

# Stability and Resiliency of Production Networks in East Asia: Implications for the Impact of the Global Recession<sup>\*†</sup>

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## Abstract

There has been rising concern that adverse effects of the recent global economic downturn spread across East Asia through international production networks. With a drastic drop in final demand, mutual ties built through supply chains would bring a synchronized contraction of trade flows across countries taking part in the production networks; however, trade relationships within the networks appear to be stable and resistant to the shocks due to relation-specific nature of the transactions. This paper highlights that transactions of intermediate goods within production networks face a higher probability of continuance compared to other transactions. Moreover, the paper presents the resilience of East Asian production networks even in face of the Asian financial and currency crisis back in 1997-98. To this end, survival analysis is conducted using the country-product level trade data, which enables us to reveal the probability of continuance once a trade relationship is established and the probability of recovery after the transaction is broken off.

**Keywords:** Duration of trade; fragmentation; East Asia; the Asian crisis

**JEL Categories:** F10; F14

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## 1. Introduction

Despite the financial origins of the recent economic downturn in the US and Europe, the impact on East Asian countries has been felt primarily through the trade channel. The export-oriented manufacturing industries and countries dependent on them have been hit the hardest in Asia (ADB, 2009a,b). Due to a drastic drop in external final demand for manufactured goods produced in East Asian countries, concern is greatest for adverse effects of the global financial crisis and economic downturn on the real economies of the region. According to the latest data for the second quarter of 2009, industrial production and exports in newly industrialized economies, i.e., Hong Kong, Rep. of Korea, Singapore, and Taipei, already show the beginning of what might be a V-shaped recovery (ADB, 2009b). Nevertheless, there is concern about the overdependence on external final demand and that through international production networks stretched across the region, East Asian countries will continue to suffer from the deteriorating economic conditions outside the region centering on the US.

The more interdependent countries are, the more quickly an economic shock originating in one country is transmitted to another. Once final demand is decreased, mutual ties built through supply chains would bring a synchronized contraction of trade flows across countries taking part in the production networks; however, trade relationships within the networks appear to be stable and resistant to the shocks due to relation-specific nature of the transactions. Given the need for coordination between upstream and downstream production processes as well as the presence of sunk costs of investing in newly fragmented production block, the network-forming firms would put priority not only on lowering production costs but on the stability of trade relationships.<sup>1</sup> In this sense, transactions of intermediate goods within production networks are necessarily based on special relationship, unlike in the case of finished products made from start to finish in one country as well as goods sold on the open market. This paper examines such stability of trade relationships within international

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<sup>1</sup> As a source of hysteresis in exports at the firm level, the role of sunk costs to enter the export market has been examined theoretically (Baldwin, 1988; Baldwin and Krugman, 1989; Dixit, 1989a,b) and empirically (Robert and Tybout, 1998; Bernard and Jensen, 2004).

production networks in East Asia and its resilience in face of the Asian financial and currency crisis back in 1997-98.

East Asian countries have expanded and deepened intraregional trade relationships since the beginning of the 1990s. Regional diversity in income levels and development stages promotes opportunities for multinational enterprises to locate fragmented production blocks in different locations with different location advantages all over the region.<sup>2</sup> In particular, the machinery industry extends the most sophisticated networks (See Fukao et al., 2003; Athukorala and Yamashita, 2006; Kimura, 2006), and the increasing importance of exports and imports of machineries are evident for each of East Asian countries. In the light of the unprecedented development of production networks along with active back-and-forth transactions of machinery parts & components, this paper basically examines intra-East Asian trade relationships of machinery parts & components, in comparison with those of finished products, so as to look into unexplored natures of production networks.

The goal of this paper is to verify the stability of international production networks in East Asia and to shed light on its resilience amid the Asian crisis. To this end, survival analysis is conducted using highly disaggregated trade data at the country-product level, which enables us to reveal the probability of continuance once a trade relationship is established and the probability of recovery after the transaction is broken off. A series of survival analyses provide an evidence to support the stability of the transactions of intermediate goods within production networks and its resilience to a temporary disruption due to economic shocks. First, machinery parts & components are more likely to be traded through long-lived relationships compared to finished products. The higher probability of continuance for parts & components is robust even after considering possible effects of the Asian crisis on the probability of continuance/discontinuance. Second, although trade relationships of machinery parts & components are no exception in that a nonnegligible portion was actually broken off amid the Asian crisis, they were more resistant than those of finished products. And,

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<sup>2</sup> For the fragmentation theory, see Jones and Kierzkowski (1990), Arndt and Kierzkowski (2001), and Deadorff (2001). In terms of international production networks in East Asia, Kimura and Ando (2005) claim the two-dimensional concept of fragmentation.

even when broken off, many of the trade relationships of parts & components were restored shortly afterward as compared to finished products as well as the case of transactions that were discontinued at times other than the Asian crisis.

This paper revisits the findings of Obashi (2009), who presents the stability of international production networks in comparison to other transactions in East Asia, by expanding the coverage of countries and years in the sample and by considering possible effects of the Asian crisis. The current paper offers further evidence that transactions of intermediate goods within production networks in East Asia are not only highly stable but also resilient to a temporary disruption due to the Asian crisis. Both of the papers contribute to a pioneering work on duration of trade by Besedeš and Prusa (2006a,b), from the perspective of international fragmentation of production. Besedeš and Prusa (2006a), who first investigated the duration of the US imports, find the observed trade relationships at the country-product level to be surprisingly volatile: only 67% of trade relationships survive one year; 49% survive four years over the period from 1972 to 1988 at the 7-digit level of Tariff Schedule of the United States (TS).<sup>3</sup> As their companion paper, Besedeš and Prusa (2006b) highlight that differentiated products have a longer duration and a higher probability of continuance than other goods, based on a search cost model of international trade. 69% of the trade relationships of differentiated products survive one year, while only 53% and 59% of the trade relationships of homogeneous goods and reference priced products do. At the fourth year, these rates decline to 52% for differentiated products and 33-38% for the other goods. Besedeš (2008) provides additional facts on the continuance of the US imports from the search cost perspective. A considerable amount of short-lived trade relationships has been also observed in Blyde (2008) for exports by Latin American countries, Nitch (2009) for German imports, and Obashi (2009) for intra-East Asian trade in machineries.

This paper is closely related to recent evidence of the existence of zero values in the bilateral trade matrix, which has been highlighted in the context of the adequacy of standard specifications of the gravity equation. Haveman and Hummels (2004) find that

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<sup>3</sup> As for the observed short-lived trade relationships, Besedeš and Prusa (2006a) discuss potential explanations including the Ricardian comparative advantage model, the product cycle model as well as the model of trade and search costs.

nearly one third of bilateral trade flows are in fact zeros at the 4-digit level of Standard International Trade Classification (SITC). Helpman et al. (2008) find that about half of the country pairs in their sample covering 158 countries do not trade with each other. Considering that zero trade flows are surprisingly common, there are five possible patterns of bilateral trade relationships through time: (i) countries have continued to trade with each other throughout the period of interest, (ii) countries have never traded with each other, (iii) countries have started trading with each other since some point in time during the period, (iv) countries initially traded with each other, but have ceased to trade since some point in time, and (v) countries stopped trading with each other at some point in time but have restarted after a certain period of break. Among these, this paper focuses on the last type of trade relationships in particular, pointing out the fact that behind the commonness of short-lived trade relationships, breaks and restorations of trade relationships occur at significant frequency. Exporting is not a once-and-forever phenomenon not only at the firm level but even at the country-product level.<sup>4</sup>

The rest of this paper proceeds as follows: the next section examines the probability of the continuance of trade relationships, employing the Kaplan-Meier method and the Cox proportional hazard model as well as outlining the duration of trade for intra-East Asian trade. Considering possible effects of the Asian crisis, Section 3 confirms that machinery parts & components have a higher probability of continuance than finished products, and examines the probability of the recovery of trade relationships discontinued at the time of the Asian crisis. The interpretation of the empirical findings and their implications for the impact of the recent global recession are discussed in Section 4. And the last section concludes.

## **2. Survival of Trade Relationships in Intra-East Asian Trade**

To examine trade relationships in intra-East Asian trade, this paper uses bilateral trade data at the 6-digit level of Harmonized System (HS) 1992 from 1993 to 2007 obtained from the United Nations Commodity Trade Statistics Database (UN

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<sup>4</sup> At the firm level, Bernard and Jensen (2004) find that former exporters have higher probabilities of exporting after having exited the export market, using a balanced panel of the US manufacturing plants.

Comtrade).<sup>5</sup> The HS 6-digit level is the most detailed disaggregated level of trade data that is internationally comparable and publically available. At the 6-digit level of HS 1992, there exist 4,013 product lines for all manufacturing industries (HS28-92) and 1124 for machinery industry (HS84-92), the latter of which are grouped into 436 parts & components and 688 finished products, following Ando and Kimura (2005). East Asia here includes 14 countries, namely, ASEAN (Brunei, Cambodia, Indonesia, Laos, Malaysia, Myanmar, the Philippines, Singapore, Thailand, and Vietnam), China, Hong Kong, Japan, and Rep. of Korea. Eight out of the 14 East Asian countries have reported trade statistics according to the HS classification throughout the period. Dataset is created by using import as well as export statistics reported by those eight countries, and consists of 152 (= 14 East Asian countries \* 13 – 6 non-reporting countries \* 5) exporter-importer pairs.

## 2.1. Duration of Trade

For each exporter-importer-product pair, whether a trade relationship is active in a given year and how long a trade relationship is continued without interruption can be identified. Table 1 reports the basic statistics for the number of years in which a trade relationship is active during 1993-2007 (15 years) for intra-East Asian trade. The figures for machinery parts & components are compared with those for finished products and other manufactured goods. Trade relationships of parts & components are more active than those of finished goods as well as other manufactured goods. For the observed exporter-importer-product pairs excluding those inactive throughout the period, the mean number of years active is 9.2 for parts & components, which is 1.5-1.7 points higher than finished products and other manufactured goods.

== Table 1 ==

The above result can be interpreted as a reflection of the difference in the duration of trade relationships. Our interest is then turned towards the length of time a certain product is continuously traded between an exporter-importer pair. For instance, if

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<sup>5</sup> See Appendix A for the details of trade data used throughout this paper.

country  $i$  started to export product  $h$  to country  $j$  in 1994 and ceased to export the product in 1998, the trade relationship is regarded as having a spell length of four. As some of trade relationships were broken off and restored after a certain period, at least a year, which is referred to as multiple spells, the number of spells by exporter-importer-product pair as well as the length of each spell should be examined.

Tables 2 and 3 report the basic statistics for the number of spells and for their lengths, respectively.<sup>6</sup> Even with aggregated trade data at the country level rather than data on the firm-level export activities, the break and restoration of trade relationships occur at significant frequency. In particular, for machinery finished products, 54 percent of exporter-importer-product pairs experience multiple spells, more than half of which, 29 percent experience more than two spells. In addition, short-lived trade relationships are more common than expected particularly for finished products. The mean length of spells is 3.9 years for finished products, which is 1.2 years shorter than parts & components.

== Tables 2 and 3 ==

## 2.2. Kaplan-Meier Estimation

Stimulated by the facts that machinery parts & components are likely to be traded through more stable relationships without interruption for a longer period of time compared to finished products as well as other manufactured goods, this and the next subsections perform survival analysis. As a first step, this subsection highlights the difference in the probability of the survival of trade relationships, i.e., continuance of trading, between machinery parts & components and finished products, employing the Kaplan-Meier method. As a second step, the next subsection confirms the difference in the probability of survival, employing the Cox proportional hazard model.

Estimated Kaplan-Meier survival rates for bilateral trade relationships at the product-line level in intra-East Asian trade in machineries are reported in Table 4, and the corresponding survival functions and hazard functions are graphed in Figure 1.<sup>7</sup>

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<sup>6</sup> As multiple spells are treated as independent, the size of observations in Table 3 is larger than that in Table 2.

<sup>7</sup> The survival function is estimated nonparametrically using the Kaplan-Meier product

The estimates for parts & components are compared with those for finished products.<sup>8</sup>

== Table 4 and Figure 1 ==

The shape of the estimated survival functions for parts & components and finished products look similar. Both curves are downward sloping with a decreasing slope. A substantial portion of trade relationships fail within the first four years, especially in the first year when the survival rates, i.e., the probability of survival, are 65% and 58% for parts & components and finished products, respectively. For the later years, on the other hand, the survival rates slowly decline by only 5-7% between the fourth and seventh years, and remain nearly constant afterwards.<sup>9</sup> As evidenced by the shape of the estimated hazard functions, a kind of threshold effect is observed. The hazard rate, i.e., the conditional probability of discontinuance, is maintained at a high level in the earlier years, but then sharply decreases once a trade relationship lasts for a certain period of time. To be more precise, the hazard rate is the probability that a particular product will not be traded between an exporter-importer pair in the  $t$ -th year given that it has been traded until the previous year.

The survival curves are similar in shapes, but the survival rates are higher for parts & components than finished products at any point of time. Such a difference is reflected in the result that the hazard rates are lower for parts & components than finished products though the hazard curves tend to converge as trade relationships last longer. In addition, the distance between the survival curves is widening in the earlier years as finished products are at an increased hazard rate while parts & components maintains a

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limit estimator, along the lines of Besedeš and Prusa (2006a) and other previous studies. The hazard function is estimated using the usual smoothing Kernel (epanechnikov) technique with a limited graphing range. The survival function of  $T$ , the time to failure event, is given by  $S(t)=\Pr(T>t)$ .  $S(t)$  equals one at  $t=0$  and decreases towards zero as  $t$  increases. The hazard function is given by  $h(t)=\Pr(T=t|T\geq t)$ . The survival and hazard functions are just alternative ways to express the same underlying failure process.

<sup>8</sup> As a reference, the Kaplan-Meier estimates for machineries including both parts & components and finished products, in comparison with those for other manufactured goods, are reported in Table A1 and Figure A1.

<sup>9</sup> Spells ended in 2007, the end year of the sample, are classified as right-censored, i.e., continued, rather than failures, i.e., discontinued. It must be appropriate to interpret the length of the right-censored spells as a minimum.



relatively constant rate.

These features are robust though estimated survival rates vary among different samples (See Table A1 and Figure A1). First, to address the left-censoring issue, survival functions are re-estimated for the sample without spells that begun in 1993. Second, survival functions are estimated using a modified sample, in which the length and number of spells are adjusted by assuming that a one-year gap between spells that last at least two years is a result of a recording error, as pointed out by Besedeš and Prusa (2006a,b).<sup>10</sup> For a reference, survival functions are also estimated only for the first spells of respective exporter-importer-product pairs and for single spells, and the aforementioned features still hold. Furthermore, these features are not limited to intra-East Asian trade (See Table A2 and Figure A2).

### 2.3. Cox Proportional Hazards Estimation

In order to confirm the difference in the probability of survival between machinery parts & components and finished products, the Cox proportional hazards model is estimated, considering country-specific and pair-specific characteristics that may influence the duration of trade. The semi-parametric Cox proportional hazards model asserts that the hazard rate for the  $m$ -th subject in the sample is

$$h(t|\mathbf{x}_m) = h_0(t) \exp(\mathbf{x}_m\boldsymbol{\beta}),$$

where  $\mathbf{x}_m$  denotes a vector of  $m$ -th subject's covariates and coefficients  $\boldsymbol{\beta}$  are to be estimated.<sup>11</sup> The Cox model is by far the most popular choice in the analysis of survival data. A particular advantage of the model is that the baseline hazard function,  $h_0(t)$ , is left unspecified and not estimated. What is assumed is that the covariates multiplicatively shift the baseline hazard which is common to all the subjects.<sup>12</sup> The hazard rate for individual subject equals to the baseline hazard when the value of all covariates is set to zero. Exponentiated respective coefficients are then interpreted as the

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<sup>10</sup> A one-year gap may be partly due to a discrete nature of trade data which is compiled on an annual basis.

<sup>11</sup> As the Cox model is a continuous model while the survival data used in this paper is on an annual basis, in which some failures occur at the same survival time (year), the Breslow (1974)'s approximation is assumed so as to treat tied failures.

<sup>12</sup> In this regard, however, estimation is to be stratified by machinery subsector, i.e., general machinery (HS84), electric machinery (HS85), transport equipment (HS86-89), and precision machinery (HS90-92), allowing the baseline hazard to vary among strata.

ratio of the hazard rates, which is referred to as hazard ratio, for a one-unit change in the corresponding covariate. Hazard ratio is greater than one if the corresponding covariate negatively affects the duration of trade, and vice versa. A ratio equal to one implies no impact on the duration of trade.

To estimate the Cox model using time-dependent covariates, the survival data are split at every observed failure time, i.e., at every year, for respective spells. As for country-year-specific characteristics, exporter country's GDP and importer country's GDP are included as standard gravity variables of economic size.<sup>13,14</sup> Supplier firms located in larger economies might be able to maintain a longer trade relationship due to larger production capacities. Meanwhile, a larger pool of potential buyers might ease accommodating demand fluctuation through switching buyers within a country, leading to a longer trade relationship at the country level.

As for pair-year-specific characteristics, the absolute value of the difference in per capita GDP between exporter and importer countries is included as a proxy for wage differential, which may reflect different factor intensity, or production technology, and factor endowment. These differences in production conditions are presumed to encourage cross-border production sharing, leading to a longer-lasting trade relationship. To capture supplier firm's competitiveness in terms of relative trading cost, the year-on-year percentage change in real exchange rate (RER) for exporter country's currency to importer country's currency is included. An increase in RER reflects that an exporter country's currency has weakened relative to importer country's currency with consideration to inflation in respective economies. If an exporter country's currency depreciates, since its supplier firms will become more competitive relative to those located in the export counterpart, the suppliers might be less likely to exit from the market.

To control for the initial size of transaction, the logarithm of trade value in the first year is included. A trade relationship started with a smaller trade value at the country level, which is probably economically less important for either or both exporter and

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<sup>13</sup> See Appendix B for the data sources of covariates.

<sup>14</sup> We would prefer value added of machinery industry of its own (ideally, disaggregated by product type) to GDP as a variable indicating the size of economic activities of machinery industry. Due to lack of data publicly available, we have no alternative but to employ GDP.

importer countries in the beginning, may face a greater risk of discontinuance. Regarding the prevalence of multiple spells, a dummy variable for subsequent spells is included, following Besedeš and Prusa (2006b). Although multiple spells are treated as independent because separated spells are highly likely to involve different firms of exporter and importer countries, the probability of survival will depend on the experience of discontinuance. A trade relationship restarted after a certain period of no trade may not fail again, owing to accumulated information about the trade counterpart at the country level. Besides these two control variables, country, country-pair, and year fixed effects are included to control for unobserved characteristics. Standard errors are clustered at the HS 6-digit product level, allowing for possible correlation within products.

Table 5 provides the Cox proportional hazards estimates for intra-East Asian trade in machineries. Our interest here is estimated coefficients for a dummy variable which takes a value of one if a trade relationship is of parts & components. The sample of interest is listed at the top of each column, and the covariates and control variables are in the first left column of the table. Units in which respective variables are measured are in parentheses.<sup>15</sup> Estimated coefficients are expressed in terms of hazard ratios.

== Table 5 ==

The result for all the observed spells during 1993-2007 reported in the second left column of the table confirms the difference in the probability of survival by product type. With allowing trade relationships of finished products to be the benchmark, those of parts & components have a 27% lower hazard rate. In other words, for parts & components, once a trade relationship is developed, it is 27% less likely to be broken off.<sup>16</sup> As for effects of other covariates on the hazard rate, all of them are estimated as

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<sup>15</sup> The unit in which a variable is measured makes no substantive difference.

<sup>16</sup> In contrast, Besedeš (2008) finds that for the US imports from developing countries, trade relationships of intermediate goods face about 10% higher probability of discontinuance than those of final goods though he examines all the merchandise trade including not only manufactured goods but also agricultural goods and mineral fuels. It is left for future research to check whether the higher probability of survival for machinery parts & components is limited to intra-East Asian trade after considering

expected.

As with the last subsection, the same Cox model is re-estimated using two different samples as a robustness check. One is the sample without 1993-origin spells, and the other is the modified sample with the one-year-gap adjustment. The estimates are qualitatively similar to the result for all the observed spells. For further reference, the estimates for the first spells sample, the single spells sample, and the sample excluding Japan are reported in the right part of the table. The patterns of estimated coefficients remain unchanged, except for the result for the single spells sample, and trade relationships of parts & components are less likely to be discontinued in each sample. By focusing on only single spells, the coefficients for both exporter's and importer's GDP become more than one, which seem to be due in part to multicollinearity issue.

### **3. Effects of the Asian Crisis**

For intra-East Asian trade in machineries, we have found that parts & components are more likely to be traded through long-lived relationships compared to finished products. In this section, the higher probability of survival for parts & components is to be verified even after considering possible effects of the Asian currency and financial crisis in 1997-98, in order to derive implications for the impact of the recent global economic downturn.

#### **3.1. The Impact on the Survival of Trade Relationships**

Among all the observed trade relationships, the proportion of the trade relationships that had been active until 1997 but were discontinued in 1998, after the outbreak of the Asian crisis, is notably higher than average. The proportion of the trade relationships that are observed in 1997 and continued or discontinued in 1998 is reported in Table 6, compared with the corresponding average figure for the rest of sample period. The proportions of the discontinued trade relationships have hovered around 13% and 20% for machinery parts & components and finished products, respectively; however, the figures for the year 1997 are exceptionally high, at 16% and 24%. Although the discontinuance share is lower for parts & components than finished products even in

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factors behind the duration of trade.

1997, the discontinuance share is markedly increased not only for finished products but for parts & components. This fact appears to be due mostly to the Asian crisis and suggests the need for controlling effects of the crisis to bear out the stability of international production networks in the East Asian region.

== Table 6 ==

In the light of possible effects of the Asian crisis on the probability of the survival of trade, Table 7 reviews the Cox proportional hazard estimates presented in Table 5. The same Cox model is re-estimated using the sample excluding the trade relationships that had been active until 1997 but were discontinued in 1998 as well as a limited sample including only trade relationships that were started in and after 1998. All the estimated coefficients are qualitatively unchanged from the result for all the observed spells, except that the coefficient for the year-on-year percentage changes in RER becomes more than one in the result for the latter limited sample. Still, even after considering the impact of the Asian crisis, trade relationships of parts & components face a 21-28% lower hazard rate with respect to those of finished products in intra-East Asian trade in machineries.

== Table 7 ==

### **3.2. Revival of Trade Relationships amid the Asian Crisis**

Next, looking into the trade relationships that were discontinued sometime during 1994-2007, the probability of revival, i.e., recovering from a disruption, is examined.<sup>17</sup> As the probability of revival, estimated Kaplan-Meier failure rates are reported in Table 8 and the corresponding failure functions and hazard functions are graphed in Figure 2. The estimates for the trade relationships discontinued in 1998 are compared with those for the trade relationships discontinued in the rest of sample period, in addition to the comparison between parts & components and finished products.

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<sup>17</sup> Failure function,  $F(t)$ , equals  $1-S(t)$ , where  $S(t)$  is survival function.

== Table 8 and Figure 2 ==

Irrespective of when trade relationships are broken off, the estimated failure curves are upward sloping with a steep slope in the earlier years for both parts & components and finished products. Among trade relationships discontinued in the same year, the probability of revival is clearly higher for parts & components than finished products at any point of time. Meanwhile, trade relationships discontinued in 1998 face a higher probability of revival compared to those discontinued in the rest of sample period. Particularly in the case of the trade relationships of parts & components that were discontinued in 1998, 59% of them are restored within the first two years, and two thirds of which are restored in just over a year. Besides, three fourth of the trade relationships are restored in 2002, at most after a four-year break. Trade relationships restored after a certain period of time may include different firms, so it would be better to treat trade relationships before and after the break as unrelated. Nevertheless, it is striking that a nonnegligible portion of trade relationships was broken off at the time of the Asian crisis, but many of them were restored within just a few years.

The hazard rate here is the conditional probability of the revival of trade relationships given that they have been inactive until the previous year. By the product type, reflecting the difference in the failure rates, the hazard rates are also higher for parts & components than finished products at any point of time, particularly in the earlier years. The estimated hazard rate is notably high for the trade relationships of parts & components that were discontinued in 1998, standing at around 25% in the third year and nearly 15% even in the seventh year though decreasing over time. More noteworthy is the slope of the hazard curve steeper for the trade relationships discontinued in 1998 than those discontinued in the rest of sample period. From another angle, the distance between the hazard curves is especially large in the earlier years, indicating that the trade relationships discontinued in 1998 are more likely to be restored shortly afterward. These results indicate that, compared to other transactions, trade relationships of parts & components were less discontinued in 1998, and even when broken off, the transactions were more resilient to a temporary disruption.

#### **4. Implications for the Impact of the Recent Global Recession**

Trade relationships of parts & components are more likely to be lasting compared to those of finished products in intra-East Asian trade in machineries, even after considering the impact of the Asian currency and financial crisis. In addition, although a nonnegligible portion of trade relationships was actually broken off amid the Asian crisis, trade relationships of parts & components are more likely to be restored shortly compared to those of finished products as well as the transactions that were discontinued in the rest of sample period. A higher probability of survival and revival for parts & components can be interpreted as indicating the stability and resiliency of the transactions of intermediate goods within international production networks in the East Asian region.

Within the networks created, coordinated, and managed by multinational enterprises across borders, each of the fragmented production blocks is not often able to function effectively without coordination between production processes. In other words, lack of even a single part or component hinders the entire production of the relevant finished product. The transaction of intermediate goods within the networks cannot be realized without coordination with upstream suppliers and/or downstream buyers, irrespective of whether an intermediate good is traded through an intra-firm or arm's length relationship.<sup>18</sup> Moreover, to connect remotely-located production blocks, service link costs including transport costs, telecommunication costs, and coordination costs are required. Service link typically has strong economies of scale in both static and dynamic sense. From the dynamic standpoint, service link plays a critical role in a firm's decision on whether or not to set up the network with sunk costs to invest in a newly fragmented production block. Given these features, unlike in the case of finished products made entirely in one country or goods sold on the open market, firms would put priority not only on lowering production costs but on the stability of relationships for transactions of intermediate goods within international production networks. Due to such

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<sup>18</sup> Some may wonder if longer-lived trade relationships of intermediate goods reflect that trade of intermediate goods is more driven by intra-firm transactions compared to trade of finished products; however, unfortunately, we cannot obtain detailed trade data classified by type of transaction, i.e., intra-firm or arm's length, as well as by product type.

relation-specific nature of the transaction, once a trade relationship is established, it would appear that the transaction of intermediate goods within production networks is more lasting and resilient to a short-term shock compared to the other transactions.

The Asian crisis of a decade ago was originated in East Asian countries themselves though recently the global financial crisis originating from the US has transmitted to East Asian countries primarily through the trade channel. Some may suspect that transactions within international production networks were hardly affected by the Asian crisis probably because those transactions depend largely on ultimate demand from outside the region centering on the US. If the US is such an important source of final demand underneath the surface of the development of production networks stretched across East Asia, transactions within the networks may be more vulnerable to decline in the US demand than to internal economic shock in the region. However, it should be noted that East Asia's reliance on the US market even as an export destination of machinery finished products has been rather diminishing.

Table 9 reports the intraregional and interregional shares of the total exports by East Asian countries, the latter of which includes East Asian exports to the US, EU, and other regions. The proportion of intra-East Asian exports of machinery parts & components rose from 45% in 1993 to 57% in 2007, whereas the proportion of interregional exports declined due to a drastic drop in the US share from 29% to 14%. More interestingly, as for machinery finished products, the intra-East Asian share slightly declined from 28% to 25% during the period, but the US share also dropped from 35% in 2000 to 26% in 2007.

== Table 9 ==

The growing share of intra-East Asian exports of machinery parts & components cannot be regarded as evidence for independence from external demand if many of them were eventually shipped out of the region, particularly to the US, in the form of finished products. In this regard, however, the destination of the East Asian exports of machinery finished products has been diversified by lessening the dependence on the US market. Furthermore, although international trade data do not include machinery finished products manufactured and sold domestically in respective countries, the importance of



East Asia's own market is increasing steadily in parallel with the continued strong growth of East Asian countries and the consequent emergence of the middle class with growing purchasing power. When taking into account all the products manufactured within the region, the proportion of machinery finished products ultimately consumed in the US appears to be much smaller.

East Asian countries have built mutually complementary economic ties along with the development of international production networks by taking advantage of regional diversity in income levels and development stages. Surely, the deepening of interdependence via supply chains across borders makes it inevitable that an economic shock originating in one country will be quickly transmitted to the other countries. Nevertheless, the diversified destinations for the East Asian exports of machinery finished products suggest that a country has only to switch to the markets of other countries if its export counterpart's demand for certain finished products is deteriorated. As long as the East Asia's export destinations other than the country mired in a slump, including East Asian countries themselves, sustain growth, a country can switch between potential markets for certain finished products. If so, the transactions of the relevant intermediate goods that are traded within production networks for assembly and manufacturing do not appear to be severely affected by the decreased final demand even in a major export counterpart, say, the US. Moreover, as presented in the last section, even if trade relationships are broken off, the ties built on production networks would still be resilient to a temporary disruption.

Indeed, according to the latest survey on the effects of the global financial crisis on the overseas business operations of Japanese firms at the end of 2008 (JETRO, 2009), there is no evidence which can be interpreted as suggesting any catastrophic damage on international production networks in East Asia.<sup>19</sup> As for the way to cope with the global economic downturn, about half of the Japanese firms with any global bases answered

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<sup>19</sup> In the case of Japanese multinational enterprises, one of the most important players in East Asian production networks, 70% of the firms with affiliates in Central and Eastern Europe expressed strong concern about the worsening business conditions due to the crisis, whereas those with affiliates in China, Hong Kong, and Vietnam seem to be less concerned about the adverse effects on their operations. In particular, for China and Vietnam, nearly 15% of the firms operating there reported no impact though at the same time 38-46% of them reported severe adverse effects.

that they would enhance their overseas operations, either by expanding existing operations (23%) or by starting new ones (23%), rather than downsizing existing operations (9%) or halting new projects (15%). Such a forward-looking and vigorous stance of Japanese firms is particularly noticeable in the electric machinery sector that extends the most sophisticated networks across East Asia.

## **5. Conclusion**

This paper aimed to shed light on the resilience of international production networks amid the Asian financial and currency crisis as well as verifying its stability after considering possible effects of the crisis. A series of survival analyses provide an evidence supporting the view that transactions of intermediate goods within production networks are more likely to be stable and resilient to a temporary disruption compared to the other transactions. Contrary to the public perception of globalizing business activities as foot-loose investments, trade relationships built through supply chains are highly stable and resilient to shocks due to the relation-specific nature of the transactions.

Even amid the recent global turmoil, the shrinkage of the US and European markets is not likely to become a profound threat to the stability of international production networks stretched across the East Asian region. Production networks will be resilient to the downturn in the US and European demand, backed by the sustained strong growth of East Asian own markets, though less economically important trade relationships might be broken off in the process of restructuring the networks to be more efficient or sophisticated.

## Appendix A. Trade Data

This paper basically uses bilateral import data, whenever they are available, from the standpoint of reliability, because country of origin is more closely verified due to tariff regulations though final destination may not be known at time of export. If the import statistics are not available for an exporter-importer pair, the corresponding export statistics are used instead, following Feenstra et al. (2005). In addition, I restrict the sample to the 19,661 country pairs including 152 intra-East Asian country pairs, either or both of which have reported trade statistics throughout the sample period.

Trade data for all the years in the sample are originally reported according to or modified to fit the 6-digit level of HS 1992 classification. By using this dataset, although we cannot observe the birth of newly-developed products within a product-line category of the HS 1992 classification, the probability of discontinuing trade relationships will be underestimated, but never be overestimated. More importantly, we do not need to concern about the censoring issue emerging from the complicated mergers and branching of codes due to the update of classification.

Since the annual data at the HS 6-digit level below \$500 (current US\$) are not reported before 2000, trade flows below \$500 are treated as if there was no trade at all for all the years in the sample.

## Appendix B. Data Sources for Other Variables

Variable	Source
GDP (constant 2000 US\$)	The World Bank's World
Per capita GDP (constant 2000 US\$)	Development Indicators (WDI) Online
The annual average of nominal exchange rate, which is deflated by WPI or CPI (2000=100) for each country	The IMF's International Financial Statistics (IFS)
Initial trade value (US\$), which is deflated by the US WPI (2000=100)	UN Comtrade; the IMF's IFS

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Figure 1. Kaplan-Meier Estimates of Survival Functions and Hazard Functions for Intra-East Asian Trade in Machineries.

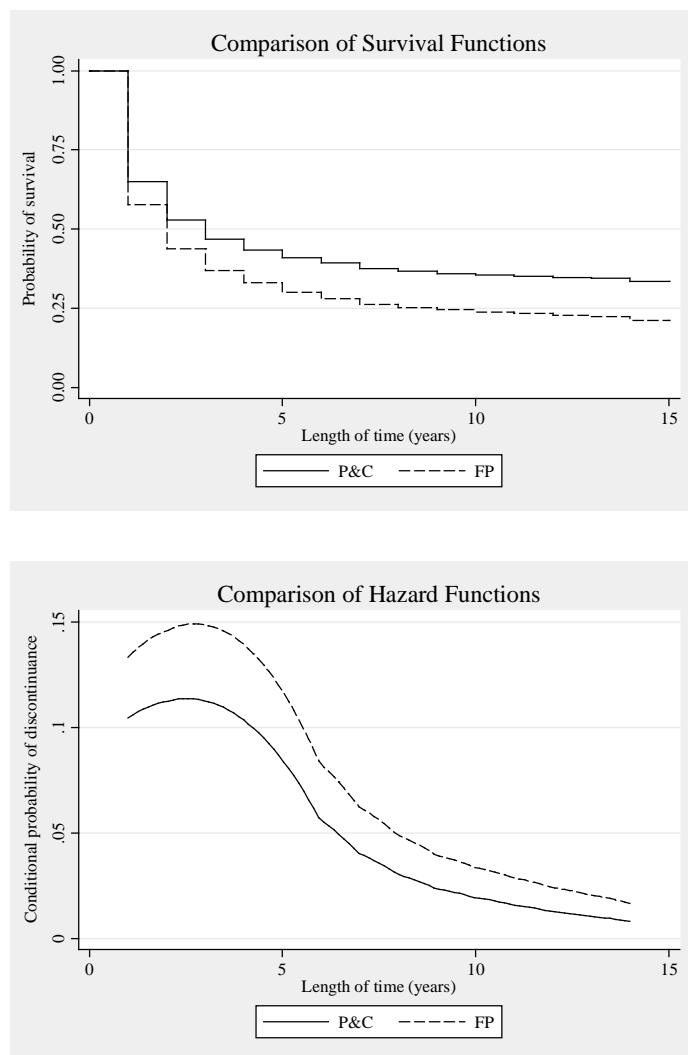


Figure 2. Kaplan-Meier Estimates of Failure Functions and Hazard Functions for Intra-East Asian Trade in Machineries.

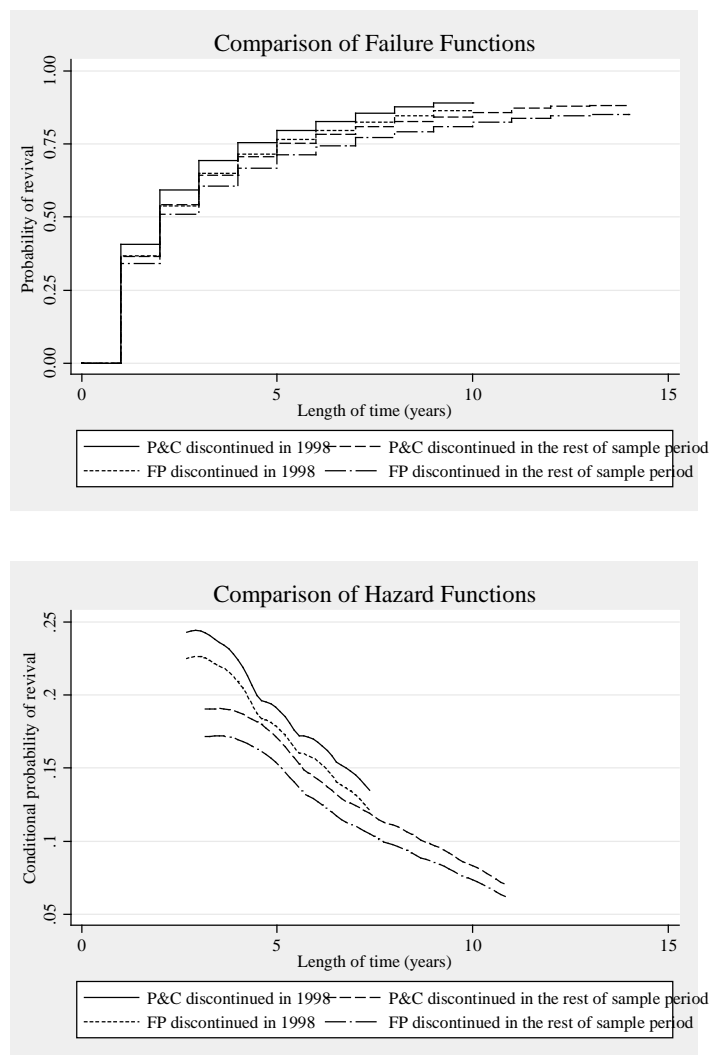


Table 1. Number of Years Active during 1993-2007 for Exporter-importer-product Pairs.

	Mean	Median	Cumulative percentages (%) by number of years active			Obs.	Share (%) in the max. possible N.	N. of product lines
			1	7	14			
			Machineries	8.3	8			
P&C	9.2	10	11.4	39.8	69.6	42,893	64.7	436
FP	7.7	7	16.3	52.6	81.0	60,561	57.9	688
Other Manuf.	7.5	7	16.3	53.8	81.7	231,927	52.8	2,889

*Note:* The number of exporter-importer pairs in the sample of East Asian countries is 152. Inactive trade relationships throughout 1993-2007 are not included in the above basic statistics.

Table 2. Number of Spells for Exporter-importer-product Pairs.

	Mean	Median	Cumulative percentages (%) by number of spells				Obs.
			1	2	3	4	
			Machineries	1.91	2	48.8	
P&C	1.81	1	53.4	76.6	91.5	98.1	42,893
FP	1.98	2	45.6	70.8	88.6	97.2	60,561
Other Manuf.	1.88	2	48.2	74.6	91.2	98.2	231,927

*Note:* Exporter-importer-product pairs of active trade relationships only.

Table 3. Length of Spells for Bilateral Trade Relationships at the Product-line Level.

	Mean	Median	Cumulative percentages (%) by length of spells					Obs.
			1	2	4	7	10	
			Machineries	4.4	2	44.3	59.0	
P&C	5.1	2	39.4	53.1	65.0	74.2	78.4	77,514
FP	3.9	2	47.5	62.8	74.9	83.6	87.1	120,047
Other Manuf.	4.0	2	45.4	60.9	73.7	82.4	86.5	436,263

*Note:* Active trade relationships only.



Table 4. Estimated Kaplan-Meier Survival Rates for Intra-East Asian Trade in Machineries.

	Estimated K-M survival rate					Obs.
	1 <sup>st</sup> year	2 <sup>nd</sup> year	4 <sup>th</sup> year	7 <sup>th</sup> year	10 <sup>th</sup> year	
P&C	0.65	0.53	0.43	0.38	0.36	77,514
FP	0.58	0.44	0.33	0.26	0.24	120,047

*Note:* The difference of survival function between parts & components and finished products is significant at the 1% level using the log-rank test.

Table 5. Cox Proportional Hazards Estimates for Intra-East Asian Trade in Machineries.

	All spells	Without 1993-origin spells	1-year-gap- adjusted	The first spells only	Single spells only	Excl. Japan
P&C dummy	0.725** (0.014)	0.790** (0.012)	0.734** (0.014)	0.702** (0.016)	0.623** (0.026)	0.734** (0.015)
Exporter's GDP (100bil US\$)	0.952** (0.002)	0.919** (0.002)	0.956** (0.002)	0.968** (0.003)	1.042** (0.007)	0.944** (0.002)
Importer's GDP (100bil US\$)	0.989** (0.002)	0.953** (0.002)	0.993** (0.002)	0.988** (0.004)	1.025** (0.005)	0.989** (0.002)
Abs. diff. in PCGDP (1,000 US\$)	0.961** (0.002)	0.935** (0.002)	0.964** (0.002)	0.982** (0.003)	0.984** (0.004)	0.974** (0.002)
% change in RER (10%)	0.985** (0.002)	0.978** (0.003)	0.999 (0.002)	0.984** (0.003)	1.025** (0.007)	0.983** (0.003)
Log of initial trade value (US\$)	0.854** (0.003)	0.917** (0.002)	0.866** (0.003)	0.830** (0.003)	0.867** (0.006)	0.868** (0.003)
Subsequent spells dummy	0.720** (0.005)	0.793** (0.005)	0.820** (0.005)			0.707** (0.005)
Obs.	822,746	373,260	837,904	580,046	454,917	613,416
N. of spells	184,576	139,024	169,418	96,982	47,634	150,630
N. of failures	123,159	101,681	108,001	65,590	16,242	103,216
Log likelihood	-1,267,300	-1,024,506	-1,108,195	-628,906	-139,454	-1,043,918

*Notes:* The sample of interest is listed at the top of each column and the covariates are in the first left column. Coefficients are expressed as hazard ratios. Robust standard errors clustered by product are in parentheses. \*\* and \* indicate significance at the 1% and 5% level. All regressions include country, country-pair, and year fixed effects, but those coefficient estimates are not reported for brevity. The estimates are stratified by machinery subsectors. Multiple spells of respective exporter-importer-product pairs are treated as independent. Trade data and GDP data are in constant 2000 U.S. dollars.

Table 6. Number of Trade Relationships Continued/Discontinued in the Next Year.

	P&C				FP			
	Continued in the next year		Discontinued (no trade) in the next year		Continued in the next year		Discontinued (no trade) in the next year	
	N.	Share (%)	N.	Share (%)	N.	Share (%)	N.	Share (%)
Trade relationships active in 1997	21,766	84.0	4,133	16.0	23,347	75.8	7,462	24.2
Average value in the rest of sample period	23,373	87.1	3,352	12.9	25,338	80.3	6,027	19.7

Table 7. Robustness Check for the Cox Proportional Hazards Estimates: Effects of the Asian Crisis.

	Excl. trade relationships ceased in 1998	Trade relationships started in and after 1998 only
P&C dummy	0.722** (0.015)	0.794** (0.013)
Exporter's GDP	0.948** (0.002)	0.895** (0.003)
Importer's GDP	0.988** (0.002)	0.927** (0.003)
Abs. diff. in PCGDP	0.958** (0.002)	0.902** (0.002)
% change in RER	0.994** (0.002)	1.013** (0.004)
Log of initial trade value	0.853** (0.003)	0.920** (0.002)
Subsequent spells dummy	0.745** (0.005)	0.777** (0.006)
Obs.	799,676	235,278
N. of spells	173,772	98,402
N. of failures	112,355	66,027
Log likelihood	-1,145,622	-644,320

Note: See notes of Table 5.

Table 8. Estimated Kaplan-Meier Failure Rates for Intra-East Asian Trade in Machineries.

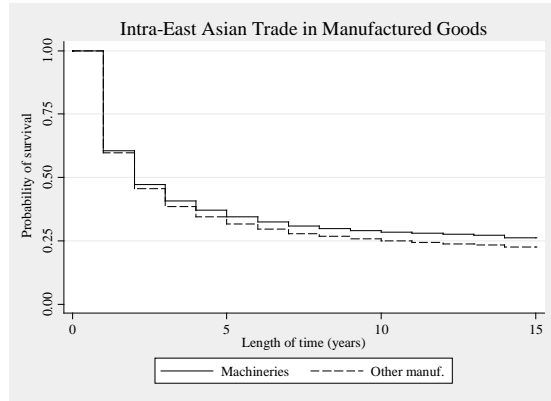
	Estimated K-M failure rate				Obs.
	1 <sup>st</sup> year	2 <sup>nd</sup> year	4 <sup>th</sup> year	7 <sup>th</sup> year	
Trade relationships discontinued in 1998					
P&C	0.41	0.59	0.75	0.85	4,133
FP	0.37	0.54	0.72	0.82	7,462
Trade relationships discontinued in the rest of sample period					
P&C	0.37	0.54	0.71	0.81	43,570
FP	0.34	0.51	0.67	0.77	78,356

*Note:* The difference of failure function between parts & components and finished products and that between trade relationships discontinued in 1998 and those discontinued in the rest of sample period are significant at the 1% level using the log-rank test.

Table 9. Composition of East Asian Exports by Destination.

Destination	Share (%)		
	1993	2000	2007
Machineries			
P&C Intra-East Asia	44.6	49.1	57.1
US	29.2	24.9	13.5
EU	15.8	15.9	13.7
Other regions	10.4	10.1	15.8
FP Intra-East Asia	27.9	26.7	24.7
US	31.4	35.3	25.9
EU	19.8	21.0	20.6
Other regions	20.8	17.0	28.7
Other Manuf.			
Intra-East Asia	49.1	48.6	42.3
US	20.3	21.6	17.9
EU	15.6	15.3	18.2
Other regions	15.0	14.6	21.7

Figure A1. Kaplan-Meier Estimates of Survival Functions for Intra-East Asian Trade: By Different Samples.



### Intra-East Asian Trade in Machineries

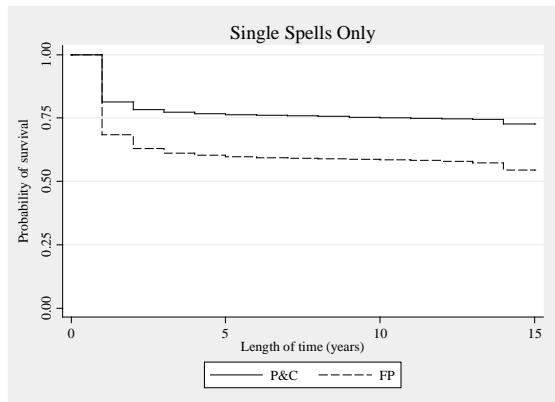
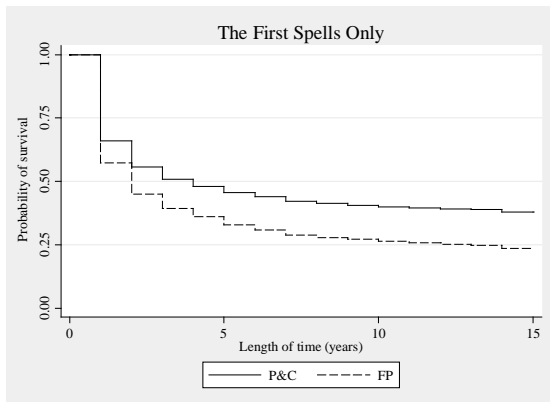
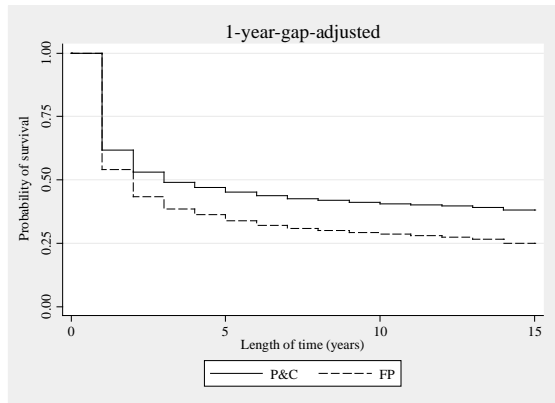
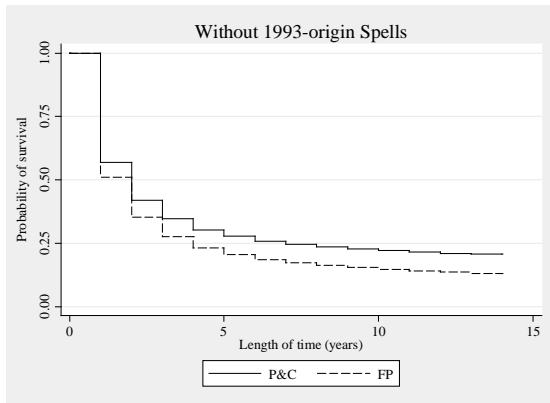


Figure A2. Kaplan-Meier Estimates of Survival Functions for Trade in Machineries: By Different Samples.

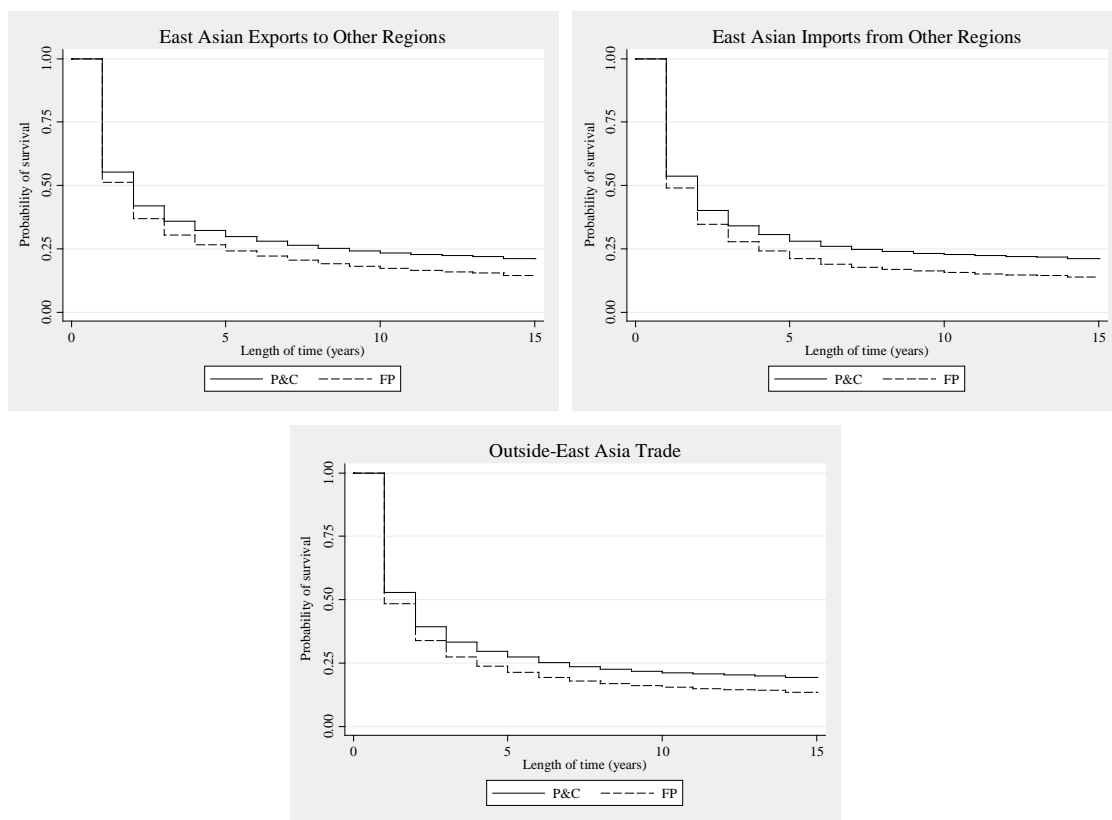


Table A1. Estimated Kaplan-Meier Survival Rates for Intra-East Asian Trade: By Different Samples.

Sample		Estimated K-M survival rate					Obs.
		1 <sup>st</sup> year	2 <sup>nd</sup> year	4 <sup>th</sup> year	7 <sup>th</sup> year	10 <sup>th</sup> year	
All manufactured goods							
All spells	Machineries	0.61	0.47	0.37	0.31	0.29	197,561
	Other Manuf.	0.60	0.46	0.35	0.28	0.25	436,263
Machineires only							
Without 1993-origin spells	P&C	0.57	0.42	0.30	0.25	0.22	56,236
	FP	0.51	0.35	0.23	0.17	0.15	93,992
1-year-gap-adjusted	P&C	0.62	0.53	0.47	0.43	0.41	71,112
	FP	0.54	0.43	0.36	0.31	0.29	110,329
The first spells only	P&C	0.66	0.56	0.48	0.42	0.40	42,893
	FP	0.57	0.45	0.36	0.29	0.26	60,561
Single spells only	P&C	0.81	0.78	0.77	0.76	0.75	22,909
	FP	0.68	0.63	0.60	0.59	0.59	27,588

*Note:* The difference of survival function between machineries and other manufactured goods and that between parts & components and finished products for each sample are significant at the 1% level using the log-rank test.

Table A2. Estimated Kaplan-Meier Survival Rates for Trade in Machineries: By Different Samples.

Sample		Estimated K-M survival rate					Obs.
		1 <sup>st</sup> year	2 <sup>nd</sup> year	4 <sup>th</sup> year	7 <sup>th</sup> year	10 <sup>th</sup> year	
East Asian exports to other regions	P&C	0.55	0.42	0.32	0.26	0.23	475,088
	FP	0.51	0.37	0.27	0.21	0.17	633,238
East Asian imports from other regions	P&C	0.54	0.40	0.31	0.25	0.23	229,944
	FP	0.49	0.35	0.24	0.18	0.16	265,062
Outside-East Asia trade	P&C	0.53	0.39	0.30	0.24	0.21	1,894,462
	FP	0.48	0.34	0.24	0.18	0.15	2,407,660

*Note:* The difference of survival function between parts & components and finished products for each sample is significant at the 1% level using the log-rank test.