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Abstract

This paper empirically analyzes the effect of exchange rate volatility on intra-Asian trade of intermediate goods at an industry level by constructing a new dataset of the industry-specific bilateral real exchange rate. As the final processed exports are destined for countries outside the Asian region, both the exchange rate and world demand are considered as a possible driving force in the cross-border fragmentation and processing trade. It is found that, in contrast to the recent studies, the exchange rate impact on intra-regional trade differs across industries. The exchange rate volatility has negative and significant effects only on the general machinery industry and a part of the electric machinery industry with more differentiated products, even when taking into account the world's demand for the final processed exports. These findings are supported by various kinds of exchange rate volatility in the short- and long-run. Our empirical results suggest that the different impact of the exchange rate volatility across industries is tied to the characteristics of traded goods in respective industries.

Keywords: Intermediate goods trade; Industry-specific exchange rate; Exchange rate volatility; Final goods exports; Production network; Asia
JEL classification: F31, F33, F14

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1. Introduction

Asian trade has been remarkably increasing with active investment and trade of foreign multinational firms. In particular, regional production networks are primarily driven by these multinationals not only from Japan but also from other East Asian countries such as Korea and Taiwan. These multinational firms located in the Mainland China and ASEAN countries, on one hand, import higher-skilled parts/components and capital goods from Japan, other East Asian and neighboring ASEAN countries and, on the other hand, export the finished goods to the US and European countries. Asia is thus characterized by the "triangular" trade with growing cross-border production fragmentation in the region.

Meanwhile, Asian countries have sought a regional monetary and exchange rate coordination especially after the 1997-98 currency crisis. Given a rapid progress of economic integration through trade and investment, regional exchange rate stability has gained a growing attention. However, it is not necessarily clear whether the exchange rate volatility affects intra-regional trade based on the production network. It is well known that what we observe in Asian trade cannot be explained properly by the textbook version of the theory of international trade.[1] The Asian production network consists of intricate combinations of intra-firm and arms-length trade transactions, where the production process of an industry is split into fragmented production blocks. A natural question is whether the volatility of regional exchange rates deteriorates the vertical intra-industry trade (VIIT) in Asia.

The purpose of this study is to investigate whether and how the volatility of exchange rate affects intra-regional production and distribution networks, characterized by trade of intermediate goods, in Asia by using a new industry-breakdown dataset of the bilateral real exchange rate. There is no clear consensus, both theoretically and empirically, as to whether the exchange rate volatility has negative or positive impact on international trade. When assuming a partial equilibrium model where exporting firms determine the volume of trade before the exchange rate is known, the effect of exchange rate uncertainty depends on the firms' risk-taking behavior and the shape of the profit function.[2] Even empirical studies have not yet demonstrated a clear-cut relationship between the exchange rate volatility and international trade, likely due to differences in the coverage of sample countries, sample period, model specifications, estimation

[1] See Kimura and Obashi (2011) for a good survey of the international production fragmentation.
[2] Clark (1973), for instance, theoretically demonstrates the negative impact of the exchange rate volatility on international trade, while Frank (1991) shows that a positive relationship can exist between the exchange rate volatility and trade.

techniques and types of the data. Interestingly, recent studies using the disaggregated trade data have found significantly negative impacts of the exchange rate volatility on intra-Asian trade (e.g., Thorbecke, 2008; Hayakawa and Kimura, 2009; Chit, et al., 2010; and Tang, 2011).

This paper differs from the previous studies in three respects. First, we use more detailed industry-breakdown data. Previous studies typically focus on one industry or aggregated intermediate goods trade. This paper deals with six industries, the general machinery, office machinery, electrical machinery, communication equipment, transport equipment, and precision instruments, based on the 2-digit level of the International Standard Industrial Classification (ISIC) Rev.3. As argued by Kimura et al. (2007), production and distribution networks of these industries are qualitatively and quantitatively the most important in Asia. Second, we construct a new dataset of the industry-specific real exchange rate to evaluate whether and how the exchange rate volatility differs across industries. The aggregate exchange rate may be inappropriate, since it cannot capture any differences in both price level and inflation across industries. Third, as the final processed exports are destined for countries outside the Asian region, not only the exchange rate but also the world demand for Asian exports of finished goods are considered as a possible driving force in the cross-border fragmentation and processing trade. Following Thorbecke (2008), we include the world's demand for the final processed exports in the regression specification as a possible explanatory variable.

Our novel finding is that, in contrast to the recent studies, the exchange rate volatility has negative and significant effect only on the general machinery industry and the electrical machinery industry, which are characterized by more differentiated export products, even when taking into account the world's demand for the final processed exports. These findings are supported by various kinds of the exchange rate volatility in the short- and long-run. Thus, the different impact of the exchange rate volatility across industries has to do with the characteristics of traded goods in respective industries.

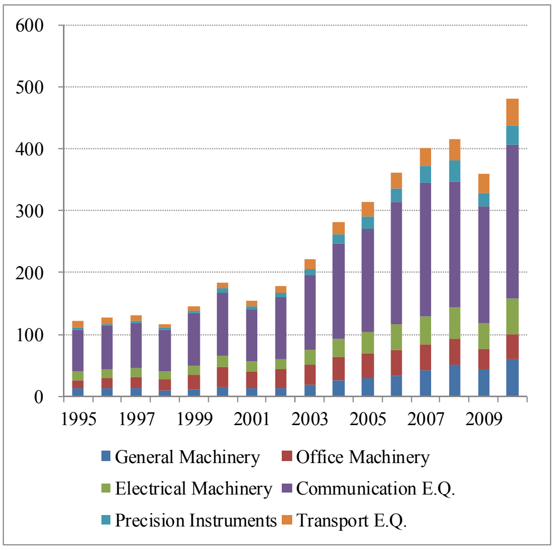
The paper is organized as follows. Section 2 presents the preliminary evidence of the Asian trade and exchange rates. Section 3 discusses the research methodology, definition of variables and description of the data. Section 4 presents our estimated results and robustness check. Finally, Section 5 concludes.

2. Preliminary Evidence of the Asian Trade and Exchange Rates

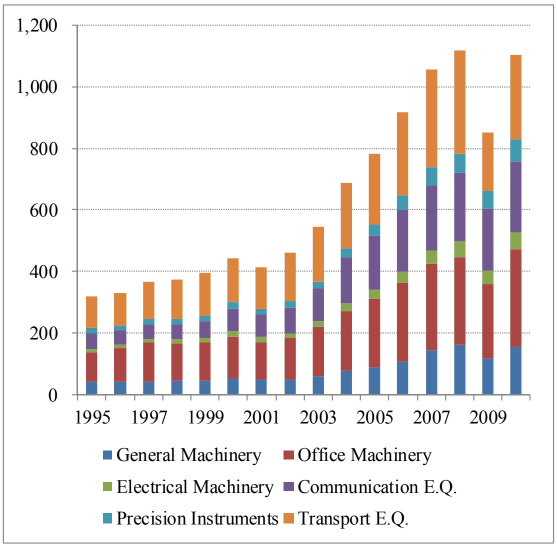
Let us first look at the recent trend of Asian trade. Figure 1 clearly shows that the triangular trade is actively conducted in Asia. Not only intra-Asian trade of intermediate goods but also finished goods exports to the world increased substantially from the early 2000s. While they fell sharply in 2009, both intra-Asian trade and exports to the world recovered quickly in 2010. Such large fluctuations have to do with a rapid and deep decline in the import demand of advanced countries, as these countries are seriously affected by the collapse of Lehman Brothers and the subsequent financial crisis. This observation indicates that intermediate goods trade in Asia is likely to be driven by the import demand of US and European countries that are the final destination for Asian finished goods exports.

Figure 1. Asian Triangular Trade: 1995-2010

1a. Intra-regional trade of intermediate goods



1b. Finished Goods Exports to the World

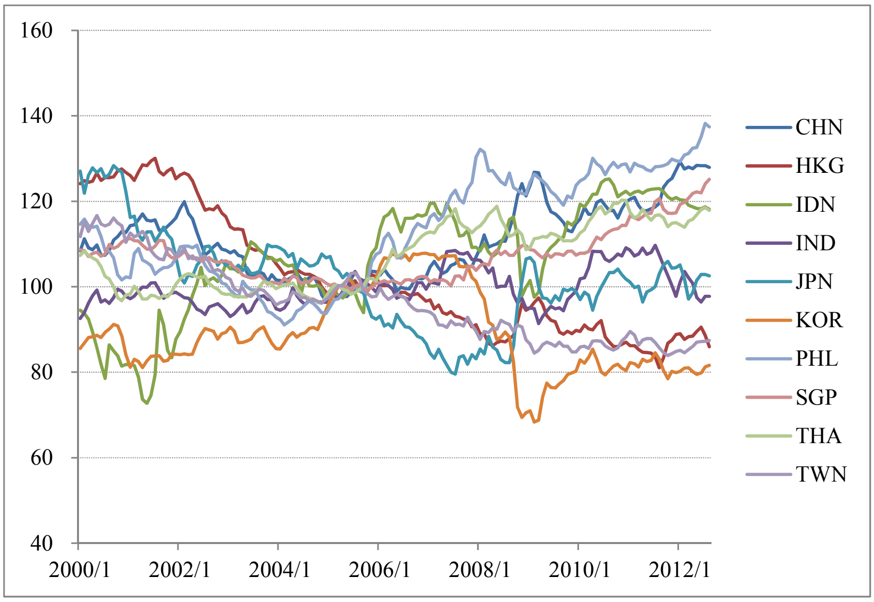


Note: Amounts of both intra-regional trade (USD billion) and finished goods exports to the world (USD billion) are calculated using the total machinery exports in 10 Asian economies: China, Indonesia, India, Japan, Korea, Malaysia, the Philippines, Singapore, Thailand and Taiwan. The machinery exports are based on the ISIC 2-digit classification that ranges from 29 to 34 (see Table 1 below). The "world" in Figure 1b is defined as the all countries except the above 10 Asian economies.

Source: Authors' calculation based on the OECD STAN database.

Asian trade may also be affected by the exchange rate fluctuations. As shown in Figure 2, the real effective exchange rate (REER) of Asian economies fluctuated to a large extent, which suggests large exchange rate fluctuations of intra-Asian currencies. Indeed, previous studies such as Thorbecke (2008), Hayakawa and Kimura (2009) and Tang (2011) analyze the effect of intra-Asian exchange rate volatility on intra-Asian trade. However, these studies use the overall exchange rate in real terms, and the industry-specific exchange rate is not considered at all.

Figure 2. Real Effective Exchange Rate of Asian Economies

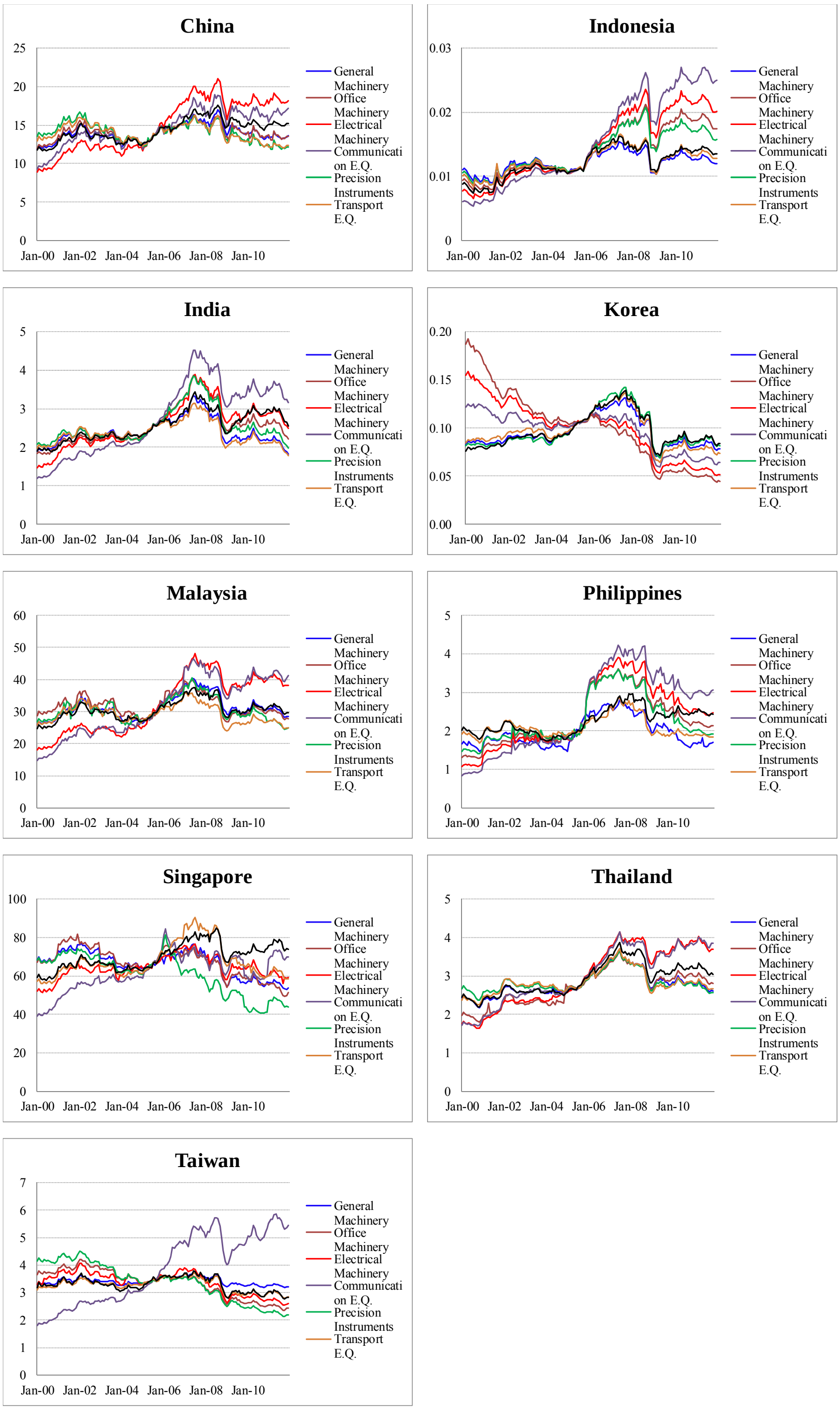


Note: CPI-based Real Effective Exchange Rates (broad indices). Monthly average (2005=100).

Source: Bank for International Settlements.

The REER in practice fluctuates differently across industries. Sato, Shimizu, Shrestha and Zhang (2012) construct the industry-specific REER of the yen and show the large differences of the REER of the yen across industries. For illustrative purposes, we use the same dataset of the industry-specific producer price index (PPI) and calculate the industry-specific bilateral real exchange rate of the yen vis-à-vis the Asian currencies from January 2000 to December 2011. Figure 3 indicates that the bilateral real exchange rate between the yen and other Asian currencies exhibits different movements across industries. As shown in Appendix Figure A1, the PPI in level has also changed differently across industries in all Asian countries. The above observation suggests that the conventional use of the real exchange rate is not sufficient for an analysis of the exchange rate impact on trade transactions. Industry-specific exchange rate is necessary for rigorous empirical examination of the effect of exchange rate changes on intra-Asian trade.

Figure 3. Industry-specific Real Exchange Rate of the Yen vis-à-vis the Asian Currencies: January 2000 through December 2011



Note: Authors' calculation using the monthly producer price index (PPI) listed in Table 1 below.

Source: IMF, *International Financial Statistics*, CD-ROM. See also Appendix Table A1.

3. Research Methodology

3.1 The Benchmark Model

The main purpose of this study is to investigate whether the exchange rate volatility has a negative impact on intra-Asian trade of intermediate goods. A number of existing studies such as Clark et al. (2004), Tenreyro (2007) and Hayakawa and Kimura (2009) empirically analyze the relationship between the exchange rate volatility and bilateral trade by using the gravity equation approach to take into account the following variables: GDP, distance between two countries, sharing of a common border and common language, etc. In our gravity equation, we also allow for the time varying exporter and importer effects to control not only for the multilateral effects proposed by Anderson and van Wincoop (2003)[3] but also for the time effects such as world business cycles, oil shock, global macroeconomic shock, etc.

Our empirical approach differs from the previous studies. First, we use the industry-specific bilateral real exchange rate between exporting and importing countries. As observed in the previous section, the level of the bilateral real exchange rate changes differently across industries. We use the industry-specific PPI data for sample countries and construct the dataset of the industry-specific bilateral real exchange rate series for each pair of Asian countries.

Second, we include the finished goods exports to the world in our gravity equation to take into consideration the import demand of the countries outside the Asian region for final goods from the Asian countries. As shown in the previous section, intra-Asian trade of intermediate goods is likely to be driven by the world demand for finished goods. Thorbecke (2008) also includes the explanatory variable of finished goods exports to the world. Since placing emphasis on industry differences, we include the industry-specific exports of final goods to the world as an extension of the gravity equation approach.

The baseline gravity equation is shown by:

$$\begin{aligned} \ln X_{ijt}^{k} = {} & \alpha_0 + \alpha_1 VOL_{ijt}^{k} + \alpha_2 FX_{jwt}^{k} + \alpha_3 \ln Y_{it} + \alpha_4 \ln Y_{jt} + \alpha_5 Dist_{ij} + \alpha_6 Adja_{ij} \\ & + \alpha_7 Lang + \alpha_8 s_{it} + \alpha_9 s_{jt} + \alpha_{10} s_t + \mu_{ijt}^{k}, \end{aligned} \tag{1}$$

[3] See Anderson and van Wincoop (2003) for a formulation of the concept of multilateral resistance, and Rose and van Wincoop (2000) for a related empirical implementation.

where t denotes time; k an industry; $\ln X_{ij}$ the natural log of exports of intermediate goods from country i to county j; VOL_{ij} the volatility of the bilateral real exchange rate between country i and country j; FX_{jw} the natural log of final goods exports from country j to the world; lnY the natural log of per capital GDP of country i and j, respectively; s_i, s_j and s multilateral effects and time effects, respectively; μ_{ijt} an error term. *Dist*, *Adja* and *Lang* represent distance, sharing of the common border and common language, respectively.

There is no clear consensus as to which proxy variable is the most appropriate for the exchange rate volatility. We employ two measures of the exchange rate volatility. The first measure is the standard deviation of the log difference of the industry-specific bilateral real exchange rate. The second one is the conditional volatility of the industry-specific real exchange rate estimated by the GARCH(1,1) model. Following Clark et al. (2004) and Chit et al. (2010), the first-difference of the log of monthly exchange rates is assumed to follow a random walk with a drift:

$$\Delta e_{ijt}^{k} = \alpha_0{}^{k} + \alpha_{ijt}^{k} \Delta e_{ijt-1}^{k} + u_{ijt}^{k},$$

where $u_{ijt} \sim N(0, h_{ijt})$ and Δe_{ijt}^{k} means the first-difference of the natural log of the bilateral real exchange rate of industry k at t period between countries i and j. The conditional variance is defined as;

$$h_{ijt}^{k} = \beta_0^{k} + \beta_1^{k} u_{ijt-1}^{k,2} + \beta_2^{k} h_{ijt}^{k},$$

where $u_{ijt-1}^{k,2}$ denotes the square of residuals, u_{ijt-1}^{k}, estimated by ARCH model at t-1 period. It has one lag of the regressed ARCH model's residual and one lag of the variance itself (1 GARCH term). The estimated standard deviation of each country pair is used as the approximation of the exchange rate volatility.

As discussed in Clark et al. (2004) and Thorbecke (2008), when considering the impact of the exchange rate volatility on trade flows, the timing issue is crucial. A number of previous studies use the lagged exchange rate volatility to investigate the impact of the exchange rate changes on trade, since trade contracts tend to be longer and the firms' pricing behavior is unlikely to be changed for a short period. However, exporters may also have more concern about the short-run exchange rate volatility, as longs as their trade contracts are very short, where it is more appropriate to use the volatility of exchange rate in the current year.

The timing issue is also related to the role of "sunk costs". Clark et al. (2004) states that firm's trade is less responsive to the short-run volatility of exchange rates, given a large investment of exporting firms in foreign markets to build marketing and distribution networks and/or to set up production facilities. Once production network is established, the relation-specific nature of intermediate goods transactions may also lessen the exchange rate effect on trade in the short-run.

This paper uses four kinds of time windows to allow for timing and uncertainty issues. First is the volatility of the exchange rate in the current year, which is called contemporaneous volatility. The second one is the volatility during the current and the previous year (i.e., the two-year volatility), and the third one is the volatility in the current year and the previous two years (i.e., the three-year volatility). The second and third indicators are for the long-run volatility. The fourth one is the volatility in the previous year, the current year and the next year. Thorbecke (2008) uses this fourth measure to allow for uncertainty of exchange rate changes, since uncertainty is a forward-looking concept.

3.2 Industry-specific Exchange Rate

We construct a new dataset of the industry-specific real exchange rate to allow for the difference in price elasticities across industries. We use the 2-digit ISIC Rev.3 for our industrial classification. As pointed out by Kimura et al. (2007), the international production and distribution networks in Asia are well developed in the general machinery, electric machinery, transport equipment, and precision machinery industries. Among twenty-three 2-digit sectors, we focus on seven sectors from ISIC-29 to 33 which are converted into six industries. The details of the industry classification are reported in Appendix Table A2.

We use the following formula to construct the industry-specific exchange rate:

$$RER_{ijt}^{k} = NER_{ijt} \times \frac{P_{jt}^{k}}{P_{it}^{k}}, \qquad (2)$$

where t denotes time; k industry; NER_{ij} the bilateral normal exchange rate; P_i and P_j the industry-specific price of home country and partner country, respectively. We use the producer price index (PPI) as the price deflator. The price data is normalized to 100 as of 2005. Table 1 shows the availability of the industry-specific price data. Since the price data of each ISIC category is not available for all countries, we use the price data of the similar industry.

Table 1. Industry-specific Price Data

<table>
<tr><th>ISIC</th><th>Industry Classification</th><th>CHN</th><th>IDN</th><th>IND</th><th>JPN</th><th>KOR</th><th>MYS</th><th>PHL</th><th>SGP</th><th>THA</th><th>TWN</th></tr>
<tr><td>29</td><td>Machinery and Equipment n.e.c.</td><td>▲</td><td>○</td><td>○</td><td>○</td><td>○</td><td>○</td><td>○</td><td>●</td><td>○</td><td>○</td></tr>
<tr><td>30</td><td>Office,Accounting and Computing Machinery</td><td rowspan="2">○</td><td>X</td><td>X</td><td rowspan="2">○</td><td>X</td><td>○</td><td>X</td><td>○</td><td>○</td><td>○</td></tr>
<tr><td>31</td><td>Electrical Machinery and Apparatus n.e.c.</td><td rowspan="3">○</td><td>●</td><td>○</td><td>○</td><td>○</td><td>○</td><td>○</td><td>○</td></tr>
<tr><td>32</td><td>Communication Equipment and Apparatus</td><td>○</td><td>X</td><td>○</td><td>○</td><td>○</td><td>X</td><td>○</td><td>○</td><td rowspan="2">○</td></tr>
<tr><td>33</td><td>Medical, Precision and Optical Instruments</td><td>○</td><td>X</td><td>○</td><td>○</td><td>○</td><td>X</td><td>●</td><td>○</td></tr>
<tr><td>34</td><td>Motor Vehicles, Trailers and Semi-trailers</td><td rowspan="2">○</td><td rowspan="2">○</td><td rowspan="2">○</td><td rowspan="2">○</td><td rowspan="2">○</td><td>○</td><td rowspan="2">○</td><td rowspan="2">○</td><td rowspan="2">○</td><td>○</td></tr>
<tr><td>35</td><td>Other Transport Equipment</td><td>○</td><td>○</td></tr>
<tr><td colspan="2">Index</td><td>PPI</td><td>WPI</td><td>WPI</td><td>CGPI</td><td>PPI</td><td>PPI</td><td>PPI</td><td>PPI</td><td>PPI</td><td>WPI</td></tr>
</table>

Notes:

All countries publish the industry specific price data that follows not ISIC but their own classification, except for Malaysia and Thailand the data of which is based on ISIC.

○ means that the data is available but not exactly corresponds to ISIC.

● means that more detailed data is available, and the industry weight data is also available.

▲ means that more detailed data is available, but the industry weight data is not available.

X means that the data is not available.

Source: See Appendix Table A1.

3.3 Data

Japan and emerging Asian 9 economies (China, Korea, India, Indonesia, Malaysia, Philippines, Singapore, Thailand and Taiwan) are analyzed in this study. The sample period for empirical analysis ranges from 2003 to 2010 not only due to the limitation of data availability on the industry-breakdown PPI but also because of the calculation of the exchange rate volatility.

The annual data on exports in terms of US dollars are taken from *OECD STAN Bilateral Trade Database by Industry and End-use (BTDIxE)*. The database presents international trade in goods flows broken down both by industry sector and by end-use categories, allowing for insights into the patterns of trade in intermediate goods between countries to track global production networks and supply chains.[4] The industry

[4] See the URL below for the details:

classification of this database is ISIC Rev.3. The trade data is deflated by the industry-specific producer price index.[5] The monthly series of the nominal exchange rate is obtained from the IMF, *International Financial Statistic*, CD-ROM. Most of the monthly series of the industry-breakdown price data are obtained from the official statistics of respective countries and the CEIC Database. The details of the data source are presented in Appendix Table A1. The GDP Data is taken from World Bank, *World Development Indicators* (WDI). The gravity variables are obtained from the World Bank website.

Table 2 presents the summary statistics of the main variables: real exports of intermediate goods and final goods and two types of the sectoral exchange rate volatility. Among six sectors, the level of intraregional intermediate goods exports of the communication equipment is the highest, while that of the precision instruments is the lowest. In exports of final goods, the level of the office machinery is the highest. The degree of the real exchange rate volatility is the highest in the office machinery and the second highest in the precision instruments.

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http://www.oecd-ilibrary.org/science-and-technology/compilation-of-bilateral-trade-database-by-industry-and-end-use-category_5k9h6vx2z07f-en

[5] We also use the aggregated PPI as a price deflator but no significant differences are found in the estimated results.

Table 2.Summary Statistics

	General Machinery	Office Machinery	Electrical Machinery	Communication Equipment	Precision Instruments	Transport Equipment
	Exports of intermediate goods and final goods					
Log of real intermediate goods exports						
Mean	13.871	13.668	13.996	15.419	12.612	13.493
S.D.	1.783	2.515	1.766	2.394	2.200	1.739
Min	8.350	5.619	9.761	7.791	5.762	8.572
Max	18.348	17.712	18.554	19.663	18.690	18.393
Log of real final goods exports						
Mean	17.308	18.102	16.557	17.864	16.579	16.622
S.D.	1.766	1.643	1.344	1.791	1.638	2.883
Min	13.873	14.849	13.570	14.347	13.475	10.099
Max	20.478	21.689	19.535	21.247	19.706	21.539
	Industry-specific real exchange rate volatility: Standard deviation					
Current year (12 months)						
Mean	0.024	0.030	0.027	0.032	0.031	0.022
S.D.	0.011	0.018	0.017	0.017	0.018	0.010
Min	0.007	0.008	0.008	0.008	0.007	0.006
Max	0.071	0.115	0.110	0.111	0.115	0.078
Current year and previous year (24 months)						
Mean	0.024	0.032	0.029	0.033	0.033	0.023
S.D.	0.010	0.016	0.016	0.015	0.016	0.009
Min	0.007	0.009	0.009	0.009	0.009	0.008
Max	0.062	0.088	0.083	0.084	0.088	0.068
Current year and previous two years (36 months)						
Mean	0.025	0.034	0.030	0.034	0.034	0.025
S.D.	0.009	0.015	0.016	0.015	0.016	0.010
Min	0.008	0.010	0.010	0.009	0.010	0.009
Max	0.054	0.083	0.076	0.077	0.083	0.059
Previous year, current year and next year (36 months)						
Mean	0.025	0.032	0.029	0.034	0.033	0.024
S.D.	0.009	0.015	0.015	0.014	0.014	0.009
Min	0.008	0.010	0.011	0.010	0.011	0.009
Max	0.054	0.083	0.076	0.077	0.083	0.059
	Industry-specific real exchange rate volatility: GARCH(1,1) Model					
Current year (12 months)						
Mean	0.025	0.033	0.030	0.034	0.034	0.024
S.D.	0.009	0.013	0.013	0.012	0.013	0.008
Min	0.011	0.012	0.011	0.013	0.011	0.009
Max	0.057	0.084	0.080	0.080	0.084	0.063
Current year and previous year (24 months)						
Mean	0.025	0.033	0.030	0.034	0.034	0.024
S.D.	0.009	0.013	0.013	0.012	0.013	0.007
Min	0.011	0.013	0.011	0.013	0.011	0.011
Max	0.056	0.079	0.079	0.079	0.079	0.062
Current year and previous two years (36 months)						
Mean	0.025	0.034	0.030	0.034	0.034	0.025
S.D.	0.008	0.012	0.013	0.012	0.013	0.007
Min	0.010	0.013	0.012	0.014	0.011	0.011
Max	0.050	0.073	0.072	0.072	0.074	0.057
Previous year, current year and next year (36 months)						
Mean	0.025	0.033	0.030	0.034	0.034	0.024
S.D.	0.008	0.012	0.013	0.011	0.012	0.007
Min	0.011	0.013	0.012	0.014	0.011	0.011
Max	0.049	0.073	0.072	0.072	0.073	0.053
Obs.	720	720	720	720	720	720

Note: Exports of intermediate goods and final goods denote the natural log of the bilateral trade amounts deflated by industry-specific producer price index (PPI).

4. Estimation Results

In the following, we report the benchmark results and two additional empirical results for robustness check from Equation (1) using the pooled OLS estimator. For all estimation, we take into account the time-varying country effect and the time fixed effect for the period from 2003 to 2010.

4.1 Benchmark Result

Table 3 presents the benchmark result with the industry-specific real exchange rate volatility calculated from the three-year data on the current year and the previous two years. Our main interest is in the difference of the exchange rate volatility impact on trade across sectors. While recent studies such as Thorbecke (2008) and Hayakawa and Kimura (2009) found a significantly negative impact of the real exchange rate volatility on machinery trade, Table 3 shows that the exchange rate impact is significantly negative only in the general machinery and the electrical machinery. As motioned above, the difference of the estimated results may be due to the differences in trade structures across sectors. These two sectors with the negative exchange rate impact may be more involved in arm's length (inter-firm) transactions, while the rest of the sectors tend to conduct intra-firm transactions.

Another interesting finding is that final goods exports to the world have significantly positive impact on trade of intermediate goods for all industries at the 1 percent significance level. For all industries, the results indicate that an increase in final goods exports from a country will increase the flow of intermediate goods into the country. Among the industries, the precision instruments industry is the most sensitive to final goods exports and the transport equipment industry is the least sensitive. Almost all coefficients of the remaining variables are estimated to be significant with expected signs, except for adjacency and ASEAN dummies. Although the theoretical foundations of gravity model suggest that two countries sharing a common border will trade more, our result shows that the adjacency dummy is significantly negative in the general machinery and electrical machinery at 5 percent level and statistically insignificant for other industries. The result is reasonable, since almost all countries in our sample do not share the common border. Our results also show that the coefficient of the importing country's income variable is larger than that of home country's (export country) income. This finding is consistent with the theoretical prediction and empirical findings of

Feenstra et al. (2001), which suggests that a country's exports are more sensitive to the importing country's income than to its own income.

Table 3. Benchmark Results: Industry-specific Exchange Rate Volatility

Variables:	*Industries*:					
	General Machinery	Office Machinery	Electrical Machinery	Communication Equipment	Precision Instruments	Transport Equipment
Exchange rate volatility	-17.07**	6.321	-26.81**	-3.773	6.261	9.725
(pervious two years and current year)	(5.43)	(13.90)	(8.89)	(8.64)	(8.07)	(14.82)
Final goods exports	0.604***	0.867***	0.604***	0.291***	0.921***	0.191***
	(0.05)	(0.07)	(0.08)	(0.04)	(0.07)	(0.05)
Exporters' GDP per capita	0.512***	0.534***	0.314***	1.343***	0.682***	0.585***
	(0.06)	(0.16)	(0.07)	(0.09)	(0.12)	(0.14)
Importers' GDP per capita	0.622***	0.725***	0.662***	0.776***	0.968***	0.528***
	(0.09)	(0.13)	(0.10)	(0.08)	(0.12)	(0.12)
Distance	-0.868***	-0.667***	-0.978***	-0.591***	-0.596***	-0.761***
	(0.06)	(0.14)	(0.07)	(0.06)	(0.09)	(0.09)
Adjacency	-0.291**	0.147	-0.438**	-0.218	-0.205	0.242
	(0.12)	(0.35)	(0.13)	(0.13)	(0.23)	(0.16)
Common Language	-0.135	-0.837***	0.175	-0.277**	0.393**	-0.375**
	(0.13)	(0.20)	(0.11)	(0.11)	(0.17)	(0.12)
ASEAN	0.342**	0.660**	-0.0261	0.195	1.485***	0.571**
	(0.12)	(0.24)	(0.14)	(0.13)	(0.19)	(0.20)
Year effects	yes	yes	yes	yes	yes	yes
Time-varying exporter effects	yes	yes	yes	yes	yes	yes
Time-varying importer effects	yes	yes	yes	yes	yes	yes
Observations	720	720	720	720	720	720
R-squared	0.924	0.866	0.912	0.953	0.885	0.771

Notes:

Standard errors are in parentheses. ***, ** and * denote the significance at 1 percent, 5 percent and 10 percent level, respectively.

The exchange rate volatility in three years (i.e., previous two years and the current year) is used for the benchmark estimation..

4.2 Robustness Check

To check the robustness of our benchmark result, we conduct additional empirical examinations. We calculated four types of the exchange rate volatility: (i) the volatility of the exchange rate in the current year, (ii) the volatility during the current and the previous year (i.e., the two-year volatility), (iii) the volatility in the current year and the previous two years (i.e., the three-year volatility), and (iv) the volatility in the previous year, the current year and the next year. We also calculate the four types of volatility by using two different exchange rates: one is the aggregate real exchange rate and the other is the industry-specific real exchange rate. Tables 4 and 5, respectively, show the results obtained from the aggregate real exchange rates and those from the industry-specific one.

In Table 4, we cannot find significantly negative impact of the exchange rate volatility on intermediate goods trade when the volatility is measured by the standard deviation. If the exchange rate volatility is estimated by the GARCH model, we find significantly negative effect on trade only in the general machinery. This result is consistent with the presumption that the aggregate real exchange rate is not appropriate for the sectoral analysis.

Table 5 clearly shows that our findings obtained from the benchmark estimation are robust even though we use different measures of the exchange rate volatility. In all cases, the significantly negative impacts are found in the general machinery and the electrical machinery.

Table 4. Robustness Check by the Aggregate Real Exchange Rate

Variables :	*Industries* :					
	General Machinery	Office Machinery	Electrical Machinery	Communication Equipment	Precision Instruments	Transport Equipment
Aggregate real exchange rate: Standard deviation						
Current year (12 months)						
Exchange rate volatility	-2.436	14.75	9.811	1.591	8.307	26.79**
	(6.26)	(11.57)	(6.78)	(8.00)	(9.53)	(11.88)
Final goods exports	0.642***	0.869***	0.735***	0.291***	0.923***	0.181***
	(0.05)	(0.07)	(0.06)	(0.04)	(0.07)	(0.05)
Previous year and current year (24 months)						
Exchange rate volatility	-2.321	16.61	10.38	-2.789	13.54	31.08**
	(6.95)	(12.38)	(8.03)	(9.23)	(10.53)	(15.55)
Final goods exports	0.642***	0.875***	0.732***	0.289***	0.930***	0.171***
	(0.05)	(0.07)	(0.06)	(0.04)	(0.07)	(0.05)
Previous two years and current year (36 months)						
Exchange rate volatility	-8.875	7.634	3.302	-10.70	11.46	29.48*
	(7.09)	(13.05)	(8.43)	(9.32)	(10.74)	(15.67)
Final goods exports	0.647***	0.878***	0.737***	0.284***	0.946***	0.170**
	(0.05)	(0.08)	(0.06)	(0.04)	(0.08)	(0.05)
previous year, current year, next year (36 months)						
Exchange rate volatility	-5.946	18.22	9.299	-0.815	20.38*	25.14
	(7.30)	(12.97)	(8.42)	(9.29)	(11.44)	(16.89)
Final goods exports	0.647***	0.871***	0.734***	0.290***	0.930***	0.173**
	(0.05)	(0.07)	(0.06)	(0.04)	(0.07)	(0.05)
Aggregate real exchange rate: GARCH(1,1) Model						
Current year (12 months)						
Exchange rate volatility	-11.12*	0.183	-1.748	-8.083	7.258	14.62
	(6.73)	(12.68)	(8.47)	(8.74)	(10.29)	(16.55)
Final goods exports	0.649***	0.861***	0.740***	0.287***	0.927***	0.180***
	(0.05)	(0.07)	(0.06)	(0.04)	(0.07)	(0.05)
Previous year and current year (24 months)						
Exchange rate volatility	-13.84*	-5.650	-2.644	-13.09	8.822	25.01
	(7.56)	(13.81)	(9.44)	(9.96)	(11.37)	(18.31)
Final goods exports	0.653***	0.851***	0.741***	0.285***	0.936***	0.169**
	(0.05)	(0.08)	(0.06)	(0.04)	(0.08)	(0.05)
Previous two years and current year (36 months)						
Exchange rate volatility	-15.69*	-4.775	-4.691	-14.96	10.20	28.67
	(8.29)	(15.62)	(10.38)	(10.46)	(12.97)	(18.89)
Final goods exports	0.656***	0.851***	0.742***	0.283***	0.942***	0.167**
	(0.05)	(0.08)	(0.06)	(0.04)	(0.08)	(0.06)
previous year, current year, next year (36 months)						
Exchange rate volatility	-16.08**	-5.448	-2.274	-12.12	12.44	25.06
	(8.17)	(16.14)	(10.25)	(10.85)	(13.01)	(20.43)
Final goods exports	0.657***	0.853***	0.741***	0.287***	0.939***	0.170**
	(0.05)	(0.08)	(0.06)	(0.04)	(0.08)	(0.05)
Year effects	yes	yes	yes	yes	yes	yes
Time-varying exporter effects	yes	yes	yes	yes	yes	yes
Time-varying importer effects	yes	yes	yes	yes	yes	yes
Observations	720	720	720	720	720	720

Notes: Standard errors are in parentheses. ***, ** and * denote the significance at 1 percent, 5 percent and 10 percent level, respectively. The estimated coefficients of gravity variables are not reported, since results are very similar in all cases.

Table 5. Robustness Check by the Industry-specific Real Exchange Rate

Variables :	*Industries* :					
	General Machinery	Office Machinery	Electrical Machinery	Communication Equipment	Precision Instruments	Transport Equipment
Industry-specific real exchange rate: Standard deviation						
Current year (12 months)						
Exchange rate volatility	-10.30**	13.68	-14.64**	3.553	2.909	8.246
	(5.02)	(10.23)	(7.23)	(5.50)	(6.60)	(11.24)
Final goods exports	0.633***	0.844***	0.664***	0.294***	0.914***	0.198***
	(0.05)	(0.07)	(0.07)	(0.04)	(0.07)	(0.05)
Previous year and current year (24 months)						
Exchange rate volatility	-13.42**	14.12	-23.19**	-3.353	3.237	12.34
	(5.09)	(12.28)	(8.40)	(7.56)	(7.39)	(13.64)
Final goods exports	0.601***	0.856***	0.586***	0.291***	0.915***	0.196***
	(0.05)	(0.07)	(0.08)	(0.04)	(0.07)	(0.05)
previous year, current year, next year (36 months)						
Exchange rate volatility	-18.30***	16.23	-26.67**	-1.618	8.052	8.066
	(5.26)	(13.92)	(9.67)	(8.87)	(8.62)	(15.19)
Final goods exports	0.608***	0.847***	0.593***	0.290***	0.908***	0.193***
	(0.05)	(0.07)	(0.08)	(0.04)	(0.07)	(0.05)
Industry-specific real exchange rate: GARCH(1,1) Model						
Current year (12 months)						
Exchange rate volatility	-19.78***	1.753	-21.67**	1.254	2.240	4.347
	(5.06)	(7.98)	(7.54)	(5.44)	(7.15)	(12.70)
Final goods exports	0.617***	0.861***	0.631***	0.293***	0.917***	0.190***
	(0.05)	(0.07)	(0.08)	(0.04)	(0.07)	(0.05)
Previous year and current year (24 months)						
Exchange rate volatility	-24.22***	5.378	-28.92***	1.067	-0.352	7.974
	(5.62)	(9.54)	(8.55)	(6.13)	(7.83)	(14.72)
Final goods exports	0.594***	0.866***	0.586***	0.292***	0.918***	0.189***
	(0.05)	(0.07)	(0.08)	(0.04)	(0.07)	(0.05)
Previous two years and current year (36 months)						
Exchange rate volatility	-26.63***	1.600	-31.74***	0.628	0.858	10.79
	(6.27)	(11.43)	(8.95)	(6.68)	(8.50)	(15.97)
Final goods exports	0.595***	0.863***	0.586***	0.292***	0.918***	0.188***
	(0.05)	(0.07)	(0.08)	(0.04)	(0.07)	(0.05)
previous year, current year, next year (36 months)						
Exchange rate volatility	-27.80***	5.450	-32.66***	-0.448	4.596	4.832
	(5.95)	(11.08)	(9.74)	(7.07)	(9.34)	(17.20)
Final goods exports	0.598***	0.863***	0.578***	0.289***	0.919***	0.190***
	(0.05)	(0.07)	(0.08)	(0.04)	(0.07)	(0.05)
Year effects	yes	yes	yes	yes	yes	yes
Time-varying exporter effects	yes	yes	yes	yes	yes	yes
Time-varying importer effects	yes	yes	yes	yes	yes	yes
Observations	720	720	720	720	720	720

Notes: Standard errors are in parentheses. ***, ** and * denote the significance at 1 percent, 5 percent and 10 percent level, respectively. The estimated coefficients of gravity variables are not reported, since results are very similar in all cases.

5. Concluding Remarks

The international production and distribution network is well developed in Asia, which results in a remarkable expansion of intermediate goods trade characterized as a vertical intra-industry trade. Since finished goods produced in the network are exported to the markets throughout the world, the demand for final goods is likely to promote the intra-Asian trade of intermediate goods. Meanwhile, the intra-regional exchange rate volatility has increased substantially among Asian countries. The exchange rate volatility, by increasing uncertainty, reduces the locational benefits of cross-border fragmentation and is likely to increase the service link cost. Consequently, it may harm the intermediate goods trade or cross-border fragmentation.

In this paper we have empirically investigated the impact of exchange rate volatility on intermediate goods exports for general machinery, office machinery, electrical machinery, communication equipment, precision instruments and transport equipment in which the networks are qualitatively and quantitatively most important. Since the price elasticity is quite different across sectors, we construct a new dataset of industry-specific real exchange rates and deflate the trade values by industry-breakdown producer price index.

It is found that, in contrast to the recent studies, the exchange rate impact on intra-regional trade differs across industries. The exchange rate volatility has negative and significant effect only on the general machinery industry and a part of the electric machinery industry with more differentiated products, even when taking into account the world's demand for the final processed exports. These findings are supported by various kinds of the exchange rate volatility in the short- and long-run. Our empirical results suggest that the different impact of the exchange rate volatility across industries has to do with the characteristics of traded goods in respective industries.

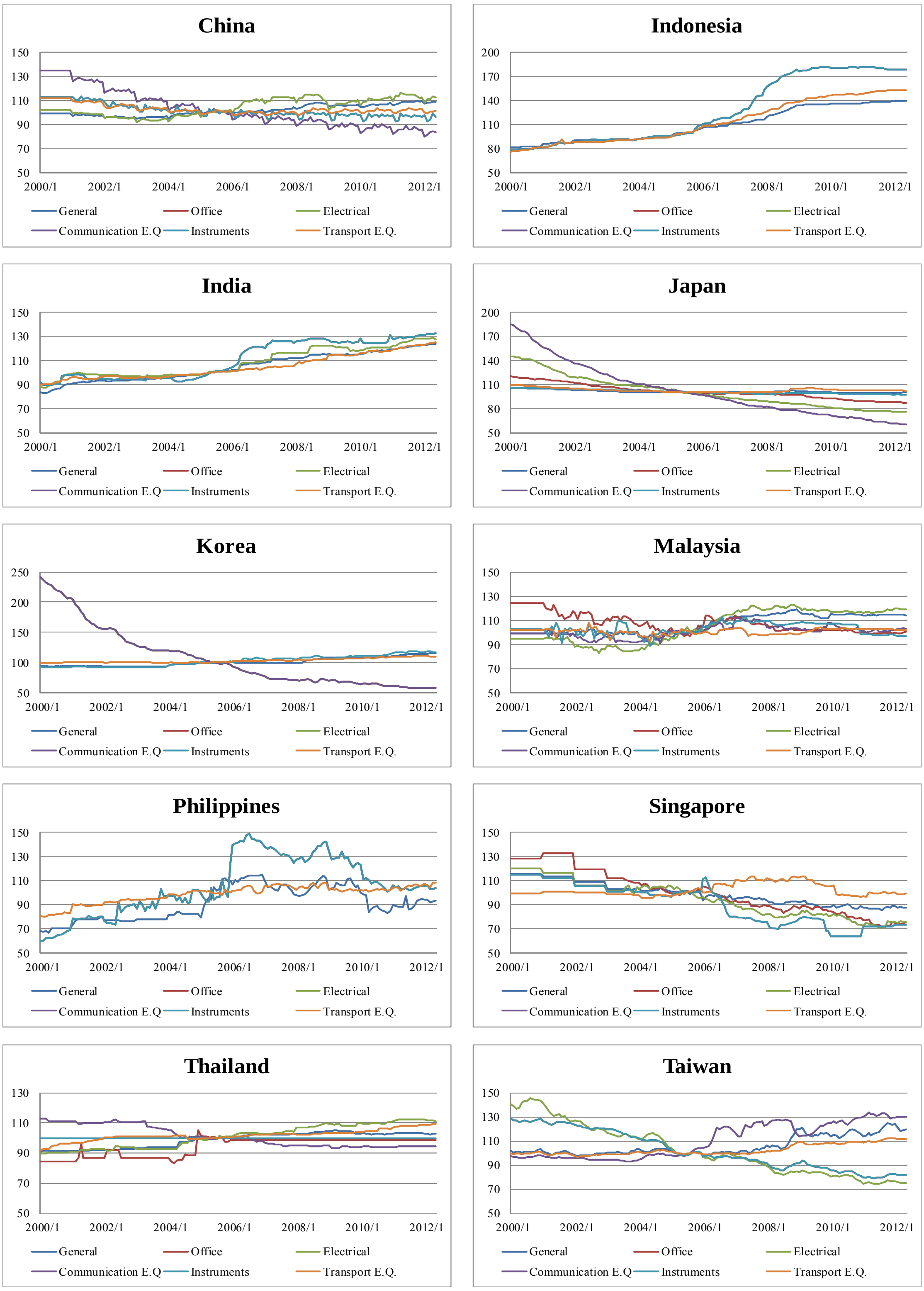
Appendix Table A1. Data Source

Country	Datasource	Link
China	1. CEIC	
	2. *China Statistical Yearbook*	
India	Office of Economic Adviser to Government of India	http://eaindustry.nic.in/
Indonesia	1. BPS, *Indikator Ekonomi* (*Economic Indicators*)	
	2. CEIC	
Japan	Bank of Japan	http://www.boj.or.jp/
Korea	The Bank of Korea	http://eng.bok.or.kr/eng/engMain.action
Malaysia	CEIC	
Philippines	1. Republic of Philippines National Statistics Office	http://www.census.gov.ph
	2. *Philippine Yearbook*	
Singapore	CEIC	
	Statistics Singapore	http://www.singstat.gov.sg/
Thailand	CEIC	
Taiwan	CEIC(include output data)	
Grivity Data	World Bank	
GDP Data	World Bank (WDI)	http://data.worldbank.org/data-catalog
Trade Data	OECD STAN Database	http://stats.oecd.org/

Appendix Table A2. Details of the Industries

ISIC 4-digit	*Industry*
	General Machinery (*Machinery and Equipment n.e.c.*)
2911	Engines and turbines, except aircraft, vehicle and cycle engines
2912	Pumps, compressors, taps and valves
2913	Bearings, gears, gearing and driving elements
2914	Ovens, furnaces and furnace burners
2915	Lifting and handling equipment
2919	Other general purpose machinery
2921	Agricultural and forestry machinery
2922	Machine-tools
2923	Machinery for metallurgy
2924	Machinery for mining, quarrying and construction
2925	Machinery for food, beverage and tobacco processing
2926	Machinery for textile, apparel and leather production
2927	Weapons and ammunition
2929	Other special purpose machinery
2930	Domestic appliances n.e.c.
	Office Machinery (*Office, Accounting and Computing Machinery*)
3000	Office, accounting and computing machinery
	Electrical Machinery (*Electrical Machinery and Apparatus n.e.c.*)
3110	Electric motors, generators and transformers
3120	Electricity distribution and control apparatus
3130	Insulated wire and cable
3140	Accumulators, primary cells and primary batteries
3150	Electric lamps and lighting equipment
3190	Other electrical equipment n.e.c.
	Communication Equipment (*Communication Equipment and Apparatus*)
3210	Electronic valves and tubes and other electronic components
3220	Television and radio transmitters and apparatus for line telephony and line telegraphy
3230	Television and radio receivers, sound or video recording or reproducing apparatus, and associated goods
	Precision Instruments (*Medical, Precision and Optical Instruments*)
3311	Medical and surgical equipment and orthopedic appliances
3312	Instruments and appliances for measuring, checking, testing, navigating and other purposes, except industrial process control equipment
3313	Industrial process control equipment
3320	Optical instruments and photographic equipment
3330	Watches and clocks
	Transport Equipment (*Motor Vehicles, Trailers and Semi-trailers*)
3410	Motor vehicles
3420	Bodies (coachwork) for motor vehicles; trailers and semi-trailers
3430	Parts and accessories for motor vehicles and their engines

Appendix Figure A1. Producer Price Index by Industry in Asia Countries



Notes: The base year is 2005. The details of the data source is shown in Appendix Table A1.

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