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Foreign Direct Investment and Exchange Rate Pass-through: Export Pricing Behaviors of Japanese Multinational Corporations

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[Abstracts]

We examine the effect of foreign direct investment by exporters on a price of their exporting products. We propose several theoretical models of foreign direct investment for both vertical market structure and horizontal expansions of plants. The features of models considered include partial ownership, bargaining power, multiple investments and capacity constraints. Existing empirical researches of foreign direct investment are mostly presented with macroeconomic aggregated data. Our micro survey data offers explanations for purpose of foreign direct investment, indicating for either distribution subsidiary, production subsidiary, or both. By distinguishing the purpose of investment, different hypothesis for the effects of foreign direct investment on exchange rate pass-through can be tested. We find significant effects of foreign direct investments for both distribution subsidiary and production subsidiary. Moreover, foreign direct investments in a European country are shown to affect exchange rate pass-through of other European countries whereas investments in an Asian country do not affect the pricing behavior in other Asian countries.

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1. Introduction

The lack of adjustment for the US current account after steady depreciation of the US dollar in the second half of the 1980s has re-motivated research examining the relationship between exchange rate and tradable prices. The less than proportionate response of tradable prices to changes in exchange rates, termed as incomplete pass-through in the literature, has been well documented in other circumstances as well. The seminal work by Dornbusch (1987) has suggested that the some features of imperfect competition, namely the number of competitors, finite demand elasticity, and etc., lead to incomplete pass-through. Krugman (1987) on the other hand extended the decades old literature to a different direction, suggesting that same features affecting incomplete pass-through can explain the international price differentials arising from exchange rate fluctuations, termed as pricing-to-market. Enormous amounts of research both theoretical and empirical have followed these works[1].

Rather than providing an additional empirical evidence of incomplete pass-through as a contribution, empirical research has recently shifted more toward focusing on the causes of incomplete pass-through. Gron and Swenson (1996) has included the degree of local production in a pass-through equation to explain the partial reduction of pass-through with exporters with local plants. Instead of reduced-form pass-through equation, Kadiyali (2000) uses a structural econometric framework to capture interacting effects of market structures and pricing strategies in the US photographic industry. Bernhofen and Xu (2000) examines the effect of market share in exporting market in pass-through equation and finds that German and Japanese firms exercised significant market power in the US petrochemical market.

Recent development in macroeconomics in so-called new open economy macroeconomics takes these incomplete pass-through and pricing-to-market phenomena seriously into their dynamic general equilibrium model[2]. From the seminal work by Obstfeld and Rogoff (1995), many researchers have attempted to incorporate pricing behaviors of firms under imperfect competition in

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[1] See Goldberg and Knetter (1997) for a recent survey.
[2] See an excellent survey for new open economy macroeconomics by Lane (2001)

order to create deviation from perfectly flexible framework, see Chari and et al. (1998) and Corsetti and Pesenti (1997). Their research motive is to create a theoretical model that is capable of producing long persistence and high volatility of exchange rate movement after monetary shock[3]. It is, therefore, also important for new open economy macroeconomics to develop a more understanding of exchange rate pass-through behavior.

Whereas demand and cost fluctuations are, for each exporting firm, exogenous parameter that influence the pricing behavior, some changes in market structure, e.g., the entry decision to foreign markets or acquisition of foreign subsidiaries, are endogenously determined parameters that also affect the optimizing behavior. In search of a larger market for products, a manufacturer begins to access to foreign markets without sufficient information for the local market. Eventually exporting firm establishes distribution and production networks by setting up a new subsidiary firm or by acquisitions of local firms.

Figure 1 indicates that the number of Japanese foreign subsidiaries has almost doubled in recent ten years, 1988 - 1997. The most significant region is Asia in which the number of foreign subsidiary has increased approximately 150 percent within the period. Figure 2 summarized the response of Japanese parent firms to a questionnaire that asks for the most significant causes for establishing foreign subsidiaries. Although inexpensive wage for labor is significant in developing countries in Asia, the major reason for foreign direct investment is to secure access for local markets.

Intuitively, it is clear that these changes in market structure might affect the pricing behavior of exporting firms, consequently, exchange rate pass-through as well. In the next section we examine subsidiary-firm level data for Japanese foreign direct investments and summarizes some distinctive features. In section 3 and 4 we provide concrete theoretical foundations for particular channels through which foreign direct investments affect exchange rate pass-through.

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[3]   There are many other empirical works that attempt to uncover the cause of long persistence and high volatility of exchange rate movement from different directions, see Engel (1999) and Cheung and Lai (2000).

Section 3 presents a model of bilateral duopoly with partial ownership and bargaining. Section 4 describes a model of substitute subsidiaries. Section 5 describes data and an econometric methodology.   Section 6 discusses the empirical results. Section 7 concludes the paper.

2. Japanese Foreign Direct Investment

In this section we closely examine the micro survey data published as the Overseas Japanese Companies Data by Toyo Keizai to summarize the overall distinctive features of Japanese foreign direct investments.   These data contains relevant information for approximately 19000 Japanese foreign subsidiaries.   The notable features can be summarized in the following three subsections; significant portion of direct shareholding by Japanese parent companies are only partial although 100%-owned subsidiaries are pervasive, the purpose of foreign direct investment for Japanese subsidiaries are distinguished between marketing and production, and multiple number of foreign direct investments in same product category can be usually attributed to different competing companies in the same industry.

2.1. Partial Ownership

"Subsidiary firm" can be defined with different magnitude of shareholding by a parent firm.   Without saying that 100% shareholding by a parent firm absolutely makes a firm subsidiary, a share exceeding 50% provides a shareholding company majority vote to fully control a subsidiary company.   However, even when shareholding of a parent company is below 50%, it can exercise controlling power over other disseminated shareholders.   First, we note distinguishing feature of international shareholding structure in Figure 3[4].   Although over 8,000 Japanese foreign subsidiaries are fully owned by corresponding Japanese parent companies, 13.8% of Japanese subsidiary firms are actually 100%-subsidiary of another Japanese subsidiary firms.   These

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[4] Out of 19,197 subsidiary firm data, information about shareholding was not obtained for 375 subsidiary firms.   We have used only 18,822 firm data, which accounted for shareholding information, for this subsection.   See Figure 5 for detailed descriptions.

4

firms do not have direct capital relationship with Japanese companies but indirectly owned via international capital network by Japanese multinational corporations. 69.4% of Japanese subsidiary are owned by Japanese parent company and local firms in a recipient country. Figure 4 and 5 represent shareholding of Japanese multinational corporations in Japanese foreign subsidiaries in the world. It points out outstanding clusters around two figures, namely 50% and 100%. Full ownership by a parent firm accounts for 51.3-64.3% of all foreign subsidiaries. This is largely due to the fact that, unless it is a joint venture with a firm in a recipient country, newly established firm, or greenfield FDI, must be entirely financed by a parent company. 50%-shareholding, which is a threshold value for absolutely majority ownership, accounts for 9.2-10.9%. It is noteworthy here that large portion of Japanese foreign subsidiary firms are not operated under full control of Japanese multinational corporations.

It is more striking that structure of subsidiary shareholding are quite different among recipient countries as we look into top three recipient countries, namely US, China and Thailand, of Japanese FDI. Whereas full ownership is more eminent, 73.9%, in the most recipient country of Japanese FDI, the US, the second most recipient country, China, observes only 24.7% of full ownership by Japanese parent company and for the third most recipient country, Thailand, it is only 16.1%, see Figures 6 - 8. These distinctive figures between the US and Asian countries of course largely reflects the difference in inward FDI policies among recipient countries. China and Thailand only recently lifted foreign ownership restrictions.

2.2 Distribution and Manufacturing FDI

With macroeconomic aggregated data, foreign direct investment are treated as general investment by foreign capital and all the strategic properties of foreign direct investment by parent companies are suppressed. With our survey data, Japanese parent companies are asked to describe the purpose or role of their subsidiaries. In figure 9, purposes of subsidiaries are categorized as

either "sales," "production," or "services, lease, R&D or others."[5]   The "sales" box and "production" box indicate that the purpose of FDI include "sales" and "production," respectively. So subsidiaries categorized in "sales" box may or may not act as "service, lease, R&D or others" subsidiaries as well.   The last box labeled as "service, lease, R&D or others" are actually those subsidiaries which did not contain response of either "sales" or "production" for the purpose of subsidiaries by their parent firms.

Over 50 percent of all subsidiaries have a function of overseas sales and 42 percent of all subsidiaries have production facility.   In the following section we need to distinguish these two main purposes of subsidiaries, namely "sales" and "production."

2.3 Multiple FDIs in Same Product Category

Since our corresponding data for exports are not firm-brand specific, our product categories include some extent of within-product heterogeneity.   Although our trade data are most disaggregated data publicly available for Japanese exports, a product category needs to be considered as a group of firm-brand specific products.   Within this category we can usually observe multiple foreign direct investments in each recipient country.   In building a theoretical model of foreign direct investment and obtaining testable hypotheses for empirical analysis, we need to scrutinize each establishment of these multiple foreign direct investments.

Specifically foreign direct investments for electronics and electronics parts industry category, we summarized top 20 major Japanese parent corporations by top 10 major Japanese-FDI-recipient countries in Table 1.   Matsushita Electronics (known internationally as Pansonics) has the most number of subsidiaries, 63 establishments, and the average of oversea subsidiaries for top 20 multinationals is over 30 establishments.   Within a broad category as electronics and electronics parts industry, one can observe multiple FDIs by same corporations. This requires a theoretical model capable of explaining for multiple FDIs in a foreign country by a

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[5] "Production" includes either production, assembly, or processing.

6

parent exporter.   However, when the business description of each subsidiary is scrutinized in Table

2 and 3 as examples, each investment by these two individual firms are intended for different

category of products or different purpose of business, i.e., production or sales.   A prospective

theoretical model capable of incorporating a case, for example, the first row of air conditioner and

the third row of electric iron subsidiaries of Matsushita Electronics in Table 2 should be built with

independently different demands for each product rather than with differentiated products in the

same industry.

3. Vertical Structure Model: Bilateral Monopolies with Partial Ownership and Bargaining

Here we focus on an equilibrium transfer price between a single exporter and a single

local firm.   We restrict the number of firms to be only one in both exporting and importing country,

in order to accentuate the role of interaction between two firms with bilateral bargaining and partial

ownership, while suppressing interaction effect from other local firms or other competing exporters.

As discussed in the previous section, we explicitly incorporate in a model that the fact large portion

of subsidiaries are partially owned and transfer price are determined in a bargaining process

between managers of parent and subsidiary firms.

In this section, preferences for consumer and technology for firms are extremely

simplified.   Demand for a Japanese export is a liner function, $q = d - P$. Subsuming feedback from

and interaction between input markets, we assume constant marginal cost for both an exporter and a

downstream firm.

An objective function for both firms is net sales profit which is margin times sales quantity,

q. Margin of a Japanese exporter is a transfer price, w, minus constant upstream marginal cost, c_U.

For a downstream firm margin is final market price, P, minus constant downstream marginal cost,

c_D, minus transfer price in terms of importing country's currency.

$$\pi_U = (w - c_U)q \tag{1}$$

$$\pi_D = (P - c_D - ew)q \tag{2}$$

It is important to note what these costs might represent for these firms.   For an exporter

c_U represents production costs and transportation costs for both domestic and international shipping. Although our focus is not on the pricing-to-market phenomena of Japanese exporters, existence of Japanese final market is implicit in this model plays an important role in international macroeconomics. However, our assumption of constant marginal cost for the exporter in this model insulates any effects might arise from Japanese final market. If we are to incorporate Japanese final market explicitly in the model, we can additionally observe pricing-to-market of exporters but exchange rate pass-through, our main concern in this paper, to importing country will not be affected.

For downstream firm c_D can play dual roles in our framework. If we are to interpret downstream firm as a local distributor, c_D represents transportation cost in importing country, other distributional cost, and any other local costs, from advertising to translation of packages. On the other hand, we could also interpret the same model as that an exporter is producing intermediate products and downstream firm is producing final product with imported intermediate goods as inputs; or an exporter is shipping unassembled products to a downstream firm which merely put these parts together to finish the products to avoid severe international trade regulation on imports of finished products in the country.

At the second-stage final market, a downstream firm chooses quantity to maximize its profits as defined in equation (2). The first order condition for downstream firm at the second stage is as follows.

$$0 = \frac{\partial \pi_D}{\partial q} = \frac{\partial P}{\partial q} q + (P - c_D - ew) \tag{3}$$

The optimal sales quantity for downstream firm can be shown to be a function of transfer price.

$$q(w) = \frac{d - c_D - ew}{2} \tag{4}$$

At the first-stage intermediate market, having demand function of consumers and optimal behavior of downstream firm as common knowledge, profit of two firms can also be expressed in terms of transfer price.

8

$$\pi_U(w) = (w - c_U)\left(\frac{d - c_D - ew}{2}\right) \tag{5}$$

$$\pi_D(w) = \left(\frac{d - c_D - ew}{2}\right)^2 \tag{6}$$

In a simple successive monopolies model, where an exporter has entire bargaining power over transaction in an intermediate market, the exporter sets transfer price to maximize its net sales revenue, equation (5), with the knowledge of derived demand schedule of downstream firm, equation (4).

However, the assumption that an exporter solely determines transfer price and a downstream firm behaves as a price-taker is not accurate description of the bilateral relationship. Although not explicitly modeled in this paper, With the option to leave from transaction, a single downstream firm should have some negotiating power.

Even if there exist other possible downstream firms in an intermediate market, specific-relationship asset invested by the exporter make transaction with this particular downstream firm more attractive. In next subsection, we will continue to investigate export pricing behavior in the case with the presence of other downstream firms for some special case.

Here, the exporter and downstream firm engage in transaction profitable to both firms, but their own profit maximizing strategies are in conflict for determining the level of transfer price of exporting products. We assume two firms engage in a non-cooperative Nash-bargaining process to determine the transfer price. The Nash-bargaining problem for these two firms can be summarized in equation (7) and (8).

$$\max_{w} \quad NB \equiv \left[\frac{1}{e}\pi_D(w)\right]^{1-\alpha}\left[\pi_U(w) + \beta\frac{1}{e}\pi_D(w)\right]^{\alpha} \tag{7}$$

$$s.t. \quad \frac{1}{e}\pi_D(w) > 0 \qquad and \qquad \pi_U(w) + \beta\frac{1}{e}\pi_D(w) > 0 \tag{8}$$

The first order condition for the Nash-bargaining solution can be rearranged as follows.

$$0 = (1-\alpha)\left[\pi_U + \beta\frac{1}{e}\pi_D\right]\frac{\partial\pi_D}{\partial w} + \alpha\pi_D\left[\frac{\partial\pi_U}{\partial w} + \beta\frac{1}{e}\frac{\partial\pi_D}{\partial w}\right] \tag{9}$$

The transfer price in terms of currency of importing country can be solved as follows.

$$ew = \frac{(\alpha-\beta)(d-c_D) + (2-\alpha)ec_U}{2-\beta} \tag{10}$$

The exchange rate pass-through can be obtained as follows.

$$\eta(\alpha,\beta) \equiv \frac{d\ln ew}{d\ln e} = \frac{(2-\alpha)ec_U}{(\alpha-\beta)(d-c_D) + (2-\alpha)ec_U} \tag{11}$$

By differentiating equation (10) by each parameters, we can obtain expected changes in the exchange rate pass-through with respect to changes in bargaining power and share of ownership. For any $\alpha \in [0,1]$ and $\beta \in [0,1]$, the exchange rate pass-through is shown to be increasing and decreasing function of α and β, respectively.

$$\frac{\partial\eta}{\partial\alpha} = \frac{(\beta-2)(d-c_D)ec_U}{[(\alpha-\beta)(d-c_D) + (2-\alpha)ec_U]^2} < 0 \tag{12}$$

$$\frac{\partial\eta}{\partial\beta} = \frac{(2-\alpha)(d-c_D)ec_U}{[(\alpha-\beta)(d-c_D) + (2-\alpha)ec_U]^2} > 0 \tag{13}$$

Attaining stronger bargaining position, i.e. increase in α, an exporter can use his market power to increase transfer price toward the monopoly pricing level. This can be understood as moving from equating marginal cost to demand schedule toward equating marginal cost to marginal revenue schedule, in which price is less responsive to change in marginal cost. This price less responsiveness leads to less exchange rate pass-through. Acquiring share of ownership in downstream firm, i.e. increase in β, an exporter can gain a new income stream from the profit of downstream by lowering transfer price away from monopoly pricing level. This is just exactly opposite movement of pricing mechanism described for increase in bargaining power.

The most probable description of foreign direct investment can be captured in changes in

10

terms of our parameters, α and β. For the convenience we use subscript 0 and 1 for parameters to denote before and after foreign direct investment. As we argued earlier some non-zero bargaining power must be distributed to both parties before any investment by an exporter takes place, that is, $\alpha_0 \in (0,1)$ and $\beta_0 = 0$. After the exporter becomes a shareholder of downstream firm, bargaining power of the exporter must not decrease, i.e. $\alpha_1 \geq \alpha_0$ and $\beta_1 > 0$. If we assume the bargaining power of an exporter does not change after acquiring share of downstream firm, change in exchange rate pass-through is obvious from equation (13) and we formally state this as next lemma.

Lemma 1: If an exporter's acquiring share of an independent local firm does not change the bargaining power of the exporter, the exchange rate pass-through increases.

Although we have not assumed any interacting relationship between α and β, it is natural to assume that share increase in ownership of downstream firm should strengthen the bargaining position of exporter. If we assume bargaining power is increasing function of share ownership, it is not obvious how foreign direct investment affect exchange rate pass-through because sign of equation (12) and (13) are opposite.

Proposition 1: If acquiring β_1 share of an independent local firm increases bargaining power of exporter by $(1-\alpha_0)\beta_1\lambda$, where λ satisfies $a_0 < \dfrac{2(\lambda-1)}{(2\lambda-1)}$, exchange rate pass-through decreases.

The condition in Proposition 1 can be better understood in Figure 9 and 10. In Figure 9 the pair α_0 and λ in the area above the curve satisfies the condition and therefore a proportional change in export price with respect to exchange rate fluctuations decreases after Japanese companies acquire share of local firms. Figure 10 represents an example for a pair of $\alpha_0 = 0.5$ and $\beta_0 = 0$, λ must be larger than 1.5 for meeting the necessary condition in Proposition

1.

4. Horizontal Expansion Model: Plants Expansion with Increasing Marginal Cost

In addition to the effect of FDI for distributor, we also examine the effect of foreign direct investment for local production in this section.   Gron and Svenson (1996) examine empirically the effect of local production plants on exchange rate pass-through in automobile industry.   Although Gron and Svenson do not provide any theoretical model, their empirical evidence indicates that the ability to produce in multiple locations gives firms more flexibility to adjust to changes in exchange rates, resulting in a smaller pass-through[6].

Focusing on local production effect, there is a very important concept we need to distinguish when analyzing exchange rate pass-through.   When a domestic manufacturing firm exports final products as automobile firms considered in Gron and Svenson (1996), owing production plants in both domestic country and a foreign country enable an exporter to adjust with flexibility to exchange rate fluctuations by modifying their production weight for two production sites.   In this case these plants across national borders function as substitutes to each other.   This effect can be called as "substitute" effect and examined with a simple model in this section.

If a domestic manufacturing firm exports intermediate products or product parts to foreign final-product manufacturing firm, these two plants function as compliments to each other.   It is compliment in a sense that increase in production at one plant leads to increase in production of the other[7].   If a newly acquired foreign plant acts as complimentary plant, our previous vertical model in section 3 can be reinterpreted as complimentary model.

In this subsection we analyze the effect of foreign direct investment for local production plant as a substitute to existing domestic plants.   Upon constructing a model, the purpose of establishing a local plant overseas needs to be carefully reexamined.   If a firm only needs to switch to foreign

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[6] However, we note that the estimated coefficients of multiple location are sometimes insignificant in their estimation result.

[7] These uses of terminology are familiar in multinational corporation literature, see Blonigen (2001).

12

production due to relatively cheap labor cost, a domestic plant can be shut down at the start of foreign production to maintain the level of firm's global production. This FDI process should be investigated by comparing two domestic plant case and one domestic plant and one foreign plant case. If a firm also intends to increase its global production level, appropriate analysis should involve the comparison of single domestic plant case and one domestic plant and one foreign plant case. In the followings, the exchange rate pass-through are examined respectively for 'single domestic plant,' 'two domestic plants,' and 'one domestic plant and one foreign plant' case.

[Single domestic plant]

First, we examine the exchange rate pass-through for single domestic plant case as a baseline for the later analysis of FDI effect on the exchange rate pass-through. Our specification for a local plant model follows very close to our local distributor model except for a slight modification on cost function. Since we focus on multi-plant model, maintaining constant marginal cost assumption from a local plant model causes a severe problem. For a multi-plant case the relative share of production for each plant becomes indeterminate if each plant has same constant marginal cost. If the level of marginal cost differs for each plants, production takes a place only on a plant with the lowest marginal cost. For international multi-plant case, this means that entire amount of production switches back and forth across national border if exchange rate fluctuates. So we assume increasing marginal cost for production in the following analysis.

Profit for a single plant firm with increasing marginal cost function is,

$$\pi_D = \frac{1}{e}\{p(q)q - ec(q)\} = \frac{1}{e}\{(d-q)q - \frac{1}{2}ec_1 q^2\} . \tag{14}$$

Rearranging first order condition for maximizing profit for single plant gives pricing equaiton as

$$p = \frac{d + dec_1}{(2 + ec_1)} . \tag{15}$$

Solving for exchange rate pass-through as equation (16), we find that incomplete pass-through holds for our model specification.

$$\frac{d \ln p}{d \ln e} = \frac{ec_1}{2 + 3ec_1 + (ec_1)^2} < 1 \tag{16}$$

[Two domestic plants]

   Before we directly compare the result for single domestic plant case with one domestic plant and one local plant case, we examine the effect of extending the number of production plants on exchange rate pass-through.

$$\pi_{DD} = \frac{1}{e}\{(d - q_1 - q_2)q_1 - \frac{1}{2}ec_1 q_1^2\} + \frac{1}{e}\{(d - q_1 - q_2)q_2 - \frac{1}{2}ec_1 q_2^2\} \tag{17}$$

$$p = \frac{2d + edc_1}{4 + ec_1} \tag{18}$$

$$\frac{d \ln p}{d \ln e} = \frac{ec_1}{4 + 3ec_1 + (1/2)(ec_1)^2} < 1 \tag{19}$$

Comparing equation (16) and (19) reveals that increase in the number of plants decreases the level of exchange rate pass-through if the curvature of cost function, denominated in foreign currency term, is not large, $ec_1 < 2$. Although we have analyzed only for plant expansion case from single plant to two plants, this condition on the curvature of cost function can be generalized for arbitrary number of plants (see the Appendix B.)

[One domestic plant and one foreign plant]

   Now we investigate the effect of establishing local plant which is substitute to domestic plants.

$$\pi_{DF} = \frac{1}{e}\{(d - q_1 - q_2)q_1 - \frac{1}{2}ec_1 q_1^2\} + \frac{1}{e}\{(d - q_1 - q_2)q_2 - \frac{1}{2}c_f q_2^2\} \tag{20}$$

14

$$p = \frac{dec_1 + dc_f + dec_1c_f}{2ec_1 + 2c_f + ec_1c_f} \tag{21}$$

$$\frac{d\ln p}{d\ln e} = \frac{ec_1 c_{f2}^2}{(2ec_1 + 2c_f + ec_1c_f)(ec_1 + c_f + (ec_1)^2)} < 1 \tag{22}$$

From equation (22) it is obvious that relative cost of domestic plant and foreign plant affects the degree of exchange rate pass-through.   However, we set these two costs equal in order to isolate a pure effect of foreign direct investment for a subsidiary production.

$$\left.\frac{d\ln p}{d\ln e}\right|_{c_f = ec_1} = \frac{(ec_1)^2}{8 + 6ec_1 + (ec_1)^2} < 1 \tag{23}$$

From comparison of equation (19) with (23), it is surprising to find that replacing a domestic plant with a foreign plant decreases the level of exchange rate pass-through if the same condition for the curvature of cost function holds, i.e., $ec_1 < 2$.   Although coincidence of these conditions is surely due to our specifications for assumptions, we believe that we can claim in general that foreign direct investment for local plants decreases exchange rate pass-through if the conditions hold for decreasing exchange rate pass-through with expansion of the number of domestic plants.

Acquiring a new foreign plant can have two distinct effects on pricing behavior of exporters.   Plant expansion effect can occur because an exporter now has a lower average marginal cost over all plants.   At the same time, portion of production cost is insulated from exchange rate shocks due to local production and that affects the price of exports from domestic plant as well. We summarize the result in the following proposition.

Proposition 2: When a new plant is established in a foreign market, either as an additional plant or as a replacing plant for a closed-down domestic plant, the level of exchange rate pass-through decreases.

5. Empirical Methodology and Data

5.1. Empirical model

In this subsection we will introduce an empirical model to capture the effect of establishing foreign subsidiaries on exchange rate pass-through, using panel data for a sample of Japanese exports and foreign direct investments. We will follow the previous panel estimation approach used in empirical exchange rate pass-through literature, in line with Knetter (1989) and Takagi and Yoshida (2001). Our innovation in pass-through estimation is inclusion of FDI variables in order to test the hypothesis that FDI affects the degree of exchange rate pass-through. In order to capture the different implication of forms of FDI, the FDI variables are constructed in a way to distinguish the purpose of investments, namely local production and local distribution.

$$p_{it} = \beta e_{it} + \gamma e_{it} FDI_{it} + \alpha_i + \lambda_t + \varepsilon_{it} \tag{24}$$

Our general estimation model for pass-through equation is expressed in equation (24). The log of price denominated in the currency of destination market, p_{it}, is regressed on the log of the foreign currency price of the Japanese yen, e_{it}, FDI variable, FDI_{it}, a fixed country effect error component, α_i, a fixed time effect error component, λ_t, and a disturbance term, ε_{it}. An exchange rate pass-through, β, is defined as a percentage change in export price with respect to a percentage change in exchange rate. Currency denomination is so chosen that complete pass-through means unity in an exchange rate pass-through coefficient. The FDI variable is multiplied by exchange rate in order to capture the effect of subsidiaries on exchange rate pass-through, rather than on the price level. Inclusion of FDI variable in the pass-through equation is utilized in Gron and Swenson (1996) although destination market is only restricted to a single country, namely the US, and FDI is strictly restricted only for US plants. Therefore, testing the effect of local production on pass-through with expanding a sample data to a panel of destination countries is also our contribution to the literature, without saying innovation of testing effect of

16

local distribution.

The fixed effect error component is necessary for eliminating absolute price level dispersion among destination countries, due to the differences in quality level of products and trade barriers. Without a directly observed cost data, estimated exchange rate pass-through might be biased since an observed price movement is also affected by the change in industry cost. Time dummy variable is introduced to capture these underlying cost fluctuations.

5.2. Hypothesis Consistent with Our Models

We have obtained from our models the general conclusion that foreign direct investments have effects on the level of exchange rate pass-through as formally presented in Section 3 and 4, however, the effect of investments can be significantly different whether investments are vertical or horizontal and whether investments has significant effects on bargaining power of an exporter in the case of vertical investment.

In section 3 we analyzed the model in which investments are directed toward downstream firms. As repeatedly stated, a downstream firm we concern in the model can be either a distribution firm or a manufacturing firm. If bargaining process between an exporter and its downstream firm is not considered, the effect of foreign direct investment is unambiguously positive on exchange rate pass-through. However, if foreign direct investment strengthen the bargaining position of an exporter, the compound effect of ownership acquirement and bargaining power shift is no longer straightforward. As formally stated in Proposition 1 in section 3, a relative increase in bargaining power of an investing exporter is large with respect to change in ownership, the effect of foreign direct investment for downstream firm on exchange rate pass-through becomes negative. This is most likely if managerial concern drives the firm's profit maximization.

In section 4 we looked at different type of foreign direct investment; horizontal expansion of manufacturing plants. In this model we needed some underlying structure to keep an exporter from shutting down domestic manufacturing plants. Otherwise, there would be no exports after foreign direct investments. Plausible underlying structures can be inclusion of dynamic concern

for exporters with sunk cost, plant-level capacity constraints, domestic labor-union opposition or some other regulatory restraints. Our choice of tool for the model was assumption of increasing marginal cost for an exporter. With this assumption we derived an unambiguous result for the horizontal plant expansion model; positive effect on exchange rate pass-through.

With our data sample, we have several firms in each category although we assumed a single exporter in our models. Without any additional assumptions, extending our model to oligopoly exporters framework can be troublesome because the first firm having an opportunity to establish its own subsidiary can lower its transfer price below exporter's marginal cost to the extent to eliminate all other competitors from the local market. This is possible because negative net sales for this exporter can be compensated with profit increase in its own subsidiary. However, this is not consistent with our observation for foreign investment data where several firms remain constantly in the market and make investments.

This counter-intuitive result might be corrected if we assume that firms in local market are capacity constrained so that there would be a limit for extra profit obtained by an exporter with a subsidiary firm by lowering its transfer price. Another assumption more in line with WTO rules is that an exporter refrains itself from selling exports below marginal cost for the fear of consequent anti-dumping duty. This lowest limit of transfer price is assumed for differentiated products for oligopoly exporters in the Appendix A-2 and we obtained similar effect of ownership on exchange rate pass-through for oligopoly cases as well.   The result is summarized as Proposition A2.

Now, we need to reinterpret the results of our models in terms of possible empirical hypothesis with our use of particular dataset.   Since we are able to distinguish the purpose of investments, i.e. distribution or manufacturing, from our data, we need to make correspondence between purpose of investments and our models.   For FDI categorized as distribution purpose, we could directly apply the results of section 3.   For manufacturing plant FDI, we need to distinguish between vertical FDI and horizontal FDI.   We summarized the expected sign of foreign direct investment effects and supporting theories with assumptions in Table 4.

18

5.3. GMM for Dynamic Panel Data Model

With consideration of the nature of time series property of dependent variable, export price, it is advisable to include the lagged dependent variable as an explanatory variable.

$$p_{it} = \delta p_{it-1} + \beta e_{it} + \gamma e_{it} FDI_{it} + \alpha_i + \varepsilon_{it} \tag{25}$$

One advantage of this framework over a static model is that it allows long-term pass-through elasticity to be different from short-term pass-through elasticity.   Coefficients of a dynamic panel data model of equation (25) is no longer unbiasedly estimated with a conventional within-transformation estimator, or least squared dummy variable estimator, hence force LSDV estimator.   Although LSDV estimator is consistent when sample size in time dimension approaches infinity, it is inconsistent for fixed T when sample size in cross-section dimension becomes infinite, see Nickell (1981) and Beggs and Nerlove (1988).   This is severe problem since many applications which use panel series data tend to have wider size of cross-section dimension than time dimension. Consistent estimation methodology is then suggested by Anderson and Hsiao (1982) with the use of instrumental variables in a differenced form,

$$\Delta p_{it} = \delta \Delta p_{it-1} + \beta \Delta e_{it} + \gamma \Delta(e_{it} FDI_{it}) + \Delta \varepsilon_{it} \tag{26}$$

where instrumental variables are chosen to be either p_{it-2} or Δp_{it-2}.   However, Arellano and Bond (1991) pointed out that Anderson and Hsiao estimator is inefficient because it neither exploits all moment conditions nor take into account of disturbance term structure.   Arelllano and Bond then proposed consistent GMM estimator for fixed T and large N.   Aggregating explanatory variables as a matrix, equation (26) can be restated as

$$\Delta p = \alpha \Delta X + \Delta \varepsilon . \tag{27}$$

With a matrix Z consisting of instrumental variables as vectors, a corresponding sample moment

condition vector is $g_N = \dfrac{1}{N}Z'\Delta\varepsilon$ and each component is a summation taken over in cross-section direction. Given a weighting matrix, A, and existence of an estimator, a GMM estimator is $\alpha_{GMM} = \{\alpha \in \arg\min g_N A g'_N\}$. For our linear estimator, a GMM estimator can be analytically solved to be

$$\alpha_{GMM} = (\Delta X'ZAZ'\Delta X)^{-1}\Delta X'ZAZ'\Delta p \tag{28}$$

As valid instruments for predetermined variables, in differenced form of (26) or (27) more than two-lagged level variable is orthogonal to current differenced disturbances. For strictly exogenous variables, Arellano and Bond (1991) suggests that all past and future level variables are orthogonal to current differenced disturbances. However, we will use only current differenced variables as instruments for strictly exogenous variables as they appear as explanatory variables in equation (26) for the ease of computation although we will exhaust all instruments for predetermined variable.

$$
Z = \begin{pmatrix}
p_{11} & 0 & 0 & 0 & \cdots & & & \Delta e_{11} & \Delta(e_{11}FDI_{11}) \\
0 & p_{11} & p_{12} & 0 & \cdots & & & \Delta e_{12} & \Delta(e_{12}FDI_{12}) \\
0 & 0 & 0 & p_{11} & p_{12} & p_{13} & & \Delta e_{13} & \Delta(e_{13}FDI_{13}) \\
0 & 0 & 0 & 0 & 0 & & \ddots & \vdots & \vdots \\
\vdots & \vdots & \vdots & \vdots & \vdots & & & & \\
p_{21} & 0 & 0 & 0 & \cdots & & & \Delta e_{21} & \Delta(e_{21}FDI_{21}) \\
0 & p_{21} & p_{22} & 0 & \cdots & & & \Delta e_{22} & \Delta(e_{22}FDI_{22}) \\
0 & 0 & 0 & p_{21} & p_{22} & p_{23} & & \Delta e_{23} & \Delta(e_{23}FDI_{23}) \\
\vdots & \vdots & \vdots & & & & \ddots & \vdots & \vdots
\end{pmatrix} \tag{29}
$$

Weighting matrix proposed for GMM1 estimator takes into account of MA(1) process of differenced disturbance,

20

$$A_1 = Z'HZ \quad \text{where} \quad H = \begin{pmatrix} h & 0 & 0 & \cdots & 0 \\ 0 & h & 0 & & \vdots \\ 0 & 0 & \ddots & 0 & 0 \\ \vdots & & 0 & h & 0 \\ 0 & \cdots & 0 & 0 & h \end{pmatrix} \quad \text{and} \quad h = \begin{pmatrix} 2 & 0 & 0 & & \\ -1 & 2 & 0 & & \\ 0 & -1 & 2 & & \\ & & & \ddots & \\ & & & -1 & 2 \end{pmatrix} \quad (30)$$

Weighting matrix for efficient GMM2 estimator is calculated from the residuals of consistent GMM1 estimator,

$$A_2 = Z' \Delta\hat{\varepsilon}\Delta\hat{\varepsilon}' Z \quad \text{where} \quad \Delta\hat{\varepsilon} = \Delta p - \alpha_{GMM1}\Delta X \quad (31)$$

Although GMM variant estimators for dynamic panel model possess desirable property of asymptotic consistency, there still remain some caveats implementing this methodology to our data sample. Formulation of GMM suggested by Arellano and Bond (1991) relays its asymptotic property on large size of cross-sections. Our data sample for annual series consists of 11 years and 10-13 cross-section countries. Although our use of monthly series data for the same period expands time dimension to 12 folds, the size of cross-section sample remains same. For monthly data, it might be more convincing to use a with-in estimator for its consistency in time dimension. Moreover, it is not clear if the large sample property of GMM estimator holds at all for our data samples[8].

In fact, there are number of research that compares the small sample property of GMM estimator with other alternative estimators. Arellano and Bond (1991) themselves simulated with the sample size of T=7 and N=100 to conclude that biases in GMM estimators are much small than within-estimator. Judson and Owen (1999) compares small sample bias of LSDV and GMM estimators for the sample size of T=5 to 30 and N=20 by Monte Carlo simulation[9].

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[8] Tauchen (1986) is, among other authors, first to report the small sample bias problem of GMM estimators.
[9] They also provide results for the sample size of N=100, but this case is not applicable for our data

5.4. Data source

The Japan Exports and Imports, Japan Tariff Association, contains values and quantities for nine-digit CCFTS-classified commodities by country[10]. The Commodity Classification for Foreign Trade Statistics, CCFTS, is based upon the Harmonized Commodity Description and Coding System, HS.   The values of commodity export are the FOB values. We calculated a unit price for each commodity from dividing corresponding value by quantity.   *The Overseas Japanese Companies Data*, Toyo Keizai, contains relevant information for approximately 19000 Japanese foreign subsidiaries.   From 68 industry classifications, electronics manufacturer (1900) and electronics wholesaler (3700) were actually used, totaling 3204 subsidiary firm data.   The average exchange rates for Taiwan are obtained from *Financial Statistics, Taiwan District, Republic of China* and other destination countries are obtained from *the International Financial Statistics*, International Monetary Fund.

5.5. Selection process for products and countries

For a preliminary empirical examination, we selected three commodities satisfying the two criteria, among the largest share in exports and sufficient FDI observation for corresponding commodity.   In addition, we narrow down the commodity classification to only electronics products due to its overwhelming share in the Japanese exports.   Some of the candidates are dispelled due to the shot length of time for the availability.   With these selection procedures, chosen are video recording or reproducing apparatus of magnetic tape-type (852110000), parts of electronic integrated circuits or microassemblies (854290000), and electrostatic photocopier (900912000)[11].   The volumes and unit prices of these products for total exports are shown in

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availability.

[10]   See Takagi and Yoshida (2001) for a more description of this data source.

[11]   The values of exports in 1998 for video, IC, and copier are 197 billion, 273 billion, and 390 billion yen, respectively.   We note that the 1998-export value of the largest export of Japan, motor cars with engine exceeding 2000cc but not exceeding 3000cc, is 2017 billion yen.

Figure 11 - 13.

For each product, sample countries are selected only if its share in 1998-export value for that product exceeds one percent share. Sample countries for video are Australia, Canada, France, Germany, Hong Kong, Italy, Netherlands, Panama, Saudi Arabia, Singapore, UAE, UK, US; for copier, Australia, Belgium, Canada, France, Germany, Hong Kong, Italy, Netherlands, New Zealand, Singapore, Taiwan, UK, US; for IC, Germany, Hong Kong, Korea, Malaysia, Philippine, Singapore, Taiwan, Thailand, UK, US. This selection process avoids unfavorably excessive volatility of export price due to a change in the composition within the product category and missing data due to the lack of transaction for more than a year.

5.6. Construction of FDI variables

As a first proxy for the relevant FDI data, we used the total number of foreign subsidiaries in electronics and electronics parts industry by country. This FDI data, denoted as *FDIIND*, is a common variable for all products. Since foreign subsidiaries for specific products are not distinguished, counting all subsidiaries in electronics industry as relevant FDI may also pick up interactive effects among subsidiaries, considered as distribution or/and production network effects. For a given product, however, it is likely to blur the significant effect of establishing a relevant subsidiary from an irrelevant subsidiary.

Next, we created product level FDI dummy variables for each product, taking a value of one if there exists a related foreign subsidiary for specific product in a destination country and a distinction between distribution and production subsidiaries is also made. *DEALB* and *PLANTN* denote for subsidiary for distribution and production, respectively. These dummy variables take a value of zero for years in which the first subsidiary is not present yet and one for years with at least one firm. Since these dummy variables do not assess the number of multiple subsidiaries, estimated coefficient may understate the effect of foreign subsidiary for a country with multiple subsidiaries. Finally, *DEALN* and *PLANTN* are created for the number of subsidiary in a destination country. The summary statistics for FDI data are given in Table 5.

6. Estimation results

6.1 Annual data

First, we have estimated exchange rate pass-through for three major electronics products, using annual data of sample period between 1988 to 1998.   Advantages of using annual data are that we can control to some extent for lagged response of export prices to the time of subsidiary establishment and use this as a preliminary investigation to be compared with the result of monthly data for robustness of our empirical results.   Table 6 - 8 presents LSDV estimation results of annual exchange rate pass-through for video, copier, and IC parts, respectively.   Surprisingly, the first column (i) of each table show that the electronics industry-wide FDI is statistically significant except for video price.   However, the estimated coefficient is less than one-thousandth of the size of the coefficients of exchange rate term.   At this aggregate level we can find only a weak evidence of FDI effect on exchange rate pass-through.

Next, we disaggregate industry-level subsidiary data further to product-specific level in oreder to match exactly to HS 9-digit product specification, as described in subsection 5.6.   Furthermore, we break down subsidiaries for the purpose of their investments; distribution or production. *DEALB* and *PLANTB* are constructed as binary dummy variable to correctly capture the presence of subsidiaries in local market without regard to the number of establishments.   We have used these dummy variables to capture the impact effect of direct ownership of Japanese subsidiary in local market, drawing clear distinction between a market in which some Japanese subsidiary are present and a market without any Japanese subsidiary.   FDI estimators in specification (ii) indicate that both distribution and production purpose investment have statistical significant effect on the degree of exchange rate pass-through, except for the production subsidiary for IC parts.   The negative signs for distribution subsidiary found for video and copier price indicates that bargaining power for exporters must have increased relatively large after establishing subsidiaries in foreign markets (see Proposition 1, section3.)

However, the positive sign of distribution subsidiary for IC parts indicates that Japanese exporters of IC parts could not have gained relatively strong bargaining position with respect to IC

24

parts customers (see Lemma 1, section 3.)   This interpretation of IC-parts result is not surprising if we consider exogenous factors in IC industry.   Here, we distinguish clearly between "IC parts" and complete "IC products".   Due to the fact competition in IC products are becoming severer each year during the sample period and prices of IC products are decreasing, faced with constantly emerging new IC products of ever-higher performance.   The condition of excessive competition in IC supply at IC product market might not allow IC-parts suppliers to gain an increase in their bargaining power over IC products manufactures.

With manufacturing plant subsidiaries, the effect on exchange rate pass-through is significantly positive for video and copier.   This is inconsistent with Proposition2, sec 4.

Instead of binary dummy variables for Japanese subsidiaries, we also used number of Japanese subsidiaries for FDI variables and the results are shown in specification (iii).   There were not any statistically significant changes in sign of coefficients except for production FDI for copier.   With this result we are left with production FDI for video being the only empirical result inconsistent with theoretical counterparts.

While we expect the sign of coefficients to be constantly negative for production FDI from our theory, it is noteworthy to state that there is a possibility of change in the sign of coefficients for distribution FDI as the number of Japanese subsidiary increases in an importing country.   It is plausible that while DEALB variable captures the breakthrough effect on exporters' bargaining position of establishing exporters' own distribution network, DEALN variable captures less dramatic increase of bargaining position of exporters.   This difference in increase of bargaining power of exporters might result in with negative coefficient of DEALB and positive coefficient of DEALN.   We try to capture this possibility by incorporating both variables in specification (iv). In specification (v), we included time dummies to control for any marginal cost changes in exporting side.

For video in Table 6, the coefficient of DEALB is statistically negative at one percent level but it is insignificant for DEALN regardless of inclusion of time dummies.   For copier in Table 7, the coefficient for DEALB and DEALN are negative and positive, respectively, both statistically

significant at five percent level with time dummies.   For these two products, the above scenario seems to be an explanation.   However, for IC parts in Table 8 it is only statistically significant for DEALN when time dummy is excluded while it is statistically significant for DEALB in both specifications.

Overall, we found that the effect of subsidiary on the degree of exchange rate are statistically significant.   For distribution subsidiaries, the existence of subsidiary, which is captured in DEALB variable, put downward effect on exchange rate pass-through for video and copier while positive effect is observed for IC-parts.   For production subsidiaries, multinational production decreases the degree of exchange rate pass-through for copier and video as expected from our theoretical sections, but it makes exchange rate pass-through higher for video prices.   Inclusion of time dummies did not affect the coefficient of subsidiary interaction term while the coefficient of exchange rate is greatly affected in some cases.

6.2 Monthly Data

From Table 9 – 11, we have summarized estimation results for the same three electronics products with monthly data.   Since export price data are expected to possess autoregressive property with the use of higher frequency data, we choose to include lagged export price as an explanatory variable instead of using ad hoc time dummy variables.   Our estimation specification is shown in equation (25) and we used least square dummy variable estimation for Table 9 - 11.

Specification (i) includes FDI variables for distribution and production as number of subsidiaries and specification (ii) adds binary distribution FDI variable to capture the structural change in the presence of Japanese subsidiaries.   Surprisingly, the results are qualitatively very similar to annual data estimation despite the differences in specification form for dynamic property of export prices.   For video, distribution subsidiaries seem to lower the degree of exchange rate pass-through while production subsidiaries increase exchange rate pass-through. For copier the sign of coefficients for distribution subsidiaries are all negative but not statistically significant if included simultaneously and production subsidiaries decrease exchange rate pass-through.   For

26

IC-parts the distribution subsidiary coefficient is positive for binary variable and negative for count variable and production subsidiary coefficient is negative.

Up to now we have only examined foreign direct investments in major importing countries[12] and discarded possibly strategically important subsidiaries in nearby countries. In specifications (iii) and (iv) we formulate two important regional variables; Asia and Europe. In these region variables, Japanese subsidiaries in countries that are excluded from our sample are also added as well as those countries in sample. We continued to distinguish between distribution and production subsidiaries but only used count data variables.

For video exports, inclusion of these regional variables does not affect the coefficients of distribution subsidiaries, however, the coefficients of production are no longer statistically significant with area variables. Europe variables are both statistically significant at one percent level while Asia variables are insignificant. Japanese subsidiaries in a neighboring European country can affect the degree of exchange rate pass-through for another country in Europe where as this is not so in Asia. Since Europe variable for production subsidiaries is positive, it has been European countries for video which drives positive sign in exchange rate pass-through estimation in other specifications in monthly data as well as annual data.

For copier exports, coefficients of FDI variables are quite robust to inclusion of regional variables. Count data for distribution subsidiaries in region are statistically significant at one percent level for both Europe and Asia. For production subsidiaries, only Europe is significant at five percent level and its sign is positive. We should not misinterpret this positive sign for production as inconsistent with our theory. It is only representing that negative effect of production on exchange rate pass-through is less in absolute term in Europe. For example, one production subsidiary in Europe decreases exchange rate pass-through 10.8 percent while one production subsidiary in Asia decreases by 12.7 percent in specification (iii).

For IC-parts exports, the coefficients of production variable become statistically insignificant

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[12] As described in section 5.5 we have narrowed country sample by selecting only those with their share in 1998-export value exceed one percent.

when regional variables are included.   All regional subsidiary variables are statistically significant with negative sign except Asian distribution variable.   It is noteworthy that the magnitude of coefficient for European production subsidiaries is about same size of those of exchange rate variable.

From these excises, we can conclude that it is more likely in Europe that Japanese subsidiary in one country affect the degree of exchange rate pass-through in neighboring counties.   This is consistent to our intuition that subsidiaries in Europe are intended to be part of European regional network for Japanese multinationals while subsidiaries in Asia might be export hub to other regions of the world.

As we noted in section 5.3, dynamic panel model specification does not necessarily obtain consistent estimators when observation is small in both direction of time and cross-section.   There is not distinct number of observations in time dimension that can assure consistency in the coefficients of explanatory variables for dynamic panel model estimation.   So we also estimated export price regression via one-step generalized method of moment suggested in Arellano and Bond (1991).   The results are summarized in Table 12 and It turned out that the signs of coefficients are same as LSDV estimators.   Moreover, we have calculated bias for LSDV estimators by using one-step GMM estimators as consistent initial estimators as suggested in Kiviet (1995). Surprisingly, bias of LSDV estimators with our 132 observation in time dimension has shown to be around one hundredth in magnitude of estimated coefficients in Table 13.   With these additional information, we can conclude our empirical result is quite robust.

7. Conclusion, Caveats, and Policy Implications

We have presented theoretical models distinguishing between distribution and production subsidiaries for foreign direct investment.   For a distribution FDI model, we have included features as partial ownership and bargaining between an exporter and a local distributor.   We have shown that exchange rate pass-through decreases only if significant increase in bargaining power for an exporter is obtained after acquiring ownership of a distribution firm.   Therefore, it is important to

28

determine what factors might affect the change in bargaining power for exporters when downstream firm is acquired. For a model of production FDI, we have shown that exchange rate pass-through unambiguously decreases when an exporter establishes local plants in an importing country.

Among Japanese multinationals playing an important role for world FDI, we have selected electronics industry, one of two most important industries in Japan, for our empirical target. For we intend to use most disaggregate trade data publicly available in Japan to match exactly with specific product foreign direct investment data, we have chosen three electronics products; namely video player, copier machine and IC-parts. Data sample are span between 1988 and 1998 to cover most active time of Japanese foreign direct investments.

Our empirical result indicates that inclusion of FDI variable properly constructed to capture the type of subsidiary and the timing of establishment is essential to the estimation of exchange rate pass-through. Observing estimation results from our limited number of products in electronics industry we tentatively conclude that establishing own distribution network in local market are more likely to strengthen significantly the bargaining power of an exporter and consequently exchange rate pass-through will be decreased. Conforming to the results of Gron and Swenson (1996), we also consistently found the significant downward effect of local production on exchange rate pass-through. Only one empirical result inconsistent with our theoretical prediction is estimated positive sign for production subsidiaries for IC products. European regional FDI variable indicates it is most phenomenal in Europe, and here we need to further investigate underlying features in production model to explain this empirical observation.

Empirically, we have also found out that Japanese subsidiaries in neighboring countries can affect the degree of exchange rate pass-through of a country in the region. Our results indicate that this is more prevalent in European region than among Asian countries. This is quite consistent to our intuition that foreign subsidiaries of Japanese multinationals in Europe are aimed for European markets while subsidiaries in Asia are constituents of an export hub for the world market.

While most explanations in exchange rate pass-through and pricing-to-market literature for different degree of export price responsiveness with respect to exchange rate among industry and

countries implicitly points to differences in market structures in addition to demand structures and production function, we are able to show explicitly the presence of foreign subsidiaries in local market can significantly change the degree of exchange rate pass-through. Moreover, we are also able to explain the dynamic behavior of exchange rate pass-through due to a change in establishment of own network for both production and distribution.

Although our theoretical models are in partial equilibrium settings, regarding the overall effect of foreign direct investment on pass-through, it is essential to incorporate the role of foreign subsidiaries in new open economy macroeconomics research. A further investigation is necessary to correctly assess the direction of effects from the ongoing world trend for globalization and regionalization on balance of payment adjustments.

Appendix A: Differentiated Products Duopoly

In this appendix, we show that general result of our model in section 3 still holds when the number of exporters is expanded to more than a single firm. We restrict our model to duopoly exporters case, but we believe that it can be generalized to N-oligopoly exporters case. We start from consumer's maximization problem and derive inverse demands for differentiated products as in Singh and Vives (1984). At consumer markets two downstream firms, D1 and D2, supply differentiated goods in a Cournot competition. Each downstream firm purchases exports from different exporters, U1 and U2. D1 (D2) bargains transfer price with U1 (U2). In this appendix we treat bargaining and ownership issues separately to clarify that same underlying forces are still present in duopoly frameworks. First, we show that increase in bargaining power for one exporter, holding constant bargaining power for another exporter, decreases the level of exchange rate pass-through, assuming zero share ownership of downstream firms by exporters. This pure bargaining effect corresponds to equation (12) in section 3. Next, we demonstrate that acquiring full ownership of a downstream firm by an exporter increases the degree of exchange rate pass-through when bargaining power for both exporters are one. This pure ownership effect corresponds to equation (13) in section 3. We therefore conclude that our result from the model in section 3 can be extended to the real world case in which multiple foreign direct investments are taken sequentially by different exporters[13].

Consumers Preferences:

Consumers are assumed to have a quadratic form utility function with symmetricity imposed for the ease of calculation. The center of our concern here are two differentiated goods, q_1 and q_2. Income is denoted as I and q_0 is the bundle of other goods and also acts as a numeraie. We also assume the coefficient for cross-product term is strictly smaller than the coefficient of

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[13] We will not show any formal analysis for the interaction effect between bargaining and ownership, however, we believe similar arguments in section 3 can be applied to oligopoly cases.

own-product term, i.e. $c < b$.[14]

$$U = q_0 + a(q_1 + q_2) - \frac{1}{2}(bq_1^2 + 2cq_1q_2 + bq_2^2)$$

$$\text{s.t.} \quad I = q_0 + p_1q_1 + p_2q_2$$

(A1)

Setting up a Lagrangian and solving for first order conditions will lead to two related inverse demand functions.

$$p_1 = a - bq_1 - cq_2$$
$$p_2 = a - cq_1 - bq_2$$

(A2)

Downstream Firms:

The profit of downstream firm is same as in section 3. Constant marginal cost, c_D, for downstream firms are same for both firms and transfer price, ew_i, is determined in a bargaining fashion with its counterpart exporter.

$$\pi_{D1} = (p_1 - c_D - ew_1)q_1$$
$$\pi_{D2} = (p_2 - c_D - ew_2)q_2$$

(A3)

Each downstream firm is assumed to be choosing their optimal quantity of exports, taking as given transfer prices of two firms and the quantity of its competitor.   The first order conditions for both firms yield best response functions.

$$q_1 = \frac{a - c_D - ew_1}{2b} - \frac{c}{2b}q_2$$

$$q_2 = \frac{a - c_D - ew_2}{2b} - \frac{c}{2b}q_1$$

(A4)

Solving simultaneous equations (A4), we can obtain derived demand functions for both export products.

$$q_1 = \frac{(2b-c)(a-c_D) - 2bew_1 + cew_2}{4b^2 - c^2}$$

(A5)

$$q_2 = \frac{(2b-c)(a-c_D) + cew_1 - 2bew_2}{4b^2 - c^2}$$

(A6)

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[14] If $c = b$, demand functions can not be obtained because coefficient matrix in (A2) is not invertible.

Using (A5) and (A6), we can obtain profit functions for two downstream firms.

$$\pi_{D1} = bq_1^2 = b\left[\frac{(2b-c)(a-c_D) - 2bew_1 + cew_2}{4b^2 - c^2}\right]^2 \tag{A7}$$

$$\pi_{D2} = bq_2^2 = b\left[\frac{(2b-c)(a-c_D) + cew_1 - 2bew_2}{4b^2 - c^2}\right]^2 \tag{A8}$$

A-1. Upstream Firms with Bargaining:

The profits for exporters are also same as in section 3. Constant marginal costs, C_U, for producing differentiated goods are equal between two exporters.

$$\begin{aligned}
\pi_{U1} &= (w_1 - c_U)q_1 = (w_1 - c_U)\left[\frac{(2b-c)(a-c_D) - 2bew_1 + cew_2}{4b^2 - c^2}\right] \\
\pi_{U2} &= (w_2 - c_U)q_2 = (w_2 - c_U)\left[\frac{(2b-c)(a-c_D) + cew_1 - 2bew_2}{4b^2 - c^2}\right]
\end{aligned} \tag{A9}$$

The following equation (A10) represents that each exporter engage in a Nash-bargaining with their counterpart downstream firms to determine their transfer prices as in.

$$\begin{aligned}
NB_1 &= \pi_{U1}^{\alpha_1}\pi_{D1}^{(1-\alpha_1)} \\
NB_2 &= \pi_{U2}^{\alpha_2}\pi_{D2}^{(1-\alpha_2)}
\end{aligned} \tag{A10}$$

Solving the first order conditions for each Nash-bargaining problem yields the best response transfer-price functions.

$$ew_1 = \frac{\alpha_1(2b-c)(a-c_D)}{4b} + \frac{(2-\alpha_1)}{2}ec_U + \frac{\alpha_1 c}{4b}ew_2 \tag{A11}$$

$$ew_2 = \frac{\alpha_2(2b-c)(a-c_D)}{4b} + \frac{(2-\alpha_2)}{2}ec_U + \frac{\alpha_2 c}{4b}ew_1 \tag{A12}$$

Solving simultaneous equations, (A11) and (A12), we can obtain equilibrium transfer prices.

$$ew_1 = \frac{(4\alpha_1 b + \alpha_1\alpha_2 c)(2b-c)}{16b^2 - \alpha_1\alpha_2 c^2}(a-c_D) + \frac{8b^2(2-\alpha_1) + 2\alpha_1 bc(2-\alpha_2)}{16b^2 - \alpha_1\alpha_2 c^2}ec_U \tag{A13}$$

$$ew_2 = \frac{(4\alpha_2 b + \alpha_1\alpha_2 c)(2b-c)}{16b^2 - \alpha_1\alpha_2 c^2}(a-c_D) + \frac{8b^2(2-\alpha_2) + 2\alpha_2 bc(2-\alpha_1)}{16b^2 - \alpha_1\alpha_2 c^2}ec_U \tag{A14}$$

Inserting equilibrium transfer prices, (A13) and (A14), into (A5) and (A6), we can obtain for equilibrium supply for two differentiated exports goods.

$$q_1 = \frac{2(2-\alpha_1)(4b^2 + \alpha_2 bc)}{(2b+c)(16 - \alpha_1\alpha_2 c^2)}(a - c_D - ec_U) \tag{A15}$$

$$q_2 = \frac{2(2-\alpha_2)(4b^2 + \alpha_1 bc)}{(2b+c)(16 - \alpha_1\alpha_2 c^2)}(a - c_D - ec_U) \tag{A16}$$

By defining the ratio of each export to total exports as $\hat{q}_1$ and $\hat{q}_2$, we can obtain the expression for industry price index.

$$ew \equiv \frac{q_1}{q_1 + q_2}ew_1 + \frac{q_2}{q_1 + q_2}ew_2 = \hat{q}_1 ew_1 + \hat{q}_2 ew_2 \tag{A17}$$

For the proof of the following propositions, we derive four differential terms with respect to bargaining power of U1 exporter.

$$\frac{\partial \hat{q}_1}{\partial \alpha_1} = \frac{-(2-\alpha_2)(4b^2 + \alpha_2 bc)(4b^2 + 2bc)}{\left[(2-\alpha_1)(4b^2 + \alpha_2 bc) + (2-\alpha_2)(4b^2 + \alpha_1 bc)\right]^2} < 0 \tag{A18}$$

$$\frac{\partial \hat{q}_2}{\partial \alpha_1} = \frac{(2-\alpha_2)(4b^2 + \alpha_2 bc)(4b^2 + 2bc)}{\left[(2-\alpha_1)(4b^2 + \alpha_2 bc) + (2-\alpha_2)(4b^2 + \alpha_1 bc)\right]^2} > 0 \tag{A19}$$

$$\frac{\partial ew_1}{\partial \alpha_1} = \frac{16b^2}{(16b^2 - \alpha_1\alpha_2 c^2)^2}\left[\left\{8b^2 - 2(2-\alpha_2)bc - \alpha_2 c^2\right\}(a - c_D - ec_U)\right] > 0 \tag{A20}$$

$$\frac{\partial ew_2}{\partial \alpha_1} = \frac{4\alpha_2 bc}{\left[16b^2 - \alpha_1\alpha_2 c^2\right]^2}\left[\left\{8b^2 - 2(2-\alpha_2)bc - \alpha_2 c^2\right\}(a - c_D - ec_U)\right] \geq 0 \tag{A21}$$

Lemma A1: An industry transfer price is represented as a convex combination of *(a - c_D)* and *ec_U*, an increase in industry transfer price implies decrease in the level of exchange rate.

Proof:

From the coefficients of *(a - c_D)* and *ec_U* in (A13) and (A14), each transfer price can be easily

34

shown to be a convex combination of *(a - c_D)* and *ec_U*. Therefore, we denote $\lambda_1, \lambda_2 \in [0,1]$ for the coefficients of *(a - c_D)* in (A13) and (A14), respectively. By definition in (A17), industry transfer price is also a convex combination of each transfer prices, namely *ew_1* and *ew_2*. We denote $\delta \in [0,1]$ for the coefficient of *ew_1*. Then, we can rewrite the industry transfer price in terms of *(a - c_D)* and *ec_U*.

$$ew \equiv \delta ew_1 + (1-\delta)ew_2$$
$$= \delta[\lambda_1(a-c_D) + (1-\lambda_1)ec_U] + (1-\delta)[\lambda_2(a-c_D) + (1-\lambda_2)ec_U]$$
$$= [\delta\lambda_1 + (1-\delta)\lambda_2](a-c_D) + [\delta(1-\lambda_1) + (1-\delta)(1-\lambda_2)]ec_U$$

It can be easily checked that the coefficients are within the range of 0 to 1 and the sum of coefficients is 1. Therefore we proved the first part of lemma and we rewrite the industry transfer price with $\hat{\delta} \in [0,1]$. $ew = \hat{\delta}(a-c_D) + (1-\hat{\delta})ec_U$.

Since *(a - c_D) > ec* and *ew* is a covex combination of these two terms, increase in *ew* must come from increase in $\hat{\delta}$. Now we derive the exchange rate pass-through for industry transfer price.

$$\frac{d\ln ew}{d\ln e} = \frac{(1-\hat{\delta})ec_U}{\hat{\delta}(a-c_D) + (1-\hat{\delta})ec_U}$$

On the other hand, increase in $\hat{\delta}$ ambiguously implies decrease in exchange rate pass-through. *Q.E.D.*

Now we are ready to state for differentiated duopoly exporters the first proposition consistent with the model in section 3 that increase in bargaining power decreases the exchange rate pass-through.

Proposition A1: If initial bargaining powers are equal for two exporters, increase in bargaining power for one exporter decreases the level of exchange rate pass-through.

Proof:

Using Lemma A1, we only need to show increase in bargaining power increases industry transfer price. The differential of industry transfer price with respect to the bargaining power of U1 exporter is as follows.

$$
\begin{aligned}
\frac{\partial ew}{\partial \alpha_1} &= \frac{\partial \hat{q}_1}{\partial \alpha_1} ew_1 + \hat{q}_1 \frac{\partial ew_1}{\partial \alpha_1} + \frac{\partial \hat{q}_2}{\partial \alpha_1} ew_2 + \hat{q}_2 \frac{\partial ew_2}{\partial \alpha_1} \\
&= \frac{\partial \hat{q}_2}{\partial \alpha_1} (ew_2 - ew_1) + \hat{q}_1 \frac{\partial ew_1}{\partial \alpha_1} + \hat{q}_2 \frac{\partial ew_2}{\partial \alpha_1}
\end{aligned}
\tag{A22}
$$

Second equality follows from using equation (A18) and (A19). Since all terms in (A22) are positive except for $(ew_2 - ew_1)$ term, industry transfer price increases if $(ew_2 - ew_1)$ term is non-negative. From (A13) and (A14), we obtain equation (A23) and $(ew_2 - ew_1)$ is non-negative if and only if $\alpha_2 \geq \alpha_1$.

$$
ew_2 - ew_1 = \frac{(8b^2 - 4bc)}{16b^2 - \alpha_1 \alpha_2 c^2} (\alpha_2 - \alpha_1)(a - c_D - ec_U)
\tag{A23}
$$

Q.E.D.

A-2. Upstream Firms with Full Ownership:

Now in this subsection we deal with ownership effect on industry transfer price. In order to simplify the argument in what follows we maintain the assumption that bargaining power of exporters are one, $\alpha_1 = \alpha_2 = 1$. In addition we restrict our analysis to the extreme case of full ownership, i.e. $\beta_i = 1$, to accentuate the incentive for driving out a competitor in which a transfer price can go down below zero. After showing that possibility, we will put reasonable restriction on the lowest transfer price; that is a marginal-cost of exporter.

[Benchmark case: no ownership]

We first derive the level of industry transfer price for a bench mark case when there is no ownership. Since market share and transfer price are same between two differentiated export products in this symmetric case, industry transfer price of (A17) can be treated to be equal to either

of transfer price, (A13) or (A14). With assumption of full ownership, industry transfer price can be reduced to (A24).

$$ew = \frac{(2b-c)}{4b-c}(a-c_D) + \frac{2b}{4b-c}ec_U \tag{A24}$$

The exchange rate pass-through can be easily obtained by log-differentiating industry transfer price.

$$\frac{d\ln ew}{d\ln e} = \frac{2bec_U}{(2b-c)(a-c_D)+2bec_U} \qquad <1 \tag{A25}$$

[Single full-ownership case]

We consider now a case in which one of exporters acquires full ownership of a counterpart downstream firm; henceforth we assume this exporter to be U1. We first need to modify the profit of U1 exporter by adding up net sales revenue and the profit of downstream subsidiary in terms of currency of exporting country.

$$\pi_{U1} = (w_1 - c_U)q_1 + \frac{1}{e}\pi_{D1} \tag{A26}$$

With using (A5) and (A7), the first order condition of maximizing (A26) can be arranged for best response transfer price function.

$$ew_1 = \frac{-c^2(2b-c)}{2b(4b^2-2c^2)}(a-c_D) + \frac{(4b^2-c^2)}{(4b^2-2c^2)}ec_U - \frac{c^3}{2b(4b^2-2c^2)}ew_2 \tag{A27}$$

Solving for equilibrium transfer price for U1 from (A12) and (A27) we can show it is actually negative.

$$ew_1 = -\frac{(4bc^2+c^3)(2b-c)(a-c_D)+(4bc^3+2b)ec_U}{16b^2(2b^2-c^2)+c^4} \tag{A28}$$

Lemma A2: If bargaining power in vertical relationship with a downstream firm entirely falls on an exporter, full-ownership acquirement of a downstream firm by one exporter leads to set transfer price below zero.

When an exporter acquires ownership of downstream firm in a monopoly exporter

framework in section 3, the exporter had an incentive to lower a transfer price because its loss in net sales revenue can be compensated with extra income stream from the increase profit of downstream firm.   Under a duopoly setting, an exporter has additional incentive to lower a transfer price further. Corresponding increase in the profit of counterpart downstream firm is augmented by squeezing out the market share of the other downstream competitor.

Since negative transfer price is only possible in a real world by subsidizing downstream firms more in absolute term than transfer price, this strategy is very unlikely to be actually taken. Moreover, anti-dumping trade rules usually forbid exporter to set its transfer price lower than its marginal cost.   Therefore, we enforce additional restriction on transfer price, $ew_i \geq ec_{Ui}$.   With this floor price restriction, maximization for the profit of U1 exporter yields a corner solution and it can be substituted in (A12) to obtain equilibrium transfer prices.

$$ew_1 = ec_U$$
$$ew_2 = \frac{(2b-c)(a-c_D)+(2b+c)ec_U}{4b}$$

(A29)

These equilibrium transfer prices can be used for (A5) and (A6) to obtain equilibrium quantities for two differentiated export products.

$$q_1 = \frac{(4b+c)}{4b(2b+c)}(a-c_D-ec_U)$$
$$q_2 = \frac{1}{2(2b+c)}(a-c_D-ec_U)$$

(A30)

Now we can use (A17), (A29) and (A30) to obtain equilibrium industry transfer price and corresponding exchange rate pass-through.

$$ew = \frac{(2b-c)(a-c_D)+(10b+3c)ec_U}{2(6b+c)}$$

(A31)

$$\frac{d\ln ew}{d\ln e} = \frac{(10b+3c)ec_U}{(2b-c)(a-c_D)+(10b+3c)ec_U}$$

(A32)

The exchange rate pass-through in (A32) can be compared with the benchmark case of (A25) to show that full-ownership acquirement of downstream firm by an exporter increases exchange rate pass-through.   We summarize the result in the following lemma.

38

Lemma A3: If bargaining power in vertical relationship with a downstream firm entirely falls on an exporter and transfer price can not be allowed to be lower than marginal cost of exporters, full-ownership acquirement of a downstream firm by one exporter increases exchange rate pass-through.

[Both full-ownership case]

We now turn to the case both exporters fully acquire ownership of each counterpart downstream firm. Since we has already derived best-response transfer-price function for U1 in equation (A27), we rewrite it here with best-response transfer-price function for U2 obtained by a symmetric argument.

$$ew_1 = \frac{-c^2(2b-c)}{2b(4b^2-2c^2)}(a-c_D) + \frac{(4b^2-c^2)}{(4b^2-2c^2)}ec_U - \frac{c^3}{2b(4b^2-2c^2)}ew_2 \qquad (A33)$$

$$ew_2 = \frac{-c^2(2b-c)}{2b(4b^2-2c^2)}(a-c_D) + \frac{(4b^2-c^2)}{(4b^2-2c^2)}ec_U - \frac{c^3}{2b(4b^2-2c^2)}ew_1 \qquad (A34)$$

Substituting (A34) into (A33), we can obtain the equilibrium transfer price for U1 exporter.

$$ew_1 = \frac{\left[A(a-c_D)+Bec_U\right]}{\left[4b(2b^2-c^2)\right]^2 - c^6}, \qquad \text{where}$$

$$A = \left\{c^5 - 2bc^2(4b^2-2c^2)\right\}(2b-c), \quad B = 2b\left\{(8b^3-4bc^2-c^3)(4b^2-c^2)\right\} \qquad (A35)$$

By summing up *A* and *B*, it can be shown that transfer price is linear combination of *(a - c_D)* and ec_U, but not a convex combination because A is non-positive. So the sign of transfer price is dependent on the relative sizes of *b* and *c* and relative size of *(a - c_D)* and ec_U. Figure 15 represents regions of sings of transfer price and transfer price is equal to marginal cost of exporters only on the bold line.

Lemma A4: If bargaining power in vertical relationship with a downstream firm entirely falls on an exporter, full-ownership acquirement of a downstream firm by both exporters leads to set transfer price below marginal cost of exporters. Transfer prices are set equal to marginal cost if and only if

$(a - c_D) = ec_U$ or $c = 0$.

From the above lemma, if we continue to assume there is some trade regulation restricting the floor price for cross-border price of tradable goods, equilibrium transfer prices are obtained at a corner solution from optimization of exporters' profits. Therefore, industry transfer price is also equal to marginal cost of exporters and the exchange rate pass-through becomes one, i.e. a complete pass-through.

Lemma 5: If bargaining power in vertical relationship with a downstream firm entirely falls on an exporter and transfer price can not be allowed to be lower than marginal cost of exporters, full-ownership acquirement of a downstream firm by both exporters yields a complete exchange rate pass-through.

We can summarize our results from this subsection about ownership effect on exchange rate pass-through using Lemma 2 to 5 in the next proposition. Although we have only provided proofs for proposition A1 and A2 in the case of duopoly, we believe similar arguments apply to the case of arbitrary number of oligopoly exporters and these propositions are basis for our hypothesis regarding a possible interaction within each export product in our empirical section.

Proposition A2: If bargaining power in vertical relationship with a downstream firm entirely falls on an exporter and transfer price can not be allowed to be lower than marginal cost of exporters, sequential foreign direct investments by different exporters in an industry of differentiated products in terms of full-ownership acquirement of a downstream firm increases the level of exchange rate pass-through.

40

Appendix B:

[General analysis of exchange rate pass-through for n-plants]

Profit for n-domestic-plants firm is,

$$\pi = PQ - eC(q_1 \cdots q_n) \quad \text{where} \quad Q \equiv \sum_{i=1}^{n} q_i . \tag{B1}$$

Summing up all first order conditions and rearrangement gives a pricing equation,

$$Pn\left(\frac{\varepsilon - 1}{\varepsilon}\right) = e\sum_{i=1}^{n} C_{qi} . \tag{B2}$$

Here, ε is price elasticity of demand defined as $\varepsilon \equiv -\dfrac{d \ln Q}{d \ln p}$.

We obtain a general pass-through equation by totally differentiating equation (B2).

$$\frac{d \ln P}{d \ln e} = 1 - \frac{d \ln\left(\frac{\varepsilon - 1}{\varepsilon}\right)}{d \ln e} + \frac{d \ln\left(\sum C_{qi}\right)}{d \ln e} \tag{B3}$$

In equation (B3) exchange rate pass-through is broken down to two components, demand elasticity term and marginal cost term. In the following we first establish that these two components are contributing to incomplete pass-through separately, with our specification for a model.

[The value of exchange rate pass-through with our model specification]

With specifications assumed in section 2 for demand function, $P = d - Q$ and cost function, $C = \sum \frac{1}{2} q_i^2$, we can obtain total production level at equilibrium by algebraically solving the n sets of first order conditions.

$$Q = \frac{nd}{2n + ec} \quad \text{where} \quad q_i = \frac{Q}{n} \quad \text{for any i.} \tag{B4}$$

$$P = \frac{nd + dec}{2n + ec} \tag{B5}$$

$$\varepsilon = \frac{n + ec}{n} \tag{B6}$$

Equation (B5) and (B6) are obtained by substituting equilibrium production value (B4) for demand function and demand elasticity.

With price elasticity of demand evaluated at equilibrium in (B6), demand elasticity term in (B3) can be derived.

$$-\frac{d \ln\left(\frac{\varepsilon - 1}{\varepsilon}\right)}{d \ln e} = -\frac{n}{n + ec} \tag{B7}$$

Marginal cost function term in (B3) can be also derived as

$$\frac{d \ln\left(\sum C_{qi}\right)}{d \ln e} = -\frac{ec}{2n + ec}. \tag{B8}$$

We confirm that each component separately reduce the exchange rate pass-through from unity. The exchange rate pass-through can be obtained by substituting (B7) and (B8) into (B3).

$$\frac{d \ln P}{d \ln e} = \frac{ec}{2n + 3ec + \frac{1}{n}(ec)^2} \tag{B9}$$

It is well known that constant elasticity demand, which can be derived from CES utility form, leads (B7) to be zero and constant marginal cost leads (B8) to be zero. Both specifications combined would result in complete pass-through as in Obstfeld and Rogoff (1995) and Betts and Devereux (2000)[15].

[The effect of increase in the number of domestic plants on the exchange rate pass-through]

We can analyze the effect of increase in the number of domestic plants on the exchange rate pass-through by partially differentiating (B3).

$$\frac{\partial\left[\frac{d\ln p}{d\ln e}\right]}{\partial n} = -\frac{\partial\left[\frac{d\ln\left(\frac{\varepsilon-1}{\varepsilon}\right)}{d\ln e}\right]}{\partial n} + \frac{\partial\left[\frac{d\ln\left(\sum C_{qi}\right)}{d\ln e}\right]}{\partial n} \tag{B10}$$

The effect of exchange rate pass-through from demand elasticity term in (B11) is negative.

$$-\frac{\partial\left[\frac{d\ln\left(\frac{\varepsilon-1}{\varepsilon}\right)}{d\ln e}\right]}{\partial n} = -\frac{ec}{(n+ec)^2} \tag{B11}$$

The effect on exchange rate pass-through from marginal cost term in (B12) is positive.

$$\frac{\partial\left[\frac{d\ln\left(\sum C_{qi}\right)}{d\ln e}\right]}{\partial n} = \frac{2ec}{(2n+ec)^2} \tag{B12}$$

The overall effect on exchange rate pass-through must be determined by relative size of (B11) and (B12).

$$\frac{\partial\left[\frac{d\ln p}{d\ln e}\right]}{\partial n} = -\frac{ec(2-\frac{(ec)^2}{n^2})}{-(2n+3ec+\frac{1}{n}(ec)^2)^2} \tag{B13}$$

---

because price elasticity of demand in each country are identical, their assumptions also put a strict restriction that exchange rate pass-through must be complete.

From equation (B13), the effect of increase in the number of domestic plants on exchange rate pass-through is decreasing if $ec < n\sqrt{2}$. This condition can be interpreted as the bounded-above condition for a curvature of cost function. The difference between the condition in the appendix and section 4 comes from an infinitesimal change effect in the appendix and discrete jump effect in section 4. It is noteworthy that bounded-above condition becomes less stringent as the number of domestic plants becomes large. Therefore, once this condition holds for expansion from single plant to two plants, it continues to hold for any extent of new plants establishments. Here, we establish that claim in section 4 do not depend on a specific number of plants we used in analysis, namely one and two.

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46

Figure1: Number of Local Subsidiaries

North America
Europe
R.O.W
Asia
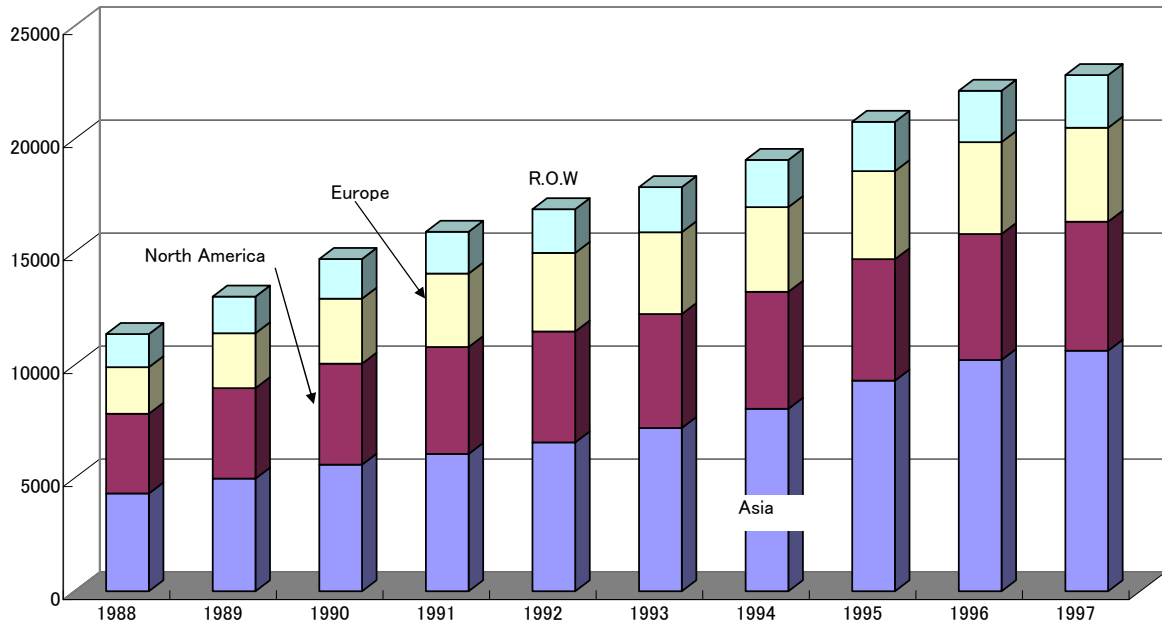
Source: Overseas Japanse Companies

Figure2: Investment Purpose by Geography
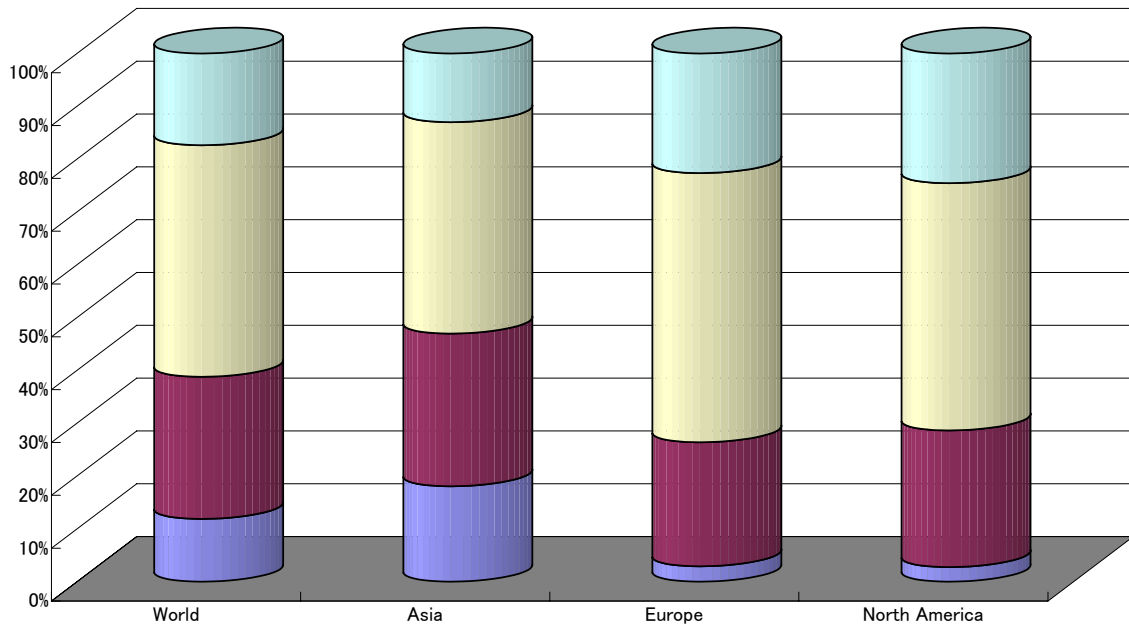
Source: Overseas Japanse Companies

Figure 3: Share of Ownership by Japanese Multinationals
[all 19,197 samples]

Number of
subsidiaries

Ownership Share percentage by Japanese firms combined
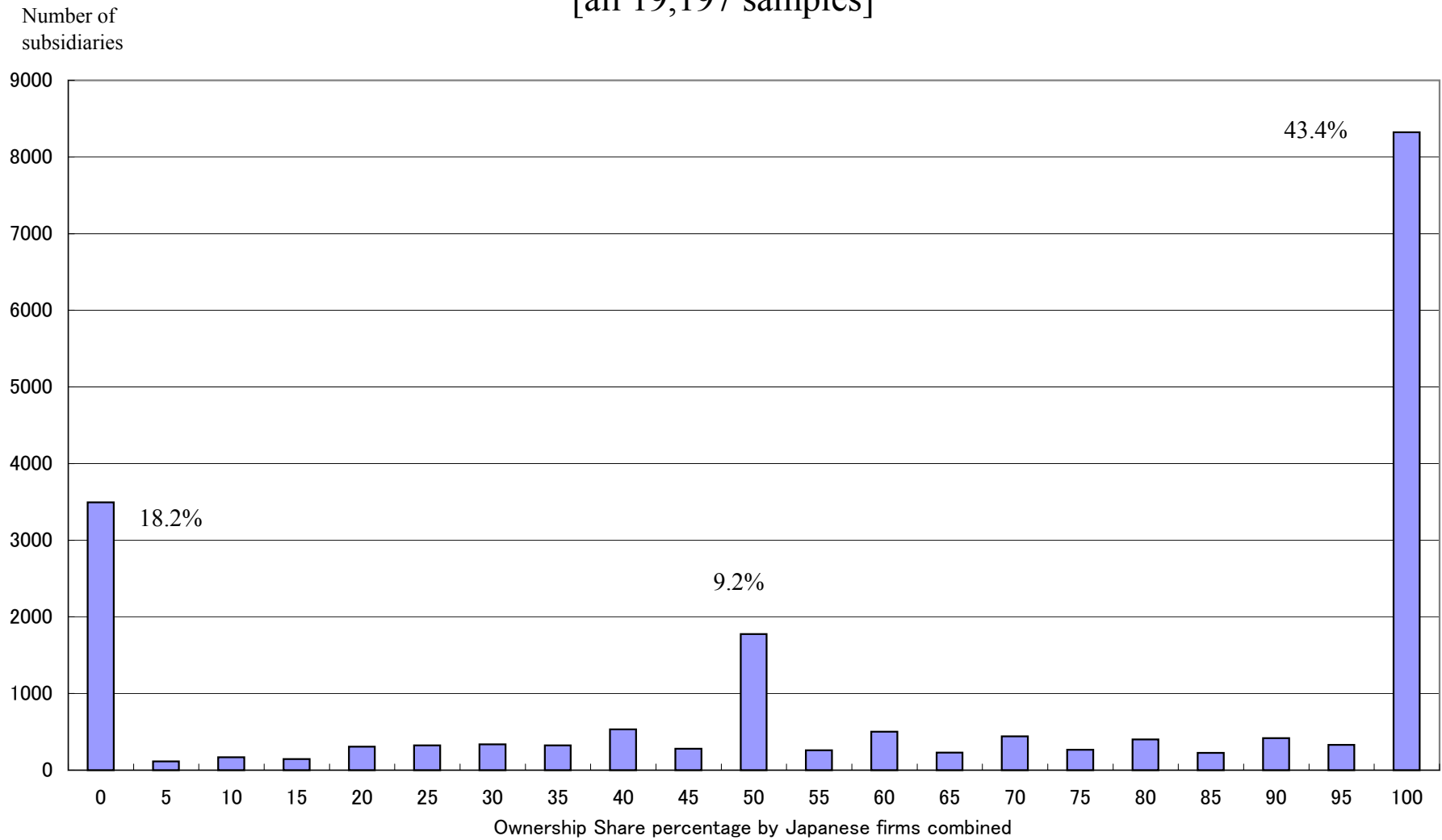
Figure4: Share of Ownership by Local Firms [all 19,197 samples]

68.8%

Shares owned by local firms are combined when there are more than one local firms. Local firms here are defined as those firms that are not either Japanese firms or Japanese foreign subsidiaries.
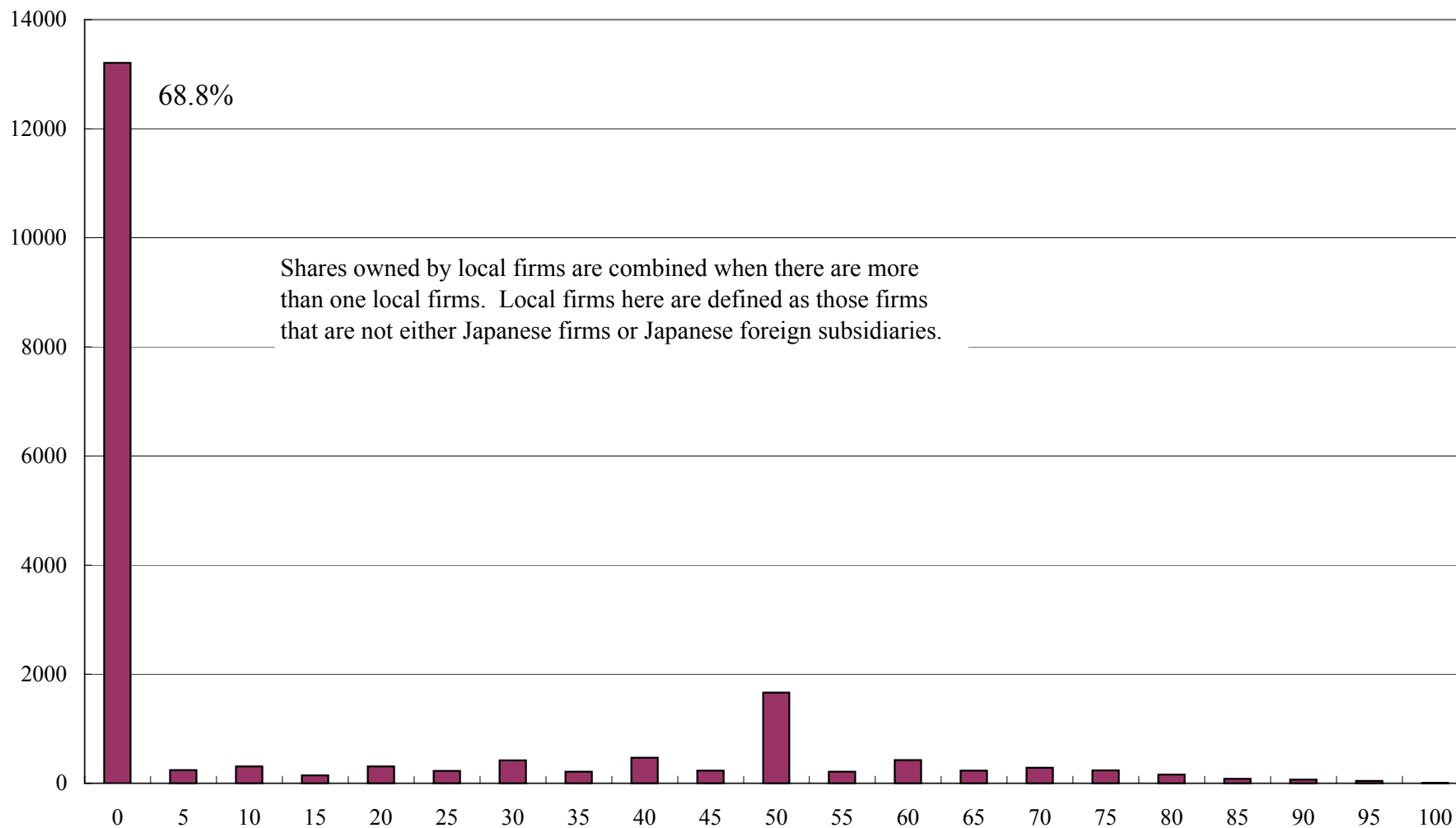
Figure 5: Ownership Structure of Japanese Subsidiaries

(Number of firms)

18,822	(69.4%)	(16.8%)	(13.8%)
13,062	(Japan + local) only		
3,164	(Japan + local) + sub		
2,596	sub only		
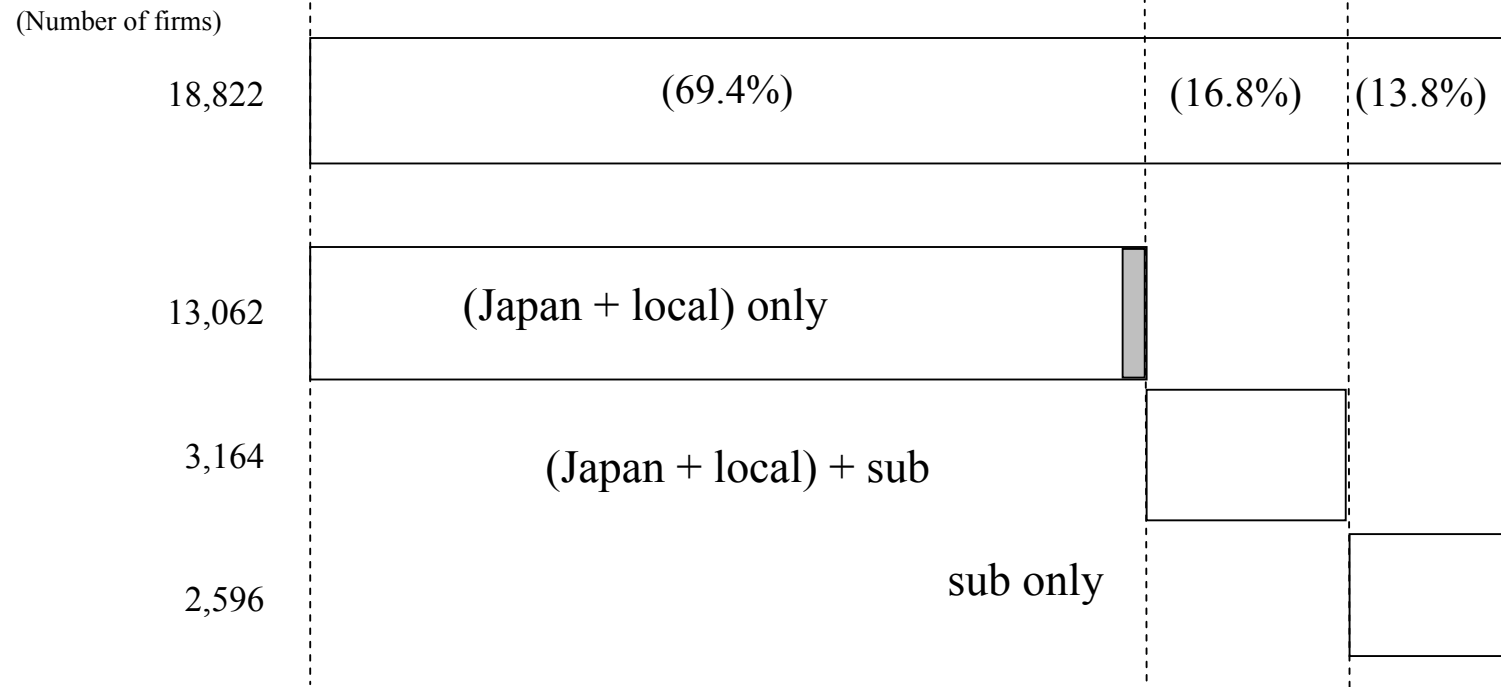
Note: 375 subsidiary firms not accounting shareholding informantion were excluded from original 19,197 data sets. In "(Japan + recipient) only" category combined shareholding by Japanese parent companies and local firms in a recipient country sums to 100% for 12,660 firms. For the remaining 402 firms in this category, the sum of shares is less than 100% due to unreported figures. "sub only" represents that combined sharehoding by Japanese parent companies and local firms in a recipient country is zero. All shares of almost all subsidiaries in this category are owned by another single subsidiary company, representing 2,300 firms. All shares of 116 firms in this category are owned by more than one subsidiary companies. For the remaining 180 firms in this category total shares do not sum up to 100% due to unreported figures. For the firms, shares of which do not sum upto 100%, are shown in shaded area. For "(Japan + local) + sub" category, direct calculation was not readily available.

Figure 6: (US) Share of Ownership by Japanese MNCs

Total = 2793 firms

Excluding those with combined share of
Japanese MNCs and US firms is zero

73.9%
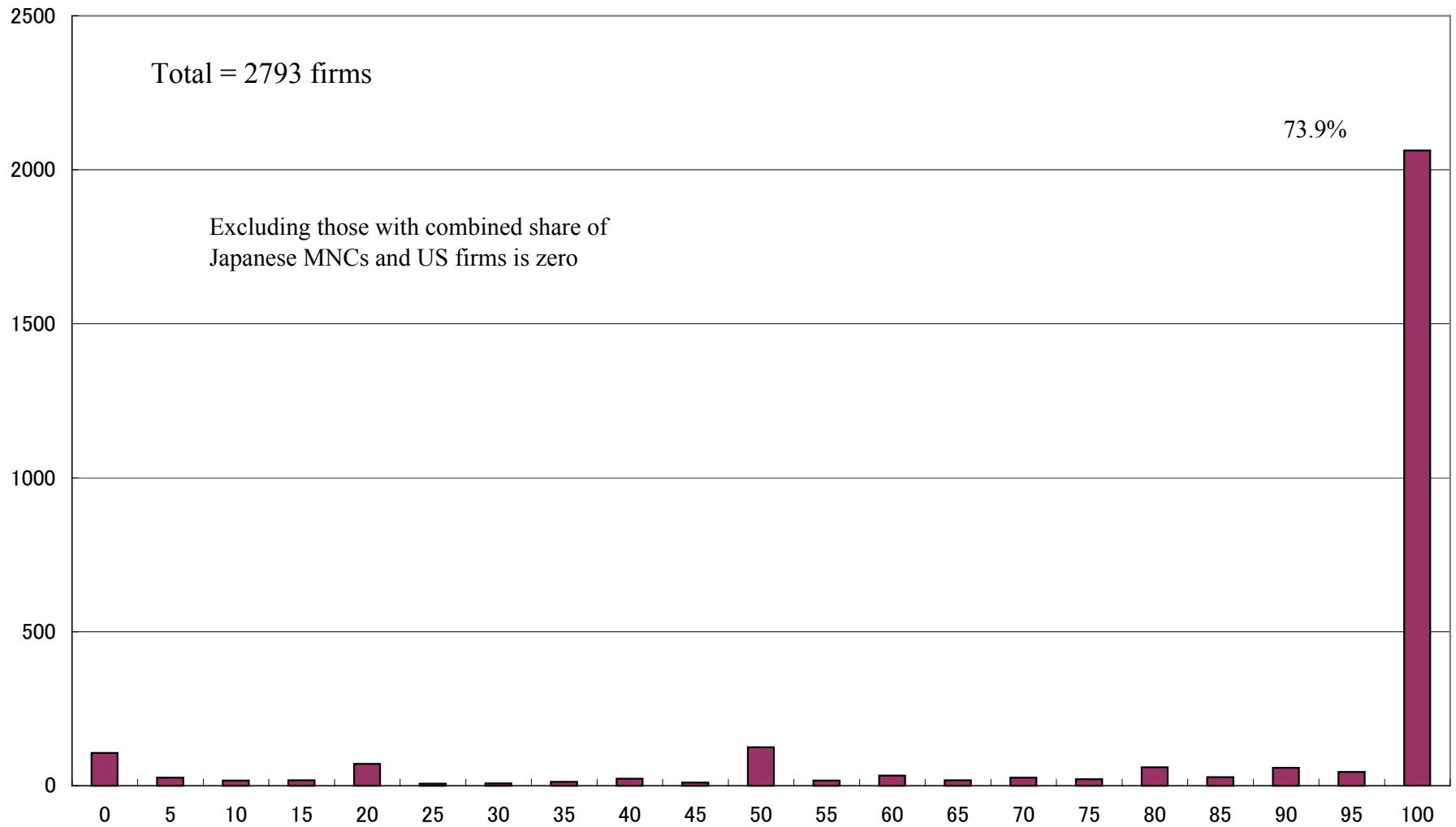
Figure 7: (China) Share of Ownership by Japanese MNCs

Total = 2271 firms

Excluding those with combined share of Japanese
MNCs and Chinese firms is zero

24.7%

17.7%
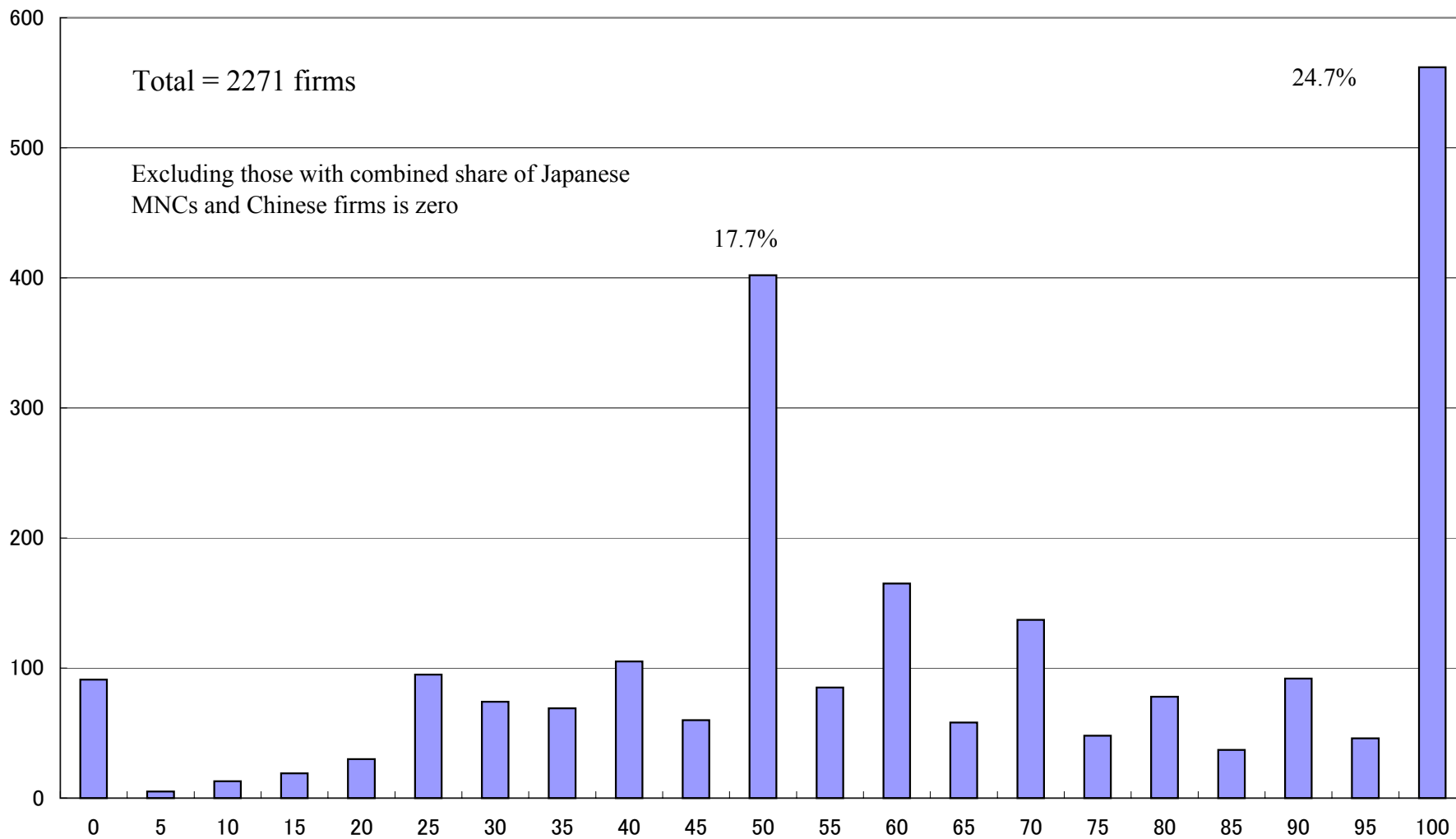
Figure 8: (Thailand) Share of Ownership by Japanese MNCs

Total = 1,269 firms

27.3%

Excluding those with combined share of Japanese MNCs
and Thai firms is zero

16.1%
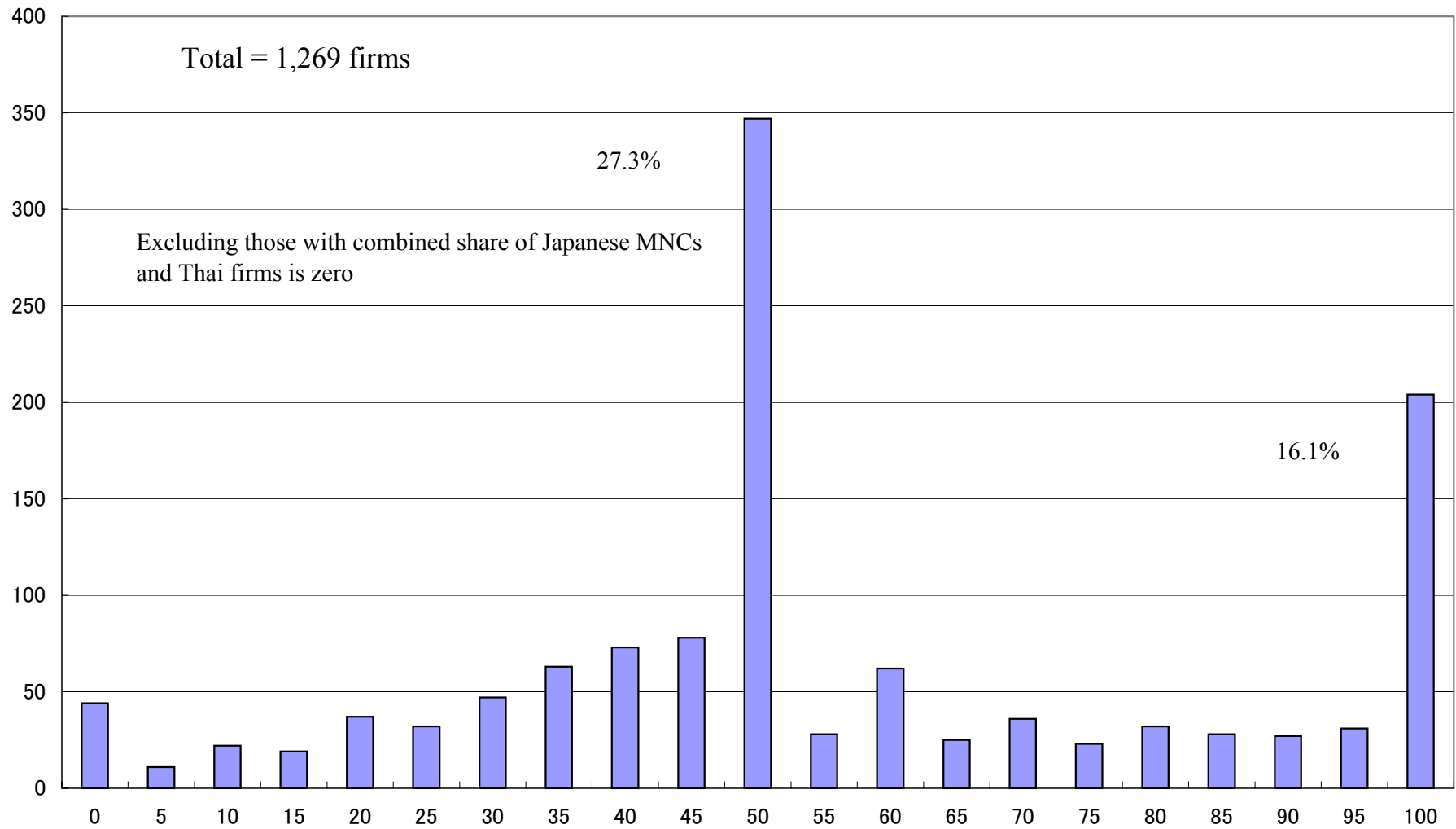
Figure 9: Purpose of FDI (Sales, Production, or both)

Total Subsidiaries   (19,197 firms)

Sales (9,675 firms), 50.4%

Production   (8,097 firms),42%

Service, Lease, R&D or others (6,480 firms)

(5,055 firms)
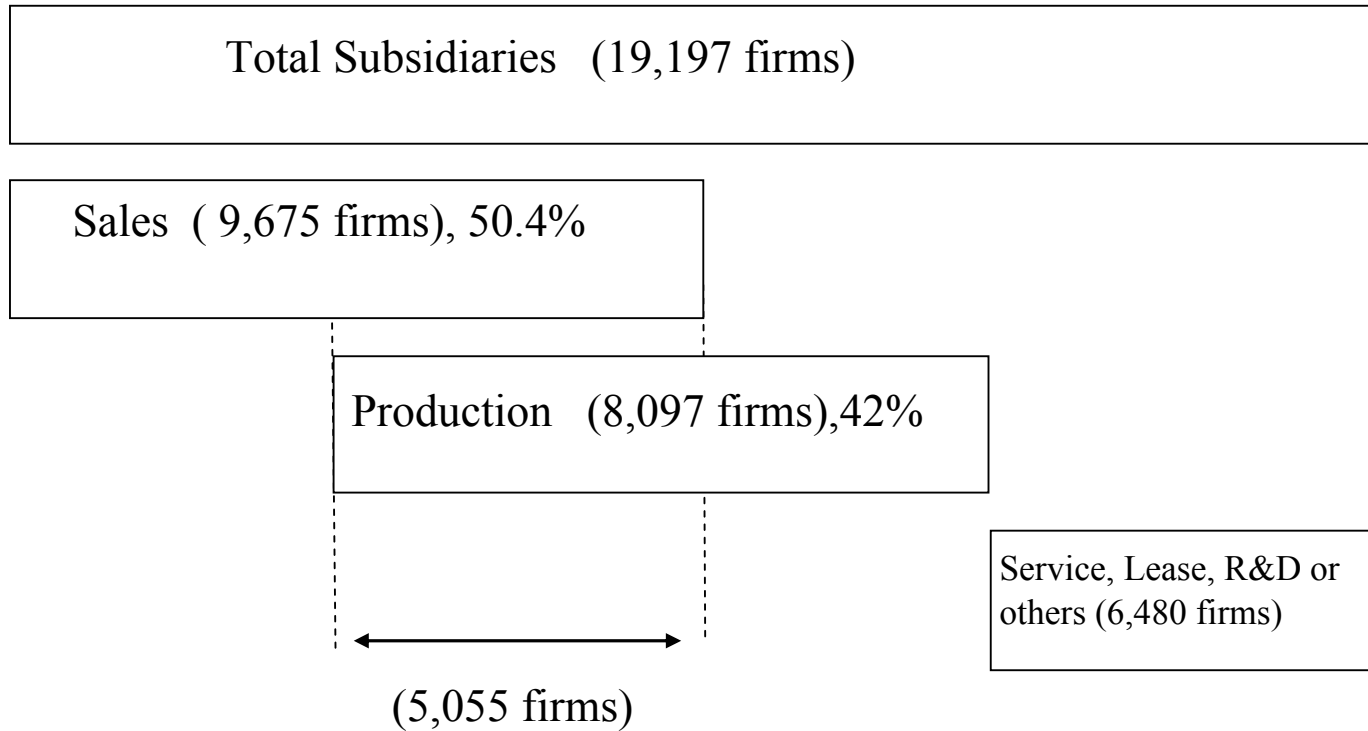
Note: The "sales" box and "production" box indicate that the purposes of FDI include "sales" and "production, " respectively. So subsidiaries counted as "sales" or "production" may or may not act as "service, lease or R&D" subsidiaries as well.

Figure 10: The parameter range condition for Proposition 1

$$\alpha < \frac{2(\lambda - 1)}{(2\lambda - 1)}$$

Lamda (y-axis), Alpha (x-axis)
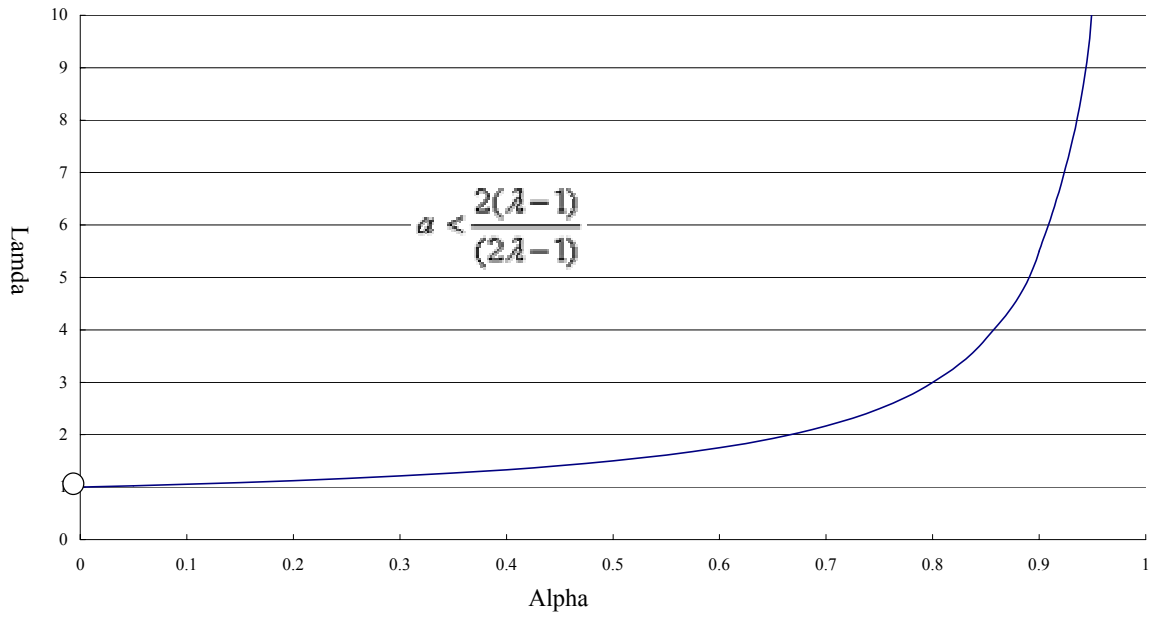
Figure 11: (Example: $\alpha_0 = 0.5$ and $\beta_0 = 0$)

$\lambda = 1.51$: Satisfying condition of Proposition 2

$\beta = 0.662$

$\lambda = 1$: Full control with complete ownership

$\lambda = 0$: No change in bargaining power

(α) (y-axis), (β) (x-axis)

Figure 12: Volumes and Unit Prices of Total Exports for Video (852110000)

Figure 13: Volumes and Unit Prices of Total Exports for Copier (900912000)
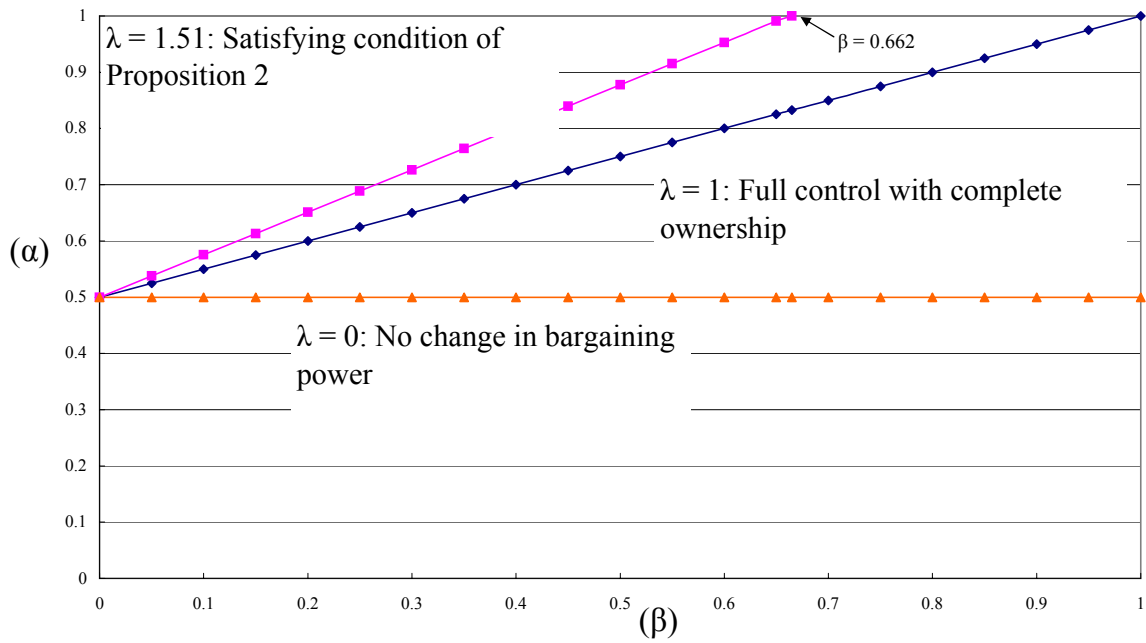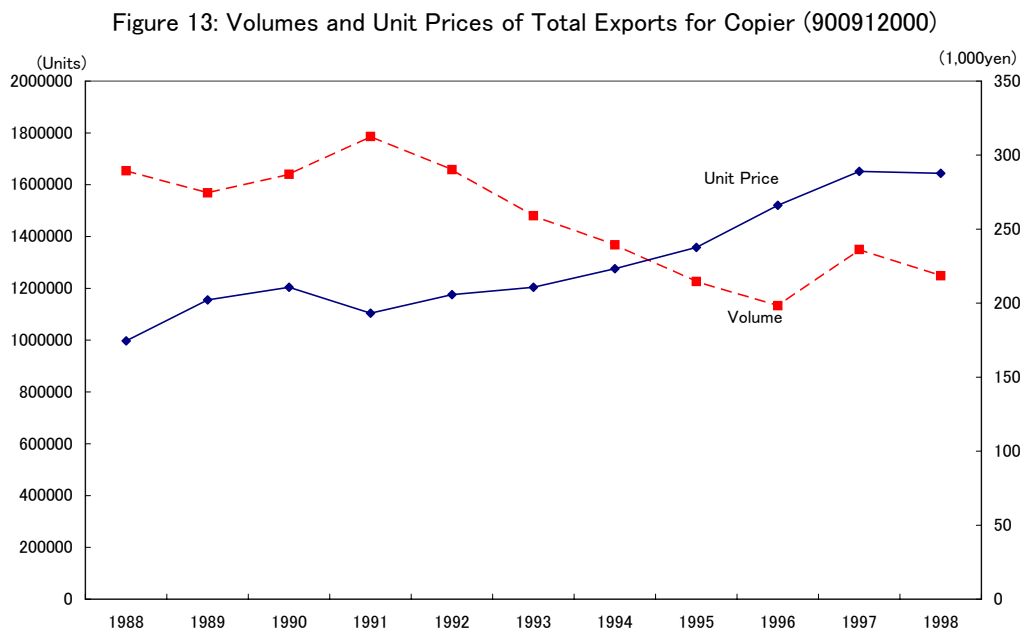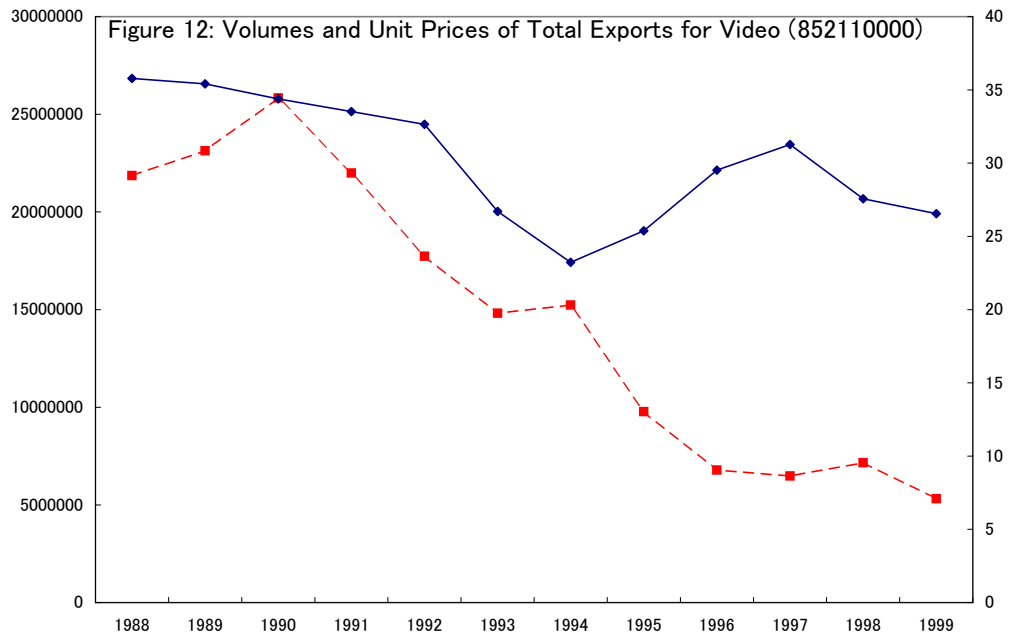
Figure 14: Volumes and Unit Prices of Total Exports for Parts of IC (854290000)
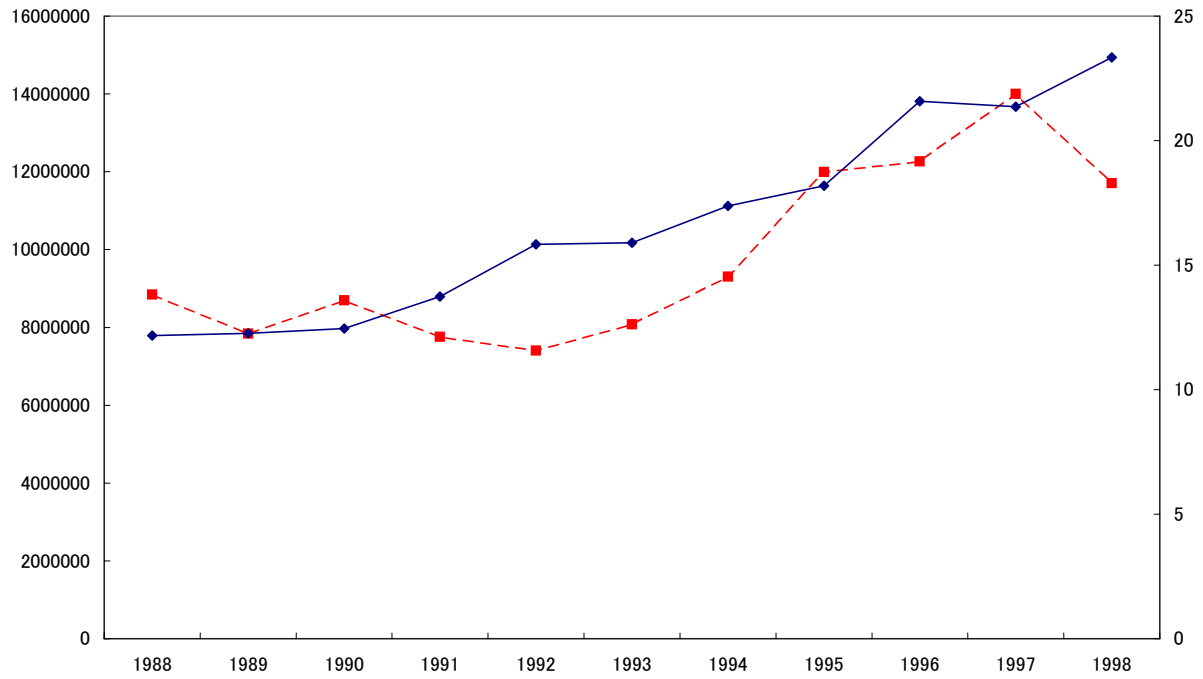
Figure16: Regions for ew_1 in Lemma A4

$ew_1 = ec_U$

$a - c_D$

$ec_U > ew_1 > 0$

$0 > ec_U$

ec_U

0

b

c
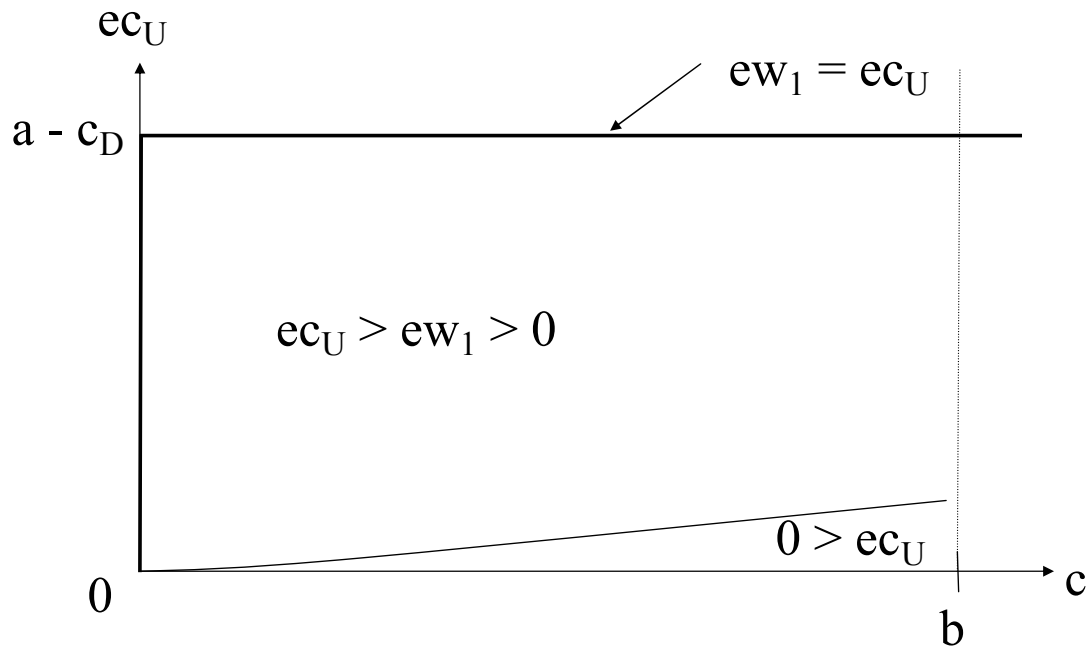
Table1 : Top 20 Japanese electronics coporations with most subsidiaries by country

Japanese parent company	China	Hong Kong	Indonesia	Malaysia	Singapore	Taiwan	Thailand	UK	Germany	USA	Total
NEC	12	4	2	4	5	3	4	4	3	5	46
TDK	6	3		1	2	1	1	1	2	12	29
Yuasa	2	1	1	2	1	1	1	3	1	3	16
Omron	5	1	1	3	2	3	1	3	5	8	32
Sharp	3	1	3	5	2	3	2	3	1	2	25
Seiko	6	2	1	1	2	2	1	2	2	4	23
Sony	5	3	1	3	2	2	4	1	3	4	28
Pioneer	1	1		1	1	2	2	3	1	6	18
Yokokawa	6		2	2	2	1	1	2	3	2	21
Kyosera	2	4		2	2	2		2	4	11	29
Mitsubishi Electronics	10	2	2	2	1	1	6	3	1	6	34
Sanyo Electronics	14	3	1		2	3	2			5	30
Sanyo Electronics Trade	5	2	3		4	1	1	3	5	6	30
Matsushita Electronics	17	2	2	10	2	5	5	5	5	10	63
Matsushita Denko	5	1	2	1	1	3	3	1	3	1	21
Toshiba	8	2	3	3	5	1	5	5	3	8	43
Victor	4		1	3	3	1	3	3	3	2	23
Hitachi	14	1	2	5	5	5	4	2	2	8	48
Fujitu	7	2		5	4	2	2	4	3	13	42
Fuji Electoroinics	9	2	1	1	2	3	1	1	1	2	23
Total	142	38	28	54	51	46	49	53	53	120	634

Note: There are 3,205 Japanese subsidiary firms in Electronics and Parts (1900) and Electronics and Parts Wholesale (3700). The table summarizes
for top 20 Japanese parent corporations with most subsidiaries by top 10 countries.

Table 2: Business description for Subsidiaries of Matsushita Electronics in China

Name of subsidiary	business description	starting date of operation
Matsushita-Wanbao(Guangzhou)Air Conditioner Co.,Ltd.	Air conditioner (production & sales)	199306
Matsushita-Wanbao(Guangzhou)Compressor Co.,Ltd.	compressor for air conditioner (production & sales)	199306
Matsushita-Wanbao(Guangzhou)Electric Iron Co.,Ltd.	electric iron (production, sales and after-service)	199212
Zhuhai Matsushita Electric Motor Co.,Ltd.	electric motor for AV and OA products (production & sales)	199305
Beijing Matsushita Communication Equipment Co.,Ltd.	pager and mobile phones (production & sales)	199207
Hangzhou Matsushita Home Appliance Co.,Ltd.	laundry machines and parts (sales & production)	199204
Matsushita Audio(Xiamen)Co.,Ltd.	headphone stereo, clock radio, stereo compo (production & sales)	199309
Shanghai Matsushita Microwave Oven Co.,Ltd.	microwave (production & sales)	199408
China Hualu Matsushita AVC Co.,Ltd.	video and main components (production & sales)	199406
Hangzhou Matsushita Motor Co.,Ltd.	electric motor for consumer electronics (production & sales)	199411
Shandong Matsushita Television & Visual Co.,Ltd.	color televisions (production & sales)	199606
Beijing Matsushita Precision Capacitor Co.,Ltd.	film condenser (production & sales)	199608
Jian Song Electric(Xiamen)Co.,Ltd.	electronics parts, monitor, motor, audio components for automobiles (production)	199604
Hangzhou Matsushita Kitchen Appliances Co.,Ltd.	rice cooker, rice polisher and parts (production & sales)	199803
Panasonic SH Industrial Sales(Shenzhen)Co.,Ltd.	manufacturing machine and factory automation related products (sales & services)	199409
Panasonic Industrial(Shanghai)Co.,Ltd.	manufacturing machine and factory automation related products (sales & services)	199604
Panasonic Industrial(Tianjin)Co.,Ltd.	manufacturing machine and factory automation related products (sales & services)	199812

Table 3: Business description for Subsidiaries of Fujitsu in US

Name of subsidiary	business description	
Fujitsu Business Communication Systems,Inc.	comunication devices (production, sales, maintenance and development)	197603
Fujitsu Microelectronics,Inc.	simiconductor (production, sales and R&D)	197908
Fujitsu Network Communications,Inc.	comunication devices (transmiter and switch) (development, prduction, sales, maintenance)	199110
Fujitsu Computer Products of America,Inc.	computer products (development, production, sales and maintenance service)	199109
HAL Computer Systems,Inc.	64-bits high SPARC prossessor (development) and Unix workstation (development, production and sales)	199005
Amdahl Corp.	computer (production & sales) and magnetic disc drive (sales)	197010
Fujitsu PC Corp.	PC computer (development, production & sales)	199602
Reliance Computer Corp.	chip set for computer and server (development)	199411
Fujitsu America,Inc.	imformatioin processing machines (imports & sales)	196807
Fujitsu Systems Business of America,Inc.	system support for computer products	198806
Fujitsu Personal Systems,Inc.	mobile computer (sales)	198801
Fujitsu-ICL Systems,Inc.	logistics system, ATM, logistics HHT (sales and maintenance)	199204
Fujitsu Compound Semiconductor,Inc.	compound semiconductor (R&D and sales)	199210

Table 4: The Summary of Expected Sign of Foreign Direct Investments Coefficients

Type of FDI	Description	Expected Sign	Supporting Theories and Conditions
distribution		+	(**Lemma 1**, Sec 3) no or small increase in bargaining power relative to increase in ownership
		-	(**Proposition 1**, Sec 3) relatively large increase in bargaining power after FDI
plants	intermediate exports, downstream firm	+	(**Lemma1**, Sec 3)
(vertical)		-	(**Proposition 1**, Sec 3)
plants	final product exports, internaional horizontal	-	(**Proposition 2**, Sec 4)
(horizontal)			

Table 5: Summary Statistics FDI Variables

Video		mean	std. dev.	min	max
	FDIIND	79.50	89.58	0	411
	DEALB	0.24	0.43	0	1
	DEALN	0.69	1.44	0	6
	PLANTB	0.31	0.46	0	1
	PLANTN	0.46	0.75	0	2
Copier					
	FDIIND	90.12	85.91	2	411
	DEALB	0.34	0.47	0	1
	DEALN	0.43	0.67	0	2
	PLANTB	0.31	0.46	0	1
	PLANTN	0.45	0.83	0	3
IC					
	FDIIND	130.98	78.53	11	411
	DEALB	0.55	0.50	0	1
	DEALN	1.04	1.31	0	5
	PLANTB	0.66	0.47	0	1
	PLANTN	1.20	1.26	0	4

Note: Sample countries for video are Australia, Canada, France, Germany, Hong Kong, Italy,
Netherlands, Panama, Saudi Arabia, Singapore, UAE, UK, US; for copier, Australia,
Belgium, Canada, France, Germany, Hong Kong, Italy, Netherlands, New Zealand,
Singapore, Taiwan, UK, US; for IC, Germany, Hong Kong, Korea, Malaysia, Philippine,

Table6: LSDV Estimators for Annual Panel Data (video price, 1988 - 1998)

Independent variable:	Specification				
	(i)	(ii)	(iii)	(iv)	(v) w/ time d.
ER	0.678***	0.593***	0.510***	0.573***	1.632***
	(0.127)	(0.123)	(0.126)	(0.124)	(0.290)
FDIIND*ER	0.000				
	(0.000)				
DEALB*ER		-0.183***		-0.197***	-0.196***
		(0.023)		(0.024)	(0.029)
DEALN*ER			-0.042	0.011	-0.005
			-0.03	(0.009)	(0.014)
PLANTB*ER		0.677**			
		(0.321)			
PLANTN*ER			0.439**	0.464***	0.514***
			(0.200)	(0.177)	(0.170)
(Nob. = 143)					
Adj-R2	0.983	0.986	0.984	0.987	0.987

Note: Figures in parenthesis are hetroskedastic-consistent standard erro; ***, **, and * indicate that the coefficient is significant at the 1, 5, and 10 percent, respectively.

Table7: LSDV Estimators for Annual Panel Data (copier price, 1988 - 1998)

Independent variable:	Specification				
	(i)	(ii)	(iii)	(iv)	(v) w/ time d.
ER	1.35***	1.255***	1.427***	1.430***	0.356
	(0.097)	(0.112)	(0.111)	(0.112)	0.235
FDIIND*ER	-0.001***				
	(0.0002)				
DEALB*ER		-0.053***		-0.016	-0.083**
		(0.019)		(0.032)	(0.035)
DEALN*ER			-0.039**	-0.027	0.079**
			(0.016)	(0.026)	(0.034)
PLANTB*ER		0.520**			
		(0.256)			
PLANTN*ER			-0.230**	-0.240**	-0.262***
			(0.100)	(0.099)	(0.082)
(Nob. = 143)					
Adj-R2	0.986	0.984	0.985	0.985	0.991

Note: Figures in parenthesis are hetroskedastic-consistent standard erro; ***, **, and * indicate that the coefficient is significant at the 1, 5, and 10 percent, respectively.

Table8: LSDV Estimators for Annual Panel Data (IC parts price, 1988 - 1998)

Independent variable:	Specification				
	(i)	(ii)	(iii)	(iv)	(v) w/ time d.
ER	1.53***	1.734***	1.510***	1.640***	1.281***
	(0.182)	(0.193)	(0.177)	(0.165)	(0.325)
FDIIND*ER	-0.000**				
	(0.000)				
DEALB*ER		0.073**		0.125***	0.123***
		(0.033)		(0.034)	(0.037)
DEALN*ER			-0.024	-0.053***	-0.021
			(0.015)	(0.012)	(0.017)
PLANTB*ER		-0.072			
		(0.070)			
PLANTN*ER			-0.054**	-0.044*	-0.032
			(0.022)	(0.023)	(0.024)
(Nob. = 110)					
Adj-R2	0.978	0.978	0.978	0.981	0.981

Note: Figures in parenthesis are hetroskedastic-consistent standard erro; ***, **, and * indicate that the coefficient is significant at the 1, 5, and 10 percent, respectively.

Table9: LSDV Estimators for Monthly Dynamic Panel (video price, 1988Jan - 1998Dec)

Independent variable:	Specification			
	(i)	(ii)	(iii)	(iv)
P(-1)	0.642***	0.614***	0.593***	0.576***
	(0.021)	(0.031)	(0.032)	(0.033)
ER	0.201***	0.236***	0.129***	0.155***
	(0.039)	(0.040)	(0.037)	(0.039)
DEALB*ER		-0.067***		-0.053**
		(0.020)		(0.021)
DEALN*ER	-0.016**	-0.002	-0.006	0.004
	(0.006)	(0.005)	(0.006)	(0.005)
PLANTN*ER	0.143**	0.171**	-0.031	0.014
	(0.071)	(0.069)	(0.081)	(0.080)
ASIAD*ER			0.007	0.007
			(0.005)	(0.005)
EUROD*ER			-0.015***	-0.012***
			(0.004)	(0.004)
ASIAP*ER			0.001	0.001
			(0.003)	(0.003)
EUROP*ER			0.094***	0.087***
			(0.021)	(0.021)
(Obs.=1703)				
Adj-R2	0.985	0.986	0.986	0.986

Note: Figures in parenthesis are heterosedasticity-consistent standard deviations; ***, **, and * indicate that the coefficient is significant at the 1, 5, and 10 percent, respectively. The estimated coefficients for country dummies are not reported here.

Table10: LSDV Estimators for Monthly Dynamic Panel (copier price, 1988Jan - 1998Dec)

Independent variable:	Specification			
	(i)	(ii)	(iii)	(iv)
P(-1)	0.539***	0.539***	0.480***	0.480***
	(0.049)	(0.049)	(0.052)	(0.052)
ER	0.690***	0.692***	0.693***	0.687***
	(0.089)	(0.090)	(0.086)	(0.087)
DEALB*ER		-0.005		0.014
		(0.013)		(0.016)
DEALN*ER	-0.016**	-0.012	-0.007	-0.020
	(0.007)	(0.010)	(0.008)	(0.014)
PLANTN*ER	-0.139***	-0.143***	-0.127***	-0.116***
	(0.027)	(0.028)	(0.026)	(0.027)
ASIAD*ER			-0.028***	-0.035***
			(0.011)	(0.012)
EUROD*ER			-0.012***	-0.012***
			(0.002)	(0.002)
ASIAP*ER			0.004	0.011
			(0.009)	(0.011)
EUROP*ER			0.019**	0.020**
			(0.008)	(0.008)
(Obs.=1703)				
Adj-R2	0.984	0.984	0.985	0.985

Note: Figures in parenthesis are heterosedasticity-consistent standard deviations; ***, **, and * indicate that the coefficient is significant at the 1, 5, and 10 percent, respectively. The estimated coefficients for country dummies are not reported here.

Table11: LSDV Estimators for Monthly Dynamic Panel (IC parts price, 1988Jan - 1998Dec)

Independent variable:	Specification			
	(i)	(ii)	(iii)	(iv)
P(-1)	0.803***	0.782***	0.756***	0.750***
	(0.021)	(0.021)	(0.023)	(0.022)
ER	0.288***	0.343***	0.462***	0.467***
	(0.044)	(0.044)	(0.047)	(0.047)
DEALB*ER		0.031**		0.017
		(0.012)		(0.013)
DEALN*ER	-0.005	-0.013***	-0.004	-0.008***
	(0.004)	(0.002)	(0.004)	(0.003)
PLANTN*ER	-0.013**	-0.012**	-0.005	-0.006
	(0.006)	(0.006)	(0.006)	(0.006)
ASIAD*ER			0.002	0.002
			(0.002)	(0.002)
EUROD*ER			-0.023**	-0.022**
			(0.010)	(0.010)
ASIAP*ER			-0.007***	-0.006***
			(0.002)	(0.002)
EUROP*ER			-0.447***	-0.379**
			(0.142)	(0.149)
(Obs.=1310)				
Adj-R2	0.990	0.990	0.990	0.990

Note: Figures in parenthesis are heterosedasticity-consistent standard deviations; ***, **, and * indicate that the coefficient is significant at the 1, 5, and 10 percent, respectively. The estimated coefficients for country dummies are not reported here.

Table 12: GMM 1-step Estimators for Monthly Dynamic Panel

Video

	coef	sd	t	p
P(-1)	-0.555	0.002	-344.408	0.00
ER	0.174	0.011	15.58982	0.00
DEALB				
DEALN	-0.051	0.015	-3.36542	0.00
PLANTB	0.013	0.003	4.594584	0.00
PLANTN	-0.087	0.025	-3.49756	0.00
ASIA-D	0.005	0.005	1.047246	0.29
EURO-D	-0.013	0.010	-1.2727	0.20
ASIA-P	0.002	0.002	1.048792	0.29
EURO-P	0.089	0.012	7.139157	0.00

Copier

	coef	sd	t	p
P(-1)	-0.459	0.001	-550.196	0.00
ER	0.660	0.013	49.71	0.00
DEALB	-0.026	0.070	-0.37	0.71
DEALN	0.029	0.021	1.35	0.18
PLANTB	0.388	0.076	5.11	0.00
PLANTN	-0.199	0.034	-5.77	0.00
ASIA-D	-0.015	0.021	-0.70	0.49
EURO-D	-0.012	0.000	-24.13	0.00
ASIA-P	-0.011	0.025	-0.44	0.66
EURO-P	0.020	0.004	5.47	0.00

IC parts

	coef	sd	t	p
P(-1)	-0.755	0.000	-1766.68	0.00
ER	0.444	0.018	24.3458	0.00
DEALB	0.022	0.014	1.573155	0.12
DEALN	-0.008	0.003	-2.56442	0.01
PLANTB	0.003	0.014	0.235945	0.81
PLANTN	-0.007	0.010	-0.67959	0.50
ASIA-D	0.000	0.001	-0.84308	0.40
EURO-D	-0.008	0.058	-0.1421	0.89
ASIA-P	-0.004	0.001	-3.21285	0.00
EURO-P	-0.357	0.115	-3.11593	0.00

Table 13: Bias for LSDV

<u>Video</u>

	LSDVc	(given GMM1)
P(-1)	0.006987	
ER	-0.000749	
DEALN	0.000232	
PLANTB	-0.000042	
PLANTN	0.000026	
ASIAD	-0.000024	
EUROD	0.000052	
ASIAP	-0.000007	
EUROP	-0.000268	

<u>Copier</u>

	LSDVc	(given GMM1)
P(-1)	0.005136	
ER	-0.001937	
DEALB	0.000103	
DEALN	-0.000111	
PLANTB	-0.001208	
PLANTN	0.000599	
ASIA-D	0.000035	
EURO-D	0.000040	
ASIA-P	0.000013	
EURO-P	-0.000127	

<u>IC parts</u>

	LSDVc	(given GMM1)
P(-1)	0.004799	
ER	-0.001200	
DEALB	-0.000068	
DEALN	0.000021	
PLANTB	-0.000015	
PLANTN	0.000027	
ASIA-D	-0.000001	
EURO-D	0.000038	
ASIA-P	0.000015	
EURO-P	0.000787	