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Shawn ARITA
University of Hawaii at Manoa

TANAKA Kiyoyasu
Institute of Developing Economies

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Shawn ARITA[a]

University of Hawaii at Manoa

Kiyoyasu TANAKA[b]

Institute of Developing Economies

Abstract

This paper develops a micro-simulation framework for multinational entry and sales activities across countries. The model is based on Eaton, Kortum, and Kramarz's (2010) quantitative trade model adapted towards multinational production. Using micro data on Japanese manufacturing firms, we illustrate the empirical regularities of multinational entry and sales activity and estimate the model's structural parameters with simulated method of moments. We demonstrate that our adapted model is able to replicate important dimensions of the in-sample moments conditioned in our estimation strategy and does a reasonable job in external model validation tests. We can replicate activity under an economic period with a far different level of FDI barriers than was conditioned upon in our estimation sample. Overall, we demonstrate the richness of the simulation framework as a quantitative tool for FDI policy analysis.

Keywords: multinational firms, FDI, firm heterogeneity, simulation, and model validation.

JEL Classification: F10; F23; L25; R12; R30

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[a] Department of Economics, University of Hawaii at Manoa, Department of Economics; e-mail: aritas@hawaii.edu

[b] *Corresponding author*: Economic Integration Studies Group, Inter-Disciplinary Studies Center, Institute of Developing Economies; address: 3-2-2 Wakaba, Mihama-ku, Chiba-shi, Chiba 261-8545, Japan; e-mail: kiyoyasu_tanaka@ide.go.jp

1. **Introduction**

The remarkable growth of offshore production by multinational firms is a key feature of economic globalization. The worldwide sales of foreign affiliates by multinationals grew an average of 11.7 percent per year for the period 1991-2005 while the global GDP and exports of goods and services grew 5.7 and 8.8 percent, respectively. In 2009, the gross product of all foreign affiliates accounted for 9.4 percent of the global GDP (UNCTAD, 2010). Multinational production has played a prominent role in global economic integration.

While many countries around the globe have opened up for foreign direct investment (FDI), manufacturing firms at home have gone through a distinctive change across different size distributions. Determining percentile bins by the volume of global sales in 1996, Table 1 tabulates the number of all firms and multinational parents in Japanese manufacturing for 1996 and 2006.[1] Total firms declined in number by 8.9 percent, but total multinationals increased by a whopping 72.5 percent. By dissecting aggregate changes, we observe that smaller and medium firms disproportionately declined in number whereas larger multinationals substantially increased. In addition, Table 2 presents the volume of sales in trillions of 2006 Japanese Yen. Total domestic sales declined in volume by 7.1 percent, but total multinational sales increased by almost 100 percent. While total global sales growth increased by 3.8 percent, almost all of the growth was concentrated at the largest 1% of firms, whereas the average small and medium sized firms contracted. Taken together, the tables indicate that larger firms have fared much better in terms of entry, exit, and survival.

=== Tables 1 & 2===

These trends illustrate a pattern of firm dynamics as a result of increasing economic integration, which have been well theorized in the heterogeneous trade models. Launched by the work of Melitz (2003), this literature emphasizes the role of heterogeneity and the self-selection of firms into servicing foreign markets. Due to high

[1] Global sales include domestic, export, and foreign affiliate sales at the parent-firm level. Results are quantitatively similar when the size is measured by domestic employment. Details of the data are explained in section 5.

fixed costs in foreign market entry, only the larger, more productive firms can exploit the opportunities from markets abroad. At the same time, increased competition from abroad puts pressure on domestic-oriented, smaller sized firms, causing the least productive ones to exit. This restructuring of production to more efficient firms generates overall aggregate productivity gains. The resulting firm dynamics carries important policy implications related to welfare gains and the asymmetric impacts of economic integration on firms.

The discussion above highlights the importance of explicitly understanding the micro-economic channels that occur at the individual firm-level and their aggregate implications they contain on the rest of the economy. However, standard econometric approaches are generally not well designed for quantifying asymmetric impacts of changes in FDI barriers across individual firms and are not capable of generating counterfactual analysis. To improve our ability to assess the impacts of increasing FDI integration, we require a quantitative framework that is capable of dissecting the aggregate shocks into firm-level components while simultaneously relating these impacts to the rest of the economy in an integrated framework.

The objective of this research is to develop a micro-simulation framework for multinational activities across countries. To our knowledge, no study has applied a framework that can quantitatively assess the impacts of changes in FDI barriers by simulating the activity at the individual firm level. To this end, we apply a model of heterogeneous firms adapted from Eaton, Kortum, and Kramarz (2010, EKK hereafter) to multinational production. EKK introduce a rich quantitative framework that is capable of simulating individual firm exporting activity, consistent with actual French manufacturing firms. Their framework is based on a monopolistic competition model of heterogeneous firms with Pareto efficiency and iceberg trade costs adapted from Melitz (2003) and Chaney (2008). We adapt their model to multinational activity by allowing firms to produce in a local market and abstract from the role of trade. Instead of incurring iceberg trade costs, heterogeneous firms must pay technology transfer and management costs to serve foreign consumers via offshore production.[2]

[2] A fundamental role of firm efficiency in building offshore production is consistent with the traditional literature on FDI in that firm-specific assets such as managerial skills, superior technology, and production processes are a key motive of direct investment (Markusen, 2002).

The entry decision depends on efficiency, fixed entry costs, and market attractiveness. The latent foreign sales are dependent on the entry hurdle and firm- and market-specific profitability. These two conditions govern the behavior of heterogeneous firms to invest abroad and generate foreign sales. The model predicts that more productive firms are more likely than less productive firms to enter a larger number of markets, to penetrate less attractive markets, and to yield larger sales per each market. These predictions point to a "pecking order" in which every multinational that invests in a certain market should establish an affiliate in all the markets that are more attractive than that market. Nevertheless, entry and demand shocks in the model allow for a deviation of the strict form of the "pecking order" in the data.

To parameterize our model to Japanese multinationals, we use a comprehensive dataset of manufacturing firms with foreign affiliates. The data set is constructed by linking two *confidential* firm-level surveys from the Japanese Ministry of Economy, Trade, and Industry (METI). Prior work such as Wakasugi et al. (2008) and Todo (2009) has used the same data to examine a systematic difference between multinational and non-multinational firms in Japan. By contrast, we illustrate and simulate the scale and scope of Japanese multinationals. Furthermore, the substantial volume of direct investment from Japan makes Japanese industries an interesting case for simulating heterogeneous multinationals. In 2009, Japan was the third largest source of FDI, following the U.S. and France (UNCTAD, 2010). However, inward FDI in Japan was significantly lower than the U.S. and France, highlighting the large role of Japanese multinational parents in domestic industries. Dissecting the micro-level data, we document the empirical regularities of multinational entry and sales activity, suggesting that the stylized patterns are in line with the main properties of our adapted model.

Following EKK, entry and latent sales conditions are re-specified to simulate heterogeneous multinational firms. To simplify the specification, aggregate parameters are connected with some features of the data, so that four parameters of underlying stochastic distributions govern the behavior of heterogeneous firms in serving a foreign market: size dispersion, entry and market shocks, and a correlation of these shocks. For our estimation strategy, we use simulated method of moments to estimate an optimal set of parameters (McFadden, 1989; Pakes and Pollard, 1989). We use the theoretical implications of the model to choose a set of four moment conditions: pecking order strings, affiliate sales distributions across markets, parent sales distribution in Japan, and multinational production intensity.

We simulate our sample of firms to obtain the set of optimal parameters, which are close to the estimates found for French firms in EKK. Our results show that the level of size dispersion for Japanese multinationals is larger than French exporting firms (EKK, 2010). The estimated variance of a market shock is very similar between Japanese and French data whereas our estimated variance of an entry shock is slightly larger. This implies that the decision to invest abroad would involve more uncertainty than the decision to export. Furthermore, the market shock has much larger variance than the entry shock, suggesting that we can precisely simulate affiliate entry more than affiliate sales.

Our simulation approach is advantageous in its ability to rigorously assess model performance through validation exercises. Our in-sample moment testing demonstrates that the model is internally consistent with the data. Our simulated multinationals fit the actual Japanese multinational activity quite well in terms of the moments used in estimation. Additionally, the simulated firms can also closely follow the level of foreign market penetration, replicating activity not conditioned in our estimation strategy. Lastly, the model does a reasonable job in out of sample simulations of 1996 multinational activity in a significantly different environment of FDI integration from what was conditioned upon in our 2006 estimation sample. Our validation exercises also reveal several shortcomings of the model. Large firms tend to invest in too many markets and small firms invest in too few markets. Additionally, the model cannot account well for Japanese multinationals motivated by offshore production for exporting. However overall, the internal and external validation tests instill a strong level of confidence in our model being used for performing quantitative analysis on multinational behavior.

The rest of the paper is organized as follows. Section 2 discusses the related literature. Section 3 describes the EKK model for multinational production with heterogeneous firms. Section 4 explains our simulation framework to generate artificial multinationals. Section 5 describes data sources and empirical features of Japanese multinational activities. Section 6 presents the estimation results and model validation tests. Section 7 concludes.

2. Related Literature

This paper is related to the literature on firm heterogeneity in the analysis of international trade and investment. Helpman et al. (2004) build on the work of Brainard (1997) and Melitz (2003) to introduce the decision to export and invest abroad in a model of heterogeneous firms. According to efficiency levels, every firm decides whether to serve a foreign market, and whether to export or produce offshore. The model predicts that only the most productive firms choose local production in which fixed costs are larger than exporting, but variable costs are lower. The productivity advantage of multinationals is consistent with the evidence provided by Head and Ries (2003) from publicly listed Japanese manufacturing firms and Girma et al. (2005) from U.K. manufacturing firms. In addition, Tomiura (2007) shows that firms with a foreign production facility are larger and more productive than firms that only export. By contrast, we highlight the role of firm heterogeneity in accounting for the location and extent of multinational production.

Recent studies on the location decision of heterogeneous multinationals are particularly relevant to our work. Aw and Lee (2008) modify the model of firm heterogeneity in horizontal and vertical FDI by Grossman et al. (2006) to account for location choices of multinationals headquartered in a middle-income country. They show that relatively productive firms engage in FDI, and the most productive firms invest in multiple markets, for which they provide evidence from Taiwanese multinationals. Chen and Moore (2010) further analyze whether host-country characteristics influence the location decision of heterogeneous multinationals. Using French firm data, they demonstrate that more productive multinationals are more likely than less productive ones to invest in less attractive markets with high investment costs.

In addition, Yeaple (2009) shows that the number and size of foreign affiliates increase with respect to productivity by U.S. parent firms. He also illustrates a systematic deviation from the strict “pecking order”, suggesting that heterogeneity in efficiency is not sufficient to explain the structure of multinational activity. Our work complements these studies, but differs in that we adopt a structural approach to estimate a set of underlying parameters of firm heterogeneity. Because we can simulate production location of heterogeneous multinationals, this approach is advantageous in that we can explicitly test the fit between the model and many features of the data

(Keane, 2010).

Finally, our research adds to the limited literature on structural econometric analysis of trade and investment. Bernard et al. (2003) incorporate heterogeneous exporting plants in the model by Eaton and Kortum (2002) to embed the plant-level exporting decision in the trade model. Two underlying parameters in production and consumption are calibrated to match two moments between simulated and real exporters, i.e., productivity and size advantages. However, parameter values are searched to match only two moments so that a model fit is not satisfactory in other features of exporting plants. In this respect, we account for many moments of multinational activities in calibration to demonstrate a good fit between simulated and real multinationals. Along the same line, EKK (2010) is a seminal work that builds a model of international trade with heterogeneous firms that is consistent with many stylized facts. As we apply their framework to multinational production, this paper can be taken in a sense as demonstrating the tractability of their model.

Additionally, Ramondo (2010) takes a structural approach to quantify gains from multinational production. Her focus differs from our analysis in that we can link a change in the global environment with multinational production at the firm-level. Along the same line with Ramondo (2010), we do not consider the role of trade in intermediate inputs and final goods by multinationals for data limitations.[3] Because we do not have access to confidential trade data, it is not possible to link manufacturing firms with their exports by destination. The lack of firm-level export sales by destination restricts us to focus exclusively on multinational production, where we leave the incorporation of exporting activity for future research.

3. An EKK Model for Multinational Production

Our model is adapted from EKK's (2010) heterogeneous exporting firm model. This model is in turn based on a class of heterogeneous trade models introduced by Melitz (2003) and incorporates stochastic entry and demand shocks and market-access

[3] See, for example, Feinberg and Keane (2006), Keller and Yeaple (2008), Garetto (2009), and Ramondo and Rodriguez-Clare (2009) for a structural model of input trading between multinational parent firms and their affiliates, which allows for substitution and complementary relationships between FDI and exports.

costs.[4] The key elements of the model are a Pareto distribution of firm efficiency, Dixit-Stiglitz demand, iceberg trade barriers, fixed entry costs, and asymmetry in markets. We briefly present a modified version of the EKK model for multinational production.

There are N host countries for local production. Each host country n has aggregate demand for manufacturing varieties X_n and factor costs w_n. We assume costly technology transfer for offshore production, giving rise to increasing marginal costs of serving foreign markets. Each pair of countries i and n is separated by technology barriers that rise in unit cost in proportion d_{ni}. In this setting, d_{ni} may be interpreted as the information costs of working broad, transaction costs of dealing with FDI policy barriers[5], costs of maintaining the affiliate, servicing network costs, and other costs associated with technology costs in offshore production.[6] For domestic production, we set $d_{ii} = 1$.

3.1 Producer Technology

Each country has a continuum of potential producers, each producing a unique good j with efficiency $z_i(j)$. A firm in home country i can produce good j in host country n by local production, with its unit costs given by:

$$c_n(j) = \frac{w_n d_{ni}}{z_i(j)} \tag{1}$$

where unit costs are increasing in host market's factor costs, w_n, and technology transfer costs d_{ni}, and decreasing in firm productivity $z_i(j)$.

As in Melitz (2003), each firm draws a random productivity parameter from some distribution. Following the trade literature, we assume a Pareto distribution. Then, a measure of potential producers with efficiency at least $z_i(j)$ is:

$$\mu_i^Z(Z \geq z) = T_i z^{-\theta}, \;\; z > 0 \tag{2}$$

4 See Helpman et al. (2004) and Chaney (2008) for extensions.

5 FDI policy restrictions may increase the costs of multinationals operating abroad in terms of ownership constraints, foreign-specific regulations, and weak legal protection of property/capital. (World Bank, 2010)

6 This feature is similar in nature to Keller and Yeaple (2008), showing that US owned foreign affiliates find it more difficult to substitute local production for imports from the multinational parent when technologies are complex. Also, it is consistent with the findings in Ramondo (2008) and Ramondo and Rodriguez-Clare (2009) that multinational costs are increasing in distance, language barriers, and national borders.

The parameter T_i governs the average level of efficiency/technology in country i, and the parameter θ governs the distribution of productivity across firms, which is assumed constant across countries. Since all goods are uniquely produced by a single firm and differ solely on the dimension of productivity, the terms "goods" and "firm" can be indexed interchangeably. Multinational firms with superior technology have lower unit costs, and spread the benefits of this efficiency through cheaper goods.

Equation (1) leads to $z_i(j) = w_n d_{ni}/c_n(j)$. Then, the measure of goods that can be produced in country n through affiliate production by firms in country i with unit cost $C \leq c$ is:

$$\mu_{ni}(C \leq c) = \mu_i^z\left(\frac{w_n d_{ni}}{c}\right) = T_i(w_n d_{ni})^{-\theta}(c)^{\theta} \tag{3}$$

A firm will enter market n if its operating profits from affiliate sales are sufficient to overcome the fixed cost of setting up an affiliate. We assume that firm j incurs a fixed cost to set up an affiliate in n as follows:

$$E_{ni}(j) = E_{ni}\varepsilon_n(j) \tag{4}$$

where E_{ni} is the general fixed cost that is constant for all firms entering n from i. The costs include both the physical costs of building a plant and the information/FDI barrier costs associated with establishing a new affiliate in a new market. The information costs are related to marketing research, foreign contacts, local recruiting for workers.[7] FDI policy barrier fixed costs may include added additional regulations required to setup an affiliate. $\varepsilon_n(j)$ is the idiosyncratic fixed cost specific to firm j entering market n. It accounts for unobservable factors in establishing a foreign affiliate by firm j in market n, with higher values indicating larger investment costs.

3.2 Market Structure

A firm j with a price $p_n(j)$ in market n faces a residual demand curve given by:

$$X_n^*(j) = \alpha_n(j)\left(\frac{p_n(j)}{P_n}\right)^{1-\sigma} X_n \tag{5}$$

where P_n is the constant-elasticity-of-substitution (CES) price index averaged across all goods produced in country n (through home and foreign technology). σ is an elasticity of substitution between any two goods with $\sigma > 1$. X_n is aggregate

[7] The fixed costs are also falling in production networks and agglomeration spillovers.

expenditure on manufacturing goods in country *n*. $\alpha_n(j)$ is an unobservable factor specific to demand for individual variety produced by firm *j* in country *n*. It can be thought as a demand shock to individual affiliate of firm *j*, with higher values indicating a preferable shock to its product sales. The * denotes the latency of our sales condition.

The price index is the expectation of the prices of individual varieties available to consumers in *n*, with Ω_n denoting the set of available goods:

$$P_n = E[\alpha_n(j)\, p_n(j)^{1-\sigma}]^{1/(\sigma-1)} \quad \forall j \in \Omega_n \tag{6}$$

With Dixit-Stiglitz preferences and monopolistic competition, each firm charges a constant markup $\bar{m} = \sigma/(\sigma-1)$ over $c_n(j)$. This yields a pricing rule:

$$p_n(j) = \bar{m}c_n(j) = \bar{m}\frac{w_n d_{ni}}{z_i(j)} \tag{7}$$

If firm *j* sells in country *n*, firm revenue is then:

$$X_n^*(j) = \alpha_n(j)\left(\frac{\bar{m}c_n(j)}{P_n}\right)^{1-\sigma} X_n \tag{8}$$

With monopolistic competition, gross profits are proportional to sales, with proportionality of $1/\sigma$. Thus, firm *j* will enter market *n* if its operating profits are sufficient to overcome the cost of entry:

$$X_n^*(j) \geq \sigma E_{ni}\varepsilon_n(j) \tag{9}$$

Substituting back in our latent sales expression, we can solve for $c_n(j)$ at this threshold level to derive the entry hurdle condition for affiliate production by firm *j* from country *i* in market *n*:

$$c_n(j) \leq \bar{c}_{ni}(j) = \left(\frac{\alpha_n(j)}{\varepsilon_n(j)}\frac{X_n}{\sigma E_{ni}(j)}\right)^{1/(\sigma-1)}\frac{P_n}{\bar{m}} \tag{10}$$

The entry condition implies that firm *j* will enter market *n* only if its unit costs are below the threshold level $\bar{c}_{ni}(j)$. Given that firm *j* passes the entry condition, it will generate foreign affiliate sales given by (8). Because most firms do not engage in multinational production and most multinationals produce only in a few destinations, the majority of sales $X_n^*(j)$ will be zero.

3.3 Entry and Latent Sales Conditions

The price index P_n in each market depends on the number of foreign affiliates entering *n* and the level of their sales while a firm's decision to establish an affiliate in turn depends on the price index P_n. From parameters T_i, X_n, $w_n, E_{ni}, z_i(j), \alpha_i(j), \varepsilon_i(j)$, we can solve for the price index and derive the following two conditions:

$$\text{Entry Hurdle: } \bar{c}_{ni}(j) = \eta_n(j)^{1/(\sigma-1)} \left(\frac{X_n}{\kappa_1 \sigma E_{ni} \Phi_n}\right)^{1/\theta} \tag{11}$$

$$\text{Latent Sales: } X_n^*(j) = \alpha_n(j) c_n(j)^{1-\sigma} \sigma E_{ni} \left(\frac{X_n}{\kappa_1 \sigma E_{ni} \Phi_n}\right)^{\frac{1}{\theta}} \tag{12}$$

where:

$$\eta_n(j) = \frac{\alpha_n(j)}{\varepsilon_n(j)},$$

$$\Phi_n = \sum_{i=1}^{I} T_i (w_i d_{ni})^{-\theta},$$

$$\kappa_1 = \frac{\theta}{\theta-(\sigma-1)} - \iint \alpha \eta^{\frac{[\theta-(\sigma-1)]}{\sigma-1}} g(\alpha, \eta) d\alpha d\eta.$$

$\eta_n(j)$ is an overall entry shock that each firm faces to enter market *n*. Φ_n summarizes the states of technology and input costs around the world, and investment barriers for implementing domestic technology abroad. A higher level of Φ_n indicates that the country is more open to FDI and is thus a more competitive market. Each individual firm faces a different entry hurdle $\bar{c}_{ni}(j)$ that differs by country, with higher values indicating lower threshold unit costs to enter the market. Thus, the entry hurdle is lower for large market, low general entry costs, and higher Φ_n.

The latent sales condition implies that given that firm *j* enters a market *n,* its overall sales is increasing in its favorable demand shock and unit costs. Latent sales are also positively related to the general entry costs. Lastly, they are increasing in the overall market attractiveness, which is captured by the last component $(X_n/\kappa_1 \sigma E_{ni} \Phi_n)^{1/\theta}$.

The entry hurdle and latent sales conditions govern the decision of firm *j* as to which market to invest and how much to generate sales in that market. From these conditions, we can derive the empirical implications on entry and sales patterns of multinational firms with heterogeneous efficiency. Specifically, the model predicts that more productive firms are more likely than less productive firms (i) to enter a larger number of markets, (ii) to penetrate the less attractive markets, and (iii) to yield larger sales per each market. These predictions suggest that firms first enter the most attractive market, and then invest progressively in less attractive markets. In this case, there is a strict hierarchy of market destinations in which more productive firms progressively enter less attractive markets.

However, the strict hierarchy is not observed in the data. In the presence of entry and demand shocks in the model, firms with identical productivity need not exhibit identical patterns of market entry and the volume of affiliate sales. Otherwise, any two of identical firms would have the same sales in any market where they enter. Thus, the model predicts a weak pecking order. To examine these empirical implications of the model, we simulate an artificial dataset of multinational firms in the following framework.

3. Simulation Framework

We turn to describe the simulation framework for estimating the structural parameters of the model. The procedure proceeds (1) to re-specify the model derivations for simulation, (2) to simulate artificial firms given a particular set of parameter values, (3) to search a set of underlying parameters that minimize the distance of moments between artificial and real firms. We denote home country *i,* by J (Japan) and an artificial firm *s,* with $s = 1, 2, \ldots, S$.

3.1 Respecification for Simulation

An artificial firm *s,* is simulated by a realization of random productivity draw $z_J(s)$, entry shock $\eta_n(s)$, and demand shock $\alpha_n(s)$. For each simulated firm, its production is governed by the entry hurdle and latent sales conditions: equations (11) and (12). However, these conditions need to be re-specified for quantification. First, the heterogeneous component of unit costs is isolated by defining $u(s) = T_J z_J(s)^{-\theta}$ as standardized unit costs. Then, the artificial firm can be generated from a simple uniform distribution that is independent of any parameters. Using the standardized unit costs, we can express the entry hurdle and latent sales conditions as:

$$\text{Entry Hurdle: } u(s) \leq \bar{u}_n\big(\eta_n(s)\big) \frac{T_J(w_n d_{nJ})^{-\theta}}{\sum_{i=1}^{N} T_i(w_n d_{ni})^{-\theta}} \frac{X_n}{\sigma E_n} \kappa_2 \eta_n(s)^{\tilde{\theta}} \tag{13}$$

$$\text{Latent Sales: } X_{nJ}(s) = \sigma E_n \left(\frac{u(s)}{\bar{u}_n(s)}\right)^{-1/\tilde{\theta}} \frac{\alpha_n(s)}{\eta_n(s)} \tag{14}$$

where $\tilde{\theta} = \frac{\theta}{\sigma - 1}$ and $\kappa_2 = \int \eta^{\theta/(\sigma-1)} g_2(\eta) d\eta$.

The term $\tilde{\theta}$ translates unobserved heterogeneity in producer efficiency into observed heterogeneity in sales. A higher value of θ implies less heterogeneity in efficiency while a higher value of σ translates a given efficiency in heterogeneity into a higher level of sales heterogeneity. Since we use data on domestic and foreign affiliate sales, we do not directly estimate θ, but can only identify the parameter $\tilde{\theta}$.

The conditions (13) and (14) contain market-level parameters that can be linked with aggregate data on multinational sales for parameterization. Following EKK, we can use a measure of all firms that pass the cost hurdle to obtain the measure of entrants into market *n*:

$$N_n = \int \left[\mu_{nJ}(\bar{c}_{nJ}(\eta))\right] g_2(\eta) d\eta = \frac{\kappa_2}{\kappa_1} \frac{X_n}{\sigma E_{nJ}} \tag{15}$$

Second, the parameter Φ_n can be related to the FDI share of source country *J* in country n, X_{nJ}/X_n, as follows:

$$\frac{\mu_{nJ}(c)}{\mu_n(c)} = \frac{T_J(w_n d_{nJ})^{-\theta}(c)^{\theta}}{\Phi_n} = \frac{X_{nJ}}{X_n} \tag{16}$$

The fraction of affiliates in market *n* employing technology from *J* is $T_i(w_n d_{ni})^{-\theta}(c)^{\theta}/\Phi_n$, which is also the fraction of spending by country *n* on goods supplied by the affiliates from *J*, X_{nJ}/X_n. Equation (16) implies that bilateral FDI shares can be used to infer the cluster of parameters including technology transfer costs from Japan, technology level in Japan, input costs in host countries, and competition from the world. Third, a measure of firms from country *J* selling to country *n* is:

$$\frac{N_{nJ}}{\pi_{nJ}} = \frac{\kappa_2}{\kappa_1} \frac{X_n}{\sigma E_{nJ}} \tag{17}$$

where $\pi_{nJ} = \frac{X_{nJ}}{X_n}$.

The number of firms from Japan can be related to FDI share from Japan, host market size, and entry costs. Lastly, the average sales of firms from Japan in country *n* are related to the entry costs:

$$\sigma E_n = \frac{\kappa_2}{\kappa_1} \bar{X}_{nJ} \tag{18}$$

The expressions above show that some parameters can be inferred from aggregate population of Japanese firms/affiliates across markets and their average sales.

To specify κ_1 and κ_2, the distribution $g(\alpha, \eta)$ is assumed to be joint lognormal. This assumption leads to the following:

$$\kappa_1 = \left[\frac{\tilde{\theta}}{\tilde{\theta}-1}\right] exp\left[\frac{\sigma_\alpha + 2\rho\sigma_\alpha\sigma_\eta(\tilde{\theta}-1) + \sigma_\eta(\tilde{\theta}-1)^2}{2}\right] \tag{19}$$

$$\kappa_2 = exp\left[\frac{\left(\tilde{\theta}\sigma_\eta\right)^2}{2}\right] \tag{20}$$

Connecting these parameters to the conditions (13) and (14), we obtain:

$$\text{Entry Hurdle: } u(s) \le \bar{u}_n\big(\eta_n(s)\big) = \kappa_2 N_{nJ}\eta_n(s)^{\tilde{\theta}} \tag{21}$$

$$\text{Latent Sales: } X_{nJ}(s) = \frac{\kappa_2}{\kappa_1}\overline{\mathrm{X}}_{nJ}\frac{\alpha_n(s)}{\eta_n(s)}\left(\frac{u(s)}{\bar{u}_n(s)}\right)^{-1/\tilde{\theta}} \tag{22}$$

The modified conditions are linked to data on Japanese multinationals and random variables from specified distributions. In the entry hurdle condition, the probability of simulated firms entering country n is based on the actual population of Japanese firms with foreign affiliates in country n. Conditional upon entry, the latent sales indicates that the distribution of sales in country n is scaled by a factor equal to the average sales of Japanese affiliates in country n.

4.2 Simulation of Multinational Firms

The entry hurdle and latent sales conditions (21) and (22) can be used to simulate individual multinational activities. An artificially generated individual producer s is characterized by its efficiency draw $u(s)$, sales shock $\alpha_n(s)$ and entry shock $\eta_n(s)$. The only data required for simulation is the population of Japanese firms/affiliates N_{nJ} and their aggregate sales X_{nJ} in each country n. The four parameters of the distribution probabilities of the model are written as $\Theta = (\tilde{\theta}, \sigma_a, \sigma_h, \rho)$: heterogeneity in observed sales, variances in sales and entry shocks, and correlation between these shocks. With the aggregate data and Θ, we can produce an artificial dataset of heterogeneous multinationals on the location and sales of their foreign affiliates.

The procedure to simulate the total number S of firms proceeds to fix a set of parameters of Θ and construct realizations for standardized unit cost $u(s)$, and random shocks $\alpha_n(s)$ and $\eta_n(s)$ for each firm s and country n. These realizations of stochastic components of each firm are fixed throughout the estimation.[8] From firm-

[8] We assume that $\alpha_n(s)$ and $\eta_n(s)$ have a joint bivariate lognormal distribution:

$$\begin{bmatrix}\ln\alpha_n(s)\\ \ln\eta_n(s)\end{bmatrix} \sim \mathrm{N}\left[\begin{pmatrix}0\\0\end{pmatrix}, \begin{pmatrix}\sigma_\alpha^2 & \rho\sigma_\alpha\sigma_\eta\\ \rho\sigma_\alpha\sigma_\eta & \sigma_\eta^2\end{pmatrix}\right].$$

To draw these realizations of random shocks, we use the choleski decomposition factor to construct $\ln a$ and $\ln\eta$ with:

and market-specific realizations, we construct the entry hurdle condition (19) for each artificial firm across each market. From the entry hurdle matrix for firm and market, we make an indicator variable Z of whether each firm establishes an affiliate in each market:

$$Z_{nk}(s) = \begin{cases} 1 & \text{if } u(s) \leq \bar{u}_n(s) \\ 0 & \text{otherwise} \end{cases} \tag{23}$$

When the entry indicator is equal to one, a simulated firm should enter the market and generate sales according to the latent sales condition (22). We calculate the volume of sales for each affiliate of firm s entering country n. In sum, this procedure allows us to simulate the country where each artificial firm s sets up an affiliate and the level of sales generated by that affiliate in that country.

4.3 Simulated Method of Moments

While the simulation procedure allows us to generate artificial multinational firms under a particular set of parameters, we do not have a prior belief about what parameters should be chosen for the simulation analysis. In this respect, we adopt the criterion that simulated multinationals should have as similar characteristics with real multinationals as possible under an *optimal* set of parameters. These characteristics are defined as *moments* of artificial and actual multinationals. In next section, we determine a particular set of characteristics of multinational activities based on actual Japanese multinationals.

Each of the moments chosen is defined as the share of multinational parent firms that fall into a set of mutually exclusive bins. We denote N_k as the number of actual firms achieving an outcome k in the actual data, and $\widehat{N}_k$ as the number of simulated firms achieving the same outcome. For each moment, the number of simulated firms falling into each outcome is weighted as follows:

$$\begin{bmatrix} \ln\alpha_n(s) \\ \ln\eta_n(s) \end{bmatrix} \sim \left[\begin{pmatrix} \sigma_\alpha\sqrt{1-\rho^2} & \rho\sigma_\alpha \\ 0 & \sigma_h \end{pmatrix}\right] \left[\begin{pmatrix} a_n(s) \\ h_n(s) \end{pmatrix}\right].$$

To avoid drawing the firms that end up not selling anywhere, productivity draws are bounded to the firms that sell in Japan and at least one foreign market. In doing so, we use the importance sampling from $u(s) = v(s)\bar{u}_J^*(s)$, where random realizations of $v(s)$ are independently drawn from a uniform distribution over interval [0,1] and $\bar{u}_J^*(s)$ is the firm-specific hurdle for entering Japanese market and at least one foreign market. As this measure serves as a sampling weight, we ensure that all draws are to be $u(s) \leq \bar{u}_J^*(s)$ and over-bias in generating more efficient firms is corrected.

$$\widehat{N}_k = \frac{1}{S}\sum_{s=1}^{S} \bar{u}(s) Z_k(s) \qquad (24)$$

where $\bar{u}(s)$ is the importance weight of each simulated firm. We define the distance between actual and artificial moments for outcome k of moments f:

$$y(\Theta) = m_{kf} - \widehat{m}_{kf}(\Theta) \qquad (25)$$

where $m_{kf} = N_{kf}$ and $\widehat{m}_{kf}(\Theta) = \widehat{\mathrm{N}}_{kf}$. N_{kf} is the share of firms with outcome k in moments f relative to the total number of Japanese multinational parents.

Equation (25) shows that an optimal set of parameters can be judged from the distance between actual and artificial moments, with the smaller distance indicating better parameters. To estimate the parameters, we employ simulated method of moments as introduced by Pakes and Pollard (1989) and McFadden (1989). This estimation method matches moments of the simulated and real data and searches for the set of parameters that minimizes the total distance between actual and simulated moments. Under the true set of parameter values Θ_0, the following moment condition is assumed to hold:

$$\mathrm{E}[y(\Theta_0)] = 0 \qquad (26)$$

An objective function can be specified under the following weighted quadratic form:

$$\widehat{\Theta} = \arg\min_{\Theta}\{y(\Theta)' \, \mathrm{W} \, y(\Theta)\} \qquad (27)$$

where $\widehat{\Theta}$ is an estimated set of parameter values.

To search for the parameters that best fit the model, we employ Nelder-Mean simplex method (Nelder and Mead, 1965; Lagarias et al. 1998). To further mitigate optimization errors, we introduce random variations to the starting values and repeat the minimization algorithm for a fixed set of artificial and real moments by 1000 times. Finally, we take the optimal parameters that give the minimum distance.

The search procedure above should provide us the best fitting parameters, which could be subject to sampling errors of real Japanese multinationals and simulation errors of artificial multinationals. Bootstrapped standard errors are computed from standard deviations between new estimates and the optimal estimates. We resample the real data with replacement and generate a new set of v^b, α^b, η^b. Then, we follow the SMM procedure to estimate a new set of parameters $\widehat{\Theta}_b$. Repeating by 25 times, we calculate:

$$V(\Theta) = \frac{1}{25}\sum_{1}^{25}(\widehat{\Theta}_b - \widehat{\Theta}^*)(\widehat{\Theta}_b - \widehat{\Theta}^*)'$$

where $\widehat{\Theta}^*$ is the original best fitting estimate of the parameters. Taking the square root of the diagonal elements gives us our standard errors where our calculations account for both sampling and simulation error.

5 Data Description

We employ two sources of firm-level surveys to construct a data set on Japanese multinational activity. We first explain each data source and describe how the empirical regularities of Japanese manufacturing firms are consistent with our adapted model. These illustrations are used to determine the moments for our estimation strategy.

5.1 Data Sources

Our data source for domestic firm activity comes from the *Kigyou Katsudou Kihon Chousa* – the Basic Survey of Japanese Business Structure and Activities – by the Japanese Ministry of Economy, Trade, and Industry (METI). The survey covers all business firms with 50 employees or more and capital of 30 million yen or more in both manufacturing and non-manufacturing sectors. The first survey was conducted in 1991 and continued annually since 1994. For estimation, this paper primarily exploits the survey in 2006.[9] The firms in the survey accounted for 5 percent of total firms and 60 percent of total employees in the Japanese manufacturing sector.[10] In terms of employment, the survey is highly representative of manufacturing activity in Japan.

Our data source for foreign affiliate sales activity comes from the *Kaigai Jigyo Katsudo Kihon Chosa* – the Basic Survey of Overseas Business Activities – by METI. A survey questionnaire is sent to all the Japanese firms in both manufacturing and non-manufacturing sectors that are headquartered in Japan with foreign business enterprises; more than 10 percent of foreign affiliate's equity shares must be owned by the Japanese parent firm. Because it is not mandatory for firms to respond to the survey, the response rate is around 60-70 percent. In 2006, there were 2,165 parent firms that accounted for 31 percent of total employees in manufacturing firms surveyed in the

[9] The survey for 1996 is used to construct Table 1 and conduct robustness checks.
[10] The survey results show 12,855 manufacturing firms with 4.9 million employees in 2006.

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We use these data sources to link Japanese parent firms with manufacturing foreign affiliates. After excluding the affiliates that were out of operation and/or have no sales figure, we were able to link 2,032 parent firms with 7,626 foreign affiliates in 70 markets in total. In this sample, the total sales by foreign affiliates was 99.1 trillion yen. The average Japanese multinationals had 4 foreign affiliates and 5.7 billion foreign sales per their affiliate. The maximum number of foreign affiliates per parent firm was 98 and the maximum affiliate sales were 425 billion yen.[11] However, some parent firms in this sample have missing figures of their domestic sales, making it infeasible to calculate a measure of their linkage between domestic and foreign sales. While including these parent firms in the sample does not alter the magnitude of our estimates, we report the estimation results for a sample of 1,656 parent firms excluding firms with missing domestic sales in Japan.

5.2 Empirical Patterns of Japanese Multinational Activities

5.2.1 Market Entry, Pecking Order, and Market Size

We use the data to describe empirical regularities of Japanese multinational firms in five dimensions. First, Figure 1 shows a relationship between market entry and market size. Panel A plots the number of parent firms investing in each market against the market size, as measured in real GDP in billions of 2000 U.S. dollars.[12] The number of firms investing in each market increases with respect to the size of host markets. A regression line for the sample used has a slope of 0.76. We also plot the data for year 1996, which closely matches the linear relationship in 2006 data.

Panel B shows the average sales of foreign affiliates in each market against the market size. Sales per affiliate increases with respect to the market size, which is consistent with the number of investing parent firms. The plots for 1996 data also point to a positive relationship. However, a regression line for the 2006 sample has a slope of 0.44, which is lower than the estimate for entry of firms. It appears that larger markets attract more entry of multinational firms, but have a weaker positive impact on average

[11] In the following sections, we convert sales in millions of U.S. dollars using the period-average of Yen-US dollar exchange rates of 116.3 in 2006.
[12] Data on real GDP come from the World Development Indicator.

affiliate sales.

=== Figure 1 ===

We turn to examine a feature of Japanese multinationals and market entry. As discussed in Yeaple (2009), firm heterogeneity in productivity predicts a "pecking order" in which every firm that invest in certain country should own an affiliate in countries that are more attractive than that country. For this examination, the first column of Table 1 presents the number of Japanese multinational parents that maintain at least one foreign affiliate in the top 5 markets: China, the United States, Thailand, Taiwan, and Indonesia. There were 1191 multinational parents entering the Chinese market in 2006, and 652 in the United States. After excluding duplicate firms among these top markets, the total multinational parents amounted to 1972. From the total number, the last column reports the fraction of multinationals that own an affiliate in each market. 59 percent of the Japanese parent firms penetrated the Chinese market whereas 32 percent of them entered the U.S. market.

We report the number of Japanese firms investing in the strings of top 5 markets while ignoring their entry in other markets. In Table 3, the market string shows that firms own an affiliate in that market string, but no other among the top 5. The second column shows the number of multinationals under such a hierarchy, with 578 multinationals in total. Among the top 5 markets, 29.3 percent of multinationals (578/1972) obey the strict pecking order. To make a benchmark, we compute the predicted probability of firms investing in each string when entry in each string is independent among the top 5. Under independence, there are 361 multinationals in total; for example, 211 multinationals (1972×0.104) would have invested in China. As 18.3 percent of multinationals follow a pecking order under independence, the data indicate the presence of pecking-order forces.

=== Tables 3 and 4 ===

5.2.2 Sales Distributions of Japanese Firms

As a cross-country pattern is described, we explore the size distribution of Japanese firms within individual markets. For the Japanese market, firm size is measured with domestic sales that aggregate firms' sales in Japan and their exports. Then, we normalize each firm's sales relative to the mean of domestic sales and compute a fraction of firms with at least that much sales.[13] For other foreign markets, we use total sales of foreign affiliates, including their sales to local, home, and third markets.

Figure 2 shows a plot of the normalized sales and the fraction of firms for Japan, China, the U.S., and Thailand. The shape of sales distributions are similar across markets and are closely associated with a Pareto distribution at least in the upper tail. This feature provides empirical support for the assumption that efficiency shocks follow the Pareto. However, the distribution starts to deviate from the Pareto in the lower tail.

=== Figure 2 ===

5.2.3 Market Entry and Sales in Japan

We turn to describe a relationship between market entry and sales in Japan. We group firms into different sets according to their entry to foreign markets. First, Japanese firms are sorted into the set of firms with the *minimum* number of foreign markets they penetrated. Panel A in Figure 3 plots the average sales in Japan for each set of firms investing at least k markets or more. Sales in Japan rise monotonically with respect to the number of markets in which multinationals own an affiliate.

=== Figure 3 ===

Second, firms are grouped by the number of markets they invested. Panel B presents a plot of average sales in Japan against the number of firms investing k markets or more, with the marker indicating the number of markets they served. For the set of firms investing a single market, there are over 1000 firms with lower average sales in Japan. As the number of markets served by them increases, the set of these firms becomes smaller and is described by higher levels of sales.

Finally, we groups firms into the set of individual markets they invested. Panel C

[13] The fraction is constructed by dividing (rank – 0.5) with the total number of firms/affiliates for each observation in a given market, where the rank is one for a firm/affiliate with the largest sales.

plots the average sales in Japan against the number of firms for each economy. The relationship is relatively noisy, especially for markets with less than 10 firms. However, the relationship becomes generally negative for markets with more than 10 firms. Thus, firms investing in more popular markets tend to have lower sales in Japan and firms penetrating less attractive markets are associated with higher levels of domestic sales.

In sum, all panels in Figure 3 indicate a significant link between domestic sales and market entry. More productive firms, as measured by the size of domestic sales, could invest in a larger number of markets and/or less attractive markets. By contrast, less productive firms invest in a smaller number of markets and/or more popular markets.

5.2.4 Multinational Production Intensity

We turn to describe the relationship between sales in Japan and foreign affiliate sales. We compute the normalized sales of foreign affiliates in each market defined by $(\mathrm{X_n(j)}/\overline{\mathrm{X}}_\mathrm{n})/(\mathrm{X_J(j)}/\overline{\mathrm{X}}_\mathrm{J})$. We divide firm *j*'s sales by the average sales in that market to remove a market effect, which is further divided by the normalized domestic sales to remove a firm-size effect.

Figure 4 plots the 90$^{\text{th}}$ percentile and median normalized sales of foreign affiliates against the number of parent firms for each market. The data is noisier for markets with less than 10 firms. In contrast, the relationship is generally positive for markets with more than 10 firms, implying that normalized affiliate sales increase with respect to the popularity of foreign markets. While EKK find small shares for normalized export intensity (below 1), we find that foreign sales are much larger relative to domestic sales (above 1).

=== Figure 4 ===

5.3 Moments

The description of Japanese multinational activities yields some empirical regularities that should be captured by the simulation of heterogeneous multinationals. Based on these empirical patterns, we set the following four moments to be matched between artificial and Japanese multinationals.

First, we choose moments of pecking order string. We compute the share of multinationals entering each possible combination of the five most popular countries for multinational production. Each string is constructed such that multinationals entering the most popular market (China) invest in less popular markets progressively. Then, we make another combination for that string such that multinationals entering the first (China) and third (Thailand) invest in less popular markets progressively. By adding up all possible combinations, we have 2^5 moments.

Second, we set moments of distribution of foreign affiliate sales across markets. We calculate q^{th} percentiles for multinational sales in each market *n,* for q =50, 75, 100. For each set of firms that enter market *n,* we use these percentiles to set up sales intervals. We then calculate the share of multinationals that fall into each of these bins. The q^{th} percentiles are calculated only from the actual data and the simulated firms are set according to these bins. ($n \times 3$ moments).

Third, we employ distribution of multinational parent sales in Japan for moments. This moment links the level of sales in Japan to the set of firms that enter market *n.* We calculate q^{th} percentiles (q = 50, 75, 100) over domestic sales in Japan for each set of firms that enter market *n*. These intervals are calculated from the actual data. We then assign the firms that fall into these bins and calculate the share of multinationals ($n \times 3$ moments).

Finally, multinational production intensity is used for moments. We make two intervals for firms whose ratio of sales in market *n* to sales in Japan is below and above 50^{th} percentile. Then, we compute the share of simulated firms that sell in each market *n* and fall into either of these percentiles.

6 Estimation Results

Simulating 100,000 firms, we first present our best fitting estimated parameters $\widehat{\Theta}$ and discuss the implications of the results. Then, we evaluate model performance through internal and external model validation tests.

6.1 Parameter Estimates

As shown in the descriptive analysis, empirical regularities are relatively noisier for markets in which a small number of foreign affiliates have entered. To mitigate the chance of noisier segments of the data adversely influencing our estimates, we exclude markets with less than 10 affiliates from our benchmark result. Table 5 presents the estimated parameters obtained from the simulation algorithm. Column (1) is our benchmark results. The parameter of size dispersion, $\tilde{\theta} = \theta/(\sigma - 1)$, is a key variable of interest, for which we obtain an estimate of 1.99 with bootstrapped standard errors of 0.43. By way of comparison, the estimate is lower than the 2.46 estimate found for French exporting firms by EKK. As the smaller value indicates greater dispersion, the result implies that Japanese multinationals have a relatively higher level of size dispersion in sales than French exporting firms.[14]

=== Tables 5===

The estimated variance of sales shock is 1.64 for Japanese multinationals whereas EKK find an estimate of 1.69 for French exporters. These figures are quite similar between multinationals and exporters. The estimated variance of the entry shock, 0.39, is also larger than the estimate of 0.34 for French exporters. Our larger estimate for the variance in sales shock may be explained by the higher level of uncertainty involved for the decision to export. The estimated variance of sales shock is larger than that of the entry shock, suggesting that the model is more effective at explaining variations across affiliate entry compared to affiliate sales.

We proceed to check the robustness of the benchmark estimates. First, we focus on host markets with over 10 foreign affiliates in column (1), but a possible concern is that the inclusion of small markets could influence the benchmark estimates. To address such concerns, we report the estimated parameters for all the markets in column (2). The results show that while our estimate for $\tilde{\theta}$ rises to 2.12, the overall point estimates and standard errors are quite similar to the benchmark.

Second, we check the sensitivity of the benchmark parameters to a different set of

[14] For a comparison, Yeaple (2009) provides an estimate of 1.5 for U.S. multinationals if the strict pecking order predicted by his model would be observed in the data. Additionally, the level of size dispersion is related to heterogeneity in firm efficiency via an elasticity of substitution, which is not estimated from the data. To get a rough estimate of efficiency dispersion from our estimated parameters, we can use an estimate of σ = 2.19 based on Japanese manufacturing data in 1994-2004 from Kang (2008). This gives us an estimate of θ = 1.99 × (2.191–1) = 2.37 for Japanese multinationals in 2006. Using measures of total factor productivity, Wakasugi et al. (2008) find that an estimated parameter of productivity dispersion was 1.69 for Japanese manufacturing firms in 2003.

moments. Among the moments used, due to differences in vertical and horizontal motivations, the pecking order of entry may not fit as well for multinational production compared to export entry. To address this concern, we exclude the pecking order moments from estimation. Column (3) shows that the estimated parameters and bootstrapped standard errors are similar to the benchmark results, suggesting that our results are robust to the different set of moments used.

Finally we estimate the structural parameters with 1996 activity. We find that our estimate for $\tilde{\theta}$ rises to 2.13 but that the difference once again falls within the range of the standard errors. Taken together, our robustness checks demonstrate that the benchmark estimates of the four parameters are not sensitive to alternative specifications of the sample and moments used for estimation.

6.2 Internal Model Validation

We use the parameters of column (1) in Table 5 to simulate a new set of 12,855 artificial firms, which is equal to total manufacturing firms in Japan for 2006. Based on our simulations, we can assess how the model replicates the characteristics of Japanese multinationals. Specifically, we compare the number of simulated firms and Japanese multinational parents along the four different moments as described in section 5.

Panel A of Figure 5a shows a scatter plot of simulated and actual firms that belong to different strings of the pecking order, with a 45-degrees straight line indicating a perfect fit of simulated firms. It is evident that majority of the scatter plots appear near the perfect fitting line, suggesting that the model replicates the actual pecking order of Japanese multinationals considerably well. However, a deviation appears to be relatively larger for the string with few multinational firms. This result is reasonable from a quantitative point of view because it is difficult to predict multinational activity for markets with limited Japanese foreign affiliate entry. Additionally, Panel B presents the similar plots for the moments of foreign affiliate sales. In this figure, we partition the firms into three sets of foreign affiliate sales percentile groups in each market, counting the number of simulated and actual Japanese firms that fall into each bin. Each plot refers to a specific market, so that we label the set of firms that fall below the 50^{th} percentile with a country code. The model fit is considerably good for Japanese multinationals in terms of the distribution of foreign affiliate sales.

Next, Panel C in Figure 5b presents the result of the moments that link sales in Japan and their foreign affiliate activities. Sorting multinational parent firms by the market they invest, we count the number of parent firms that fall below the 50^{th}, $50\text{-}75^{th}$, and $75\text{-}100^{th}$ percentiles of their sales in Japan. The number of actual firms is plotted for each bin against the number of simulated firms, along with a perfect fitting line. We find that the model fit is also good in terms of the moments for sales in Japan. However, the difference is larger for the bins with small number of firms. Finally, Panel D shows the similar plots for the moments of multinational production intensity. For each market in which firms invest, we count the number of simulated and actual firms that fall below and above the 50^{th} percentiles of the share of foreign affiliate sales relative to domestic sales. The figure suggests that the model captures the real moments of Japanese multinationals well.

=== Figure 5a & 5b ===

6.3 External Model Validation

We have seen that the model is able to replicate the moments of Japanese multinational activities, for which underlying parameters are estimated to fit the model with data. As in-sample moments are examined for a predictive power of the model, our assessment up to this point is regarded as an internal validation of the model. However since the assessment is based on moments conditioned in the estimation strategy, alone it does not well inform us of the model's performance out of such contexts. Furthermore it is unlikely to give us much confidence in its ability to forecast multinational activities in an environment with a significantly different level of FDI barriers. To improve our confidence in the model's predictive ability, we perform two sets of additional validation tests that are based off simulations not conditioned in our estimated moment conditions.

First, we simulate multiple market entries by Japanese multinationals. The model predicts that penetration of foreign markets is increasing in firm productivity. Figure 6a shows the set of firms according to how many markets they have entered. These set of simulations were not conditioned in the model but we see that the simulated firms is able to roughly follow the number of actual firms across multiple market entries. However, too few firms enter smaller set of countries whereas too many firms enter a large set of countries. This suggests that large firms are investing in too many markets and small firms in too few. This is likely to be related to the rigid fixed costs imposed in the model where multinationals establishing larger affiliates will have higher investment startup costs. By contrast, the model assumes that entry fixed costs are not related to the size of global operations by multinational parent firm. As result, the model does not allow small firms to pay a small fixed cost to establish a foreign affiliate of small size. This assumption may help us to explain why the model slightly misses this set of moments.

Next we proceed to analyze whether the model can explain Japanese multinational activities in 1996. Using our estimated structural parameters in 2006, we simulate the model with the FDI barriers and market sizes inferred from the 1996 data and assess how well the model is able to replicate Japanese multinational activities in 1996. Because investment barriers are likely to have dramatically changed for Japanese manufacturing firms from 1996 to 2006, this external validation test is in the spirit of the “non-random holdout sample”. That is, we assess a model fit by the sample that differs significantly from the estimation sample along the dimension that the model is meant to predict and falls outside the support of the data (Keane and Wolpin, 2007). If our 1996 simulations are found reasonable, we can gain further confidence that the model is useful for predicting an impact of changes in FDI barriers on multinational activities.

Figures 6b and 6c replicates the scatter plots of out of sample moments for 1996. To be consistent with prior analysis of a model fit, we follow the simulation procedure for predicting the moments in 2006. Based on Panels A through D, we find that the model is able to replicate the real activity of 1996 Japanese firms reasonably well. The model fit is considerably strong along various features of multinational activities. However, we also observe that the predictive ability of the model is slightly weaker than what was found in the 2006 simulations. We tend to under-simulate sales of foreign affiliates and domestic sales in Japan while the model reasonably captures the moments of multinational production intensity.

=== Figure 6a, 6b&6c===

The observed deviations between the distribution of real and simulated firms suggests that Japanese firms in 1996 may contain slight structural deviations from the 2006 period. Our robustness estimates in table 5, suggests a lower level of dispersion (higher $\tilde{\theta}$) may be found for 1996 sales activity. While the model assumes a fixed distributional structure in sales, forces outside the model could have led to slight deviations in the actual distribution of sales from the structural parameter estimates[15]. Nevertheless, we find that a replication of Japanese multinationals in 1996 is reasonable and offers further credibility in the model being able to simulate individual multinational activities given changes in the economic environment.

6.4 Where Does the Model Fail?

We have shown that our framework can reasonably simulate Japanese multinational activities which are based on entry and sales conditions dictated by the model. Because the model is constructed to capture only key elements of multinational behaviors in a simple way, our model does not take into account other potentially important motivations for FDI. In particular, a critical feature of multinationals that is missing in our model is firm exporting activity. To assess how this simplification of the model affects its ability to replicate Japanese multinational behavior, we focus exclusively on vertical oriented firms for which more than 50% of sales by their foreign affiliates are yielded from exports to Japan.

We compare vertical FDI firms in the data with firms that are simulated as prescribed by the model. Figure 7 shows that real vertical activity is systematically different from the simulations of the model. Real Japanese vertical firms activity is much smaller than what is found by our simulated firms for affiliate production in the United States, Europe, and other markets more generally classified as market-seeking destinations rather than factor-seeking. By contrast, we find that real Japanese vertical firm activity is much larger than our simulated firm activity for China and Vietnam, countries that are more likely to be driven by factor cost differentials.

[15] One factor that could lead to a higher level of dispersion for 2006 firms is increasing levels of exporting activity. Since we estimate our distribution parameter based strictly off of conditional sales on firm/multinational entry and do not account for export activity, our estimates of $\tilde{\theta}$ may be biased upward (Levchenko and Giovanni, 2010). While our model ignores exporting activity, increasing levels of trade during the past decade could increase this bias.

=== Figure 7 ===

7. Conclusion

This research introduces a new micro-simulation framework for examining multinational activity across home and host countries. Based on the structural approach of Eaton, Kortum, and Kramarz (2010), the model is designed to simulate entry and sales activity of heterogeneous firms across asymmetric countries in the presence of fixed entry costs and costly technology/management transfer. The model yields empirical implications consistent with Japanese multinational activities in 2006. Matching the model with data on Japanese multinationals, we estimated the structural parameters with simulated method of moments and found the parameter estimates to be in line with previous studies and robust to different estimation designs. The fully quantified model allows us to simulate entry and sales of foreign affiliates of Japanese firms.

Through internal and external validation exercises, we rigorously tested how well the model performed in replicating real multinational activity. Our results demonstrated that the model could strongly replicate in-sample moments. Multinational activity not conditioned in the estimation strategy also performed considerably well. While our 1996 out-of-sample predictions contained slight deviations from the data, the overall simulations suggest that the model is externally consistent with the Japanese multinational activity from a decade prior. We also found several shortcomings of the model. First, large firms invest in too many countries, and small firms invest in too few. Second, we tend to under-simulate the level of sales of Japanese multinationals in both home and foreign markets. Lastly, the model poorly explains vertically motivated multinationals. Nonetheless, the predictive power of the model was found robust to the estimation strategy, and yields considerable support for its ability to replicate Japanese multinational activities.

Our research highlights the richness of our simulation framework for understanding multinational activity, but there are two potential extensions of this work. First, we can embed the model into a complete general equilibrium to calibrate the rest of Japan's macro-economy in a global setting. This allows us to conduct counterfactual analysis of the impacts from changes in FDI policies at the individual firm level. The resulting framework will be capable of not only quantifying the economic gains from FDI, but in assessing the distributive impacts of economic integration and its more complex restructuring effects on firms. This future computational model will generate a useful quantitative tool for evaluating policy designs related to FDI. Second, we can incorporate an interaction between trade and FDI in firm-level decisions, which will lead to complex integration strategies of heterogeneous firms servicing foreign markets. Future research is to combine firm exporting and FDI activity in an integrated micro-simulation framework.

Table 1. Firm Entry and Exit by Initial Size in 1996 and 2006

Initial Size Interval (percentile)	# All Firms			# Multinationals		
	Year		Change from 1996	Year		Change from 1996
	1996	2006		1996	2006	
0 to 10	1,411	1,376	-35	0	3	3
10 to 20	1,410	1,276	-134	5	13	8
20 to 30	1,411	1,178	-233	3	20	17
30 to 40	1,412	1,229	-183	11	40	29
40 to 50	1,412	1,202	-210	16	36	20
50 to 60	1,414	1,191	-223	27	73	46
60 to 70	1,411	1,299	-112	51	113	62
70 to 80	1,413	1,229	-184	75	185	110
80 to 90	1,412	1,409	-3	184	359	175
90 to 99	1,270	1,309	39	464	677	213
99 to 100	141	157	16	124	137	13
Total	14,117	12,855	-1,262	960	1,656	696

Notes: Percentile bins are determined by parent firms' global sales in 1996; all firms include domestic and multinational firms in manufacturing; we drop firms with *missing* domestic sales.
Source: Basic Survey of Japanese Business Structure and Activities, and Basic Survey of Overseas Business Activities from METI.

Table 2. Firm Growth by Initial Size in 1996 and 2006

Initial Size Interval (percentile)	Domestic Sales			Multinational Sales			Global Sales		
	Year		Change from 1996	Year		Change from 1996	Year		Change from 1996
	1996	2006		1996	2006		1996	2006	
0 to 10	1.21	1.17	-0.04	0.0	0.0003	0.0003	1.21	1.17	-0.04
10 to 20	2.07	1.87	-0.20	0.001	0.003	0.002	2.07	1.87	-0.20
20 to 30	2.84	2.36	-0.48	0.001	0.01	0.005	2.84	2.37	-0.47
30 to 40	3.73	3.23	-0.50	0.003	0.02	0.02	3.73	3.25	-0.48
40 to 50	4.93	4.15	-0.78	0.01	0.03	0.02	4.94	4.18	-0.76
50 to 60	6.61	5.48	-1.13	0.02	0.07	0.05	6.62	5.55	-1.07
60 to 70	9.23	8.45	-0.78	0.06	0.15	0.09	9.29	8.60	-0.69
70 to 80	14.2	12.2	-2.06	0.11	0.32	0.21	14.4	12.5	-1.85
80 to 90	26.9	26.0	-0.90	0.54	1.31	0.77	27.5	27.3	-0.13
90 to 99	110.4	110.1	-0.30	8.89	16.5	7.66	119.3	126.6	7.30
99 to 100	234.6	212.1	-22.5	38.0	76.5	38.4	272.7	288.6	15.9
Total	416.8	387.1	-29.7	47.7	94.9	47.2	464.5	482.0	17.5

Notes: Percentile bins are determined by parent firms' global sales in 1996; sales are in trillions of 2006 Japanese Yen; domestic sales include purely domestic sales of all firms; multinational sales include only sales of foreign affiliates by multinational firms.

Source: Basic Survey of Japanese Business Structure and Activities, and Basic Survey of Overseas Business Activities from METI.

Table 3: Japanese Firms Investing in the Top 5 Countries

Market	Number of Multinationals	Fraction of Multinationals
China	1191	0.59
United States	652	0.32
Thailand	525	0.26
Taiwan	318	0.16
Indonesia	311	0.15
Total	1972	

Note: Total indicates the total number of multinational parent firms that invest in these top 5 markets.

Table 4: Japanese Firms Investing in the Strings of Top 5 Countries

		If FDI in each string is independent in the top 5	
Market String*	Number of Multinationals	Predicted Probability	Number of Multinationals
CHN	479	10.4%	211
CHN-USA	60	5.1%	104
CHN-USA-THA	29	1.9%	38
CHN-USA-THA-TWN	6	0.4%	7
CHN-USA-THA-TWN-IND	4	0.1%	1
Total	578		361
Multinationals in Pecking Order	29.3%		18.3%

* The market string shows that firms invest in that market(s), but no other among the top 5.

Table 5. Estimation Results of Parameters

	(1)	(2)	(3)	(4)
Markets	Markets with over 10 affiliates	All Markets	Markets with over 10 affiliates	Markets with over 10 affiliates
Year	2006	2006	2006	1996
Moments	All	All	No Pecking Order String	All
Variable				
$\tilde{\theta}$	1.99	2.12	1.95	2.13
(size dispersion)	(0.43)	(0.95)	(0.64)	(0.53)
σ_a	1.64	1.64	1.66	1.36
(variance of sales shock)	(0.07)	(0.10)	(0.08)	(0.11)
σ_h	0.39	0.52	0.34	0.45
(variance of entry shock)	(0.31)	(0.16)	(0.42)	(0.43)
ρ	-0.62	-0.55	-0.64	-0.99
(correlation of sales and entry shocks)	(0.34)	(0.25)	(0.51)	(0.56)

Notes: figures indicate parameter estimates of each variable for a minimum value of the objective function; parentheses are bootstrapped standard errors from initial fixed parameter estimates with 1000 repetitions; each bootstrapping simulates 100,000 firms and uses randomly sampled Japanese firms.

Figure 1. Entry and Sales by Market Size

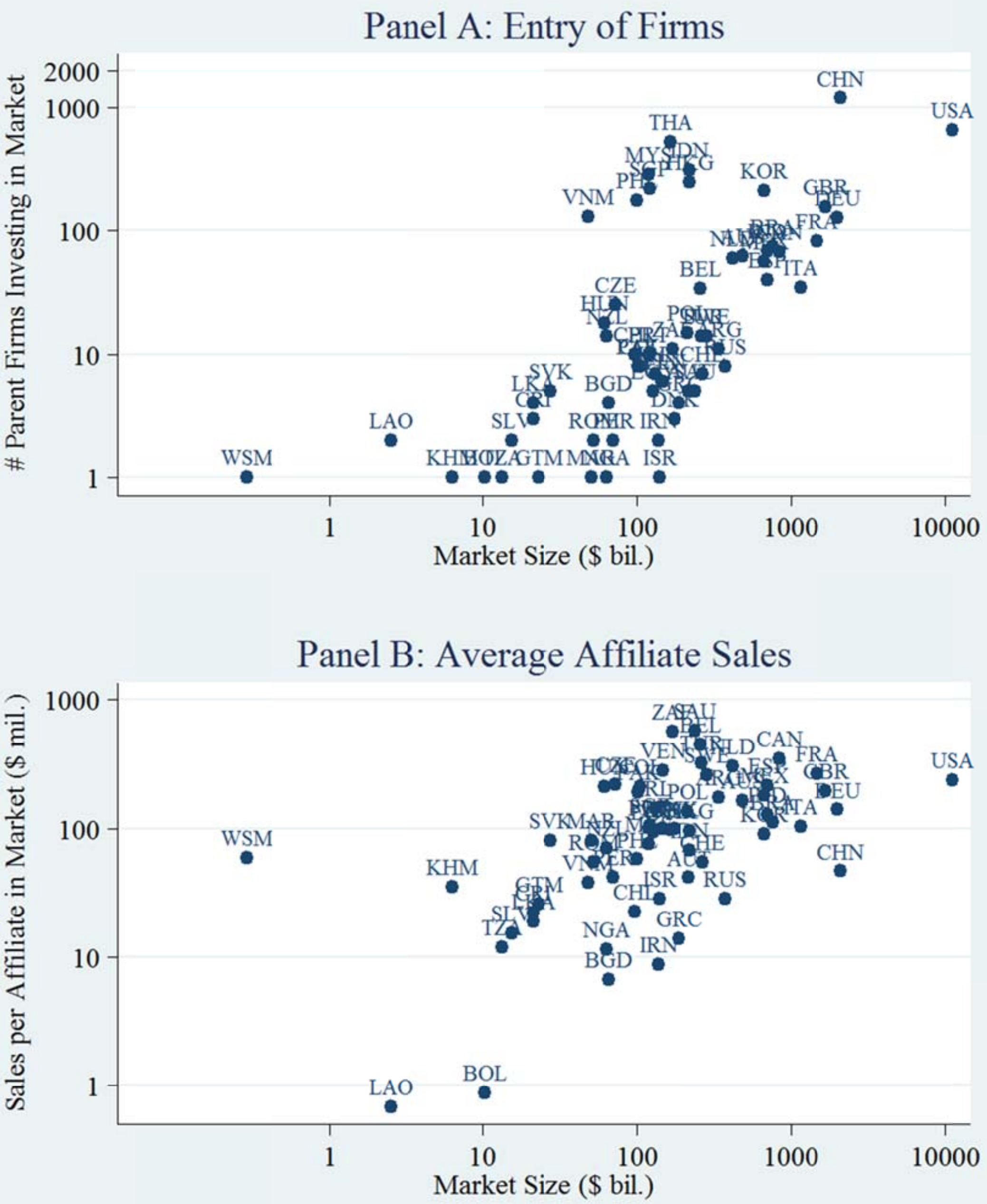


Figure 2. Sales Distribution of Japanese Firms

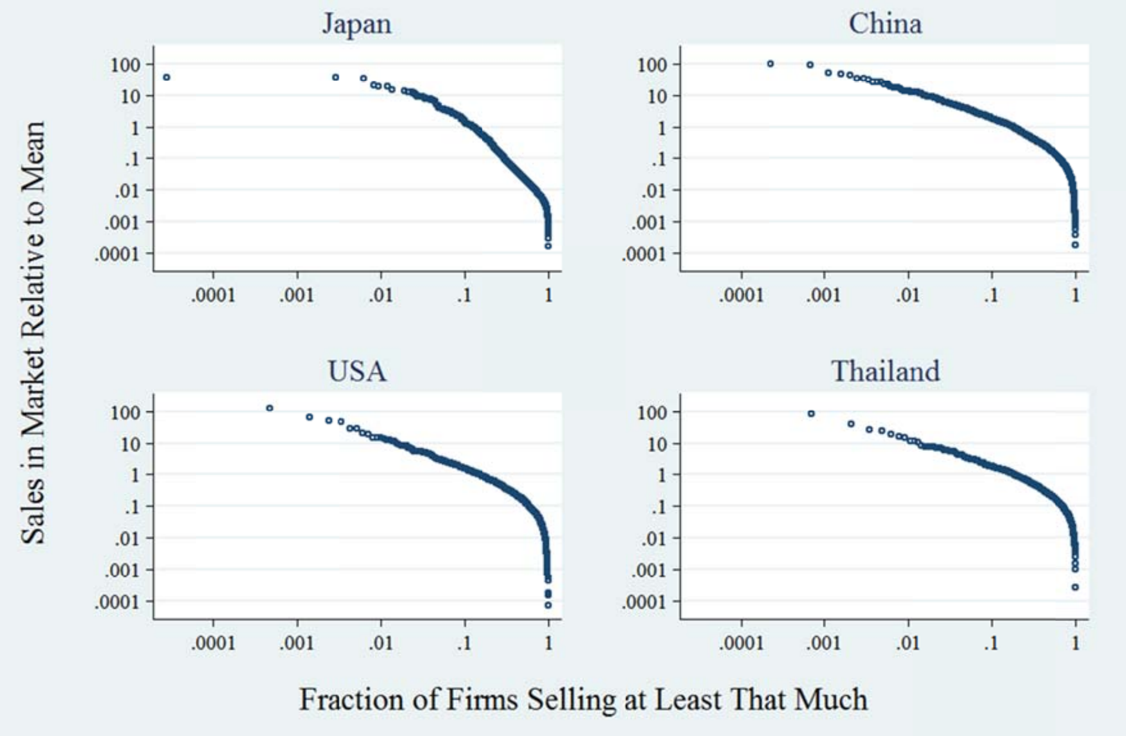


Figure 3. Sales in Japan and Market Entry

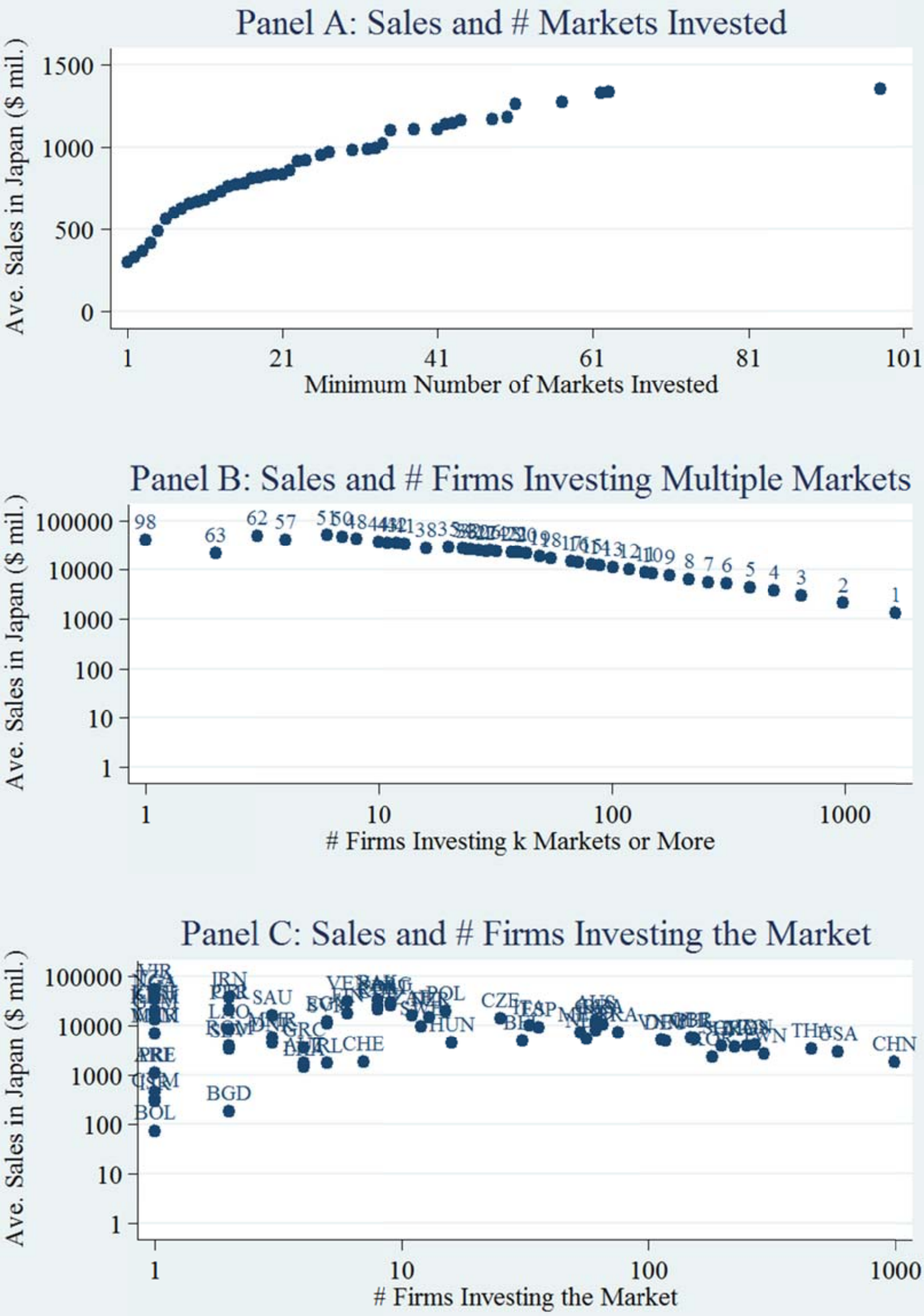


Figure 4. Multinational Production Intensity

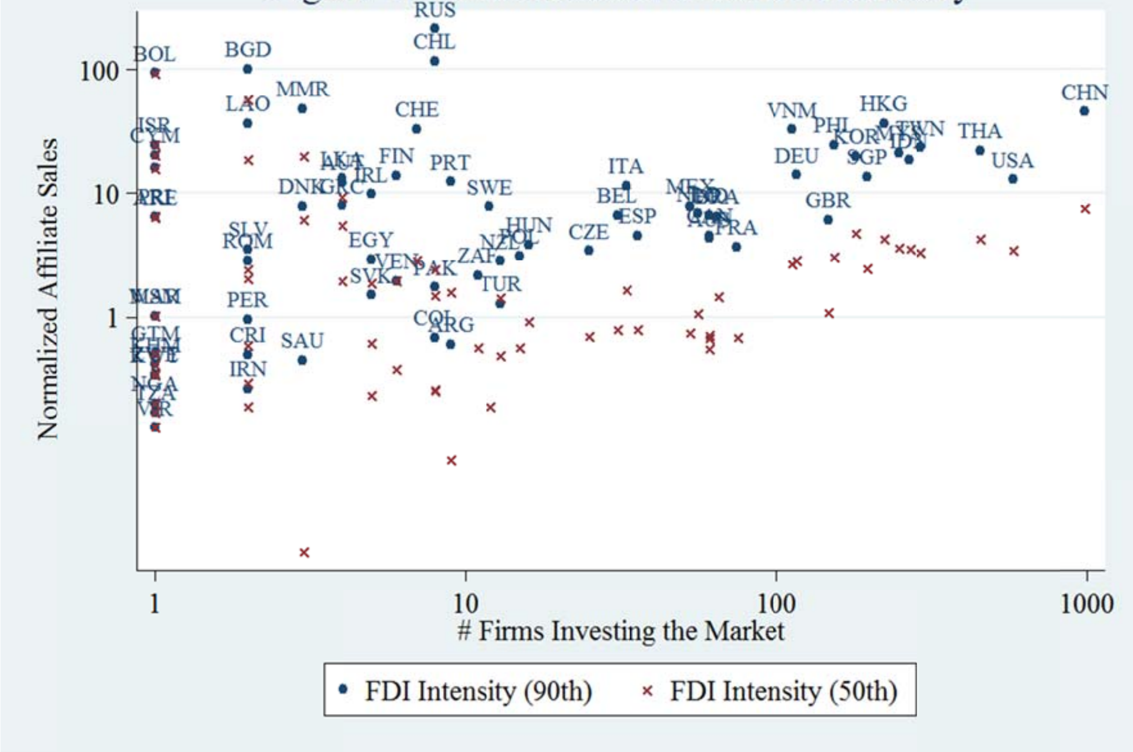
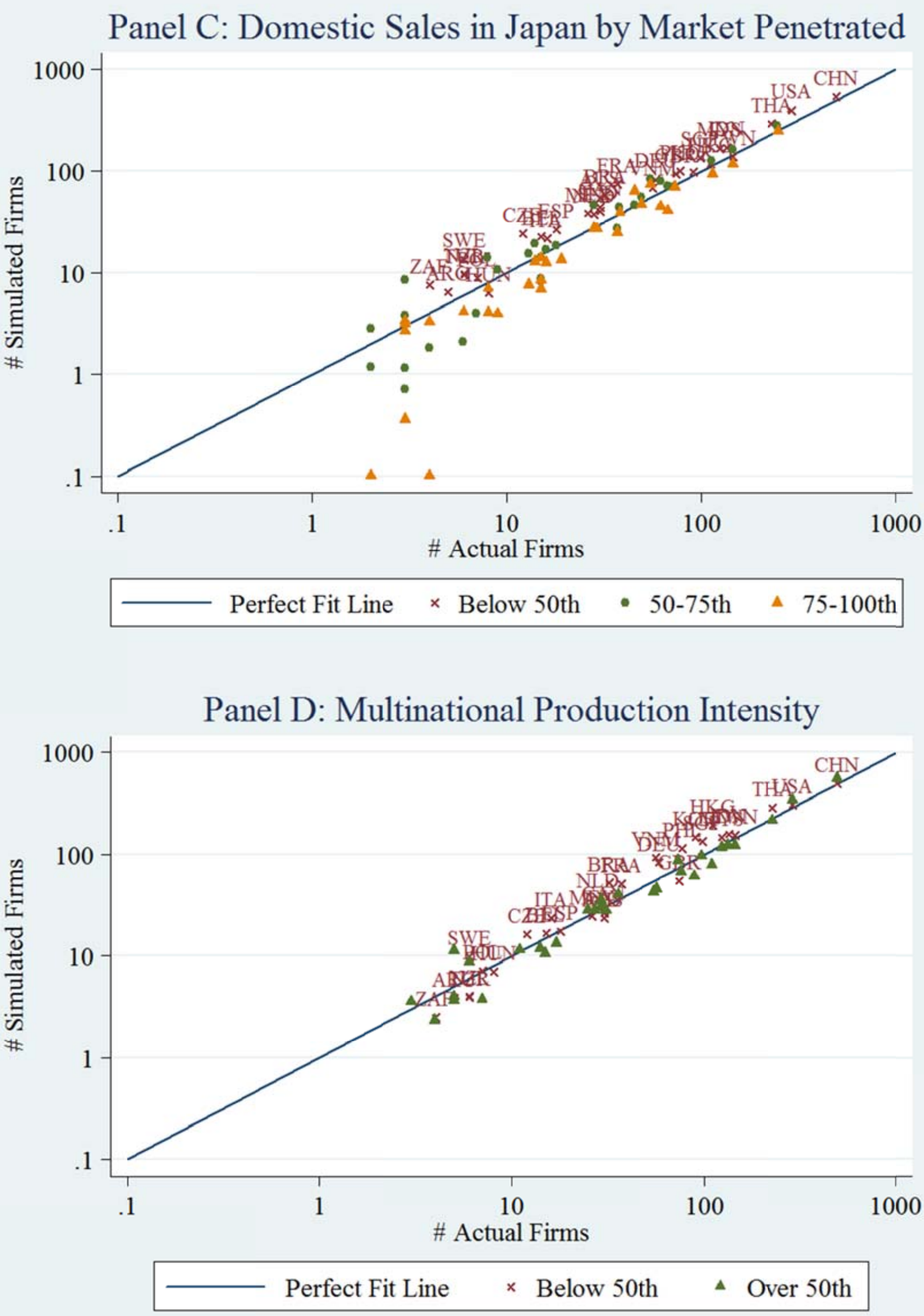


Figure 5a. In-Sample Predictions

Figure 5b. In-Sample Predictions



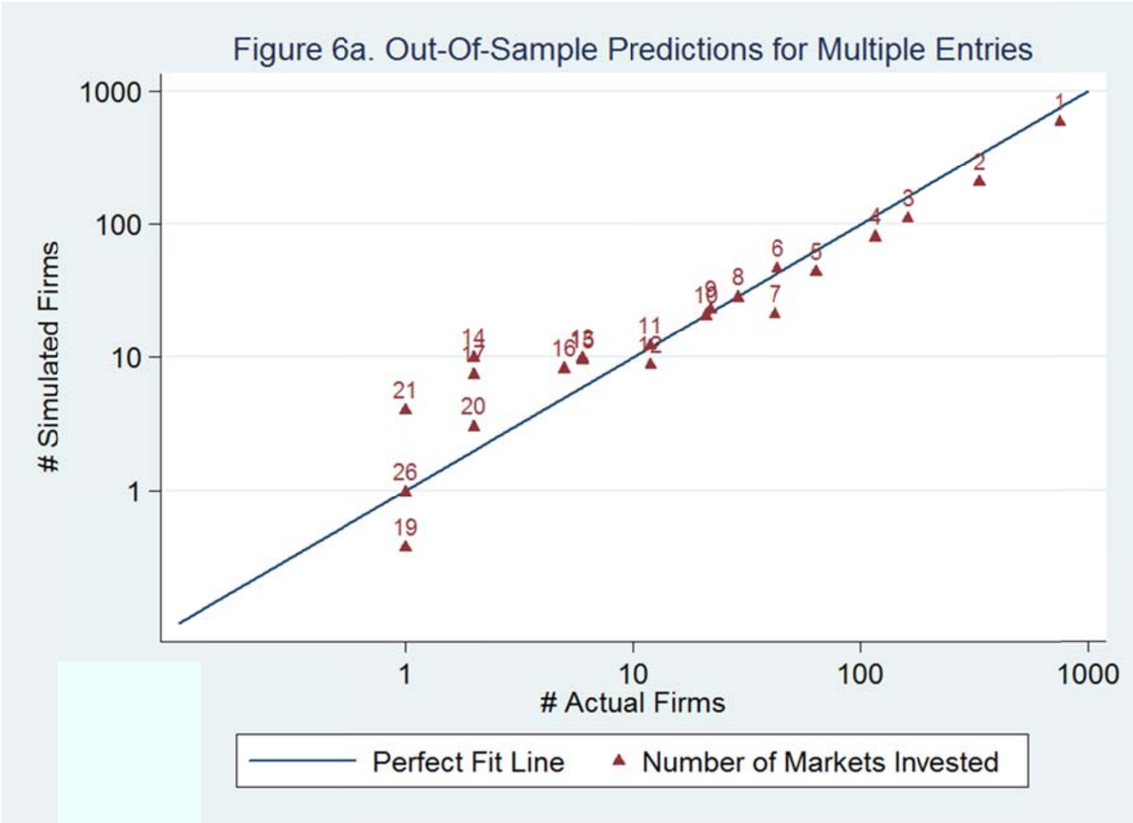


Figure 6a. Out-Of-Sample Predictions for Multiple Entries
Simulated Firms
Actual Firms
1000
100
10
1
1
10
100
1000
Perfect Fit Line
Number of Markets Invested

Figure 6b. Out-Of-Sample Predictions for 1996

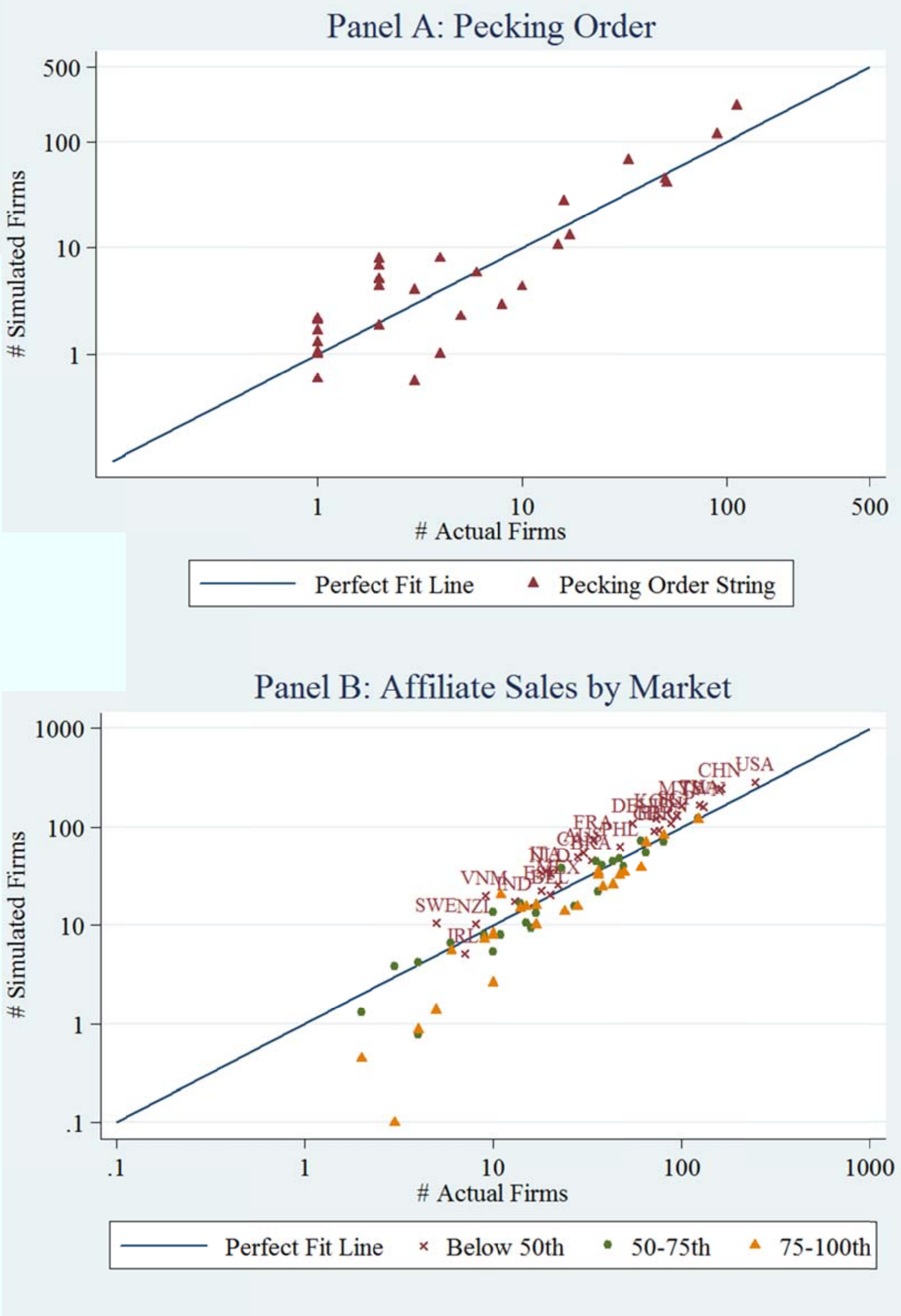


Figure 6c. Out-Of-Sample Predictions for 1996

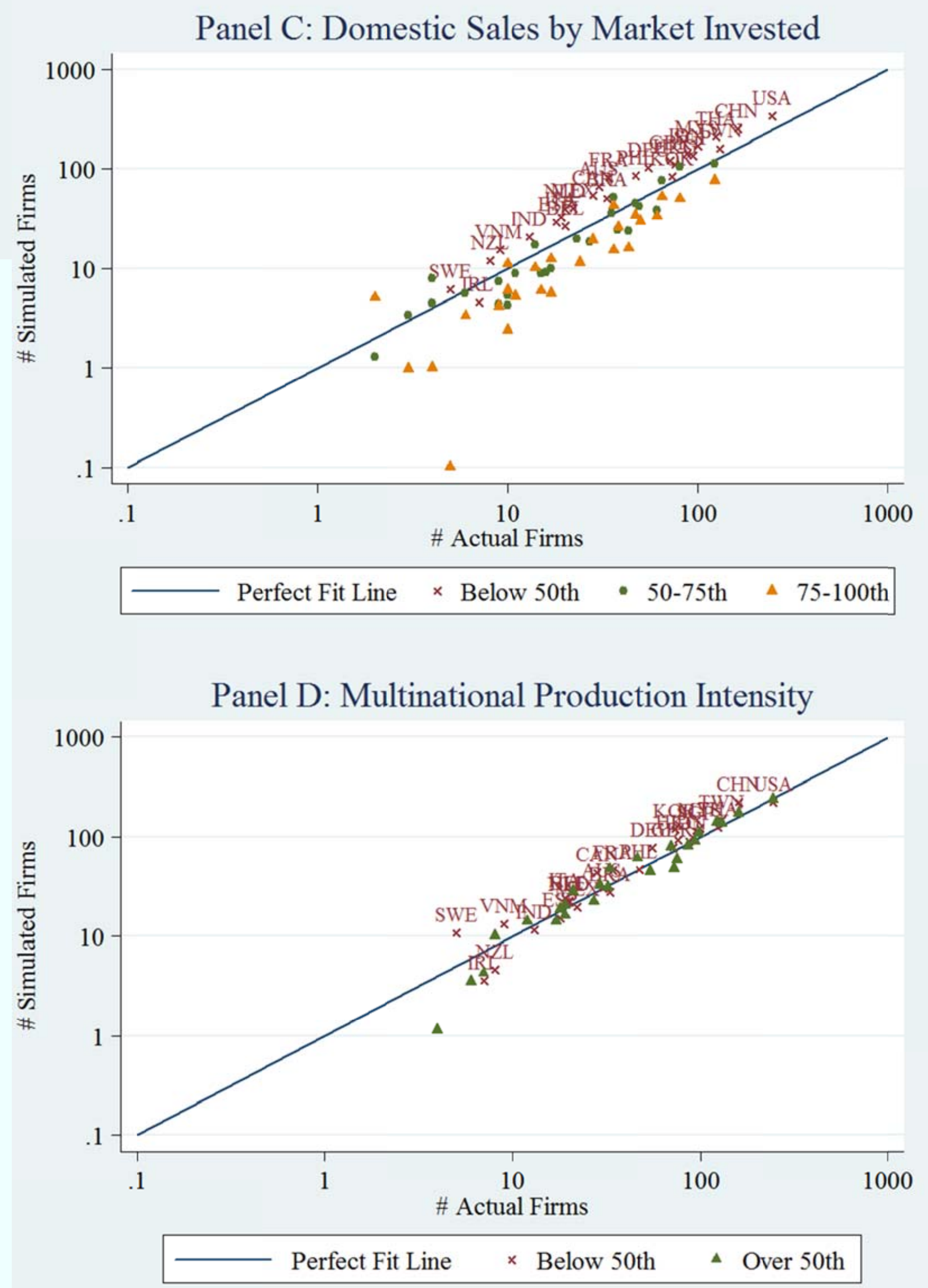
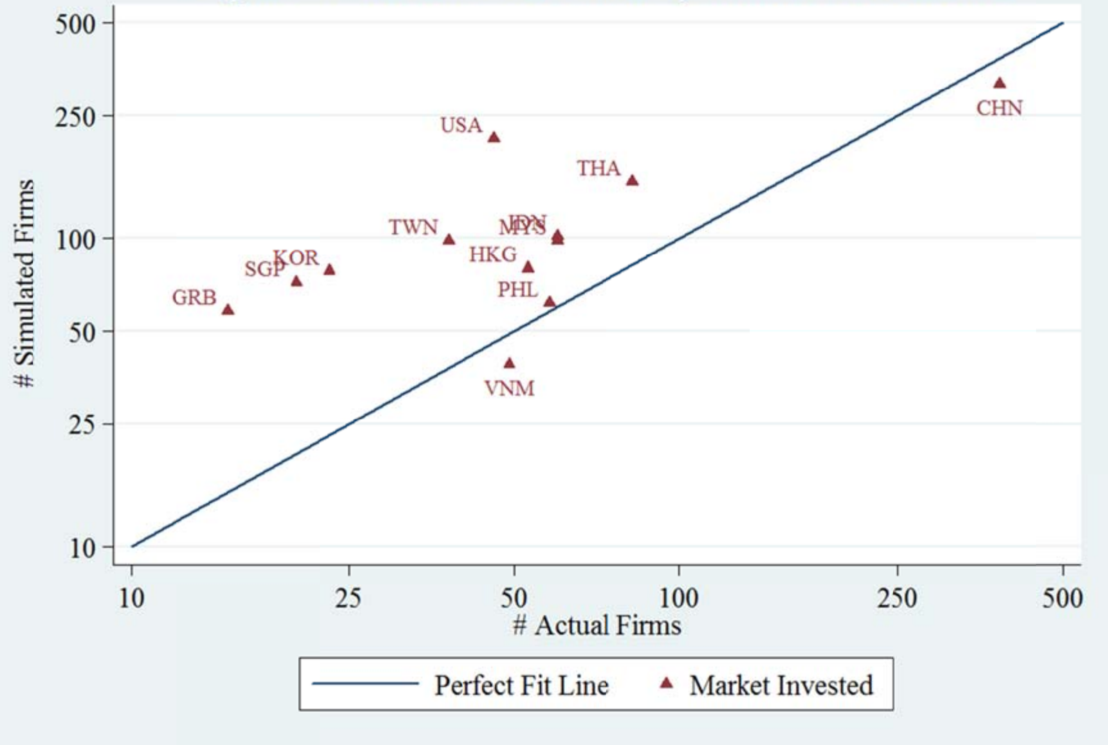


Figure 7. Vertical FDI Firms by Market Penetrated



References

Aw, B. Y., and Lee, Y. 2008, “Firm Heterogeneity and Location Choice of Taiwanese Multinationals”, Journal of International Economics, vol. 75, no. 1, pp. 167-179.

Bernard, A. B., Eaton, J., Jensen, J. B., and Kortum, S. 2003, “Plants and Productivity in International Trade”, American Economic Review, vol. 93, no. 4, pp. 1268-1290.

Brainard, S. L. 1997, “An Empirical Assessment of the Proximity-Concentration Trade-off between Multinational Sales and Trade”, American Economic Review, vol. 87, no. 4, pp. 520-544.

Chaney, T. 2008, “Distorted Gravity: The Intensive and Extensive Margins of International Trade”, American Economic Review, vol. 98, no. 4, pp. 1707-1721.

Chen, M. X., and Moore, M. O. 2010, “Location Decision of Heterogeneous Multinational Firms”, Journal of International Economics, vol. 80, no. 2, pp. 188-199.

Eaton, J., Kortum, S., and Kramarz, F. 2010, “An Anatomy of International Trade: Evidence from French Firms”, *Forthcoming* in Econometrica.

Eaton, J., and Kortum, S. 2002, “Technology, Geography, and Trade”, Econometrica, vol. 70, no. 5, pp. 1741-1779.

Feinberg, S. E., and Keane, M. P. 2006, “Accounting for the Growth of MNC-Based Trade Using a Structural Model of U.S. MNCs”, American Economic Review, vol. 96, no. 5, pp. 1515-1558.

Garetto, S., 2009, “Input Sourcing and Multinational Production”, Mimeo.

Girma, S., Kneller, R., and Pisu, M. 2005, “Exports versus FDI: An Empirical Test”, Review of World Economics/Weltwirtschaftliches Archiv, vol. 141, no. 2, pp. 193-218.

Grossman, G.M., Helpman, E., and Szeidl, A. 2006, “Optimal Integration Strategies for the Multinational Firm”, Journal of International Economics, vol. 70, no. 1, pp. 216-238.

Head, K., and Ries, J. 2003, “Heterogeneity and the FDI versus Export Decision of Japanese Manufacturers”, Journal of the Japanese and International Economies, vol. 17, no. 4, pp. 448-467.

Helpman, E., Melitz, M. J., and Yeaple, S. R. 2004, “Export versus FDI with Heterogeneous Firms”, American Economic Review, vol. 94, no. 1, pp. 300-316.

Kang, K., 2008, “How much have been the export products changed from homogeneous to differentiated? Evidence from China, Japan, and Korea”, China Economic Review 19, 128-137.

Keane, M. P. 2010, “Structural vs. Atheoretic Approaches to Econometrics”, Journal of Econometrics, vol. 156, no. 1, pp. 3-20.

Keane, M. P., and Wolpin, K. I., 2007, “Exploring the Usefulness of a Nonrandom Holdout Sample for Model Validation: Welfare Effects on Female Behavior”, International Economic Review, vol. 48, no. 4, pp. 1351-1378.

Keller, W., and Yeaple, S. R. 2009, “Global Production and Trade in the Knowledge Economy”, C.E.P.R. Discussion Papers.

Lagarias, J. C., Reeds, J. A., Wright, M. H., and Wright, P. E. 1998, “Convergence Properties of the Nelder-Mead Simplex Method in Low Dimensions”, SIAM Journal on Optimization. vol. 9 no. 1, pp. 112-147.

Levchenko, A. A., J. Di Giovanni, and R. Ranciere, 2010, “Power Laws in Firm Size and Openness to Trade: Measurement and Implications”, IMF Working Papers 109, 1-31.

Markusen, J. R. 2002, “Multinational firms and the theory of international trade”, MIT Press, Cambridge and London.

McFadden, D. 1989, “A Method of Simulated Moments for Estimation of Discrete Response Models Without Numerical Integration”, Econometrica, vol. 57, No. 5, pp. 995-1026.

Melitz, M.J. 2003, “The Impact of Trade on Intra-industry Reallocations and Aggregate Industry Productivity”, Econometrica, vol. 71, no. 6, pp. 1695-1725.

Nelder, J. A., and Mead, R. 1965, "A Simplex Method for Function Minimization", Computer Journal, vol. 7, pp. 308-313.

Pakes, A., and Pollard, D. 1989, "Simulation and the Asymptotics of Optimization Estimators", Econometrica, vol. 57, no. 5, pp. 1027-1057.

Ramondo, N., 2010, A Quantitative Approach to Multinational Production, Mimeo.

Ramondo, N., and Rodriguez-Clare, A. 2009, "Trade, Multinational Production, and the Gains from Openness", NBER Working Papers No. 15604.

Todo, Y. 2009, "Quantitative Evaluation of Determinants of Export and FDI: Firm-Level Evidence from Japan", RIETI Discussion Paper Series 09-E-019.

Tomiura, E. 2007, "Foreign Outsourcing, Exporting, and FDI: A Productivity Comparison at the Firm Level", Journal of International Economics, vol. 72, no. 1, pp. 113-127.

UNCTAD, 2010, "World Investment Report 2010". United Nations, New York.

Yeaple, S.R. 2009, "Firm Heterogeneity and the Structure of U.S. Multinational Activity", Journal of International Economics, vol. 78, no. 2, pp. 206-215.

Wakasugi, R., Todo, Y., Sato, H., Nishioka, S., Matsuura, T., Ito, B., and Tanaka, A., "The Internationalization of Japanese Firms: New Findings Based on Firm-Level Data", RIETI Discussion Paper Series 08-E-036.

Investment Climate Advisory Services. 2010, "Investing Across Borders", World Bank Group, Washington D.C.