry trade is consistent with this view, although the two issues are conceptually distinct.

The rest of the paper is structured as follows. Section II presents a simple model illustrating that propagation of shocks across borders is driven by value-added trade more than by gross trade. Section III describes the data. Section IV provides OLS and IV estimates of the impact of trade on BCS using both gross and valued added trade data. As a robustness check, Section V re-estimates our main regressions using the original OECD-WTO TiVA data as well as an alternative measure of BCS. Section VI extends the analysis by exploring whether the impact of trade integration on BCS differed during the global financial crisis. Section VII concludes.

II. An Illustrative Model

This section presents a simple three-country model to show that the propagation of shocks across countries depends on the value added traded between them. Indeed, as shown below in a special example, even when there is no direct gross trade between two countries, shocks still propagate between them via their trade with the third country, an illustration of the "third country effect" mentioned in the introduction.

We start by noting that in typical IRBC models in the tradition of Backus, Kehoe and Kydland (1992), goods are exported either as final consumption goods or as intermediate inputs to produce final goods that are immediately consumed by the importing country. Therefore, trade is written entirely in value-added terms, leaving no space for the discussion of value-added trade vs. gross trade, and making these models unsuitable for the question at hand. Recently, Johnson (2014b) develops a multi-country, multi-sector IRBC model that allows for countries to share productions along the global supply chain, and for gross trade to differ from value-added trade. Although a thorough calibration and simulation of such a model is beyond the scope of this paper, this section discusses a static variant of Johnson (2014b) to provide a theoretical rationale for our empirical findings in the following sections. To simplify the analysis, we assume that there is trade in intermediate goods but not in final goods.

A. An IRBC Model with Global Supply Chains

The world consists of three economies. In each of them, the representative household is endowed with one unit of labor, supplied inelastically, and has log preferences over its final consumption good: $U_{it} = \log(C_{it})$, where C_{it} is the final good produced and consumed in country i at time t.

Each country produces a tradable good under perfect competition. The good is produced using a Cobb-Douglas technology with constant returns to scale. In particular, output of country i at time t, denoted by Q_{it} , is

$$Q_{it} = Z_{it}(L_{it})^{\alpha_i}\left(\prod_{j=1}^{3} X_{ji,t}^{\omega_{ji}}\right), \qquad \alpha_{\mathrm{i}} + \sum_j \omega_{\mathrm{ji}} = 1, \tag{1}$$

where L_{it} is the amount of labor employed in country i, α_i is the labor share of production, $X_{ji,t}$ is the quantity of intermediate input from country j used by country i, and Z_{it} is the idiosyncratic productivity shock to country i. Exponent ω_{ji} denotes the share of good j in the total production of good i. In view of the Cobb-Douglas technology in (1) and competitive factor markets, ω_{ji} also measures the value of spending on input j per dollar of output i. Let $\boldsymbol{\Omega} = (\omega_{ji})_{3\times 3}$ denote the world input-output matrix. Good i can either be consumed in the producing country or be used as an intermediate input for production in other countries. Therefore,

$$Q_{it} = C_{it} + \sum_{j=1}^{3} X_{ij,t} \tag{2}$$

In this static model, we assume financial autarky, which implies that trade is balanced in every country. As discussed in Johnson (2014b) and earlier in Cole and Obstfeld (1991), in the presence of Cobb-Douglas technology, complete insurance across countries is achieved through changes in relative prices in the decentralized economy. Therefore, we can solve for equilibrium quantities via the social planner's optimization problem with weight μ_i attached to country i: $\max_{\{X_{ij}\}} \sum_{i=1}^{3} \mu_{\mathrm{i}} \log(C_{it})$, subject to constraints (1) and (2).

Let $\lambda_{i,t}$ be the Lagrange multiplier of the resource constraint. It also captures the shadow price of country j's good. The first-order conditions are given by

$$\mu_i = \lambda_{it} C_{it} \tag{3}$$

$$\omega_{ji}\lambda_{it} Q_{it} = \lambda_{jt} X_{ji,t} \tag{4}$$

To see the effect of shocks, we first log-linearize the above conditions (1)-(4) around the steady-state equilibrium. This generates the following equations:

$$\hat{C}_{it} = -\hat{\lambda}_{it}, \tag{5}$$

$$\hat{X}_{ji,t} = \hat{\lambda}_{it} - \hat{\lambda}_{jt} + \hat{Q}_{it}, \tag{6}$$

$$\hat{Q}_{it} = \hat{Z}_{it} + \sum_{j=1}^{3} \omega_{ji} \hat{X}_{ji,t}, \tag{7}$$

$$\hat{Q}_{it} = \frac{C_i}{Q_i}\hat{C}_{i,t} + \sum_{j=1}^{3} \frac{X_{ij}}{Q_i} \hat{X}_{ij,t}, \tag{8}$$

where any variable $\hat{x}_t$ denotes the log-deviation of x_t from its steady state.

Substituting (5) and (6) into (7) and rearranging terms, we get $\hat{Q}_{it} = -\hat{\lambda}_{it}$, which is a familiar result under Cobb-Douglas technology. Substituting this equation back into (7) and (8), we have $\hat{Q}_{it} = \hat{Z}_{it} + \sum_{j=1}^{3} \omega_{ji} \hat{Q}_{jt}$, which in matrix notation becomes

$$\hat{\boldsymbol{Q}}_t = \left(\boldsymbol{I} - \boldsymbol{\Omega}'\right)^{-1} \hat{\boldsymbol{Z}}_t. \qquad (9)$$

Equation (5) and $\hat{Q}_{it} = -\hat{\lambda}_{it}$ together imply $\hat{Q}_{it} = \hat{C}_{it}$. In addition, in this simple economy real GDP equals real consumption, i.e. $Y_{it} = C_{it}$, since trade is balanced and there is no capital and therefore no investment. As a result, growth in real GDP equals growth in real gross output: $\hat{Y}_{it} = \hat{Q}_{it}$. Equation (9) shows that country-specific shocks are transmitted across countries and affect GDP growth through the Leontief inverse $\left(\boldsymbol{I} - \boldsymbol{\Omega}'\right)^{-1}$, which strictly depends on world input-output linkages as captured by matrix $\boldsymbol{\Omega}$.

B. Value-added Exports vs. Gross Exports

To derive value-added exports in this economy, we first rewrite the resource constraint (2) as: $P_{it}Q_{it} = P_{it}C_{it} + \sum_{j=1}^{3} \omega_{ij} P_{jt}Q_{jt}$, given that $\omega_{ij} = \frac{P_{it} X_{ij,t}}{P_{jt}Q_{jt}}$. Expressing it in matrix notation, we have $\boldsymbol{q}_t = \left(\boldsymbol{I} - \boldsymbol{\Omega}\right)^{-1} \boldsymbol{f}_t$, where $\boldsymbol{q} = (P_1Q_1, P_2Q_2, P_3Q_3)'$ and $\boldsymbol{f} = (P_1C_1, P_2C_2, P_3C_3)'$ are the value of output and final good expenditure, respectively.

Value-added exports from country i to j correspond to the value of goods produced by i and used directly and indirectly to produce final goods absorbed in country j. Thus, bilateral value-added exports across countries, denoted by va_{ijt}, can be computed as the element of the matrix $\boldsymbol{va}_t = (va_{ijt})_{3\times3}$:

$$\boldsymbol{va}_t = \left(\boldsymbol{I} - \boldsymbol{\Omega}\right)^{-1} diag(f_{jt}). \qquad (10)$$

Gross exports from country i to country j, on the other hand, are given by $ex_{ijt} = P_{it}X_{ij,t} = \omega_{ij} q_{jt}$.

To illustrate why value-added trade is better at capturing the trade linkages than gross trade, let us consider a specific input-output matrix that does not feature domestic intermediate inputs, namely $\boldsymbol{\Omega} = \begin{pmatrix} 0 & \omega_{12} & \omega_{13} \\ \omega_{21} & 0 & \omega_{23} \\ \omega_{31} & \omega_{32} & 0 \end{pmatrix}$. The above Equation (9) can be rewritten as

$$\hat{\boldsymbol{Y}}_t = \kappa \begin{pmatrix} 1-\omega_{32}\omega_{23} & \omega_{21}+\omega_{23}\omega_{31} & \omega_{31}+\omega_{32}\omega_{21} \\ \omega_{12}+\omega_{13}\omega_{32} & 1-\omega_{31}\omega_{13} & \omega_{32}+\omega_{31}\omega_{12} \\ \omega_{13}+\omega_{12}\omega_{23} & \omega_{23}+\omega_{21}\omega_{13} & 1-\omega_{21}\omega_{12} \end{pmatrix} \hat{\boldsymbol{Z}}_t,$$

where $\kappa = |\boldsymbol{I} - \boldsymbol{\Omega}'|^{-1}$.

Consider output growth in country 1 at time *t*:

$$\hat{Y}_{1t} = \kappa\left[(1-\omega_{32}\omega_{23})\hat{Z}_{1t} + (\omega_{21}+\omega_{23}\omega_{31})\hat{Z}_{2t} + (\omega_{31}+\omega_{32}\omega_{21})\hat{Z}_{3t}\right] \qquad (11)$$

This shows that positive shocks in country 2 raise country 1's output not only through direct trade reflected in ω_{21}, but also indirectly via a "third-country effect" captured by the compound term $\omega_{23}\omega_{31}$. The overall impact of $\hat{Y}_1$ to $\hat{Z}_2$ is $\omega_{21}+\omega_{23}\omega_{31}$. Likewise, the impact of shocks in country 3 on country 1 is captured by the elasticity $\omega_{31}+\omega_{32}\omega_{21}$.

According to (10), the value added exported by country 2 to country 1 (as a fraction of country 1's nominal GDP) is $\omega_{21}+\omega_{23}\omega_{31}$, and the value added exported by country 3 to country 1 is $\omega_{31}+\omega_{32}\omega_{21}$. These are exactly the elasticities in (11) that capture the respective responses of real GDP in country 1 to shocks in countries 2 and 3.

In contrast, gross exports do not take into account the compound terms $\omega_{23}\omega_{31}$ and $\omega_{32}\omega_{21}$, i.e. they ignore third-country effects. Consider further as a special case that country 3 does not directly trade with country 1 (i.e. $\omega_{31}=\omega_{13}=0$). Countries 1 and 3 would then appear to be unconnected if trade is measured using conventional gross trade statistics, even though the indirect linkages via the supply chain still transmit shocks between them.

Through this example, we have shown that in the presence of global supply chains, trade in value added, more than gross trade, matters for BCS across countries. The next sections investigate this issue empirically.

III. Data and Measurement

A. Business Cycle Synchronization

Throughout this paper, in line with recent literature (for instance, Kalemli-Ozcan, Papaioannou and Perri, 2013; Kalemli-Ozcan, Papaioannou and Peydro, 2013; Abiad *et al.* 2013) and following the original idea of Morgan, Rime and Strahan (2004), we adopt the measure of "instantaneous" BCS that can be computed at any point in time rather than over a particular interval. Concretely, using annual data—which is the available frequency for valued added trade data—we calculate the instantaneous quasi-correlation of real GDP growth rates of country *i* and *j* in year *t* as:[4]

$$QCORR_{ijt} = \frac{(g_{it} - g_i^*)(g_{jt} - g_j^*)}{\sigma_i^g \sigma_j^g},$$

where g_{it} denotes the output growth rate of country *i* in year *t*, and g_i^* and σ_i^g represent the mean and standard deviation of output growth of country *i*, respectively, during the sample period. The growth rate is measured as the log difference of real GDP, taking the data from the IMF *World Economic Outlook* database.

As a robustness check for our findings, we also re-run the econometric analysis using the usual Pearson correlation of growth rates rather than our quasi-correlation measure. Over four sub-periods of our 1995-2013 sample, we compute:

$$CORR_{ij\tau} = corr(g_{it}^{\tau}, g_{jt}^{\tau}),$$

where $CORR_{ij\tau}$ is the Pearson correlation coefficient for *quarterly* growth rates of countries i and *j* in period τ, and g_{it}^{τ} is the growth rate of country i in quarter t of period τ.

B. Trade integration

We compute two bilateral trade integration variables, one in gross terms and the other one in value-added terms:

- *Gross Exports of country i to country j,* X_t^{ij}, is the conventional gross trade integration variable used in previous literature. It is sourced from the IMF's *Direction of Trade Statistics Yearbook*.

- *Domestic Value Added Embodied in Gross Exports of country i to country j,* DVA_t^{ij}, is derived from the 2013 release of the OECD-WTO TiVA database (for methodological details, see OECD-WTO, 2012). It denotes the domestic value added exported, *both* directly and indirectly, from country *i* to country *j* in year *t*. The indirect component includes the domestic value added exported by country *i* to a third country *k*, as intermediate inputs in the production of goods and services exported by country *k* to country *j*. DVA_t^{ij} sums up two contributions to total domestic value added exported from country *i* to country *j*: i) the contribution from industries that produce

[4] Earlier literature often measured output comovement between two economies by the rolling Pearson correlation of actual or detrended growth rates between a country pair over a window period. This artificially introduced autocorrelation of the BCS time series due to a high degree overlapping observations throughout the sample. Also, unlike our quasi-correlation measure computed for a given year, these measures are bounded between -1 and 1. As argued by Inklaar *et al.* (2008), if the BCS measure lies between -1 and 1, the error terms in the regression are unlikely to be normally distributed.

exported goods and services; ii) the contribution from domestic supplier industries made through domestic upstream transactions.

While the OECD-WTO TiVA database provides invaluable data on exports in value added terms, the database only covers years 1995, 2000, 2005, 2008, and 2009. In order to obtain annual data, we first construct annual time series in line with national accounts concepts by using United Nation's COMTRADE in combination with national accounts data. These series can be viewed as proxies for the OECD-WTO value-added data. We then use *growth rates* of the proxy series to interpolate the OECD-WTO dataset's levels between available years, and also to extrapolate beyond 2009. Our methodology for constructing the proxy series is similar to that used by Timmer et al. (2012) in constructing a continuous annual time series for the World Input-Output Database (WIOD) initiative, and is also broadly consistent with that used by Johnson and Noguera (2012a; 2012b) to construct value-added trade series for a smaller set of countries over a longer period. The Data Appendix explains in much detail our methodology.

As a robustness check, we also construct domestic value added in exports based on WIOD following the methodology in Johonson and Noguera (2012a). We find that there is remarkable similarity between bilateral value-added trade intensity calculated using our dataset and its counterpart using WIOD (the within-country-pair correlation is 0.82; see section V and the Data Appendix for more detail). An important advantage of the annual dataset we construct using the OECD-WTO TiVA database it is that it was compiled after WIOD was released and therefore uses more recent raw data, and also features a more accurate treatment of processing trade particularly for emerging economies such as China (Jones et al, 2014). A further advantage is that TiVA has wider country coverage; using it allows us to include more emerging economies in our study, while WIOD only includes 7 emerging economies outside the Euro area.

Bilateral trade intensity is then computed following the conventional definition in the literature, including in Frankel and Rose (1998), except that we define it in a value added sense. Specifically,

$$T_{ijt}^{VA} = \ln\left(\frac{DVA_t^{ij} + DVA_t^{ji}}{GDP_{it} + GDP_{jt}}\right),$$

where T_{ijt}^{VA} represents the (logarithm of) bilateral value added trade intensity of country-pair *i* and *j* at time *t*; GDP_{it} is the GDP of country *i* at time *t*, and DVA_t^{ij} denotes the total domestic value added exported (both directly and indirectly) from country *i* to country *j* in year *t*.

Bilateral trade intensity in gross terms is computed in a similar fashion as:

$$T_{ijt}^{Gross} = \ln\left(\frac{X_t^{ij} + X_t^{ji}}{GDP_{it} + GDP_{jt}}\right),$$

where T_{ijt}^{Gross} represents the (logarithm of) bilateral gross trade intensity of country-pair i and j at time t.

Descriptive statistics and within (country-pair) correlations between variables are presented in Table 1. Most noticeable is the rather low within correlation between bilateral gross trade intensity and value added trade intensity, about 0.2. This can, and will account for the difference in results when using one rather than the other, and further strengthen the case for using value added trade data given that these better capture bilateral trade linkages between countries.

Table 1. Descriptive Statistics and Variables' "within" Correlations

	Panel A: Descriptive Statistics						
	Mean	st. dev.	Min	p25	p50	p75	Max
Quasi-correlation	0.45	1.49	-6.82	-0.06	0.12	0.48	11.74
Trade Intensity (gross)	-6.86	1.56	-12.33	-7.87	-6.78	-5.82	-1.58
Trade Intensity (VA)	-7.54	1.47	-14.33	-8.43	-7.45	-6.60	-3.25
Banking Integration	-6.48	2.18	-13.60	-7.85	-6.37	-4.91	-1.07
Similarity in production structures	0.48	0.23	0.01	0.29	0.48	0.65	1.36
Intra-industry trade (VA)	0.35	0.11	0.02	0.30	0.37	0.43	0.66

	Panel B: "within" Correlations amongst Explanatory and Dependent Variables			
	Trade Intensity (gross)	Trade Intensity (value added)	Banking integration	Quasi-correlation
Trade Intensity (gross)	1.00	0.19	0.01	0.00
Trade Intensity (VA)	0.19	1.00	0.02	0.06
Banking integration	0.01	0.02	1.00	0.05
Quasi-correlation	0.00	0.06	0.05	1.00

Sources: OECD-WTO Trade in Value Added database; Bank for International Settlements; Authors' estimates.

C. Financial integration

We control for the effect of banking integration, which has been found to affect output synchronization (Kalemli-Ozcan, Papaioannou and Peydro, 2013; Kalemli-Ozcan, Papaioannou and Perri, 2013) and whose omission could potentially entail omitted variable bias.

Banking integration data are based on bilateral locational banking statistics by residency from BIS confidential and restricted databases. Using locational data by residency is conceptually consistent with the residency principle of national accounts and the balance of payments. We have total bilateral external positions (both assets and liabilities separately) over 1990- 2013 for BIS-reporting countries vis-à-vis individual partner countries. Based on these data, the banking integration variable is defined as in e.g. Abiad *et al.* (2013) as the (logarithm of the) ratio of the stock of bilateral assets and liabilities between countries i and j in year t to the sum of these two countries' external assets and liabilities vis-à-vis the entire world in the previous year $t-1$:

$$BI_{ijt} = \ln\left(\frac{BP_t^{ij}+BP_t^{ji}}{BP_{t-1}^{iworld}+BP_{t-1}^{jworld}}\right),$$

where BI_{ijt} is bilateral banking integration between countries *i* and *j* in year *t*, BP_t^{ij} is the stock of assets and liabilities of country *i*'s banks vis-à-vis country *j*, and BP_{t-1}^{iworld} is the total stock of asset and liabilities of country i vis-à-vis the world in year $t-1$.

Our results regarding trade integration below are robust to expressing financial integration instead as a ratio of the sum of the two countries' GDPs.

D. Other controls and extensions

In some specifications, with the view to both extending the analysis and checking for the robustness of our core results, we control for further variables that have been widely used in past literature. As in Kalemli-Ozcan, Papaioannou and Peydro (2013), we control for the possibility of different growth dynamics across countries through the log of the product of the two countries' GDP, the log of the product of the two countries' population, and the absolute difference in log GDP per capita, all of which lagged one year.

We also control for similarity between the two countries' production structures through the following indicator of similarity in industrial structure as in Imbs (2004), SIS_{ijt} :

$$SIS_{ijt} = -\sum_{h=1}^{n}\left|S_t^{i,h} - S_t^{j,h}\right|,$$

where $S_t^{i,h}(S_t^{j,h})$ is the share of industry *h* in the GDP of country *i* (country *j*) in year *t*, and the multiplication by (-1) turns the dispersion index into a similarity index.

Finally, we add to the longstanding debate on whether intra-industry trade and inter-industry trade differ in their impact on BCS by using value-added rather than gross trade data. In the presence of industry-specific shocks, theory suggests that greater bilateral trade integration should be associated with a higher degree of GDP growth co-movement if the share of intra-industry trade is higher, all else equal. Using gross trade data, Imbs (2004) and Inklaar et al. (2008) find supportive evidence for the theory, while Baxter and Kouparitsas (2005) point to the lack of robustness of intra-industry trade in such regressions. Here, using our available value-added trade data for 18 industries at the two-digit (ISIC Rev3) level, we compute the following Grubel-Lloyd index of intra-industry trade, IIT_{ijt} :

$$IIT_{ijt} = 1 - \frac{\sum_{h=1}^{n}\left|DVA_t^{ij,h} - DVA_t^{ji,h}\right|}{\sum_{h=1}^{n}\left(DVA_t^{ij,h} + DVA_t^{ji,h}\right)},$$

where $DVA_t^{ij,h}$ and $DVA_t^{ji,h}$ denote the total domestic value added exported from country *i* to country *j*, and from country *j* to country *i*, respectively, in year t in industry *h*. The higher the index value, the greater the share of intra-industry trade relative to inter-industry trade between the two countries. It is well-known that the Grubel-Lloyd index is sensitive to the granularity of the trade classification. Unfortunately, unlike gross trade data, value-added trade data are only available at a fairly aggregated level. For this reason, we view this part of our econometric analysis as more tentative.

IV. TRADE AND BUSINESS CYCLE SYNCHRONIZATION: OLS AND IV ESTIMATES

A. OLS estimates

Our baseline econometric specification follows most recent practice in the literature:

$$QCORR_{ijt} = \alpha_{ij} + \alpha_t + f\left(TRADE_{ijt-1}\ , FINANCE_{ijt-1}, CONTROLS_{ijt-1}\right)\ + \varepsilon_{ijt}, \qquad (12)$$

where $QCORR_{ijt}$ is the instantaneous quasi-correlation (as defined above) between country-pair *i* and *j* at time *t*; α_{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*; α_t is a time effect, which accounts for time-varying common factors affecting all countries. TRADE, FINANCE and CONTROLS denote bilateral trade intensity integration, bilateral financial integration and other control variables in the previous year, respectively.

Table 2 presents OLS estimates of equation (12) on annual data covering 63 countries over 1995-2013. Due to the presence of serial correlation, standard errors are clustered at country-pair level in all models, to allow for autocorrelation and arbitrary heteroskedasticity for each pair.[5] In line with recent papers using a similar framework, bilateral gross trade intensity turns out to be insignificant (columns 1 and 2). By contrast, value-added trade intensity appears to be significant at the 1% confidence level (columns 3 and 4). The effect of banking integration is negative and significant, as in Kalemli-Ozcan, Papaioannou and Peydro (2013). The value of the value-added trade coefficient and its statistical significance remain comparable when additional controls are incorporated (column 5). This provides preliminary evidence that while gross trade does not seem to affect BCS, value-added trade does. Furthermore, that impact appears to be larger when the degree of intra-industry trade is

[5] We follow recent practice (e.g. Kalemli-Ozcan, Papaioannou and Peydro, 2013) in clustering at the country-pair level, also given our fairly large number of clusters. An alternative could have been to implement the two-way clustering technique of Cameron, Gelbach and Miller (2011) and cluster at both country *i* and *j* levels. Taking this approach would not affect our main finding that bilateral value-added trade intensity has a statistically significant impact on BCS. Indeed when re-running all of the regressions presented below but clustering standard errors at country *i* and *j* levels instead, the coefficient of interest remains statistically significant at least at the 5% confidence level across all specifications (results available from the authors upon request).

higher (column 6).[6] Among the other controls, the indicator of similarity in industrial structure is correctly signed but statistically insignificant at conventional levels.[7]

Table 2. Business Cycle Synchronization and Trade: OLS

	OLS	OLS	OLS	OLS	OLS	OLS
Dependent Variable: Quasi-correlation of output growth rates	(1)	(2)	(3)	(4)	(5)	(6)
Trade intensity (gross)	0.040	0.032				
	(1.617)	(0.875)				
Trade intensity (VA)			0.038***	0.100***	0.078***	0.080***
			(2.631)	(3.878)	(3.006)	(3.076)
Banking integration		-0.053***		-0.053***	-0.056***	-0.056***
		(-4.840)		(-4.922)	(-5.274)	(-5.306)
Similarity in production structures					0.073	0.071
					(1.303)	(1.266)
Product of log GDP					-0.394***	-0.399***
					(-3.571)	(-3.616)
Product of log population					-1.303***	-1.267***
					(-5.899)	(-5.702)
Absolute difference in log PPP GDP per capita					-0.151	-0.152
					(-1.290)	(-1.297)
Intra-industry trade (VA)					-0.067	-0.012
					(-0.550)	(-0.097)
Trade intensity X Intra-industry trade (VA)						0.153*
						(1.905)
Country-pair fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Year-fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	17,912	12,326	18,243	12,382	12,341	12,341
R-squared	0.562	0.628	0.560	0.628	0.631	0.631

Sources: Authors' estimates

Note: Robust t-statistics in parentheses. Standard errors are clustered at country-pair level. *** p<0.01, ** p<0.05, * p<0.1

[6] The typically insignificant direct effect of the intra-industry trade index in both these OLS and the IV regressions below is not surprising. The structure of trade should be expected to matter primarily in interaction with the intensity of trade, indeed at the extreme it should not matter if the intensity of trade were close to zero.

[7] The presence of our indicator of intra-industry trade and the log difference in GDP per capita in these regressions could potentially weaken the estimated impact of similarity in industrial structure if these variables were highly correlated. However, in practice, the indicator of similarity in industrial structure bears a low correlation with both intra-industry trade and the log difference in GDP per capita—both correlations coefficients are below 0.05 in our sample. One reason for the low correlation between the indicators of intra-industry trade and similarity in industrial structure, in particular, is that two countries which produce similar goods may not necessarily export them, and when they do they may export these goods to other countries without necessarily exporting them to each other.

B. IV estimates

Endogeneity and measurement error are concerns when estimating the impact of trade on BCS. Trade might be endogenous in the sense that BCS may be driven by some omitted or unobservable variables that are correlated with trade; or there might be reverse causality as higher BCS may induce greater trade intensity. In this context, OLS would be both inconsistent and biased. This concern is only partly addressed by using lagged trade intensity variables, and by including country-pair fixed effects—which address endogeneity insofar as omitted variables or the transmission mechanism through which BCS affects trade are time-invariant, such as, for example, geographical proximity, culture, etc. Furthermore, there are worries that measurement error may affect the OLS estimates, particularly given that the original value added trade data from OECD-WTO rely upon detailed data on trade flows and imperfect input-output matrices that are themselves subject to measurement error.

Instrumental variable regressions can go some way toward addressing these issues. The baseline regression with banking integration as a control (column 4 in Table 2), and the regression with all controls and the interaction between trade intensity and intra-industry trade (column 6 in Table 2) are re-estimated using two alternative instruments for bilateral trade intensity:

- *Bilateral tariff.* This is the average import tariff applied to each other by the two countries considered, averaged across all products. Tariff data at the product level are sourced from the WTO's Integrated Database (IDB) and UNCTAD's Trade Analysis and Information System (TRAINs) database (accessed via the WITS platform). Tariff profiles for MFN statutory applied duties are taken, in the first instance, from the IDB. All aggregations across products are based on the weighted duty averages generated by WITS.

- *Preferential trade agreement covering the two countries considered*. We rely on the April 2013 update by the WTO of the dataset on the content of preferential trade agreements (PTAs) that was originally constructed for the 2011 *World Trade Report*. The updated version consists of a comprehensive breakdown of 100 PTAs signed between 1958 and 2011. The instrumental variable is computed as the sum of existing provisions (scored 1 when a liberalization provision is present in the agreement that covers the two countries considered, and 0 when not present—or when there is no PTA between the two countries altogether) in 14 areas (for details, see WTO, 2011): free trade agreement on industrial goods; free trade agreement on agriculture goods; customs information; export taxes elimination; sanitary and phytosanitary measures; technical barriers to trade; state trading enterprises; antidumping; countervailing measures; state aid; public procurement; trade-related investment measures (TRIMs); liberalization of trade in services; trade-related aspects of intellectual property rights (TRIPs).

Both instruments are bilateral and time-varying as needed. They are helpful to address measurement error, but they may not fully address reverse causality as they might affect BCS through other channels. As a result, one should be careful in making a causal interpretation of the corresponding IV regressions.

The IV results are presented in Tables 3 (instrumentation with tariffs) and 4 (instrumentation with PTAs). In both cases, the first-stage regressions are satisfactory and show a significant effect of import tariffs on trade intensity. Turning to the second-stage regressions, the key finding from OLS estimates that value added trade intensity has a highly significant impact on BCS while gross trade does not still holds when trade intensity is instrumented (columns 1 and 2). The interaction between value-added trade intensity and (value-added) intra-industry trade is now statistically significant at the 1% confidence level, strengthening the finding that trade has a larger impact on BCS when the degree of intra-industry trade is higher (Tables 3 and 4, column 3). While the estimated coefficient of value-added trade intensity varies across the different instrumentation approaches, it is always larger than its OLS counterpart shown in Table 2, suggesting that measurement error is indeed a serious concern. The effect of value added trade is economically significant: for instance, based on the IV coefficient in column 2 of Table 4, the increase in trade intensity observed over the period 1995-2013 has accounted for an increase in the correlation of annual growth rates for the median country pair of close to 0.1.

It is worth noting that while the impact of trade on BCS is found to be statistically significant for country pairs involving at least one advanced economy, it is not for country pairs that involve only emerging economies (Tables 3 and 4, column 4). This finding is qualitatively consistent with the results in Kraay and Ventura (2007) or Calderon, Chong and Stein (2007). Exploring the causes for the much weaker—indeed insignificant in the present paper—impact of trade on BCS among emerging country pairs goes beyond the scope of this paper. Nonetheless, among the various causes put forward in the literature, one on which our work sheds light is the smaller degree of intra-industry trade among emerging country pairs vis-à-vis other pairs. Our finding that a higher degree of intra-industry trade amplifies the impact of trade intensity on BCS appears to apply equally to emerging country pairs and others; indeed an interaction between trade intensity, the degree of intra-industry trade and the emerging country-pair dummy variable—controlling for all implicit interactions as needed—is statistically insignificant (result not reported here, available upon request). Therefore a combination of above-average bilateral trade intensity and above-average degree of intra-industry trade does have a statistically significant impact on the co-movement of an emerging country pair. But in practice, emerging country pairs show a lower average degree of intra-industry trade in our dataset, which for a given degree of trade intensity implies less growth co-movement than for other country pairs, all else equal. It should be acknowledged that this explanation for the smaller impact of trade on BCS among emerging country pairs is, however, only partial, as it cannot account for the statistically insignificant *direct* effect of trade on BCS for emerging country pairs in Tables 3 and 4.

Table 3. Business Cycle Synchronization and Trade: IV

(Instrument: Bilateral Tariffs)

	IV	IV	IV	IV
Dependent Variable: Quasi-correlation of output growth rates	(1)	(2)	(3)	(4)
Trade intensity (gross)	-0.097			
	(-1.642)			
Trade intensity (VA)		0.173***	0.148***	0.189***
		(5.717)	(4.026)	(5.818)
Banking integration	-0.073***	-0.074***	-0.061***	-0.064***
	(-6.108)	(-6.150)	(-5.192)	(-5.141)
Similarity in production structures			0.081	
			(1.204)	
Product of log GDP			0.076***	
			(3.638)	
Product of log population			-0.135***	
			(-9.369)	
Absolute difference in log PPP GDP per capita			-0.065***	
			(-3.441)	
Intra-industry trade (VA)			-0.232*	
			(-1.753)	
Trade intensity X Intra-industry trade (VA)			0.218***	
			(4.808)	
Trade intensity (VA) X EM-EM dummy				-0.194***
				(-4.730)
EM-EM dummy				0.108***
				(2.713)
Country-pair fixed effects	Yes	Yes	Yes	Yes
Year-fixed effects	Yes	Yes	Yes	Yes
Observations	12,326	12,382	12,341	12,341
R-squared	0.628	0.628	0.636	0.611

Sources: Authors' estimates

Note: Robust t-statistics in parentheses. Standard errors are clustered at country-pair level. *** p<0.01, ** p<0.05, * p<0.1

Table 4. Business Cycle Synchronization and Trade: IV
(Instrument: Preferential Trade Agreement)

	IV	IV	IV	IV
Dependent Variable: Quasi-correlation of output growth rates	(1)	(2)	(3)	(4)
Trade intensity (gross)	-0.097*			
	(-1.691)			
Trade intensity (VA)		0.226***	0.198***	0.103**
		(8.559)	(6.530)	(2.532)
Banking integration	-0.065***	-0.060***	-0.059***	-0.059***
	(-5.418)	(-5.033)	(-5.039)	(-4.807)
Similarity in production structures			0.039	
			(0.593)	
Product of log GDP			-0.390***	
			(-2.700)	
Product of log population			-1.042***	
			(-2.621)	
Absolute difference in log PPP GDP per capita			-0.133	
			(-1.018)	
Intra-industry trade (VA)			-0.182	
			(-1.407)	
Trade intensity X Intra-industry trade (VA)			0.666***	
			(4.797)	
Trade intensity (VA) X EM-EM dummy				-0.141***
				(-9.409)
EM-EM dummy				0.108***
				(2.713)
Country-pair fixed effects	Yes	Yes	Yes	Yes
Year-fixed effects	Yes	Yes	Yes	Yes
Observations	11,397	11,397	11,397	12,339
R-squared	0.635	0.635	0.636	0.627

Sources: Authors' estimates
Note: Robust t-statistics in parentheses. Standard errors are clustered at country-pair level. *** p<0.01, ** p<0.05, * p<0.1

V. Regressions Based on Original OECD-WTO TiVA Data and WIOD Data

Given that we have used *annual* value-added trade data while the original OECD-WTO TiVA dataset is available only for selected years, as a robustness check we re-run our regressions using only original OECD-WTO data. To this end, we consider a panel that includes four periods of our original sample (1990–95, 1996-2000, 2001-07 and 2008-13), over which we calculate for each country pair the bilateral Pearson correlation coefficient based on *quarterly* GDP growth rates. On the right-hand side, we consider bilateral value-added trade intensity only for those years for which the raw OECD-WTO TiVA data are available. Thus, for the periods 1990–95, 1996-2000, 2001–07 and 2008–13, we use OECD-WTO trade intensity values for the years 1995, 2000, 2005 and (an average of) 2008–09, respectively, which are the only available years. Other explanatory variables including banking integration are average values over the sub-period considered. This exercise demonstrates that our main result is not sensitive either to the definition of BCS or to the interpolation method we have used to construct our annual dataset.

The regressions (Table 5.1) confirm that while gross trade is not significantly associated with synchronization, value added trade is. The size of the coefficient varies across the different IV specifications but is overall fairly comparable to its size in the same specifications featured in Tables 3 and 4. Furthermore, the interaction between trade intensity and the degree of intra-industry trade remains significant in these regressions.

Table 5.1. Business Cycle Synchronization and Trade: 4 period Models for Robustness

	OLS	IV=tariff	IV=PTA	OLS	IV=tariff	IV=PTA	IV=tariff	IV=PTA
Dependent variable: correlation of quarterly output growth rates	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Trade intensity (gross)	0.043	0.511	-0.549					
	(1.196)	(0.522)	(-1.642)					
Trade intensity (VA)				0.057**	0.148***	0.091***	0.111***	0.094***
				(2.488)	(3.225)	(5.091)	(4.045)	(4.850)
Banking integration	0.009	-0.017	-0.001	-0.019*	-0.024*	-0.012*	-0.018**	-0.015**
	(0.893)	(-1.274)	(-0.211)	(-1.859)	(-1.705)	(-1.742)	(-2.254)	(-2.330)
Similarity in production structures							0.045	0.046
							(1.254)	(1.331)
Product of log GDP							-0.073***	-0.068***
							(-4.003)	(-4.011)
Product of log population							0.053***	0.052***
							(3.569)	(3.598)
Absolute difference in log PPP GDP per capita							-0.055***	-0.056***
							(-3.026)	(-3.224)
Intra-industry trade (VA)							-0.015	-0.007
							(-0.470)	(-0.235)
Trade intensity X Intra-industry trade (VA)							0.179**	0.199***
							(2.481)	(3.049)
Country-pair fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year-fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	2,034	1,828	1,828	2,034	1,828	1,828	1,828	1,828
R-squared	0.620	0.628	0.628	0.621	0.628	0.628	0.637	0.637

Sources: Authors' estimates

Note: Robust t-statistics in parentheses. Standard errors are clustered at country-pair level. *** p<0.01, ** p<0.05, * p<0.1

As an additional robustness check, we calculate another set of value-added trade intensity data using the World Input-Output Database (WIOD) —which contains harmonized annual cross-country input-output tables from 1995 to 2011 for 35 industries and 40 countries—and re-run the regressions based on the alternative data. To construct the value-added exports data from the world input-output tables, we follow the methodology described in Johnson and Noguera (2012a).[8] Bilateral trade intensity in value-added terms is then calculated in the same way as before (see Section II.B). We find that the bilateral trade intensity data based on WIOD is highly correlated with its counterpart in our (TiVA) data, with *within* correlation equal to 0.82 (year-by-year Pearson correlations are shown in the Appendix).

Table 5.2 shows that using the alternative measures of value-added exports does not alter our results in any significant way. The coefficients on value-added trade intensity are positive and statistically significant across all specifications, and the magnitude of the coefficients is comparable to the previous results in Tables 3 and 4.

Table 5.2. Business Cycle Synchronization and Trade: Robustness Check Using WIOD Data

	OLS	IV=tariff	IV=PTA	IV=tariff	IV=PTA
Dependent Variable: Quasi-correlation of output growth rates	(1)	(2)	(3)	(4)	(5)
Trade intensity (VA)	0.104**	0.209***	0.253***	0.176***	0.251***
	(2.258)	(7.275)	(6.802)	(6.247)	(9.615)
Banking integration	-0.067***	-0.017	-0.028*	-0.031***	-0.038***
	(-4.491)	(-1.345)	(-1.710)	(-5.506)	(-8.343)
Similarity in production structures				0.169***	0.171***
				(4.408)	(4.582)
Product of log GDP				0.166***	0.098***
				(6.024)	(3.072)
Product of log population				-0.098***	-0.085***
				(-6.975)	(-6.145)
Absolute difference in log PPP GDP per capita				-0.086***	-0.091***
				(-5.255)	(-5.482)
Intra-industry trade (VA)				0.064	-0.141
				(0.665)	(-1.477)
Trade intensity X Intra-industry trade (VA)				0.195***	0.104**
				(4.058)	(2.197)
Country-pair fixed effects	Yes	Yes	Yes	Yes	Yes
Year-fixed effects	Yes	Yes	Yes	Yes	Yes
Observations	10,951	10,803	10,100	10,803	10,100
R-squared	0.628	0.486	0.529	0.628	0.621

Sources: Authors' estimates

Note: Robust t-statistics in parentheses. Standard errors are clustered at country-pair level. *** p<0.01, ** p<0.05, * p<0.1

[8] Specifically, using the Leontief inverse $(I - A)^{-1}$ where A is the world input-output matrix of intermediate inputs needed to produce one unit of output in a given industry in a given country and I is the identity matrix, value added content in exports of country i, which is the country of interest, can be written as $\sum_j (I - A)^{-1} f_{j \neq i}$. $f_{j \neq i}$ is a vector of final goods absorbed outside country i.

VI. EXTENSION: THE IMPACT OF TRADE INTEGRATION ON SYNCHRONIZATION DURING THE GLOBAL FINANCIAL CRISIS

As a simple extension, we also implement a suggestive test for whether trade integration has a higher impact on BCS during crisis times than during tranquil times. The approach is similar to that of Kalemli-Ozcan, Papaioannou and Perri (2013) for banking integration. Kalemli-Ozcan, Papaioannou and Peydro (2013) identify a negative effect of banking integration on BCS in general, consistent with the workhorse international real business cycle model of Backus, Kehoe and Kydland (1992), but Kalemli-Ozcan, Papaioannou and Perri (2013) find this effect to be weakened during the global financial crisis (GFC). They interpret this as evidence that the specific nature of the shock—a shock to financial intermediation, with global banks pulling out funds across the board—contributed to spread the crisis internationally, thereby increasing output synchronization.

Concretely, we re-estimate the baseline IV regressions of Table 3 and 4 including now interactions between trade and banking integration variables, on the one hand, and all time dummies on the other.[9] Results are presented in Table 6, showing here only the interaction term for the GFC (2009 dummy). For comparison purposes, we show both the baseline IV regressions featured in Tables 3 and 4 (Table 6, columns 1 and 3) and the same specifications incorporating interactions (Table 6, columns 2 and 4). The estimates suggest that the impact of trade integration was more positive during the GFC than during normal times—and so was the effect of financial integration, which is found to shift from negative to positive. While endogeneity might *a priori* be a concern given that the GFC and major crises led to a contraction in trade, this issue is mitigated here by lagging trade intensity by one year and instrumenting it. Looking into the possible theoretical explanation(s) for this larger effect of trade during the GFC goes beyond the scope of this paper. However, the suggestive evidence provided here is at least consistent with the view that the crisis was a disruption that disorganized production along vertical supply chains, causing large synchronized declines in output (see e.g. the discussion in Levchenko, Lewis and Tesar, 2010, who in a sample of imports and exports disaggregated at the 6-digit NAICS level find that sectors used as intermediate inputs experienced significantly higher percentage reductions in both imports and exports during the GFC).

[9] A more parsimonious model was also estimated featuring only the interaction between trade intensity and the global financial crisis (year 2009) dummy. Results, in particular for interaction terms, were largely similar to those obtained when the full set of time dummies is included.

Table 6. Business Cycle Synchronization and Trade: IV

	IV=tariff	IV=tariff	IV=PTA	IV=PTA
Dependent Variable: Quasi-correlation of output growth rates	(1)	(2)	(3)	(4)
Trade intensity (VA)	0.173***	0.180***	0.226***	0.231***
	(5.717)	(5.602)	(8.559)	(8.253)
Banking integration	-0.074***	-0.037***	-0.060***	-0.026*
	(-6.150)	(-2.671)	(-5.033)	(-1.922)
Trade Intensity * GFC Dummy		0.911***		0.980***
		(11.800)		(12.806)
Banking Integration * GFC Dummy		0.370***		0.379***
		(6.429)		(6.540)
Country-pair fixed effects	Yes	Yes	Yes	Yes
Year-fixed effects	Yes	Yes	Yes	Yes
Observations	12,382	11,397	11,397	11,397
R-squared	0.628	0.629	0.635	0.622

Sources: Authors' estimates

Note: Robust t-statistics in parentheses. Standard errors are clustered at country-pair level. *** p<0.01, ** p<0.05, * p<0.1

VII. CONCLUSION

The impact of trade intensity on output synchronization has been subject to extensive theoretical and empirical research, with mixed results. However, existing literature has not recognized the implications of fragmented international supply chains for the measurement of trade linkages between countries, and thereby for their impact on synchronization. Our empirical evidence shows that once it is measured in value added terms, bilateral trade intensity has a sizeable positive, statistically significant, and robust impact on synchronization, as in Frankel and Rose's seminal papers. There is also some evidence that the nature of trade matters; the degree of intra-industry trade appears to amplify the impact of trade integration on synchronization. Our main finding might *a priori* be seen as implying that the trade-comovement puzzle is alive and well. However, establishing this point formally would require calibrating an IRBC model to value-added data and making a comparison between the implied response of comovement to bilateral (value-added) trade intensity and our estimated baseline coefficient. Such a comparison would require calibrating a global supply chain model similar to Johnson (2014b), in which value-added trade and gross trade are distinct. We leave this for future research.

Finally, our results, together with other findings in recent literature, suggest that understanding the increasingly fragmented world supply chains may have far reaching implications for a broad range of economic issues, including not just business cycles but also, for instance, real exchange rate measurement, the impact of exchange rate on trade flows, or exchange rate pass through.

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DATA APPENDIX: CONSTRUCTION OF THE ANNUAL VALUE ADDED EXPORT SERIES

This Appendix describes in detail our methodology for constructing the annual bilateral value-added exports, based on the 2013 release of the OECD-WTO Trade in Value Added (TiVA) database. One advantage of using the TiVA time series for benchmark years over using the World Input Output Database (WIOD) is that TiVA treats processing trade more accurately, particularly for emerging economies such as China (Jones et al., 2014). Another advantage is that TiVA has wider country coverage than WIOD and enables us to include more emerging market economies in the analysis.

Based on OECD's inter-country input-output tables, TiVA publishes data on bilateral value added in exports at ISIC 2-digit industry level for selected years: 1995, 2000, 2005, 2008, and 2009. To generate annual value-added exports data, we interpolate the available TiVA data before 2009 and extrapolate the data for 2010-2013.

Specifically, based on concordances provided by United Nations (UN) Comtrade, we first match sectoral trade statistics (at 5-digit SITC level) with the end-use (intermediate vs. final) industry classifications (according to the Broad Economic Classification). We then adjust the original sectoral export series so that they are consistent with the national accounts statistics. The concordance of SITC to ISIC is used to map detailed trade data with national accounts data. Specifically, for each observation at the exporter-importer-sector level, we extract the intermediate input imports from the original gross export data to create a new bilateral export proxy at the sector level. The annual growth rates of the proxy series for value-added exports are then used to interpolate and extrapolate the TiVA data to generate continuous annual data as explained below.[10]

Bilateral trade statistics based on SITC (revision 2), BEC, and International Standard Industrial Classification (ISIC, revision 3) are obtained from the UN Comtrade database accessed through the World Bank's World Integrated Trade Solution platform. National Income Accounts (NIAs) data are from the IMF's World Economic Outlook (WEO) database and converted to U.S. dollars using the period average exchange rates from the WEO.

[10] Note that this approach of separating intermediate input trade from final goods trade is similar to Johnson and Noguera (2012a; 2012b) and Timmer et al. (2012), although these papers also construct annual cross-country input-output table for a more limited set of countries. The latest version of WIOD—constructed based on national supply-and-use tables for benchmark years—contains annual cross-country input-output tables from 1995-2011, but out of the 40 economies it covers, only a few are emerging economies (e.g. China and India are the only Asian emerging economies covered in WIOD). In practice, as shown at the end of this appendix, the correlation between trade intensity variables constructed using TiVA data and the WIOD data for 1995, 2000, 2005, 2008, and 2009 is quite high, and is higher for advanced economy country pairs compared to the available emerging economy country pairs.

Our step-by-step approach is the following:

Step 1: Using trade statistics, we first construct bilateral trade shares for each country in our sample with its partner countries. Specifically, country i's exports share to country j (x_{ijt}) and imports share from country j (m_{ijt}) in time t correspond to:

$$x_{ijt} = X_{ijt} / \sum_j X_{ijt} \quad (1)$$

$$m_{ijt} = M_{ijt} / \sum_j M_{ijt} \quad (2)$$

where X_{ijt} is the value of gross exports from country i to country j, and M_{ijt} is the value of gross imports of country i to country j in time t .

We then multiply these shares with exports and imports data from the NIAs (denoted by X_{it}^{NA} and M_{it}^{NA}), in order to obtain bilateral exports and imports that are also consistent with the national accounts (denoted by X_{ijt}^{NA} and M_{ijt}^{NA}, respectively):

$$X_{ijt}^{NA} = x_{ijt} X_{it}^{NA}, \quad (3)$$

$$M_{ijt}^{NA} = x_{ijt} M_{it}^{NA}, \quad (4)$$

Step 2: Using the UN correspondence tables for ISIC, SITC, and BEC classifications[11], we construct sectoral trade statistics according to the end-use categories (i.e. intermediate vs. final use). Let IX_{ij} stand for the value of intermediate exports from i to j, IM_{ij} the value of intermediate imports, and FX_{ij} the value of final goods exports. We first adjust bilateral trade data to be consistent with the NIAs, assuming that intermediate exports (imports) account for the same proportion of trade in the NIAs as in the trade statistics:

$$IX_{ijt}^{NA} = \frac{IX_{ijt}}{X_{ijt}} X_{ijt}^{NA} \quad (5)$$

$$IM_{ijt}^{NA} = \frac{IM_{ijt}}{M_{ijt}} M_{ijt}^{NA} \quad (6)$$

$$FX_{ijt}^{NA} = \frac{FX_{ijt}}{X_{ijt}} X_{ijt}^{NA} \quad (7)$$

Next we construct the series of exports of intermediate inputs and exports of final goods at the exporter-importer-sector level that are in line with national accounts as follows:

$$IX_{ijkt}^{NA} = \frac{IX_{ijkt}}{IX_{ijt}} IX_{ijt}^{NA} \quad (8)$$

$$IM_{ijkt}^{NA} = \frac{IM_{ijkt}}{IM_{ijt}} IM_{ijt}^{NA} \quad (9)$$

$$FX_{ijkt}^{NA} = \frac{FX_{ijt}}{X_{ijt}} FX_{ijt}^{NA} \quad (10)$$

where the subscript k represents the sector. Given these trade series, adjusted exports from country i to j in sector k can be calculated according to:

[11] We rely on multiple correspondence tables, as direct concordance from BEC to ISIC is not available. The concordance is available at http://unstats.un.org/unsd/cr/registry/regot.asp?Lg=1. For services sectors, in the absence of bilateral services trade data, in line with previous literature we impute bilateral services data by using bilateral trade shares for goods that aggregates to match the multilateral trade in services in NIAs.

$$X^{NA}_{ijkt} = IX^{NA}_{ijkt} + FX^{NA}_{ijkt} - IM^{NA}_{ijkt} \qquad (11)$$

Step 3: Next, we use the annual growth rates of exports obtained in (11) to interpolate the missing years in the TiVA data. In order to minimize the differences in fluctuations between the adjusted series (11) and the interpolated TiVA data, we first calculate the average annual growth rate ($\bar{g}^{X}_{ijkt}$) of the adjusted series in (11), for the periods 1995-2000, 2000-2005, 2005-2008:

$$\bar{g}^{X}_{ijkt} = \left(\frac{X^{NA}_{ijkt}}{X^{NA}_{ijkt-n}}\right)^{\frac{1}{n}} - 1, \quad t = 2000, 2005,\ 2008. \qquad (12)$$

We then subtract from the actual growth rate of the adjusted series in year t the annual average growth rate for the corresponding period (e.g. we compute the difference between the growth rate in 1996 and the average annual growth rate over 1995-2000):

$$\Delta g^{X}_{ijkt} = \left(\frac{X^{NA}_{ijkt}}{X^{NA}_{ijkt-1}} - 1\right) - \bar{g}^{X}_{ijkt}. \qquad (13)$$

Similarly, we calculate the average annual growth for the same periods (1995-2000, 2000-2005, 2005-2008) using the original TiVA data.

$$\bar{g}^{VA}_{ijkt} = \left(\frac{VA_{ijkt}}{VA_{ijkt-n}}\right)^{\frac{1}{n}} - 1, \qquad (14)$$

where VA_{ijk} is the value added embodied in exports in sector k from i to j as published in the TiVA (2013) database.

Finally, we construct the proxy of annual value-added exports growth by adding up the average growth rate of the TiVA series in (14) and the growth deviation in (13):

$$g^{VAproxy}_{ijkt} = \bar{g}^{VA}_{ijkt} + \Delta g^{X}_{ijkt} \qquad (15)$$

Step 4: Using the growth rates in (15), we interpolate TiVA's domestic value-added export series at the bilateral industry level before 2009, and extrapolate the series over the period 2010-2013. We thereby obtain annual industry-level (interpolated) TiVA series that are then aggregated at the bilateral country level to generate the value-added export proxies, VA^{proxy}_{ijt}.

As a robustness check, we also constructed domestic value-added exports using WIOD input-output tables during 1995-2011, following the methodology described in Johnson and Noguera (2012a). The year-by-year correlations between our trade intensity variable in value-added terms and its counterpart estimated using WIOD data range from 0.935 to 0.974 for the full sample. For the sample of advanced economies, the correlations range from 0.95 to 0.98, while for emerging-economy pairs, the correlations are slightly smaller, ranging from 0.88 to 0.97. The within correlations are also high (see Table A.1 below).

Table A.1: Correlations between Trade Intensity (VA) Based on TiVA vs. Trade Intensity (VA) using WIOD data

	Full sample	Advanced Economy country-pairs	Emerging Economy country-pairs
	Within Correlations		
1995-2011	0.82	0.90	0.77
	Pairwise Pearson Correlations		
1995-2011	0.95	0.95	0.92
1995	**0.96**	**0.97**	**0.88**
1996	0.96	0.97	0.89
1997	0.96	0.97	0.90
1998	0.95	0.97	0.89
1999	0.94	0.97	0.88
2000	**0.96**	**0.97**	**0.91**
2001	0.96	0.97	0.97
2002	0.97	0.96	0.97
2003	0.96	0.95	0.96
2004	0.94	0.98	0.96
2005	**0.97**	**0.98**	**0.97**
2006	0.97	0.97	0.95
2007	0.97	0.97	0.94
2008	**0.97**	**0.97**	**0.90**
2009	**0.97**	**0.97**	**0.88**
2010	0.96	0.96	0.91
2011	0.95	0.96	0.90

Note: For highlighted years (i.e. 1995, 2000, 2005, 2008, and 2009), correlations are between trade intensity based on original TiVA data and trade intensity based on WIOD data.