Intermediate Inputs Trade and The Effect of Synchronized TFP on the Trade Co-movement Puzzle

Makoto Tanaka

Very Preliminary and Incomplete

Abstract

Intermediate inputs trade is considered as a conduit for shocks; shocks are reflected on prices of intermediate inputs, which in turn affects productivities of countries who import them, resulting in bilateral synchronized TFP. In the context of the trade co-movement puzzle, this mechanism is often treated as the presumptive key to generate substantial GDP co-movement in response to the increase of bilateral trade. But is it? Under the perfect competition, and with constant returns to scale gross production function, I non parametrically decompose the GDP co-movement to show that the intermediate inputs trade have no explicit first order effects on GDP co-movement. Furthermore based on the decomposition, I show the notion that intermediate inputs trade synchronizes TFP to generate substantial amount of GDP co-movement might not be valid under the assumption.

1 Introduction

Piling empirical evidence shows that countries with stronger trade linkages have more output correlation.[1] Most of the time, this is considered as the sign of the transmission of technology shocks through international trade. Yet standard international business cycle models (IRBC models hereafter) à la Buckus, Kehoe, and Kydland (1992) struggle to replicate this relationship, resulting in the trade co-movement puzzle.

Of many suggested solutions, introducing intermediate inputs trade into the model is considered as the presumptive key to solve the trade co-movement puzzle.[2] The underlying mechanism is that more two countries trade intermediate goods with each other, the more likely countries are to be affected by foreign technology shocks even though their domestic technology does not change, resulting in more synchronized aggregate productivity, which in turn generates higher GDP co-movement.

The idea that international trade synchronizes TFP to create higher GDP co-movement first appears in Kose and Yi (2006), which documents the puzzle originally. Liao and Santacreu (2015) uncovered that the model exhibits endogenous aggregate productivity correlation with monopolistic competition and extensive

[1] See Frankel and Rose (1998),... among many others.

[2] For example de Soyres and Gaillard (2019) specifically focus on the role of intermediate inputs trade.

margin fluctuations in trade; a productivity shock in one country is embedded in newly traded intermediate goods to propagate to another country. They build the model with this mechanism to significantly improve the trade co-movement slope using the Solow residual as a proxy for an aggregate productivity.

Though the mechanism seems plausible, empirically we do not know how much influential the correlation of productivities is on the trade co-movement slope. In this paper, firstly I build the nonparametric decomposition of the GDP co-movement with perfect competition and constant returns to scale production function to show that the intermediate inputs trade has no first order effects on the GDP co-movement. In addition I show that as long as we use the Solow residual as a proxy for an aggregate productivity, the decomposition is valid regardless of the form of competition. Then based on the decomposition I investigate whether the fraction of TFP synchronization on GDP co-movement is increasing with intermediate inputs trade.

If the intermediate goods trade truly synchronizes aggregate productivities to create higher GDP co-movement, we expect the fraction of aggregate productivities' correlation to be increasing with the intermediate inputs trade. However, we find that the increase is surprisingly small compared to the increase of the fraction of factor supply correlation in the data. This fact suggests the notion that technology transfer through intermediate inputs trade is a missing link in the model to resolve the trade co-movement puzzle is not valid under the standard assumptions.

2 Trade Irrelevance and Nonparametric Decomposition of GDP Co-movement

In this section, I non-parametrically decompose the bilateral GDP covariance with standard assumptions in the literature with intermediate inputs trade and explore the role of the trade to synchronize the output correlation.[3]

Consider real GDP function in country i at period t described as

$$Y_{it} = f^i(K_{it}, L_{it}, X_{it}; \mathbf{Z}_t) - P_i X_{it},$$

where K is capital, L is labor, X is a composite intermediate good, which combines intermeidiates coming from all over the world, and $\mathbf{Z}_t$ is a collection of productivity level in potentially all countries. Based on Kehoe and Ruhl (2008), under the efficient economy intermediate inputs do not have first-order impact on real GDP change due to the envelope theorem:

$$\left.\frac{dY_{it}}{dX_{it}}\right|_{t=\text{steady state}} = \left.\frac{\partial f^i(K_{it}, L_{it}, X_{it}; \mathbf{Z}_t)}{\partial X_{it}}\right|_{t=\text{steady state}} - P_i = P_i - P_i = 0.$$

The subscript here represents time period, and any variables without time dimension represent steady state values, which I set to be base year. This result ensures that Hulten's Theorem (1978) hold even in open economy with intermediate inputs trade.

[3]Similar decomposition can be found in Huo, Levchenko, and Pandalai-Nayar (2019), and Baqaee and Farhi (2019).

Theorem. *When the economy is perfectly competitive and the aggregate production function is constant returns to scale, real GDP change can be approximated by*

$$\Delta \log(Y_{it}) = \frac{w_i L_i}{GDP_i}\Delta \log(L_{it}) + \frac{r_i K_i}{GDP_i}\Delta \log(K_{it}) + \frac{f_z^i}{GDP_i}\Delta \log(\mathbf{Z}_t),$$

regardless of whether the country uses foreign intermediate inputs. Then the domestic technology change can be approximated by the variant of the Solow residual:

$$\Delta \log(Z_{it}) \equiv \frac{f_z^i}{GDP_i}\Delta \log(\mathbf{Z}_t) = \Delta \log(Y_{it}) - \frac{w_i L_i}{GDP_i}\Delta \log(L_{it}) - \frac{r_i K_i}{GDP_i}\Delta \log(K_{it}).$$

Since growth rate is defined as the deviation from the steady state, $\Delta \log(Y_{it}) \equiv \log(\frac{Y_{it}}{Y_i})$, the following relation holds for every variable.

$$\log\left(\frac{Y_{it}}{Y_{it-1}}\right) = \log\left(\frac{Y_{it}}{Y_i}\frac{Y_i}{Y_{it-1}}\right) = \Delta \log(Y_{it}) - \Delta \log(Y_{it-1}).$$

Two things stand out in the theorem. One is that there is no explicit effect of intermediate inputs trade on the growth of real GDP up to fist-order,which makes it difficult to understand the role of trade to synchronize the GDP. The other is that $\Delta \log(Z_{it})$ is the approximation of the collection of productivity shocks in all countries, the structure of the correlation depends on intermediate inputs trade.

The decomposition shows that when the economy is perfectly competitive and the gross production function is constant returns to scale, the aggregate productivity of the country always can backed out by the variant of the Solow residual even with the interdependencies between countries.

On the other hand, we can also show that as long as we use the Solow residual as a proxy for the aggregate productivity, which is the convention in the international business cycle literature, the decomposition holds regardless of the form of competition.[4]

Proposition. *As long as we use the Solow residual as a proxy for an aggregate productivity, the decomposition is valid regardless of the form of competition.*

Proof. The change of the Solow residual is

$$\Delta \log(A_{it}) = \Delta \log(Y_{it}) - \alpha_i \Delta \log(L_{it}) + (1 - \alpha_i)\Delta \log(K_{it}),$$

which immediately implies that the decomposition holds with

$$\begin{aligned} \frac{w_i L_i}{GDP_i} &= \alpha_i \\ \frac{r_i K_i}{GDP_i} &= 1 - \alpha_i. \end{aligned}$$

Then $\Delta \log(Z_{it}) = \Delta \log(A_{it})$.

Hereafter I use the Solow residual for the aggregate productivity.[5]

[4]See Huo, Levchenko, and Pandalai-Nayar (2020) for the discussion of another issue to use the Solow residual in the international business cycle.

[5]Note that $\Delta \log(A_{it})$ can be correlated for another reason as pointed out by de Soyres and Gaillard (2019); it might contains changes in aggregate profits and extensive margin of international

With foreign country j having the same structure of real GDP function, growth rate of two countries can be written in a matrix form:

$$\begin{pmatrix} \Delta\log(y_{it}) \\ \Delta\log(y_{jt}) \end{pmatrix} = \begin{pmatrix} \alpha_i & 1-\alpha_i & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & \alpha_j & 1-\alpha_j & 1 \end{pmatrix} \begin{pmatrix} \Delta\log(l_{it}) \\ \Delta\log(k_{it}) \\ \Delta\log(a_{it}) \\ \Delta\log(l_{jt}) \\ \Delta\log(k_{jt}) \\ \Delta\log(a_{jt}) \end{pmatrix},$$

where $\Delta\log(y_{it}) \equiv \Delta\log(Y_{it}) - \Delta\log(Y_{it-1})$ and other variables are redefined analogously.

Assuming $\Delta\log(A_{it})$ is stationary, variance-covariance matrix can be calculated as follows.

$$E\left(\begin{pmatrix} \Delta\log(y_{it}) \\ \Delta\log(y_{jt}) \end{pmatrix}\begin{pmatrix} \Delta\log(y_{it}) \\ \Delta\log(y_{jt}) \end{pmatrix}^T\right) = \begin{pmatrix} Var(\Delta\log(y_{it})) & Cov(\Delta\log(y_{it}), \Delta\log(y_{jt})) \\ Cov(\Delta\log(y_{it}), \Delta\log(y_{jt})) & Var(\Delta\log(y_{jt})) \end{pmatrix},$$

where $Cov(\Delta\log(y_{it}), \Delta\log(y_{jt})) = \alpha_i\alpha_j\sigma_{ij}^{l} + (1-\alpha_i)(1-\alpha_j)\sigma_{ij}^{k} + \alpha_i(1-\alpha_j)\sigma_{ij}^{lk} + (1-\alpha_i)\alpha_j\sigma_{ji}^{lk} + \alpha_i\sigma_{ij}^{la} + \alpha_j\sigma_{ji}^{la} + (1-\alpha_i)\sigma_{ij}^{ka} + (1-\alpha_j)\sigma_{ji}^{ka} + \sigma_{ij}^{a}$. Here σ_{ij}^{la} represents covariance between labor supply changes in country i and productivity shocks in country j in this order.

With a further assumption: capital is predetermined, the decomposition can

trade coming from imperfect competition, which are likely to be affected by technology shocks from other countries.

be simplified

$$Cov(\Delta\log(y_{it}), \Delta\log(y_{it})) = \underbrace{\alpha_i\alpha_j\sigma^l_{ij}}_{\text{Terms of Trade}} + \underbrace{(1-\alpha_i)(1-\alpha_j)\sigma^k_{ij}}_{\text{Resource Shifting}} + \underbrace{+\alpha_i\sigma^{la}_{ij} + \alpha_j\sigma^{la}_{ji}}_{\text{Propagation}} + \underbrace{\sigma^a_{ij}}_{\text{TFP Correlation}} \quad (1)$$

Following the literature, the expression can be divided into four effects: terms of trade effects, resource shifting effects, downstream propagation, and correlated shocks. It is well documented that terms of trade fluctuations induced by productivity shocks are likely to generate positive correlation in labor supply.[6] On the other hand, resource shifting effects are expected to be negative because a country receiving positive shocks increases marginal product of capital to draw investment from other countries. The direct transmission channel explains how labor supply reacts to foreign shocks, and the last term captures the correlation of shocks.

For standard IRBC models, $\{\sigma^l_{ij}, \sigma^k_{ij}, \sigma^{la}_{ij}, \sigma^{la}_{ji}\}$ are endogenous variables and σ^a_{ij} is an exogenous variable, which implies that the international trade has four channel to affect GDP co-movement. Based on the observation, we can describe the trade co-movement puzzle as the symptom that standard IRBC models fail to generate substantial GDP co-movement through the four channels in response to the increase of bilateral trade, which leads to the attempt to endogenize σ^a_{ij}.

[6]Since the labor supply is the function of the real wage in the standard model, positive/negative technology shocks affect other countries can increase/decrease domestic labor supply through the terms of trade.

3 Synchronized TFP and the Trade Co-movement Puzzle

I use Penn World Table version 9.1 and World Input Output Database of 2013 release, which covers 40 countries for every year from 1995 to 2011 to study how each component in Eq.(1) changes as intermediate inputs trade increases. If endogenous TFP correlation is the missing mechanism in standard IRBC models, we expect the fraction of TFP increases more with intermediate inputs trade than the fraction of factors, which barely changes in response to the increase of trade in the canonical model.

Define trade intensity in intermediates as

$$\text{Trade Intensity}_{ij}^{m} \equiv \frac{1}{T}\sum_{t=1}^{T} \log\left(\frac{EX_{ijt}^{m} + EX_{jit}^{m}}{GDP_{it} + GDP_{jt}}\right),$$

where EX_{ijt}^{m} and EX_{jit}^{m} represent the trade of intermediate goods between the countries.

Based on Eq.(1), the GDP correlation is decomposed into three components: Factors Co-movement, Propagation, and TFP Correlation.

$$\text{Cor}(\Delta\log(y_{it}), \Delta\log(y_{jt})) = \underbrace{\frac{\text{Factors}}{(\text{Var}(y_{it})\text{Var}(y_{jt}))^{1/2}} + \frac{\text{Propagation}}{(\text{Var}(y_{it})\text{Var}(y_{jt}))^{1/2}}}_{\text{Non TFP}} + \frac{\text{TFP Correlation}}{(\text{Var}(y_{it})\text{Var}(y_{jt}))^{1/2}}.$$

We regress the following equation to see how each component reacts to the increase of trade in intermediates and if TFP correlation becomes more important to generate GDP co-movement as the trade increases.[7]

$$\frac{\text{Factors}}{(\text{Var}(y_{it})\text{Var}(y_{jt}))^{1/2}} = \text{Constant} + \beta_1 \times \text{Trade Intensity}_{ij}^m + e_{ij} \quad (2)$$

$$\frac{\text{TFP Correlation}}{(\text{Var}(y_{it})\text{Var}(y_{jt}))^{1/2}} = \text{Constant} + \beta_2 \times \text{Trade Intensity}_{ij}^m + e_{ij} \quad (3)$$

$$\frac{\text{Non TFP}}{(\text{Var}(y_{it})\text{Var}(y_{jt}))^{1/2}} = \text{Constant} + \beta_3 \times \text{Trade Intensity}_{ij}^m + e_{ij}. \quad (4)$$

Table 1: Decomposed GDP Co-movement and Intermediate Inputs Trade

	Dependent variable:		
	Factor Co-movement	TFP Correlation	Non TFP
	(1)	(2)	(3)
Trade Intensity	0.068***	0.016***	0.073***
	(0.007)	(0.004)	(0.009)
Constant	0.705***	0.210***	0.837***
	(0.052)	(0.030)	(0.070)
Observations	706	706	706
R^2	0.125	0.022	0.082
Adjusted R^2	0.123	0.020	0.081
Residual Std. Error (df = 704)	0.190	0.112	0.255
F Statistic (df = 1; 704)	100.213***	15.527***	62.750***

Note: Standard errors in parentheses. *p<0.1; **p<0.05; ***p<0.01

Table1 summarizes the key result of this paper. Column (1) and column (2) report the fractions of trade co-movement slope that can be explained by the co-movement in factors and TFP respectively. By comparing the two, we find that

[7] I estimate them by 2SLS. For the first stage, I used the same instrumental variables for trade intensity as Kose and Yi (2006): log of distance, adjacency dummy, and common language.

the majority of the variation due to the increase in intermediate inputs trade can be attributed to the variation of factor co-movement. This leads to the conclusion that international business cycle models which improve the estimation of the trade co-movement slope by incorporating endogenous TFP correlation might attribute "too much" to the TFP correlation.

As is discussed in the previous section, the slope reported in column (3) is the slope that the standard model should capture through four endogenous variables. The slope is smaller than what is estimated by regressions in the spirit of Frankel and Rose (1998) but much larger than what is implied by Imbs (2004), suggesting that the transmission of productivity shocks through trade is a strong channel to create business cycle synchronization.

4 Conclusion

In this paper I show that with perfect competition and constant returns to scale gross production function, trade in intermediates has no first order impacts on the changes in real GDP. In addition, as long as we use the Solow Residual as a proxy for the aggregate productivity, regardless of the form of competition, the result holds. Then I non-parametrically decompose the GDP co-movement to study if the notion that intermediate inputs trade synchronize TFP to create substantial GDP co-movement survives in the data.

Using Penn World Table version 9.1 and World Input Output Database of 2013 release, I show that the fraction of the trade co-movement slope that can be attributed to the TFP co-movement is surprisingly small compared to what is implied by papers which try to solve the trade co-movement puzzle by incorporating endogenous TFP correlation mechanism. The result implies that lacking the mechanism of endogenous TFP correlation is not the main reason for standard international business cycle models to fail to replicate the trade co-movement slope.

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Appendix

A Trade and Co-movement Slope: GDP and TFP

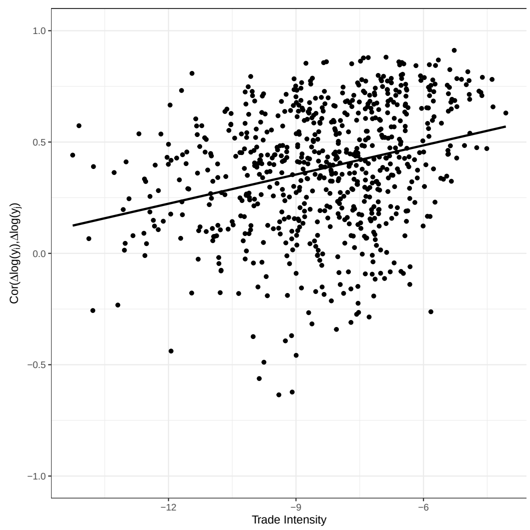

Figure 1: Intermeidates Trade and GDP Co-movement

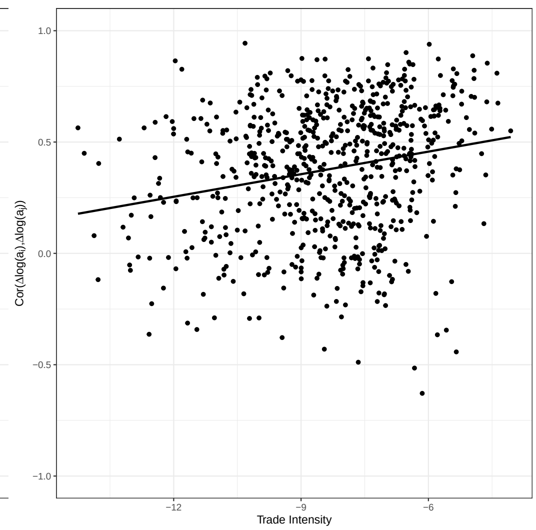

Figure 2: Intermediates Trade and TFP Co-movement

In figures each point corresponds to a country pair. Figure 1 illustrates the relation between the trade intensity and the GDP co-movement, which is often time interpreted as the sign of transmission of aggregate productivity shocks to generate business cycle co-movement. Figure 2 plots the TFP co-movement against the trade intensity and displays the similar pattern as Figure 1. As discussed in Kose and Yi (2006), the fact that the TFP co-movement also increases with trade intensity is considered as one of evidences of endogenous TFP correlation.

B Decomposed Trade and Co-movement Slope: Factor and TFP

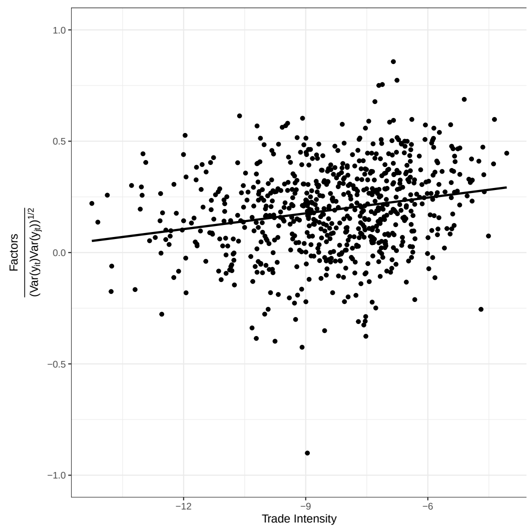

Figure 3: Adjusted Factor Contribution

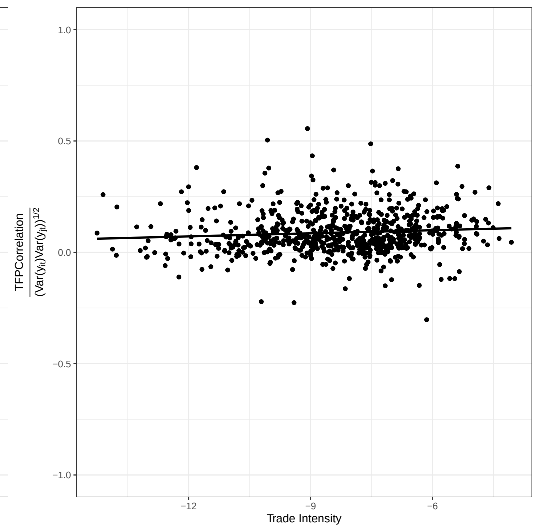

Figure 4: Adjusted TFP Contribution

Figures are depicted based on the decomposition in section 3. As you can see in Figure 4, once we adjusted TFP correlation by $(\text{Var}(y_{it})\text{Var}(y_{jt}))^{1/2}$ instead of $(\text{Var}(a_{it})\text{Var}(a_{jt}))^{1/2}$, the slope becomes flatter than the slope in Figure 2.

C Covariance Decomposition

Inspired by Foerster, Sarte, and Watson (2011), I calculate the relative importance of TFP co-movement to generate GDP co-movement based on Eq. (1):

$$R^2_{ij}(TFP) \equiv \frac{\sigma^a_{ij}}{Cov(\Delta\log(y_{it}), \Delta\log(y_{jt}))}.$$

Figure 5 shows that the fraction of the TFP co-movement in the GDP co-movement is relatively small, 5.5% to 32.4% for half of country pairs, compared to what de Soyres and Gaillard (2019) implies.[8] This fact suggests that the correlation of TFP might not as important as it seems to be in the context of the GDP co-movement regardless of whether they are correlated endogenously or exogenously.

By calculating $\mathrm{Cov}(\Delta \log(y_{it}) - \Delta \log(a_{it}), \Delta \log(y_{jt}) - \Delta \log(a_{it}))$, we can also identify the fraction of the factor co-movement in the GDP co-movement as a counterpart to the fraction of synchronized TFP. The analogous statistics is defined as

$$R_{ij}^2(Factor) \equiv \frac{\mathrm{Cov}(\Delta \log(y_{it}) - \Delta \log(a_{it}), \Delta \log(y_{jt}) - \Delta \log(a_{it}))}{\mathrm{Cov}(\Delta \log(y_{it}), \Delta \log(y_{jt}))},$$

and the corresponding figure is depicted below.

Figure 6 shows that for majority of countries, factor co-movement accounts for well over 50% of GDP co-movement.

[8] Instead of using the Solow residual as a proxy for the aggregate productivity, they back out aggregate productivities by calculating productivities that rationalize the structural model.

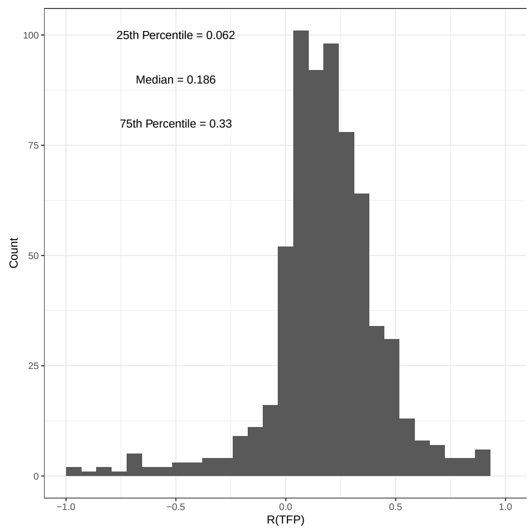

Figure 5: The TFP Co-movement in the GDP Co-movement

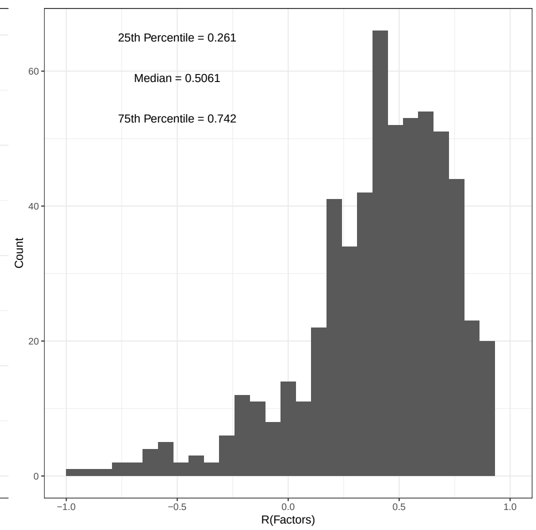

Figure 6: The Factor Co-movement in the GDP Co-movement

D The Frankel and Rose Regression

I estimate the slope of the figure by 2SLS in the spirit of Frankel and Rose (1998):

$$\frac{\text{Cov}(\Delta\log(y_{it}), \Delta\log(y_{jt}))}{(\text{Var}(y_{it})\text{Var}(y_{jt}))^{1/2}} = \text{Constant} + \beta \times \text{Trade Intensity}_{ij} + e_{ij},$$

where $\text{Trade Intensity}_{ij} = \frac{1}{T}\sum_{t=1}^{T} \text{Trade Intensity}_{ijt}$. For the first stage, I used the same instrumental variables for trade intensity as Kose and Yi (2006): log of distance, adjacency dummy, and common language.

Table 2 reports the baseline result. The regression point estimate shows that a point increase in trade intensity increases an output correlation by 0.09, which is consistent with previous estimates although I use trade in intermediates instead of overall trade.

Table 2: Intermediate Goods Trade and GDP Co-movement

	Dependent variable:
	GDP Co-movement
Trade_Intensity	0.088***
	(0.010)
Constant	1.047***
	(0.073)
Observations	706
R^2	0.106
Adjusted R^2	0.105
Residual Std. Error	0.269 (df = 704)
F Statistic	83.638*** (df = 1; 704)
Note:Standard errors in parentheses	*p<0.1; **p<0.05; ***p<0.01