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SATO, Kiyotaka
Yokohama National University

ZHANG, Shajuan
Chuo University

The Research Institute of Economy, Trade and Industry
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Do Exchange Rates Matter in Global Value Chains?*

Kiyotaka Sato† and Shajuan Zhang‡

Abstract

We empirically investigate whether global value chains (GVCs) can affect export responsiveness to real exchange rate volatility by constructing two measures of GVC participation at bilateral and sectoral levels from OECD Inter-Country Input-Output (ICIO) Tables. The 2016 edition covers 63 countries and 16 manufacturing sectors between 1995 and 2011. A panel estimation shows that the negative effect of exchange rate volatility on exports is significantly mitigated by GVC participation, which is supported by various robustness checks. Moreover, if regional value chains were better-developed and deepened, exchange rate fluctuations among regional countries would have less negative influence on regional trade.

Keywords: Global Value Chains (GVCs), Inter-Country Input-Output Table, GVC participation, exports, exchange rate volatility
JEL classification: F31, F33, F14

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† Corresponding Author: Department of Economics, Yokohama National University, and School of Business and Law, Edith Cowan University. Email: sato@ynu.ac.jp
‡ Faculty of Economics, Chuo University. Email: sj-zhang@tamacc.chuo-u.ac.jp

1. Introduction

A traditional criticism of flexible exchange rate regimes concerns the negative effect of exchange rate volatility on international trade, even though this negative impact is theoretically and empirically ambiguous (Auboin and Ruta, 2012). Byrne *et al*. (2008) emphasized that ambiguous results may be caused by aggregation bias. By using disaggregated data, recent studies have found a more robust negative relationship between exchange rate volatility and trade flows (Thorbecke, 2008; Hayakawa and Kimura, 2009; Tang, 2014; and Sato, *et al*., 2016). The effect of exchange rate volatility on trade is also affected by various factors, such as accessibility to hedging instruments and production structures (Auboin and Ruta, 2012). However, whether exchange rate changes or volatility matters in global value chains (GVCs) remains an open question that has not yet been fully investigated in existing studies about the relationship between exchange rates and trade.

Given increasing importance of GVCs (Hummels, *et al*., 2001; Feenstra and Jensen, 2009), using annual *bilateral* and *sectoral* data from OECD Inter-Country Input-Output (ICIO) Tables (2016 edition), this paper empirically investigates how and to what extent GVCs affect exports' responsiveness to real exchange rate volatility. We employ a panel framework, covering 63×62 country pairs and 16 manufacturing sectors, from 1995 to 2011, based on these ICIO Tables.[1] We focus on manufacturing exports, because cross-border production sharing is more important in this sector. We use real exchange rates' volatility and levels as exchange rate variables in our empirical analysis. To solve a possible endogeneity problem of exchange rate volatility for exports, we employ an IV estimator.

How do GVCs affect real exchange rate volatility's influence on trade? GVCs could lower the responsiveness of exports to real exchange rate volatility through two channels. First, when participating in GVCs, exporters could improve their exchange risk management by offsetting export revenues and import payments. Participation in GVCs could take place through forward or backward linkages. In the former, a

[1] In this study, we used the 2016 edition of the ICIO Tables, which included information from no later than 2011. 2015 information is used in the April, 2019 edition.

country's domestic value added, embodied in intermediate goods, is re-exported to a third country, while in the latter, a country uses imported, intermediate inputs to produce export goods. Currency appreciation can, on the one hand, weaken export price competitiveness and hence reduce export revenues, but it also lowers the cost of imported inputs, which likely offsets the negative export revenue effect. In addition, because of the relationship-specific nature of intermediate goods transactions, production network partnerships tend to be quite stable. Once production network is established, it is difficult for firms to switch foreign suppliers or to find new buyers when exchange rates change (Obashi, 2010). Thus, a country's participation in GVCs could mitigate the negative impact of real exchange rate volatility on exports.

This paper employs two GVC participation measures to investigate how GVCs affect the relationship between real exchange rate volatility and exports. The first measure, following Koopman, *et al.* (2010), investigates the depth of bilateral production sharing by adding up either forward or backward linkages. To identify different value-added components of bilateral and sectoral gross exports resulting from GVC activities, we rely on Wang, *et al*.'s (2013) method to decompose bilateral, sectoral gross exports in an ICIO table. Figure 1 illustrates the decomposition of bilateral gross exports. A forward linkage is defined as the ratio of domestic value added embodied in intermediate goods re-exported to a third country (IV_{ijt}^{k}, or (2) in Figure 1) to gross exports. A backward linkage is defined as the ratio of foreign content in exports (FC_{ijt}^{k}, or (5) plus (6) in Figure 1) to gross exports.

The second measure, also following Wang, *et al*. (2013), focuses on pure double-counted terms that result from the back and forth trade of intermediate goods. To our knowledge, this measure is used for the first time in this study. The higher the value of these two GVC participation measures, the deeper the bilateral production sharing.

Our paper adds to the recent literature about the role of production sharing in exchange rate movements and trade. Eichengreen and Tong (2015) argued that while appreciation of the Chinese renminbi improved the valuation of firms exporting final goods to China, it had little effect on those exporting intermediate goods for China's processing exports. Ahmed, *et al*. (2017), who empirically examined how the formation of GVCs affected the exchange rate elasticity of exports, found that GVC participation

reduces the real effective exchange rate (REER) elasticity of manufacturing exports by 22 percent, on average. Cheng, *et al*. (2016) found that exports' exchange rate elasticity is smaller when the import content of GVC exports is larger. These studies confirm that exchange rate changes have an offset effect on GVC trade, an important reason why GVCs also may influence the effect on trade of real exchange rate volatility. Different from the existing works, we contribute to the literature by showing that GVCs also affect how real exchange rate volatility impacts exports.

Our novel findings are as follows: first, while real exchange rate volatility has a significantly negative effect on exports, a country's participation in GVCs reduces the magnitude of this effect through either forward or backward linkages. This finding is supported by various robustness exercises. Second, if the degree of a country's participation in GVCs exceeds a threshold level, exchange rate volatility has a positive effect on that country's exports.

These findings have important implications. If regional value chains were well-developed and deepened, exchange rate fluctuations among regional countries would less negatively influence regional trade. In Asia, for instance, regional exchange rate stability has been an important research question, especially when considering regional economic and monetary integration.[2] Our empirical findings suggest that regional exchange rate arrangements would be unnecessary in Asia if GVCs grew significantly through active and growing intra-Asian trade.

The remainder of this paper is organized as follows: Section 2 discusses the research method, defines variables, and describes the data. Section 3 presents our estimated results, and a robustness check is conducted in Section 4. Section 5 concludes the study.

2. Empirical Method

2.1 Model Specification

To investigate how GVCs' participation affects exports' responsiveness to real

[2] See, for instance, Ito, *et al*. (1998), Ogawa and Shimizu (2006), and Ong and Sato (2018) for empirical research about Asian exchange rate arrangements.

exchange rate volatility, we consider a standard regression that is widely used in the literature. To this regression we add a measure of real exchange rate volatility, its interaction with GVC participation, and other controls. More specifically, the following equation is estimated:

$$\ln Exp_{ijt}^{k} = \beta_0 + \beta_1 Vol_{ijt} + \beta_2 Vol_{ijt} \times PGVC_{ijt-1}^{k} + \beta_3 PGVC_{ijt-1}^{k} + \delta' D_{ijt}^{k} + \eta_{ij}^{k} + u_t + \varepsilon_{ijt}^{k} \quad (1)$$

where k, i, j, and t denote sector, exporter, importer, and year, respectively; $\ln Exp_{ijt}^{k}$ is a natural logarithm of real exports, and Vol_{ijt} represents bilateral, real, exchange rate volatility between country i and country j, which is normalized in the regressions to zero mean and unit standard deviation. $PGVC_{ijt-1}^{k}$ is a GVC participation index measuring the bilateral supply chain network intensity between country i and j at sector k. We use a lagged variable to allow for the possibility that *PGVC* may be endogenous to real exports. D_{ijt}^{k} is a set of other common control variables, according to a standard gravity model of international trade, including country i's real GDP (Y_i), country j's real GDP (Y_j), country i's price index (P_i), and country j's price index $(P_{j,})$ proxied by country i and j's real, effective exchange rates, respectively. To capture the relative price effect, we also include a bilateral, real, exchange rate, defined as the nominal exchange rate of country i's currency against country j's currency, multiplied by the relative price of country j to country i. η_{ij}^{k} is a specific, unobservable, exporter-importer, sector-specific effect that captures time invariant, country-specific, sector-specific and country-pair factors. Therefore, we do not include time-invariant gravity variables, such as a distance, an adjacency dummy, and a language dummy into the model's specification. u_t is a time-fixed effect that controls for all common shocks to all country pairs and industries, such as changes in world demand, technological change, and oil price shocks. ε_{ijt}^{k} is an error term.

We expect that the sign of β_1 is negative and that the sign of β_2 is positive. β_2 captures the heterogeneous effect of real exchange rate volatility on trade. That is, because of the offsetting effect of exchange rate changes and the stability of production networks, participation in GVCs could reduce the negative effect of real exchange rate

volatility on exports. Moreover, when β_2 and β_3 have opposite signs, a threshold value exists where the negative impact of real exchange rate volatility on exports can be totally offset by GVC participation:

$$\frac{\partial \ln Exp_{ijt}^{k}}{\partial Vol_{ijt}^{k}} = \beta_2 + \beta_3 PGVC_{ijt}^{k} \geq 0 \Leftrightarrow PGVC_{ijt}^{k} \geq -\frac{\beta_2}{\beta_3} \qquad (2)$$

IV Estimates

Endogeneity needs to be considered when estimating the impact of real exchange rate volatility on exports. There are two potential endogeneity issues. First, a potential simultaneity bias exists when a higher degree of trade integration reduces exchange rate volatility (Obstfeld and Rogoff, 1995; Hau, 2002; Broda and Romalis, 2011; Calderon and Kubota, 2018). This also can result from central banks' attempts to stabilize exchange rates with their main trading partners. Because of simultaneity bias, a negative relationship between exchange rate variability and exports would not necessarily mean that the former causes the latter. Second, exports may be driven by certain omitted or unobservable variables that correlate with exchange rate volatility. This concern cannot be fully addressed by using country-pair-sector and fixed-year effects, because these factors can vary. Thus, an OLS estimator would be both inconsistent and biased. To deal with such possible endogeneity issues, an IV estimation is employed in this study.

In this paper, which relies on one of the theories of exchange rate determination, namely, the uncovered interest parity (UIP) condition (in natural logarithms), we use relative interest rate volatility as an instrumental variable for exchange rate volatility:

$$i_{it} - i_{jt} = E_t \ln S_{ijt+1} - \ln S_{ijt} = \Delta E_t \ln S_{ijt+1}$$

where i_{it} is the nominal interest rate of country *i,* and i_{jt} is the corresponding interest rate of country *j*. S_{ijt} is the nominal exchange rate of country *i*'s currency versus country *j*'s currency, E_t is the expectation operator at time *t*, and Δ is the

first-difference operator. By rearranging the above UIP at time t–1, we obtain the following condition:

$$i_{it-1} - i_{jt-1} = \Delta \ln S_{ijt}$$

which indicates that exchange rate changes are determined by the relative interest rate between country i and j. By analogous reasoning, we assume that real exchange rate volatility is correlated with the volatility in relative interest rates.[3] Monthly interest rate data is taken from the International Monetary Fund's (IMF) *International Financial Statistics* and from each country's *National Bureau of Statistics.*

2.2. Data and Variables

2.2.1 Data

Our sample covers 63 countries and 16 manufacturing sectors between 1995 and 2011. The sample period, sample countries, and sector coverage are determined by the availability of trade data. All trade data assessing the role of GVCs are taken from OECD ICIO Tables (2016 edition). Given the importance of cross-border linkages in the manufacturing sector, we focus on exports in 16 manufacturing sectors. Details regarding sector classifications are shown in Table 1. GDP data is taken from the World Bank's *World Development Indicators*. All other data are obtained from the IMF's *International Financial Statistics*. Month-end data is used for nominal exchange rates.

2.2.2 Key Variables

Exchange Rate Volatility

To measure exchange rate volatility, we use a moving, sample, standard deviation of a one-month variation in the log bilateral monthly real exchange rate,

[3] Short-run changes in *real* exchange rates may be governed by corresponding changes in *nominal* exchange rates. In practice, nominal and real exchange rates move very closely. Thus, based on UIP conditions, we chose the volatility in relative *nominal* interest rates between two countries as an instrumental variable for *real* exchange rate volatility.

which is widely used in the literature[4]:

$$Vol_{ijt} = sd(\Delta q_{ijt-T+1}) = \sqrt{\frac{1}{12T}\sum_{k=1}^{T}(\Delta q_{ijt-k+1} - \Delta\overline{q_{ijt-T+1}})^2},$$

where t is the year, T is the year window, and $12T$ denotes the number of months. Δq_{ijt} is the first difference of the natural log of bilateral monthly real exchange rates (RER).[5] As discussed in Clark, *et al*. (2004), when considering the impact of exchange rate volatility on trade flows, timing is crucial. For a robustness check, this paper uses three kinds of time windows to allow for timing and uncertainty issues, specifically, the current year (12 months), current and previous years (24 months), and current, previous and future years (36 months). All measures of exchange rate volatility are standardized to have zero mean and unit standard deviation. Thus, if the measure of exchange rate volatility increases by one unit, exchange rate volatility increases by one standard deviation.

Global Value Chain (GVC) Participation

GVCs divide up production so that different production stages can be conducted in different countries, with intermediate inputs crossing national borders multiple times. A country can be involved in cross-border production sharing in two ways: it either uses imported, intermediate inputs to produce its export goods (backward linkage) or domestically produces intermediate goods for other countries' exports (forward linkage). The higher the level of either backward or forward linkage, the more deeply a country is involved in GVCs. Measuring GVC participation can be difficult, because conventional trade statistics do not always identify the usage of traded goods. However, recent developments in Input-Output (IO) analysis allows us to trace the

[4] See, for instance, Rose (2000), Clark, *et al.* (2004), Byrne, *et al.* (2008), Hayakawa and Kimura (2009), Chit, *et al.* (2010), and Sato, *et al.* (2016).

[5] Although the first difference approach is widely used in the literature, it might fail to reflect actual fluctuations in exchange rate movements when exchange rates are volatile over periods as long as three months or more. As a robustness check, we also computed exchange rate changes over a three-month period, and these results were quite similar with our benchmark results.

sources and destinations of different value-added components of gross exports, even at bilateral and sectoral levels (Koopman, *et al*., 2014; Wang, *et al*., 2013).

To identify different value-added components of bilateral and sectoral gross exports resulting from GVC activities, we rely on the decomposition method developed by Wang, *et al*. (2013). Decomposition is done from the user's perspective, that is, domestic value-added, embedded in a specific sector's gross exports, can include value-added from other home sectors, such as a service sector. The equation in Appendix 1 is a mathematical framework that decomposes bilateral and sectoral gross exports into 16 terms. The details of each term are show in Appendix 1, Table A2. In Figure 1, these 16 terms are placed into six groups, based on each component's source and destination. DVA_{ijt}^{k} is the domestic value-added ultimately absorbed by direct importers. IV_{ijt}^{k} is the domestic value-added embodied in other countries' exports of intermediate inputs (i.e., a forward linkage). RDV_{ijt}^{k} is a domestic value-added initially exported that eventually returns to the home country. DDC_{ijt}^{k} is a domestic value-added double-counted in export production, that is, exported by a home country twice or more. FVA_{ijt}^{k} is foreign value-added used in the production of exports, from both direct importers and other countries. FDC_{ijt}^{k} is foreign value-added, double-counted in export production, that is, exported by foreign countries twice or more. The sum of FVA_{ijt}^{k} and FDC_{ijt}^{k} represents the foreign content (FC_{ijt}^{k}) of export production (i.e., a backward linkage).

We use two measurements of GVC participation to assess GVCs' effect on the relationship between exchange rate volatility and exports. A country can engage in GVCs either through forward or backward linkages. Thus, following Koopman, *et al*. (2010), we define the first bilateral and sectoral GVC participation index as the sum of backward forward linkages:

$$FL_{ijt}^{k} = \begin{cases} \dfrac{IV_{ijt}^{k}}{Exp_{ijt}^{k}}, & Exp_{ijt}^{k} \neq 0 \\ 0 \quad , & Exp_{ijt}^{k} = 0 \end{cases}$$

$$BL_{ijt}^{k} = \begin{cases} \dfrac{FC_{ijt}^{k}}{Exp_{ijt}^{k}}, & Exp_{ijt}^{k} \neq 0 \\ 0 \quad , & Exp_{ijt}^{k} = 0 \end{cases}$$

$$^{1}PGVC_{ijt}^{k} = BL_{ijt}^{k} + FL_{ijt}^{k}$$

where FL_{ijt}^{k} is the index of forward linkages and BL_{ijt}^{k} is the index of backward linkages between countries *i* and *j* at sector *k*. IV_{ijt}^{k} is country *i*'s value-added, embodied in sector *k*'s gross exports to country *j,* which were used in country *j*'s exports.[6] FC_{ijt}^{k} is the foreign content in country *i*'s gross exports to country *j* in sector *k*, and Exp_{ijt}^{k} is country *i*'s gross exports to country *j* in sector *k*. $^{1}PGVC_{ijt}^{k}$ is a sectoral and bilateral GVC participation index.

The second measure of participation in GVCs is derived from Wang, *et al*. (2013), who focused on pure double-counting terms, i.e., DDC_{ijt}^{k} and FDC_{ijt}^{k} (see Figure 1). In GVCs, intermediate goods move across national borders multiple times before they produce final goods and are counted in gross trade at each time. The more back and forth trade of intermediate goods, the larger the amount of pure double-counting terms. Thus, an increase in pure double-counting terms indicates greater cross-country production sharing. The formula is given by:

$$^{2}PGVC_{ijt}^{k} = \begin{cases} \dfrac{DDC_{ijt}^{k} + FDC_{ijt}^{k}}{Exp_{ijt}^{k}}, & Exp_{ijt}^{k} \neq 0 \\ 0 \quad , & Exp_{ijt}^{k} = 0 \end{cases}$$

where DDC_{ijt}^{k} is a purely double-counted domestic value, part of country *i*'s value-added gross exports to country *j* in sector *k*. FDC_{ijt}^{k} is a purely double-counted foreign value embodied in country *i*'s exports to country *j* in sector *k*.[2] $PGVC_{ijt,}^{k}$, another GVC participation index, quantifies the extent of a country's participation in GVCs, differently from $^{1}PGVC_{ijt}^{k}$. While $^{1}PGVC_{ijt}^{k}$ shows how a country is engaged

[6] IV_{ijt}^{k} includes all upstream sectors in country *i*'s contributions to value-added in sector *k*'s exports.

in GVCs, ${}^{2}PGVC_{ijt}^{k}$ measures the depth of cross-country production sharing. In this paper, using these two GVC participation indices, we focus only on export activities. Higher levels of ${}^{1}PGVC_{ijt}^{k}$ and ${}^{2}PGVC_{ijt}^{k}$ indicate, through GVCs, deeper production sharing between country *i* and country *j* in sector *k*. If no gross exports exist between country pairs, we define that no direct production sharing exists either, that is, ${}^{1}PGVC_{ijt}^{k}$=0 and ${}^{2}PGVC_{ijt}^{k}$=0 if $Expt_{ijt}^{k} = 0$.

2.2.3 Other Variables

Real Exports

Bilateral and sectoral gross exports are directly calculated from the OECD ICIO Tables (2016 edition) by summing up exports of intermediate goods and final goods in current U.S. dollars. We converted all export data into *constant* U.S. dollars, using the annual, average, nominal exchange rate of each country's currency vis-à-vis the U.S. dollar as of 1995, the first sample year in this paper. If a country's exports are denominated in current U.S. dollars, they will be automatically affected by changes in the value of a national currency against the U.S. dollar. This also may cause correlations between bilateral exports and the bilateral exchange rate versus a trading partner's currency. To remove this potential source of endogeneity bias and to construct real export data, we construct dollar constant real exports by converting all export data into constant 1995 U.S. dollars and deflating them by each country's consumer price index (CPI).[7]

Real Exchange Rates

We construct a bilateral real exchange rate using nominal exchange rates vis-a-vis the U.S. dollar and the CPI for the United States and other countries.[8] An

[7] Export amounts in constant U.S. dollars are also published by the World Bank (https://databank.worldbank.org/source/world-development-indicators), whose calculation of export amounts in constant U.S. dollars is presented on its website. This calculation method is basically the same as ours. See the following website: (https://datahelpdesk.worldbank.org/knowledgebase/articles/114943-what-is-your-constant-u-s-dollar-methodology)

[8] Conversion rates from European Monetary Union (EMU) currencies to Euros is derived from *Eurostat*: http://ec.europa.eu/eurostat/web/exchange-rates

increase in the bilateral real exchange rate means a real depreciation of an exporter's currency.

Price Index

We define the price indexes P_i and P_j as country i and j's real effective exchange rates (REERs), respectively. For the 62 trading partners in our sample, REER, which typically measures a country's export price competitiveness, is computed as the weighted average of a country's RER:

$$P_i = \prod_{j \neq i}^{62} RER_{ijt}^{\alpha_j}, \quad \sum_{j=1}^{62} \alpha_j = 1$$

where RER_{ijt} is the real exchange rate between country i and country j. α_j is the weight of each trading partner, that is, the share of each trading partner in country i's total imports.

Descriptive Statistics of Main Variables

Summary statistics of the main variables are presented in Table 1. Panel A provides basic descriptive statistics for each variable, and panel B shows correlations between pairs of variables. As shown in Table 1, the GVC participation data scale of two measures (*PGVC1* and *PGVC2*) is quite different. The mean of *PGVC1* is 0.428, while that of *PGVC2* is only 0.071. Since the backward linkage mean value is 0.296, much higher than that of a forward linkage (0.132), countries' engagement in GVCs takes place mainly through backward linkages. To further evaluate the role of GVC integration, we also report the 25th, 50 ^{th,} and 75 th percentile of GVC participation. These three measures of exchange rate volatility have similar mean values of 0.030, 0.033, and 0.036, respectively.

3. Empirical Results

We begin our analysis by examining the direct effect of exchange rate volatility on real exports and then look at interactions between these measures and GVC

participation.

Exchange Rate Volatility and Exports

By using separate OLS IV estimators, Tables 2 and 3 present estimated results of Equation (1) without interaction terms. Each Table displays the results of six regressions using three measures of exchange rate volatility. E.R. volatility$_1$ measures real exchange rate volatility in the current year (12 months), E.R. volatility$_2$ measures real exchange rate volatility for two years (24 months: the current and the previous year), and E.R. volatility$_3$ measures real exchange rate volatility for three years (36 months: the previous year, the current year, and one year in the future). We include the natural log of the price index and the real GDP for countries *i* and *j*, as well as country-pair-sector and year-fixed effects in all regressions. As shown at the bottom of Table 3, we also report the main results of first-stage regressions for the IV estimator.

Table 2 shows that the estimated coefficients of real exchange rate volatility are significantly negative in columns (1)–(2) and columns (5)–(6), but are not statistically significant in columns (3)–(4). These results indicate that while real exchange rate volatility tends to have a negative effect on real exports, the effect is not robust. However, since results from the OLS estimator might be biased by endogeneity problems, we consider results of the IV estimator, which are more precise than those of the OLS estimator.

As shown in Table 3, while the estimated coefficients of exchange rate volatility, based on E.R. volatility$_1$, are not statistically significant, the estimated coefficients of real exchange rate volatility based on the other two measures are significantly negative, even at the one percent level. These results are consistent with Clark, *et al*. (2004) who suggested that exchange rate volatility has a negative effect on trade for a relatively long period of time. Specifically, Clark, *et al*. (2004) argued that a firm's trading is less responsive to short-term exchange rate volatility, because a large investment in foreign markets typically is required to build marketing and distribution networks and/or to set up production facilities. The magnitude of these significantly negative coefficients is much larger than the corresponding amounts obtained from the OLS estimator. When exchange rate volatility increases by one standard deviation, real

exports decrease by 19–20 percent (Table 3), indicating that the negative effect of exchange rate volatility on trade is quite large.

We also found that a real, level exchange rate has a positive and significant effect on real exports. This is consistent with traditional macroeconomic models, which predict that currency depreciation promotes exports through expenditure-switching mechanisms, by changing the relative price between exports and local products. However, even when a level, bilateral, real exchange rate is added to the regressions, the estimated coefficients of real exchange rate volatility change little. Thus, the channel through which real exchange rate volatility affects exports may differ from that of a level exchange rate.

Exchange Rate Volatility, Exports, and Global Value Chains

To test whether and to what extent GVC participation affects real exchange rate volatility's impact on exports, we use two measures of GVC participation. The lagged value of each GVC participation measure allows for the possibility that GVC may be endogenous to exports. Since we find a significantly negative effect for two measures of real exchange rate volatility (E.R. volatility$_2$ (24 months) and E.R. volatility$_3$ (36 months)), we hereafter present results focusing on these two measures.

Using these two different measures of GVC participation, Tables 4 and 5 present estimated results of Equation (1) with interaction terms. Each Table shows both results, obtained from the OLS and IV estimator, based on two measures of real exchange rate volatility. We include the log of real GDP, the price index for countries *i* and *j,* and the log of bilateral RER, as well as country-pair-sector and year fixed effects in all regressions. We report only the primary variables of estimated coefficients.

As shown in Table 4, all single terms of real exchange rate volatility are significantly negative, and all interaction terms between real exchange rate volatility and GVC participation are significantly positive at the one percent level in all columns. These results indicate that GVC participation could reduce the negative effect of real exchange rate volatility on real exports. In other words, the deeper the production sharing between two countries, the smaller the negative effect of real exchange rate

volatility on exports. This result is consistent with Sato, *et al*. (2016), who showed that the effect of real exchange rate volatility on exports differs across industries, and that real exchange rate volatility has a weaker impact on industries with relatively well-established GVCs. By contrast, our result differs from the findings of Hayakawa and Kimura (2009) and Tang (2014). They found that negative effects of real exchange rate volatility more likely occur in intermediate goods trade. This may imply that GVCs augment the negative effect of real exchange rate volatility on trade, because GVCs arise from trade in intermediate goods. However, these studies' empirical results were different from ours, because they did not distinguish GVC-related intermediate-goods trade from non-GVC-related intermediate-goods trade.[9]

To quantitatively assess the economic importance of GVC participation, at the bottom of each column, we provide the effect of real exchange rate volatility using $\beta_2 + \beta_3 PGVC,$ when the measure of GVC participation increases from the 25th percentile to the 75th percentile. Since the estimated sign of real exchange rate volatility's single term is different from that of its interaction with GVC participation, we can compute a threshold level of GVC participation. As shown in Table 4, the threshold level ranges from 0.29 to 0.47, above which exchange rate volatility promotes exports. In column (1) of Table 4, where the measure of GVC participation increases from zero to the 25th percentile (0.303 in our data), the negative effect of one standard deviation increase in real exchange rate volatility declines from 16 percent to 5 percent. When GVC participation increases to the 50th percentile (0.440 in our data), the negative effect further decreases to 0.4 percent. Interestingly, if a country is involved in GVCs at the 75th percentile level (0.575, higher than the threshold level in our data), real exchange rate volatility has a positive effect on exports. In other words, a one standard deviation increase in real exchange rate volatility raises real exports by 4.4 percent. Thus, we found that GVC participation has an *offsetting* effect on real exchange rate volatility's negative influence on exports.

Columns (3)–(4) of Table 4, providing results obtained from IV estimator, indicate that GVC participation has a much larger offsetting effect. For example, when

[9] By definition, GVC-related, intermediate-goods trade crosses national borders at least twice, and non-GVC-related, intermediate-goods trade only goes across national borders once.

GVC participation increases from zero to the 25th percentile, the negative impact of exchange rate volatility on exports turns positive, which indicates that GVC participation largely reduces the negative effect. These results suggest that GVC participation plays an offsetting role in the negative relationship between real exchange rate volatility and exports and also that this effect is economically important.

Following Wang, *et al*. (2013), we next use the second measure of GVC participation, which focuses on double-counting terms. As shown in Table 5, the sign of both real exchange rate volatility's single terms and interaction terms with GVC participation are basically the same as the signs of the corresponding coefficients presented in Table 4. Almost all coefficients are statistically significant at the one percent level in all of Table 5's columns, even though the magnitude of the estimated coefficients is somewhat different from the corresponding magnitude obtained from Table 4 (likely explained by the different data scales for the two measures of GVC participation). Thus, although we use different measures of GVC participation, our main finding does not change: GVC participation reduces the negative effect of real exchange rate volatility on exports. Although the magnitude of the estimated coefficients is quite different from that in Table 4, due to the different data scales for these two measures, GVC participation in the relationship between exchange rate volatility and exports is large. As show in column (1) of Table 5, when the second measure of GVC participation increases from the 25th to the 50th percentile, the negative effect of a one standard deviation increase in exchange rate volatility declines from 6.9 percent to 3.6 percent. This offsetting effect becomes much larger when using the IV estimator (columns (3)–(4) in Table 5). Thus, with different measures of GVC participation, the offsetting effect of GVC participation on the negative relationship between exchange rate volatility and exports is found to be robust.

We proceed to examine backward and forward linkages' impact on how exchange rate volatility negatively affects exports. Table 6 shows that the estimated coefficients of interaction terms of exchange rate volatility with backward and forward linkages are significantly positive in all columns, even at the one percent significance level. Thus, we can conclude that a country's GVC participation, through either backward or forward linkages, will reduce the negative effect of exchange rate volatility

on exports.

4. Robustness Check

To check the robustness of our main result, we conduct four additional empirical examinations. In the following tables, we only show estimated coefficients for the main variables (namely, real exchange rate volatility), its interaction term with different measures of GVC participation, bilateral RER, and GVC participation. All other control variables, such as country-pair-sector and yearly fixed effects, are included in each regression. Overall, we show that our main result in the previous section is quite robust. A country's GVC participation will alleviate the negative effect of exchange rate volatility on its exports. The details of each examination are as follows.

First, exchange rate volatility can affect GVC participation. In other words, GVC participation might be endogenous to exchange rate volatility, which could partially confound GVC participation shocks with exchange rate shocks. To solve this possible endogeneity, we obtain residuals of GVC participation that cannot be explained by exchange rate volatility. We regressed each measure of GVC participation on exchange rate volatility and re-ran our regressions using residualized GVC participation measures. Table 7 shows that all interaction terms of exchange rate volatility with GVC participation are significantly positive at the one percent level in all columns. This supports our main result that GVC participation mitigates the negative effect of real exchange rate volatility on exports, even after controlling for the endogeneity of GVC participation to exchange rate volatility.

Second, the two measures of GVC participation do not include GVC-related production activities that satisfy domestic final demand. For example, domestic value-added initially exported but eventually returning home (RDV_{ijt}^{k} in Figure 1) is another way that a country could engage in GVCs. Thus, our two measures might not fully reflect the extent to which a country is involved in GVCs. To overcome this possible weakness, we decompose bilateral exports into two components: GVC-related and non-GVC-related activities, based on whether or not they cross national borders twice or more for production. In Figure 1, the non-GVC-related component includes

DVA_{ijt}^{k}, and the rest of GVC-related activities include IV_{ijt}^{k}, RDV_{ijt}^{k}, DDC_{ijt}^{k}, FVA_{ijt}^{k}, and FDC_{ijt}^{k}. Then, we regress each component on real exchange rate volatility and other control variables to reexamine the impact of GVC participation, the result of which is presented in Table 8. By comparing GVC-related exports (columns (2)–(4) in Table 8) with non-GVC-related exports (columns (6)–(8) in Table 8), we found that real exchange rate volatility has a larger negative effect on non-GVC-related exports than on GVC-related exports. These results also support our main result that GVC participation alleviates the negative effect of exchange rate volatility on exports.

Third, to exclude any disturbances caused by the currency crisis in 1997 and the global financial crisis in 2008, we reestimated equations from a 1999-2007 subsample, whose results are presented in Table 9. Although the magnitude of estimated coefficients is different from that in the entire sample, signs of single terms and interaction terms are the same as in our benchmark results, which suggests that our main result is quite robust. Thus, even after controlling for disturbances caused by these two financial crises, GVC participation significantly offsets the negative relationship between real exchange rate volatility and exports.

Finally, we conducted a reestimation, using IO data from the World Input-Output Database (WIOD). Results are presented in Table 10. Estimated signs of single terms and interaction terms are the same as in our benchmark results. This also supports our main result, even when IO data sources are different.

5. Concluding Remarks

In this paper, we empirically investigated whether and how GVC participation affects exchange rate volatility's effect on exports, using OECD ICIO Tables (2016 edition), covering 63 countries between 1995 and 2011. We focused on manufacturing sectors, because cross-border production sharing is well-established in this sector. We employed both an OLS estimator and an IV estimator to deal with possible endogeneity problems. We built two measures of GVC participation to gauge the degree of bilateral production sharing. The first, developed by Koopman, *et al*. (2010), measures both forward and backward linkages. The second, proposed by Wang, *et al*. (2013), captures

pure double-counting terms that arise from the back and forth trading of intermediate goods between two countries. The second measure is a novel one, and this paper is the first study that uses it in an empirical analysis.

Our findings are two-fold. First, while real exchange rate volatility has a large negative effect on exports, a country's participation in GVCs lessens the negative impact of exchange rate volatility on exports. Such offsetting of GVC participation does not change even when a country engages in GVCs through either forward or backward linkages. This finding is supported by various robustness exercises. Second, if the degree of a country's participation in GVCs exceeds a threshold level, exchange rate volatility has a positive effect on that country's exports.

These findings have important implications. If regional value chains were well-developed and deepened, exchange rate fluctuations among regional countries would be less likely to have a negative influence on regional trade. In Asia, for instance, regional exchange rate stability has been an important research question, especially when considering regional economic and monetary integration. Our empirical findings suggest that regional exchange rate coordination would not be a matter of concern in Asia if GVCs developed faster through burgeoning intra-Asian trade.

References

Ahmed, S., M. Appendino and M. Ruta (2017), "Global Value Chains and the Exchange Rate Elasticity of Exports." *The B.E. Journal of Macroeconomics*, 17(1), pp.1–24.

Auboin, M. and M. Ruta (2012), "The Relationship between Exchange Rates and International Trade: A Review of Economic Literature." CESIFO Working Paper, No. 3868.

Broda, C., and J. Romalis (2011), "Identifying the relationship between trade and exchange rate volatility." In: Commodity Prices and Markets – East Asia Seminar on Economics, Volume 20, edited by Ito, T., and A.K. Rose (eds.). University of Chicago Press, pp.79–110.

Byrne, J. P, J. Darby and R. MacDonald (2008), "US Trade and Exchange Rate Volatility: A Real Sectoral Bilateral Analysis." *Journal of Macroeconomics*, 30(1), pp.238–259.

Calderon, C. and M. Kubota (2018), "Does higher openness cause more real exchange rate volatility?" *Journal of International Economics*, 110, pp.176–204.

Cheng, K. C., G. H. Hong, D. Seneviratne and R. V. Elkan (2016), "Rethinking the Exchange Rate Impact on Trade in a World with Global Value Chains." *International Economic Journal*, 30(2), pp.204–216.

Chit, M. M., M. Rizov and D. Willenbockel (2010), "Exchange Rate Volatility and Exports: New Empirical Evidence from the Emerging East Asian Economies." *The World Economy*, 33(2), pp.239–263.

Clark, P. B., N. Tamirisa, S. J. Wei, A. Sadikov and L. Zeng (2004), "A New Look at Exchange Rate Volatility and Trade Flows." IMF Occasional Paper 235, International Monetary Fund, Washington DC.

Eichengreen, B. and H. Tong (2015), "Effects of Renminbi Appreciation on Foreign Firms: The Role of Processing Exports." *Journal of Development Economics*, 116, pp.146–157.

Feenstra, R. and J. B. Jensen (2009), "Evaluating Estimates of Materials Offshoring from U.S. Manufacturing." NBER Working Paper 17916.

Hau, H. (2002), "Real Exchange Rate Volatility and Economic Openness: Theory and Evidence." *Journal of Money, Credit and Banking*, 34, pp.611–630.

Hayakawa, K. and F. Kimura (2009), "The effect of exchange rate volatility on international trade in East Asia." *Journal of The Japanese and International Economies*, 23(4), pp.395–406.

Hummels, D., J. Ishii and K.M. Yi (2001), "The Nature and Growth of Vertical Specialization in World Trade." *Journal of International Economics*, 54(1), pp.75–96.

Ito, T., E. Ogawa and Y. Sasaki (1998), "How did the Dollar Peg Fail in Asia?" *Journal of the Japanese and International Economies*, 12(4), pp.256–304.

Koopman, R., W. Powers, Z. Wang, S.J. Wei (2010), "Give Credit Where Credit Is Due: Tracing Value Added in Global Production Chains." NBER Working Paper No. 16426.

Obashi, A. (2010), "Stability of production networks in East Asia: duration and survival of trade." *Japan and the World Economy*, 22(1), pp.21–30.

Obstfeld, M., and K.S. Rogoff (1995), "Exchange Rate Dynamics Redux. *Journal of Political Economy*," 103, pp.624–660.

Ogawa, E. and J. Shimizu (2006), "AMU Deviation Indicators for Coordinated Exchange Rate Policies in East Asia and their Relationships with Effective Exchange Rates." *The World Economy*, 29 (12), pp.1691–1708.

Ong, S.L. and K. Sato (2018), "Regional or Global Shock? A Global VAR Analysis of Asian Economic and Financial Integration." *North American Journal of Economics and Finance*, 46, pp.232–248.

Rose, A., 2000, "One money, one market: the effect of common currencies on trade." *Economic Policy*, 15(30), pp.7–45.

Sato, K., J. Shimizu, N. Shrestha and S. Zhang (2016), "Industry-specific Exchange Rate Volatility and Intermediate Goods Trade in Asia." *Scottish Journal of Political Economy*, 63(1), pp.89–109.

Sato, K., and N. Shrestha (2014), "Global and Regional Shock Transmission: An Asian Perspective." CESSA Working Paper, 2014-04.

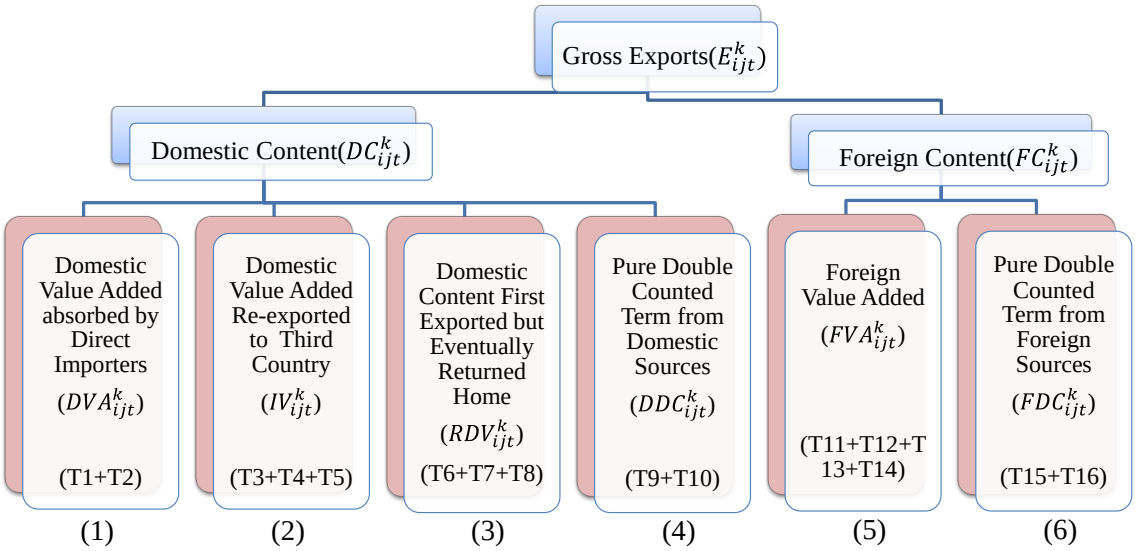
Shrestha, N. and K. Sato (2015), "Global Financial Crisis and Shock Transmission: Supply- or Demand-driven Shock?" CESSA Working Paper, 2015-10.

Tang, H. C. (2014), "Intra-Asia Exchange Rate Volatility and Intra-Asia Trade: Evidence by Type of Goods." *The World Economy*, 37(2), pp.335–352.

Thorbecke W. (2008), "The effect of exchange rate volatility on fragmentation in East Asia: Evidence from the electronics industry." *Journal of The Japanese and International Economies*, 22(4), pp.535–544.

Wang, Z., S.J. Wei and K. Zhu (2013), "Quantifying International Production Sharing at the Bilateral and Sector Level." NBER working paper.

Figure 1 Gross Exports' Decomposition



Source: Authors' illustration, based on Wang, *et al*. (2013).

Table 1. Summary of Main Variables

	Panel A: descriptive statistics							
	Log of Real Exports	E.R. Volatility (12 months)	E.R. Volatility (24 months)	E.R. Volatility (36 months)	GVC Participation (PGVC1)	GVC Participation (PGVC2)	Backward Linkage	Forward Linkage
Mean	13.679	0.030	0.033	0.036	0.428	0.071	0.296	0.132
Std.Dev.	5.739	0.025	0.023	0.026	0.220	0.080	0.173	0.126
Min	0.000	0.001	0.002	0.002	0.000	0.000	0.000	0.000
P25	11.698	0.018	0.021	0.022	0.303	0.013	0.191	0.032
P50	14.931	0.026	0.029	0.031	0.440	0.048	0.290	0.103
P75	17.439	0.037	0.038	0.041	0.575	0.100	0.398	0.197
Max	30.371	0.348	0.236	0.265	1.017	0.830	0.912	0.934

	Panel B: correlations among main explanatory and dependent variables							
	Log of Real Exports	E.R. Volatility (12 months)	E.R. Volatility (24 months)	E.R. Volatility (36 months)	GVC Participation (PGVC1)	GVC Participation (PGVC2)	Backward Linkage	Forward Linkage
Log of Real Exports	1.000	-0.088	-0.130	-0.158	0.572	0.314	0.463	0.365
E.R. Volatility(12 months)	-0.088	1.000	0.713	0.520	-0.063	-0.050	-0.046	-0.046
E.R. Volatility(24 months)	-0.130	0.713	1.000	0.807	-0.099	-0.076	-0.076	-0.069
E.R. Volatility(36 months)	-0.158	0.520	0.807	1.000	-0.140	-0.108	-0.109	-0.096
GVC Participation (PGVC1)	0.572	-0.063	-0.099	-0.140	1.000	0.798	0.822	0.621
GVC Participation (PGVC2)	0.314	-0.050	-0.076	-0.108	0.798	1.000	0.552	0.639
Backward Linkage	0.463	-0.046	-0.076	-0.109	0.822	0.552	1.000	0.065
Forward Linkage	0.365	-0.046	-0.069	-0.096	0.621	0.639	0.065	1.000

Table 2. The Effect of Real Exchange Rate Volatility on Exports: OLS

Variables	(1)	(2)	(3)	(4)	(5)	(6)
E.R. Volatility (12 months)	-0.013**	-0.015**				
	(0.006)	(0.006)				
E.R. Volatility (24 months)			0.007	0.005		
			(0.009)	(0.009)		
E.R. Volatility (36 months)					-0.039***	-0.041***
					(0.010)	(0.010)
Log Real E.R.		0.818***		0.816***		0.819***
		(0.046)		(0.046)		(0.046)
Log Real GDP of Exporter	3.222***	3.244***	3.224***	3.246***	3.218***	3.241***
	(0.050)	(0.050)	(0.050)	(0.050)	(0.050)	(0.050)
Log Real GDP of Importer	1.809***	1.787***	1.812***	1.790***	1.806***	1.784***
	(0.054)	(0.054)	(0.054)	(0.054)	(0.054)	(0.054)
Log Price Index of Exporter	1.201***	0.547***	1.185***	0.533***	1.214***	0.558***
	(0.034)	(0.050)	(0.034)	(0.050)	(0.034)	(0.049)
Log Price Index of Importer	-0.115***	0.538***	-0.131***	0.521***	-0.103**	0.551***
	(0.035)	(0.049)	(0.035)	(0.049)	(0.035)	(0.049)
Year Effects	x	x	x	x	x	x
Exporter-Importer-Sector Effects	x	x	x	x	x	x
No.observations	1062432	1062432	1062432	1062432	1062432	1062432

Note: Robust standard errors are clustered at the country-pair-sector level in parentheses: *=10% significance level; **=5% significance level; ***=1% significance level.

Table 3. The Effect of Real Exchange Rate Volatility on Exports: IV

Variables	(1)	(2)	(3)	(4)	(5)	(6)
E.R. Volatility (12 months)	0.016	0.013				
	(0.011)	(0.011)				
E.R. Volatility (24 months)			-0.199***	-0.201***		
			(0.036)	(0.036)		
E.R. Volatility (36 months)					-0.187***	-0.189***
					(0.035)	(0.035)
Log Real E.R.		0.811***		0.826***		0.825***
		(0.047)		(0.047)		(0.047)
Log Real GDP of Exporter	3.281***	3.296***	3.254***	3.269***	3.273***	3.291***
	(0.051)	(0.051)	(0.051)	(0.051)	(0.051)	(0.051)
Log Real GDP of Importer	1.853***	1.838***	1.809***	1.793***	1.816***	1.799***
	(0.054)	(0.054)	(0.055)	(0.051)	(0.054)	(0.054)
Log Price Index of Exporter	1.149***	0.503***	1.313***	0.655***	1.273***	0.614***
	(0.034)	(0.050)	(0.042)	(0.055)	(0.039)	(0.052)
Log Price Index of Importer	-0.150***	0.496***	0.013	0.670***	-0.025	0.632***
	(0.036)	(0.050)	(0.045)	(0.058)	(0.041)	(0.055)
Year Effects	x	x	x	x	x	x
Exporter-Importer-Sector Effects	x	x	x	x	x	x
No.observations	1040704	1040704	1042528	1042528	1046464	1046464

First-Stage	E.R. Volatility (12 months)	E.R. Volatility (24 months)	E.R. Volatility (36 months)
Volatility in Relative Interest Rate	1.666***	0.142***	0.170***
	(0.004)	(0.004)	(0.005)

Note: Robust standard errors are clustered at the country-pair-sector level in parentheses: *=10% significance level; **=5% significance level; ***=1% significance level.

Table 4. The Effect of Real Exchange Rate Volatility and GVC Participation: ^{1}PGVC

	OLS		IV	
Variables	(1)	(2)	(3)	(4)
E.R. Volatility(24 months)	-0.160***		-0.177***	
	(0.014)		(0.020)	
E.R. Volatility(36 months)		-0.136***		-0.233***
		(0.016)		(0.021)
E.R. Volatility(24 months)×	0.354***		0.609***	
Participation in GVCs($^{1}PGVC_{t-1}$)	(0.032)		(0.053)	
E.R. Volatility(36 months)×		0.291***		0.758***
Participation in GVCs($^{1}PGVC_{t-1}$)		(0.037)		(0.056)
Participation in GVCs($^{1}PGVC_{t-1}$)	5.455***	5.455***	5.428***	5.451***
	(0.057)	(0.057)	(0.057)	(0.058)
Log Real E.R.	0.801***	0.798***	0.785***	0.791***
	(0.039)	(0.039)	(0.040)	(0.039)
Log Real GDP of Exporter	x	x	x	x
Log Real GDP of Importer	x	x	x	x
Log Price Index of Exporter	x	x	x	x
Log Price Index of Importer	x	x	x	x
Year Effects	x	x	x	x
Exporter-Importer-Sector Effects	x	x	x	x
	Quantification			
P25 GVC	-0.053	-0.048	0.008	-0.003
P50 GVC	-0.004	-0.008	0.091	0.101
P75 GVC	0.044	0.031	0.173	0.203
Threshold Value of GVCs ($-\beta_1/\beta_2$)	0.452	0.467	0.291	0.307
No.observations	999936	999936	982144	986080

Note: Robust standard errors are clustered at the country-pair-sector level in parentheses: *=10% significance level; **=5% significance level; ***=1% significance level.

Table 5. The Effect of Real Exchange Rate Volatility and GVC Participation: ^{2}PGVC

Variables	OLS		IV	
	(1)	(2)	(3)	(4)
E.R. Volatility(24 months)	-0.082***		-0.043**	
	(0.011)		(0.017)	
E.R. Volatility(36 months)		-0.068***		-0.081***
		(0.013)		(0.017)
E.R. Volatility(24 months)× Participation in GVCs($^2PGVC_{t-1}$)	0.968***		1.882***	
	(0.118)		(0.261)	
E.R. Volatility(36 months)× Participation in GVCs($^2PGVC_{t-1}$)		0.860***		2.644***
		(0.133)		(0.279)
Participation in GVCs($^2PGVC_{t-1}$)	8.960***	8.968***	9.161***	8.823***
	(0.151)	(0.152)	(0.157)	(0.263)
Log Real E.R.	0.869***	0.883***	0.872***	0.877***
	(0.045)	(0.044)	(0.045)	(0.045)
Log Real GDP of Exporter	x	x	x	x
Log Real GDP of Importer	x	x	x	x
Log Price Index of Exporter	x	x	x	x
Log Price Index of Importer	x	x	x	x
Year Effects	x	x	x	x
Exporter-Importer-Sector Effects	x	x	x	x
	Quantification			
P25 GVC	-0.069	-0.057	-0.019	-0.047
P50 GVC	-0.036	-0.027	0.047	0.046
P75 GVC	0.015	0.018	0.145	0.183
Threshold Value of GVCs ($-\beta_1/\beta_2$)	0.085	0.079	0.023	0.031
No.observations	999936	999936	982144	986080

Note: Robust standard errors are clustered at the country-pair-sector level in parentheses: *=10% significance level; **=5% significance level; ***=1% significance level.

Table 6. The Effect of Real Exchange Rate Volatility, Conditional on Backward and Forward Linkages

	OLS		IV	
Variables	(1)	(2)	(3)	(4)
E.R. Volatility(24 months)	-0.161***		-0.217***	
	(0.014)		(0.019)	
E.R. Volatility(36 months)		-0.274***		-0.281***
		(0.017)		(0.020)
E.R. Volatility(24 months)× Backward Participation in GVCs	0.397***		0.774***	
	(0.040)		(0.066)	
E.R. Volatility(24 months)× Forward Participation in GVCs	0.231***		0.533***	
	(0.059)		(0.109)	
E.R. Volatility(36 months)× Backward Participation in GVCs		0.588***		0.933***
		(0.047)		(0.069)
E.R. Volatility(36 months)× Forward Participation in GVCs		0.402***		0.716***
		(0.070)		(0.112)
Backward Participation in GVCs	6.443***	6.459***	6.415***	6.431***
	(0.073)	(0.073)	(0.073)	(0.073)
Forward Participation in GVCs	3.788***	3.808***	3.775***	3.816***
	(0.086)	(0.086)	(0.087)	(0.087)
Log Real E.R.	0.737***	0.743***	0.722***	0.729***
	(0.039)	(0.039)	(0.040)	(0.039)
Log Real GDP of Exporter	x	x	x	x
Log Real GDP of Importer	x	x	x	x
Log Price Index of Exporter	x	x	x	x
Log Price Index of Importer	x	x	x	x
Year Effects	x	x	x	x
Exporter-Importer-Sector Effects	x	x	x	x
No.observations	999936	999936	982144	986080

Note: Robust standard errors are clustered at the country-pair-sector level in parentheses: *=10% significance level; **=5% significance level; ***=1% significance level.

Table 7. The Effect of Real Exchange Rate Volatility, Conditional on Residualized GVC Participation

	OLS		IV	
Variables	(1)	(2)	(3)	(4)
E.R. Volatility(24 months)	-0.053***	-0.038***	-0.047***	-0.037**
	(0.006)	(0.008)	(0.013)	(0.015)
E.R. Volatility(24 months)×	0.416***		1.864***	
Participation in GVCs(${}^{1}PGVC_{t-1}$)	(0.068)		(0.157)	
E.R. Volatility(24 months)×		1.122***		6.760***
Participation in GVCs(${}^{2}PGVC_{t-1}$)		(0.257)		(0.561)
Participation in GVCs(${}^{1}PGVC_{t-1}$)	5.436***		5.485***	
	(0.057)		(0.059)	
Participation in GVCs(${}^{2}PGVC_{t-1}$)		8.926***		9.468***
		(0.153)		(0.169)
Log Real E.R.	0.797***	0.884***	0.776***	0.879***
	(0.039)	(0.044)	(0.040)	(0.045)
Log Real GDP of Exporter	x	x	x	x
Log Real GDP of Importer	x	x	x	x
Log Price Index of Exporter	x	x	x	x
Log Price Index of Importer	x	x	x	x
Year Effects	x	x	x	x
Exporter-Importer-Sector Effects	x	x	x	x
No.observations	999936	999936	982144	986080

Note: Robust standard errors are clustered at the country-pair-sector level in parentheses: *=10% significance level; **=5% significance level; ***=1% significance level.

Table 8. The Effect of Real Exchange Rate Volatility: GVC-Related and Non-GVC-Related Exports

	GVC-related Exports				Non GVC-related Exports			
	OLS		IV		OLS		IV	
Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
E.R. Volatility (24 months)	0.0105		-0.157***		-0.003		-0.252***	
	(0.008)		(0.034)		(0.008)		(0.034)	
E.R. Volatility (36 months)		-0.033***		-0.146***		-0.049***		-0.242***
		(0.010)		(0.034)		(0.010)		(0.034)
Log Real E.R.	0.844***	0.847***	0.852***	0.851***	0.782***	0.786***	0.792***	0.793***
	(0.044)	(0.044)	(0.044)	(0.045)	(0.044)	(0.044)	(0.045)	(0.044)
Log Real GDP of Exporter	x	x	x	x	x	x	x	x
Log Real GDP of Importer	x	x	x	x	x	x	x	x
Log Price Index of Exporter	x	x	x	x	x	x	x	x
Log Price Index of Importer	x	x	x	x	x	x	x	x
Year Effects	x	x	x	x	x	x	x	x
Exporter-Importer-Sector Effects	x	x	x	x	x	x	x	x
No.observations	1062432	1062432	1042528	1046464	1062410	1062410	1042507	1046442

Note: Robust standard errors are clustered at the country-pair-sector level in parentheses: *=10% significance level; **=5% significance level; ***=1% significance level.

Table 9. The Effect of Real Exchange Rate Volatility, Conditional on GVC Participation, Using a Subsample Period from 1999 to 2007

	OLS		IV	
Variables	(1)	(2)	(3)	(4)
E.R. Volatility(24 months)	-0.209***	-0.157***	-0.269***	-0.133***
	(0.034)	(0.018)	(0.051)	(0.029)
E.R. Volatility(24 months)× Participation in GVCs(${}^{1}PGVC_{t-1}$)	0.282***		0.582***	
	(0.074)		(0.119)	
E.R. Volatility(24 months)× Participation in GVCs(${}^{2}PGVC_{t-1}$)		0.932***		1.147**
		(0.198)		(0.367)
Participation in GVCs(${}^{1}PGVC_{t-1}$)	2.502***		2.549***	
	(0.076)		(0.078)	
Participation in GVCs(${}^{2}PGVC_{t-1}$)		4.491***		4.524***
		(0.202)		(0.215)
Log Real E.R.	0.950***	0.989***	0.935***	0.979***
	(0.048)	(0.050)	(0.048)	(0.051)
Log Real GDP of Exporter	x	x	x	x
Log Real GDP of Importer	x	x	x	x
Log Price Index of Exporter	x	x	x	x
Log Price Index of Importer	x	x	x	x
Year Effects	x	x	x	x
Exporter-Importer-Sector Effects	x	x	x	x
No.observations	499968	499968	494016	494016

Note: Robust standard errors clustered at country-pair-sector level in parentheses, * 10% significance level; ** 5% significance level; ***1% significance level.

Table 10. The Effect of Real Exchange Rate Volatility, Conditional on GVC Participation, Using WIOD Trade Data from 1995 to 2011

	OLS		IV	
Variables	(1)	(2)	(3)	(4)
E.R. Volatility(24 months)	-0.114***	-0.0780***	-0.524***	-0.292***
	(0.0273)	(0.0133)	(0.0529)	(0.0158)
E.R. Volatility(24 months)×	0.149**		0.644***	
Participation in GVCs(${}^{1}PGVC_{t-1}$)	(0.0570)		(0.0994)	
E.R. Volatility(24 months)×		0.595***		1.651***
Participation in GVCs(${}^{2}PGVC_{t-1}$)		(0.130)		(0.158)
Participation in GVCs(${}^{1}PGVC_{t-1}$)	3.896***		3.992***	
	(0.135)		(0.136)	
Participation in GVCs(${}^{2}PGVC_{t-1}$)		4.616***		4.954***
		(0.257)		(0.261)
Log Real E.R.	0.125**	0.166**	0.150**	0.188**
	(0.0552)	(0.0574)	(0.0553)	(0.0576)
Log Real GDP of Exporter	x	x	x	x
Log Real GDP of Importer	x	x	x	x
Log Price Index of Exporter	x	x	x	x
Log Price Index of Importer	x	x	x	x
Year Effects	x	x	x	x
Exporter-Importer-Sector Effects	x	x	x	x
No.observations	349440	349440	349440	349440

Note: Robust standard errors are clustered at the country-pair-sector level in parentheses: *=10% significance level; **=5% significance level; ***=1% significance level.

Appendix 1. Method of Gross Export Decomposition

$$E_{sr} = (1)V_s B_{ss}{}^{t} \# Y_{sr} + (2)V_s L_{ss}{}^{t} \# A_{sr} B_{rr} Y_{rr} + (3)V_s L_{ss}{}^{t} \# A_{sr} \sum_{t \neq s,r}^{G} B_{rt} Y_{tt}$$
$$+ (4)V_s L_{ss}{}^{t} \# A_{sr} B_{rr} \sum_{t \neq s,r}^{G} Y_{rt} + (5)V_s L_{ss}{}^{t} \# A_{sr} \sum_{t \neq s,r}^{G} \sum_{u \neq s,r}^{G} B_{rt} Y_{tu}$$
$$+ (6)V_s L_{ss}{}^{t} \# A_{sr} B_{rr} Y_{rs} + (7)V_s L_{ss}{}^{t} \# A_{sr} \sum_{t \neq s,r}^{G} B_{rt} Y_{ts} + (8)V_s L_{ss}{}^{t} \# A_{sr} B_{rs} Y_{ss}$$
$$+ (9)V_s L_{ss}{}^{t} \# A_{sr} \sum_{t \neq r}^{G} B_{rs} Y_{st} + (10)(V_s B_{ss} - V_s L_{ss})^{t} \# A_{sr} X_r$$
$$+ (11)V_r B_{rs}{}^{t} \# Y_{sr} + (12)V_r B_{rs}{}^{t} \# A_{sr} L_{rr} Y_{rr} + (13) \sum_{t \neq s,r}^{G} V_t B_{ts}{}^{t} \# Y_{sr} + (14) \sum_{t \neq s,r}^{G} V_t B_{ts}{}^{t} \# A_{sr} L_{rr} Y_{rr}$$
$$+ (15)V_r B_{rs}{}^{t} \# A_{sr} L_{rr} E_{r^*} + (16) \sum_{t \neq s,r}^{G} V_t B_{ts}{}^{t} \# A_{sr} L_{rr} E_{r^*}$$

Source: Wang, *et al*. (2013)

Table A1. Industry Classifications

ICIO 34 industry list (TiVA 2016)		ISIC Rev.3
3	Food products, beverages and tobacco	15, 16
4	Textiles, textile products, leather and footwear	17, 18, 19
5	Wood and products of wood and cork	20
6	Pulp, paper, paper products, printing and publishing	21, 22
7	Coke, refined petroleum products and nuclear fuel	23
8	Chemicals and chemical products	24
9	Rubber and plastics products	25
10	Other non-metallic mineral products	26
11	Basic metals	27
12	Fabricated metal products except machinery and equipment	28
13	Machinery and equipment n.e.c	29
14	Computer, electronic and optical products	30, 32, 33
15	Electrical machinery and apparatus n.e.c	31
16	Motor vehicles, trailers and semi-trailers	34
17	Other transport equipment	35
18	Manufacturing n.e.c; recycling	36, 37

Table A2. Definition of Decomposition Terms

	Description
T1	Domestic value added (DVA) exports in final goods exports
T2	DVA in intermediate exports to the direct importer and absorbed there
T3	DVA in intermediate exports used by the direct importer to produce intermediate exports for production of third countries' domestic used final goods
T4	DVA in intermediate exports used by the direct importer producing final exports to third countries
T5	DVA in intermediate exports used by the direct importer producing intermediate exports to third countries
T6	Returned DVA in final goods imports from the direct importer
T7	Returned DVA in final goods imports via third countries
T8	Returned DVA in intermediate imports
T9	Double counted DVA used to produce final goods exports
T10	Double counted DVA used to produce intermediate exports
T11	Direct importer's value added (VA) in source country's final goods exports
T12	Direct importer's VA in source country's intermediate goods exports
T13	Third countries' VA in final goods exports
T14	Third countries' VA in intermediate goods exports
T15	Direct importer's VA double counted in exports production
T16	Third countries' VA double counted in exports production

Source: Wang, *et al*. (2013).