Foreign Direct Investment, Exports and Aggregate Productivity*

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Abstract

Empirical evidence confirms that trade exposure can shift resources towards the most efficient firms in an industry and induce substantial increases in aggregate productivity. Although recent studies document that much of world trade is controlled by multinational firms, few examine the effect of foreign direct investment decisions on resource allocation and aggregate productivity. This paper presents an open economy model where producers make simultaneous production and export decisions across different countries. In particular, the model highlights the interaction between firms' location and export decisions and their effect on aggregate productivity. The model is estimated using detailed plant-level Indonesian manufacturing data. The results are broadly consistent with the pattern of productivity, exports and foreign investment across firms. Counterfactual policy experiments suggest that there are substantial productivity gains due to international trade and FDI. Moreover, they highlight that evaluating the substitutability and complementarity of trade and investment is crucial to determining the aggregate effects of international trade and foreign direct investment policy.

KEYWORDS: exports, foreign direct investment, firm heterogeneity, aggregate productivity, resource allocation

JEL: C23, E23, F21, O40

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1 Introduction

This paper builds a model of international trade and foreign direct investment (FDI) with heterogeneous firms. While firms can set up plants in foreign countries in order to access foreign markets as in Helpman, Melitz and Yeaple (2004), the model also allows firms to locate plants abroad in order to export back to the country of origin. The model highlights how differences in production, location and export costs affect the structure of international trade. The model is estimated using Indonesian plant-level manufacturing data. The estimated model is used to perform counterfactual experiments that assess the positive and normative effects of barriers to trade and FDI.

Recent evidence suggests that the current volume and direction of trade are intimately related to multinational production decisions. It is estimated that total sales from multinational firms accounts for 60% of world GDP and over 35% of world trade in 2001.[1] At the same time, empirical studies have repeatedly confirmed that trade can substantially impact resource allocation across firms and aggregate productivity. Pavcnik (2002) and Trefler (2004) find that increasing openness induces productivity gains among exporters in Chile and Canada, while Pavcnik (2002) also finds increases in aggregate Chilean productivity. Yet, few studies have examined the role of FDI on trade flows, resource allocation and their effect on aggregate productivity.

A separate but related set of empirical evidence suggests that among firms producing in a given country, multinational firms are the most productive. Domestic exporters are reportedly less productive than multinationals, but significantly more productive than domestic non-exporters.[2] This paper confirms these productivity differences across foreign and domestic firms in Indonesia and provides new evidence emphasizing important differences across foreign owned firms. The data suggests that firms who invest in Indonesia to serve that market are substantially more productive than those who invest in Indonesia as a platform for exports.

This paper extends the international trade and FDI framework of Helpman, Melitz and Yeaple (2004) by allowing firms to offshore production in a foreign country. In this environment, firms may set up plants in foreign countries for two reasons. First, as in Melitz, Helpman and

[1] Ramondo (2006).

[2] Helpman, Melitz and Yeaple (2004) and Arnold and Javorcik (2005) compare multinationals, exporters and non-exporters. Roberts and Tryout (1997), Clerides, Lack and Tryout (1998), Bernard and Jensen (1999), Aw, Chung, and Roberts (2000), Bernard et. al. (2003) and Eaton, Kortum, and Kramarz (2004) compare exporters and non-exporters.

Yeaple (2004), firms can set up plants solely to access the local market in foreign countries. Relative to a model without FDI, such as Melitz (2003), FDI provides an additional avenue for firms to make sales to foreign consumers. Second, in this model firms can also set up plants in a foreign country in order to export back to the country of origin.[3] Thus, this paper constructs a parsimonious model that simultaneously allows firms to engage in FDI for both market access and export-platform production. The advantage of this approach is that all of the model's predictions can be readily tested. Moreover, the model is used to empirically assess the influence of policy on plant-level decisions, and thus provides a framework for evaluating economic policy and predicting changes in aggregate productivity, exports and FDI.

The model is estimated using a panel of Indonesian manufacturing plants. As a common host of multinational corporations, Indonesia is a country of particular interest (Ramstetter and Sjoholm (2006)). The estimated model captures the pattern of productivity, exports and market share across firms with different ownership and export status. The results document that the mean of domestic productivity at the steady state is substantially higher than the estimated mean at entry, indicating that endogenous exit decisions play an important role in determining aggregate productivity. Moreover, this paper performs a number of counterfactual policy experiments demonstrating that restrictions on FDI and trade can potentially have widely different effects on aggregate productivity. The counterfactual experiments suggest that the impact of FDI restrictions account for a fall in average total factor productivity between 31 and 41 percent across industries. In contrast, average total factor productivity is estimated to fall by less than 3 percent across food, metals and textiles industries. Since foreign and domestic plants respond differently to policy change, failing to account for these differences will lead to biased estimates of the impact of trade restrictions.

The welfare impact on Indonesia of simultaneous trade and FDI restrictions are estimated to be approximately 1 percent across industries. However, when trade or FDI are individually restricted, the welfare impacts are often very small. This last result occurs because trade (FDI) flows provide some insurance against FDI (trade) restrictions.

The next section outlines the differences across and within foreign and domestic producers. The third section presents a model of exports and FDI with heterogeneous firms and countries, while the fourth describes the estimation methodology. The fifth section presents empirical

[3]See Antras and Helpman (2004) and Grossman, Helpman and Sziedl (2006) for examples.

results and the sixth section concludes.

2 Empirical Motivation

In this section I briefly describe the Indonesian manufacturing data and provide summary statistics to characterize patterns across plants with varying degrees of international integration.

2.1 Data

I use the Indonesian manufacturing census for 1993-1996. The data set reports the total value of domestic and export sales, the percentage of foreign ownership and the number of workers. I determine the export status of each firm by checking whether the value of export sales is positive or zero. Likewise, I determine the ownership status of each firm by checking whether foreign investors hold a positive amount of equity in the plant.[4] Nominal values are converted to real values using the industry output price deflators. I identify the entry/exit decisions by observing the number of workers across years. After cleaning the data, I use an unbalanced panel of 24,519 plants. Each plant is observed for at least one year between 1993 and 1996.[5]

2.2 Exports and Foreign Ownership

It is well known that multinational and/or foreign-owned firms are typically the largest firms in a country. Table 1 documents this fact for Indonesian manufacturing plants between 1993-1996. Although only six percent of all firms have any foreign ownership, foreign firms account for more than one quarter of total output and over one third of all exports in manufacturing. Moreover, foreign firms are not solely export oriented but also capture one quarter of the Indonesian domestic market for manufactured goods. This suggests that Indonesia may also be an important market for foreign plants.

A common explanation for these findings is that multinational firms are substantially larger and more productive than their domestic counterparts.[6] Comparing the second and third rows with the fourth and fifth rows of Table 2 it is evident that foreign plants are also more capital-intensive, use a higher fraction of skilled employees and have greater output and value added

[4] Using other threshold values (e.g. 10% or 50% of equity) yielded similar results.
[5] I omit 729 plants which are wholly owned by the government.
[6] See Helpman, Melitz and Yeaple (2004) for an example.

Table 1: Foreign Plants Over Time

	1993	1994	1995	1996	1993-1996 avg.
Exports	0.30	0.38	0.35	0.38	0.36
Output	0.23	0.27	0.29	0.34	0.28
Domestic Market Share	0.20	0.22	0.27	0.31	0.25
% of Firms	0.06	0.06	0.06	0.06	0.06

Notes: The top three rows document the percentage of the total manufacturing sales attributed to foreign firms. The bottom row documents the percentage of foreign manufacturing plants.

per worker than their domestic counterparts.

Similarly, it is often stated that domestic exporters are relatively large, capital and skill-intensive, and more productive relative to domestic non-exporters.[7] The bottom two rows of Table 2 are consistent with this result for the Indonesian manufacturing sector. Although the Indonesian data confirms that foreign plants are always larger and more productive than their domestic counterparts with the same export status, the disparity in differences across export groups is striking. For instance, while foreign exporters are approximately twice as large and productive as domestic exporters, foreign non-exporters are ten to fifteen times larger than domestic non-exporters and produce eight times the output per worker.

Table 2: Descriptive Statistics

	Total Sales[a]	Export Intensity[a,b]	Labor	Skill Ratio[c]	Capital	K/L Ratio[a]	Output/ Worker	V-A/ Worker[d]	No. of Obs.
All	35.47	0.70	185.57	0.14	6.00	0.02	0.12	0.04	72,732
Plants	(261.88)	(0.33)	(613.13)	(0.15)	(22.00)	(0.03)	(0.59)	(0.15)	—
Foreign	166.38	0.71	700.14	0.18	30.13	0.06	0.35	0.12	2,563
Exporters	(381.88)	(0.34)	(1,047.91)	(0.17)	(47.30)	(0.05)	(0.58)	(0.23)	—
Foreign	167.76	—	411.23	0.28	29.09	0.09	0.48	0.17	1,803
Non-Exporters	(361.14)	—	(649.24)	(0.20)	(49.08)	(0.06)	(1.08)	(0.36)	—
Domestic	81.14	0.70	445.81	0.15	14.53	0.03	0.16	0.05	10,784
Exporters	(495.38)	(0.33)	(1,192.23)	(0.14)	(37.84)	(0.03)	(0.37)	(0.12)	—
Domestic	11.77	—	74.25	0.10	1.81	0.01	0.06	(0.03	57,582
Non-Exporters	(139.75)	—	(286.21)	(0.14)	(8.43)	(0.02)	(0.50)	(0.13)	—

Notes: Reported numbers are sample means with standard deviations in parentheses. (*a*) In millions of Indonesian Rupiahs. (*b*) Computed using the sample of exporting plants. (*c*) The ratio of skilled to total workers. (*d*) Value-added per worker.

The differences between foreign exporters and non-exporters are less obvious. Several studies have previously examined the differences across a variety of attributes for domestic exporters

[7]See Kasahara and Lapham (2008) for an example.

and non-exporters, but few have examined differences across ownership status,[8] and even fewer have examined differences *across* foreign firms. Although foreign exporting plants employ almost twice as many workers, they earn little more revenue, employ a smaller percentage of skilled workers, are less capital-intensive and produce less output per worker than foreign non-exporters on average. The difficulty in comparing foreign exporters and non-exporters arises from the fact that exporters serve multiple markets from one plant while non-exporters only serve the Indonesian market. On average foreign exporting plants sold 63.5 million rupiahs worth of goods to the Indonesian market per year. Thus, foreign non-exporters sold approximately 2.5 times more on average than foreign exporters sold to the Indonesian market.

While the mean differences between firms with different export and ownership status are striking, it is not clear that they are statistically significant. In fact, the standard deviations are often large, particularly for foreign firms where there are fewer observations. Following Bernard and Jensen (1999) and Kasahara and Lapham (2007) I estimate the export and ownership premia using a pooled ordinary least squares regression over the 1993-1996 period:

$$\ln X_{it} = \alpha_0 + \alpha_1 d^x_{it}(1 - d^{fdi}_{it}) + \alpha_2 d^x_{it} d^{fdi}_{it} + \alpha_3(1 - d_i t^x) d^{fdi}_{it} + Z_{it}\beta + \epsilon_{it}, \tag{1}$$

where X_{it} is a vector of plant attributes such as total employment, domestic sales, output per worker, average wages, the percentage of non-production workers and capital per worker. A firm's export status is captured by the dummy variable d^x_{it}, while d^{fdi}_{it} is a dummy variable capturing whether any of the plant's equity is held by foreign investors. Last, Z_{it} is matrix of control variables including industry dummies at the 5-digit ISIC level, year dummies, province dummies, municipality dummies and total employment to control for size. The export premium α_1 is the average log point difference between exporters and non-exporters among domestic plants. The foreign exporter premium α_2 is the average log point difference between domestic non-exporters and foreign exporters, while the foreign non-exporter premium α_3 is the average log point difference between domestic and foreign plants who do not export.

The results in Table 3 show that there are not only substantial differences between domestic exporters and non-exporters but also between foreign exporters and non-exporters. Column 3

[8]See Bernard and Jensen (1999) document differences across non-exporters and exporters. A notable study examining the differences across ownership status using the Indonesian manufacturing census is Arnold and Javorcik, 2005.

indicates that foreign non-exporters tend to demonstrate the highest premia across all measures other than those related directly to size. In particular, foreign non-exporting plants tend to demonstrate higher productivity foreign exporters or domestic plants.[9] Similar results are found at the industry level.[10] It is natural to ask why the larger, more productive foreign non-exporters do not export while the smaller, less productive foreign exporters do. A likely explanation is that foreign non-exporters are part of larger multinational corporations that serve multiple markets though multiple plants located in different countries.[11] I will further develop this hypothesis to explain the effects of foreign barriers to trade and FDI across different plants in Indonesia.

Table 3: Export & Ownership Premia

	Pooled OLS: 1993-1996		
Export/Ownership Status	Domestic Exporters	Foreign Exporters	Foreign Non-Exporters
Output per Worker	0.217	0.710	0.871
	(0.012)	(0.021)	(0.024)
Value-Added per Worker	0.399	0.894	0.997
	(0.012)	(0.021)	(0.024)
Average Wage	0.114	0.443	0.604
	(0.007)	(0.013)	(0.015)
Non-Production/Total Workers	0.086	0.006	0.246
	(0.010)	(0.018)	(0.021)
Capital per Worker	0.351	0.712	0.932
	(0.011)	(0.019)	(0.022)
Domestic Sales	-0.789	-0.043	0.848
	(0.016)	(0.030)	(0.029)
Total Sales	0.250	0.737	0.883
	(0.014)	(0.024)	(0.027)
Total Employment	1.062	1.528	1.045
	(0.010)	(0.019)	(0.022)
No. of Observations		72732	

Notes: Standard errors are in parentheses.

[9]See the Supplementary Appendix for a discussion on the possible impact of transfer pricing, differences in tax-rates across countries or mark-ups across heterogeneous firms. The Supplementary Appendix also includes Within Groups regressions that document that these results are robust the inclusion of fixed effects.

[10]With the exception of the chemicals industry. Results for the chemicals industry (which includes fuel and natural gas) are reported in Table 2 of the Supplemental Appendix.

[11]It may also be possible that non-exporting plants are part of a multi-plant firm where another plant is responsible for exports of finished products. However, in 1996 only 8 percent of foreign non-exporters report that their plant belongs to a "group of companies" in Indonesia (this question was not asked in other years).

3 A Model of FDI and Exports

3.1 Environment

There are two countries, Home and Foreign, which are endowed with non-depreciating stocks of labour, L. All foreign country variables are starred. Consumers supply capital and labour inelastically. Their preferences are defined by a Cobb-Douglas utility function over the agriculture product z and a continuum of manufactured goods indexed by v: $U = z^{1-\delta}\left[\int_{v\in V} q(v)^{\alpha} dv\right]^{\delta/\alpha}$. The elasticity of substitution between different varieties of manufactured goods is given by $\varepsilon = 1/(1-\alpha) > 1$.

In each country there are two sectors: a homogeneous good sector (agriculture) and a differentiated good sector (manufacturing). The agricultural sector is characterized by a continuum of potential firms that can enter freely and produce a homogeneous agricultural product, z, with linear technology, $z = \phi_l l$. Producers hire labour on perfectly competitive markets which pins down the relative wage across countries. It is assumed that the foreign agricultural technology is more productive than the technology employed in the home country, $\phi_l^* > \phi_l$, so that wages in the foreign country are greater than those in the home country.

The manufacturing sector is the primary focus of this paper. It is characterized by a continuum of monopolistically competitive firms that produce horizontally differentiated goods. Individual manufacturing firms are indexed by i and the endogenous measure of manufacturing producers be denoted by M.

There exists an unbounded measure of ex ante identical potential entrants. To enter the market each potential entrant must pay a sunk cost, f_e. Once the entry cost is paid, each firm receives a productivity draw a from the distribution, $G_a(a)$, and an extreme cost shock with constant probability ξ. A firm's productivity level is constant over the life of the firm. If the firm suffers the extreme cost shock it is forced to exit the industry. Conditional on survival, each firm can decide to exit immediately or to produce according to the linear production function $q = l/a$ where l is labour hired on competitive markets. To keep the model as transparent as possible, this paper focuses on the case in which both foreign and domestic exporters and non-exporters are present. Each country has four types of firms: non-exporters, exporters, multinational non-exporters and multinational exporters.

Entrants and incumbents draw idiosyncratic shocks $(\epsilon_{it}^{\chi}(0), \epsilon_{it}^{\chi}(1))^{\chi}$ at the beginning of each period. These shocks are interpreted as unobserved state variables. The shock $\epsilon_{it}^{\chi}(0)$ is the return if the firm chooses to exit, while the shock $\epsilon_{it}^{\chi}(1)$ along with continuation value, specified in the Bellman equation below, is the return from producing. Conditional on the productivity level a and the idiosyncratic shocks ϵ_{it}^{χ}, the firm decides whether or not to continue to operate. The shocks ϵ_{it}^{χ} are independent of alternatives and are drawn from the extreme-value distribution with scale parameter ϱ^{χ}. Without these shocks the model predicts that all firms below a certain threshold will exit. This is inconsistent with the large number of small firms observed in the data.

If a firm chooses to produce in period t, it then draws cost shocks associated with FDI and international trade. Firms first receive a shock associated with the decision to maintain a plant abroad $(\epsilon_{it}^{fdi}(0), \epsilon_{it}^{fdi}(1)) \equiv \epsilon_{it}^{fdi}$. The return from not maintaining a plant abroad is the sum of the shock $\epsilon_{it}^{fdi}(0)$ along with the continuation value of not engaging in FDI, while the sum of the shock $\epsilon_{it}^{fdi}(1)$ along with the continuation value of engaging in FDI is the return from FDI. Conditional on its FDI decision, a firm then receives a shock associated with its trade decision $(\epsilon_{it}^{x}(0), \epsilon_{it}^{x}(1)) \equiv \epsilon_{it}^{x}$ where $\epsilon_{it}^{x}(0)$ and the continuation value from not trading is the return from choosing not to trade and $\epsilon_{it}^{x}(1)$ and the continuation value from trading is the return from choosing to trade. Note that if the firm engages in FDI, the foreign trade cost shock is drawn from a different extreme-value distribution. The FDI, domestic trade and foreign trade shocks are all independently drawn from extreme-value distributions with the respective scale parameters ϱ^{fdi}, ϱ^{x} and ϱ^{x*}.

Firms differ with respect to their productivity level a, their current FDI and export status and their past FDI and export status. Denote a firm's decision by $d_{it} \equiv (d_{it}^{fdi}, d_{it}^{x}) \in \{(0,0),(0,1),(1,0),(1,1)\}$ where d_{it}^{fdi} is the firm's decision to maintain a plant abroad and d_{it}^{x} is the firm's decision to export. If a firm decides to engage in FDI or export that decision takes a value of 1, and is 0 otherwise. All new entrants are assumed to enter the market without any FDI or export experience, $d_{it} = (0,0)$.

To produce domestically, each firm must pay a non-stochastic fixed overhead cost f each period. If the firm also decides to export abroad it bears an additional one-time suck cost c_x, per-period fixed cost f_x and iceberg transport costs $\tau > 1$ per unit shipped to the foreign country. As in Helpman, Melitz and Yeaple (2004) the firm may choose to set up production in the foreign country rather than export to that market. While the firm saves on the export costs, c_x and f_x, and on the transport costs, τ, by choosing to produce abroad, it incurs the an additional fixed overhead cost, f_{fdi} and a one-time sunk cost c_{fdi} associated with the initial plant set-up abroad.

Firms may choose not to produce domestically at all. In this case, each firm sets up a plant abroad and exports back to its country of origin. The firm then incurs the fixed costs f, f_x and f_{fdi} and the transport cost τ each period, along with the sunk costs c_x and c_{fdi} in the initial period. If $c_{fdi} > 0$ and $f_{fdi} > 0$, any firm that produces abroad to export back home incurs higher fixed and sunk costs and the same transport costs of a home exporter. Thus, to give firms an incentive to produce abroad and export there must be some difference in factor prices (wages) across countries.

Given a firm's current and past FDI and export decisions they incur the following set of fixed and sunk costs in a given period:

$$F(d_{it}, d_{i,t-1}) = \begin{cases} f & \text{for } (d_{it}^{fdi}, d_{it}^{x}) = (0,0) \\ f + f_x + c_x(1 - d_{i,t-1}^{x}) & \text{for } (d_{it}^{fdi}, d_{it}^{x}) = (0,1) \\ f + f^* + f_{fdi}^* + c_{fdi}^*(1 - d_{i,t-1}^{fdi}) & \text{for } (d_{it}^{fdi}, d_{it}^{x}) = (1,0) \\ f^* + \zeta_{f_x} f_x^* + f_{fdi}^* + [\zeta_{c_x} c_x^*(1 - d_{i,t-1}^{x}) + c_{fdi}^*](1 - d_{i,t-1}^{fdi}) & \text{for } (d_{it}^{fdi}, d_{it}^{x}) = (1,1) \end{cases}$$

where starred variables denote costs incurred in the foreign country. The sunk and fixed export costs are interpreted as forming and maintaining distribution and service networks in export markets. It is important to note that firms must pay this cost even if they are exporting back to their home market, but the sunk and fixed cost may be reduced through the parameters ζ_{c_x} and ζ_{f_x}. These parameters capture the complementarity between foreign ownership and exporting to foreign markets. The fixed and sunk FDI costs include the distribution, servicing, overhead and set up costs of operating a subsidiary abroad. The relative size of the fixed costs plays an important role in determining each firm's optimal production and export decisions.

It is well known that the Dixit-Stiglitz (1977) framework generates a demand function $\gamma R P^{1-\varepsilon}/p^{\varepsilon}$ for each variety where R is the total revenue earned in each country, P is an index of manufacturing prices and p is the price chosen by each individual producer.[12] Since demand is exogenous to each individual producer the optimal pricing rule for each firm depends only the

[12] $R = wL$ where L is the total amount of labour and w is the wage in the home country. The price index is $P = [\int_V p(v)^{1-\varepsilon} dv]^{1/(1-\varepsilon)}$

firm-specific productivity level $p(a) = \frac{aw}{\alpha}$ where w is the wage in the home country. The revenue earned by a plant with productivity level a_i producing for market $j = h, f$ can be written as

$$r_{it}^{j} = (mc_i B^j)^{1-\varepsilon} \tag{2}$$

where $mc_i = w/a_i$ if the firm is not exporting to market j and $mc_i = w\tau/a_i$ if the firm is exporting to market j and w is wage in the country where production occurs.

3.2 FDI & Exports

FDI and export decisions will depend primarily on both firm-specific characteristics (productivity) and differences across countries (wages, fixed/sunk costs, size). The model has several intuitive implications. First, since there is a fixed cost associated with entering export markets, firms that export will be more productive than domestic non-exporters. Second, higher fixed and sunk costs associated with maintaining a plant abroad suggests that multinational firms will be more productive than their domestic counterparts. The decision to become a non-exporting, rather than an export-platform oriented multinational is more complex.

Suppose that the foreign country is a large, high-wage country, while the home country is relatively small and characterized by low-wages. Consider the export and FDI decisions facing foreign country firms. The first decision is whether to produce domestically and export abroad versus producing abroad and exporting back to the country of origin. This decision will clearly depend upon the cost of exporting in either direction. However, even if transport costs are equal there will be substantial differences in these two production and export decisions. Abstracting from differences in country size and transport costs, the advantage to exporting from the foreign country is that the foreign firm incurs lower fixed and/or sunk overhead costs. The disadvantage is that labour costs are high. Thus, foreign firms that produce in the home country must be productive enough to afford the higher fixed and sunk costs.

Similarly, consider a firm deciding whether to produce all units abroad and export back to the foreign country versus opening a plant in each country. By producing all units abroad the firm incurs the lowest marginal costs on each unit of output and saves the extra fixed costs from operating multiple plants. However, by producing all units abroad the firm incurs the transport cost on each unit exported. This is particularly costly when the foreign country is large.[13]

A number of other production and export possibilities are purposely omitted here. For instance, it is possible that foreign investors may open plants in the home country exclusively for sales to the home country consumers without operating a plant in any other country. This possibility is excluded for two reasons. First, the data do not separately identify plants which are multinationals and those which stand-alone but have foreign ownership. Second, Indonesia is a small country relative to its major sources of FDI, such as Japan, the United States and Western Europe. If foreign investors are able to profitably operate a plant which sells exclusively to Indonesian consumers, it is likely they are also able to the same in their home countries. Ramstetter and Sjoholm (2006) analyze the Indonesian data over a longer time period and indicate that foreign owned plants in Indonesia are typically part of multinational corporations and the Indonesian government has been particularly concerned with attractive FDI from foreign multinational corporations.

Table 4 documents the other production and sales combinations that are purposely restricted from the set possibilities by placing bounds on the fixed and transport costs. The first row of Table 4 shows that firms can locate in the home country and produce only for the home country or both markets, but not just the foreign market. As in Melitz (2003) this possibility is excluded since less than two percent of all Indonesian plants receive all revenues from export sales. Similarly, in the second row, foreign plants that receive all revenues from export sales are excluded it is likely that these plants do so to protect technological advantages, patents or product features from local rivals or have unique contractual arrangements with Indonesian officials. Fortunately, few plants receive all revenue from export sales.[14] The last row simply indicates that if a firm produces in both countries, then it must sell in both countries. Since firms must pay all of the fixed costs to produce in a given country and the Dixit-Stiglitz framework implies some residual demand for each variety, selling to local consumers can always increase profits. Lastly, in equilibrium no firm will serve the same market by both exports and FDI.[15]

[13] The Supplemental Appendix documents theoretical bounds on the costs that partition firms into distinct productivity rankings.

[14] Most plants (93%) have positive amounts of domestic sales. See Antras and Helpman (2004) for a model with incomplete contracts and vertical integration.

[15] Rob and Vettas (2001) use uncertainty in a dynamic setting to explain this phenomenon.

Table 4: Production and Sales Combinations

Production	Sales Location		
Location	Home	Foreign	Both
Home	Yes*	No	Yes
Foreign	No	Yes*	Yes
Both	No	No	Yes

*Only if the ownership is the same as the country where production is located.

3.3 Exit & Entry Decisions

Consider the dynamic component of a manufacturer's decision problem. At the beginning of each period, a producer's state is given by their productivity level a_i and their previous FDI and export decisions, $d_{i,t-1}$. The Bellman equations for a producer originating in the home country are written as follows:

$$V(a_i, d_{i,t-1}) = \int \max\{\epsilon^{\chi}(0), W(a_i, d_{i,t-1}) + \epsilon^{\chi}(1)\} dH^{\chi}(\epsilon^{\chi}), \tag{3}$$

$$W(a_i, d_{i,t-1}) = \int \max\{J(a_i, d_{i,t-1}, 0) + \epsilon^{fdi}(0), J(a_i, d_{i,t-1}, 1) + \epsilon^{fdi}(1)\} dH^{fdi}(\epsilon^{fdi}) \tag{4}$$

$$J(a_i, d_{i,t-1}, 0) = \int \left(\max_{d^{x'}} \pi(a_i, d_{i,t-1}, d^{x'}) + \beta V(a_i, d') + \epsilon^{x}(d^{x'}) \right) dH^{x}(\epsilon^{x}) \tag{5}$$

$$J(a_i, d_{i,t-1}, 1) = \int \left(\max_{d^{x'}} \pi(a_i, d_{i,t-1}, d^{x'}) + \beta V(a_i, d') + \epsilon^{x^*}(d^{x'}) \right) dH^{x^*}(\epsilon^{x^*}) \tag{6}$$

where H^{χ}, H^{fdi}, H^{x} and H^{x^*} represent the cumulative distributions of ϵ^{χ}, ϵ^{fdi}, ϵ^{x} and ϵ^{x^*}, respectively. The parameter $\beta \in (0,1)$ is the discount factor. Thus, the value function $V(\cdot,\cdot)$ characterizes the firm's exit decision, while $W(\cdot,\cdot)$ describes the firm's decision whether to engage in FDI. Similarly, $J(\cdot,\cdot,1)$ is the continuation value of a firm which has decided to maintain a plant abroad, while $J(\cdot,\cdot,0)$ is the continuation value of a firm that only produces in its country of origin. Note that export decisions are made after the FDI decision. The advantage of this decision structure is that it allows for natural separation between foreign and domestic export decisions. A potential drawback is that firms make an FDI decision before realizing their export shock.[16]

[16] Similar empirical results are found using alternative timing structures. Decision trees are included in the Supplemental Appendix.

3.4 Equilibrium

This paper focuses on a stationary equilibrium where aggregate variables and the distribution of productivity are constant over time. Denote the stationary distribution of productivity across incumbent firms by $\mu(a,d)$. Although firms exit home and foreign markets as they receive the various firm-specific shocks outlined above, these changes are exactly offset by new entrants of each type in equilibrium. For convenience, time subscript is dropped and the firm's state is denoted as (a_i, d_i).

Under free entry the expected value of the firm must be equal to the fixed entry cost f_e:

$$\int V(a,(0,0))g_a(a)da = f_e \tag{7}$$

where $g_a(a)$ is the distribution of initial productivity draws.

A stationary equilibrium requires that the number of exiting firms must equal the number of successful new entrants. Specifically,

$$M\int\left(\sum_d P^{\chi}(\chi=0|a,d)\mu(a,d)\right)da = M_e\int P^{\chi}(\chi=1|a,(0,0))g_a(a)da, \tag{8}$$

where M is the mass of incumbents, M_e is the total mass of entrants that attempt to enter the market, $P^{\chi}(\chi=0|a,d)$ is the probability of a firm of type (a,d) exiting the market and $P^{\chi}(\chi=1|a,d)=1-P^{\chi}(\chi=0|a,d)$ is the probability of a firm (a,d) choosing to not exit. Using the properties of extreme-value distributed random variables, the probability of producing this period $(\chi=1)$ is calculated as:

$$P^{\chi}(\chi=1|a,d) = (1-\xi)\left(\frac{\exp(W(a,d)/\varrho^{\chi})}{\exp(0)+\exp(W(a,d)/\varrho^{\chi})}\right) \tag{9}$$

where ξ is the exogenous probability of exit and $W(\cdot,\cdot)$ is defined as in equation (4).

The conditional choice probabilities for all possible FDI and export decisions follow the nested logit formula.[17] Conditional on operating, the probability of maintaining a plant abroad is given by

$$P^{fdi}(d^{fdi'}=1|a,d,\chi=1) = \frac{\exp(J(a,d,(1,d^x)/\varrho^{fdi})}{\sum_{\bar{d}^{fdi}}\exp(J(a,d,(\bar{d}^{fdi},d^x))/\varrho^{fdi})} \tag{10}$$

[17] See McFadden (1978).

while the conditional probability of producing everything in the country of origin is given by $P^{fdi}(d^{fdi'} = 0|a, d, \chi = 1) = 1 - P^{fdi}(d^{fdi'} = 1|a, d, \chi = 1)$ and $J(\cdot, \cdot, \cdot)$ is given in equations (5)-(6). Similarly, conditional on operating and choosing to maintain a plant abroad, the firm's export choice probability can be calculated as

$$P^x(d^{x'}|a, d, \chi = 1, d^{fdi'} = 1) = \frac{\exp([\pi(a, d, (d^{x'}, 1)) + \beta V(a, d')]/\varrho^{x^*})}{\sum_{d^{x'}} \exp([\pi(a, d, ((d^{x'}, 1)) + \beta V(a, d')]/\varrho^{x^*})}. \quad (11)$$

The choice probability for exporting conditional on *not* engaging in FDI is analogous to (11) where the scale parameters are replaced with their unstarred counterparts.

The final condition required for a stationary equilibrium is that the measure of firms of with state (a, d) is constant over time. Define the probability of FDI and export as

$$P^d(d_{it}|a_i, d_{i,t-1}) = P^{fdi}(d_{it}^{fdi}|a_i, d_{i,t-1})P^x(d_{it}^x|a_i, d_{i,t-1}, d_{i,t-1}^{fdi})$$

and $P^{fdi}(d_{it}^{fdi} = 1|a_i, d_{i,t-1}) = 0$ for Indonesian plants by assumption. The equilibrium condition can therefore be written as

$$\begin{aligned} M\mu(a, d) &= MP^{\chi}(\chi = 1|a, d)\sum_{d'} P^d(d|a, d', \chi = 1)\mu(a, d) \\ &\quad + M_e P^{\chi}(\chi = 1|a, (0, 0))P^d(d|a, (0, 0), \chi = 1)g_a(a) \end{aligned} \quad (12)$$

The first term on the right-hand side of (12) is the measure of incumbent producers who do not exit and have state (a, d) in the current period. The second term is the measure of new entrants with the same state.

4 Structural Estimation

This paper extends Rust's (1987) *nested logit* dynamic programming framework to examine the nature of exit, export and FDI decisions in the presence of stochastic fixed costs. The following subsections describe the data described, construct the likelihood function and discuss the identification of the model's parameters.

4.1 Data

The primary source of data is the Indonesian manufacturing census between 1993 and 1996. The census enumerates all plants with at least 20 employees. This paper focuses on Indonesian food, textile and manufactured metals industries since they are among Indonesia's largest industries and receive substantial foreign direct investment.[18] A total of 669 plants that are owned entirely by the Indonesian government are omitted. The food, textile and manufactured metals industry data consists of unbalanced panels of 6,042, 4,491 and 2,497 plants, respectively, where each plant is observed for at least one year between 1993 and 1996.

The advantage of this data set relative to many other plant-level data sets is that it includes the percentage of foreign ownership for each individual plant. Define a foreign plant as any plant that has positive foreign ownership as a foreign plant. In over 66% of the foreign firms in the sample, foreign investors own at least 50% of the equity, while foreign investors own at least 25% of foreign firms in 95% of the sample.[19] Similarly, exporters are identified as plants that receive any positive revenues from export sales.

The unit of observation is that of the individual plant, not the firm. To estimate the model it is necessary to assume that all foreign plants are part of a multinational firm and that all domestic plants are strictly national firms.[20] Ramstetter and Sjoholm (2006) analyze the same Indonesian data and indicate that foreign owned plants in Indonesia are typically part of multinational corporations. Moreover, to the extent that the model captures the decision of foreign plants to enter Indonesia, the model's implications for Indonesia will remain valid.

The data do not reveal the export destinations of each plant. However, Table 5 suggests that Indonesian industries that earn a higher percentage of revenues from exports are more likely to export to developed countries. Along with the discussion in Section 2, this would suggest that foreign exporters in export-intensive industries are likely to export to developed countries. To be conservative all foreign exporters are assumed to export exclusively to developed countries.

This paper focuses the following four variables for each plant i in year t: χ_{it}, r_{it}, d^x_{it} and

[18] Approximately 58% of all foreign plants in the Indonesian manufacturing census are in the food, textiles and manufactured metals industries (2-digit ISIC codes).

[19] A description of the Indonesian manufacturing sector, data coverage over this period, and a discussion of foreign ownership in Indonesia can be found in Blalock and Gertler (2005).

[20] Other papers use data that directly connects parents and subsidiary plants (e.g. Helpman, Melitz and Yeaple (2004)). However, Baily, Hulten and Campbell (1992) show that accounting for productivity differences across all plants is particularly important when evaluating policy. Last, the OECD (2006) reports that Indonesia received 14,352 million US dollars of FDI from 1993-1996, while it supplied 40 million US dollars worth of FDI.

Table 5: Indonesian Export Destinations

Industry	Export Intensity[a]	% of Industry Exports to Developed Nations	No. of Obs.
Wood	0.67	58%	1,860
Textiles	0.55	75%	1,816
Food	0.46	64%	956
Manufactured Metals	0.41	49%	892
Minerals	0.41	47%	275
Chemicals[b]	0.35	47%	1,065
Basic Metals	0.33	32%	144
Paper	0.27	19%	147

Notes: Data compiled from the United Nations Commodity Trade Statistics 1994. (a) Export Intensity is the mean export intensity of all exporting firms in the industry. (b) Firms in the petroleum industry are omitted as they were large outliers. This resulted in the removal of twelve plant-year observations.

d_{it}^{fdi}. Nominal values of total sales are converted to the real value of total sales, r_{it}, using the manufacturing output price deflator. The binary variables d_{it}^{x} and d_{it}^{fdi} are constructed by checking the value of export sales and foreign ownership in each year. The entry/exit decision, χ_{it} is identified by checking whether plants employed a positive number of workers in each year. Descriptive statistics for all four variables are found in Table 6. Table 6 reveals substantial variation across variables and high exit and entry rates over the sample period. These are particularly important for identifying the choice probabilities as well as the initial distribution of productivity shocks.

Table 6: 1993-96 Descriptive Statistics

	Total Sales[a]	Export Sales[a,b]	Labour	Mark-Up Rate[c]	% Foreign Plants[d]	Entry Rates[e]	Exit Rates[f]	No. of Plants
Food	25.51	44.67	106.64	0.26	0.02	0.15	0.09	6,042
	(410.97)	(312.42)	(703.44)	(0.18)	—	—	—	—
Metals[g]	45.77	45.70	168.87	0.33	0.10	0.16	0.06	2,497
	(210.26)	(102.67)	(325.05)	(0.19)	—	—	—	—
Textiles	38.35	56.76	245.09	0.26	0.04	0.15	0.08	4,491
	(198.91)	(144.16)	(730.25)	(0.16)	—	—	—	—

Notes: Reported numbers are sample means with standard deviations in parentheses. (a) In millions of Indonesian Rupiahs. The percentage change is calculated as the mean percentage change across plants. (b) Computed using the sample of exporting plants. (c) The mark-up rate is computed as (revenue-variable cost)/revenue where variable cost is measured as the sum of materials, energy, fuel and the wages paid to production workers. (d) The average is computed as the percentage of plants with foreign ownership. (e) The number of new entrants divided by the total number of plants in 1993. (f) The number of exiting plants divided by the total number of plants. (g) Metals refers to manufactured metals rather than basic metals.

4.2 The Likelihood Function

Define φ_τ to be a function of iceberg shipping costs,[21] $\varphi_\tau \equiv (1-\varepsilon)\ln\tau$. It is assumed that total revenue is measured with error and that exogenous technological change occurs at rate ρ. By modifying the profit functions to include measurement error and a time trend, equation (2) can be used to write the logarithm of *observed* revenue for any plant i as

$$\ln r_{it} = \rho_t t + \ln\varphi_b(1-d^x_{it}) + \ln[\varphi_b + \varphi_w \exp(\varphi_\tau)]d^x_{it} - \ln a_i + \nu_{it} \qquad (13)$$

where r_{it} is observed revenue, φ_w measures the ratio of wages across countries $(w^*/w)^{1-\varepsilon}$, φ_b is a function of the country sizes and prices $(B^*/B)^{1-\varepsilon}$ and ν_{it} is the associated measurement error. Equation (13) highlights an important limitation of the data: the data only documents the revenue, exports and ownership from plants located in Indonesia. Estimating the model requires imposing some consistency across plants located in different countries. In particular, it is assumed that every foreign non-exporting plant also produces in a separate plant located in the foreign country with the same firm-specific productivity level as the plant located in Indonesia.

A firm's detrended net profit may be expressed as:

$$\pi(a, d_{i,t-1}, d_{it}) = r(a, d_{it}) - F(d_{i,t-1}, d_{it}) \qquad (14)$$

where the value of $\pi(\cdot)$ depends on the vector of parameters to be estimated by maximum likelihood, θ:[22]

$$\theta = (\rho, \varphi_b, \varphi_\tau, f, f_x, f_{fdi}, c_x, c_{fdi}, \zeta_{f_x}, \zeta_{c_x}, \xi, \varepsilon, \varrho^\chi, \varrho^x, \varrho^{x^*}, \varrho^{fdi}, \sigma_a, \sigma_{a^*}).$$

Define the variable $\bar{\chi}_{it}$ be a variable that takes a value of 0 if a plant exits the data and 1 otherwise. Thus, the probability of $\bar{\chi} = 1$ for domestic plants is simply the probability that $\chi = 1$, $P^{\bar{\chi}}_\theta(\bar{\chi}_{it} = 0|a_i, d_{i,t-1}) = P^\chi_\theta(\chi_{it} = 0|a_i, d_{i,t-1})$. However, a foreign plant may exit because

[21] Allowing transport costs to vary across foreign and domestic plants makes little difference to the final results.

[22] The detrended firm's problem uses a trend-adjusted discount factor $\beta\exp(\rho)$ when solving the Bellman's equation. The discount factor is not estimated and is set to 0.96. It is difficult to identify the discount factor β in dynamic discrete choice models. Also, the mean of the distribution of initial productivity draws is assumed to be the same for Indonesian and foreign firms.

of a shock that causes the firm to die entirely or because it chooses to produce in its country of origin instead:

$$P_\theta^{\bar{\chi}^*}(\bar{\chi}^*_{it} = 0|a_i, d_{i,t-1}) = P_\theta^{\chi}(\chi_{it} = 0|a_i, d_{i,t-1}) + P_\theta^{\chi}(\chi_{it} = 1|a_i, d_{i,t-1}) P_\theta^{fdi}(d_{it}^{fdi} = 0|a_i, d_{i,t-1}).$$

Denote $T_{i,0}$ as the first year the firm appears in the data. Then, conditional on a_i and $d_{i,t-1}$ the likelihood contribution of plant i in year $t > T_{i,0}$ is

$$L_{it}(\theta|a_i, d_{i,t-1}) = \begin{cases} P_\theta^{\bar{\chi}}(\bar{\chi}_{it} = 0|a_i, d_{i,t-1}) & \text{for } \bar{\chi}_{it} = 0 \\ \underbrace{P_\theta^{\bar{\chi}}(\bar{\chi}_{it} = 1|a_i, d_{i,t-1})}_{\text{Stay/Exit}} \underbrace{P^d(d_{it}|a_i, d_{i,t-1}, \chi_{it} = 1)}_{\text{FDI/Export}} \underbrace{g_\nu(\tilde{\nu}_{it}(a_i))}_{\text{Revenue}} & \text{for } \bar{\chi}_{it} = 1 \end{cases}$$

where starred values replace unstarred values for foreign plants. Note that the endogeneity of the export, FDI and exiting decisions are controlled by simultaneously considering the likelihood contribution from each decision.

In the first year of the sample, T_{i0}, only plants that chose to stay in the market are observed. Thus, the likelihood contribution of these plants in the initial year is calculated conditional on $\chi_{it} = 1$:

$$L_{it}(\theta|a_i, d_{i,t-1}) = P^d(d_{it}|a_i, d_{i,t-1}, \chi_{it} = 1) g_\nu(\tilde{\nu}_{it}(a_i))$$

Let $T_{i,1}$ denote the last year plant i appears in the data. Then, the likelihood contribution from each plant i is

$$L_i(\theta|a_i, d_{i,T_{i,0}}) = \prod_{t=T_{i,0}+1}^{T_{i,1}} L_{it}(\theta|a_i, d_{i,t-1}).$$

It is well known that the joint distribution of unobserved productivity a_i and export/FDI status $d_{i,t-1}$ depends crucially on whether entering plants are observed in the initial year of the sample (Heckman (1981)). In the initial year of the sample it is assume that the pair $(a_i, d_{i,t-1})$ is drawn from the stationary distribution $\mu(a, d)$. If plant i enters the sample after the initial year, it is assumed that a_i is drawn from the distribution of initial draws upon successful entry into Indonesia

$$g_a^e(a) = \frac{P^{\bar{\chi}}(\bar{\chi} = 1|a, d_{t-1})}{\int P^{\bar{\chi}}(\bar{\chi} = 1|a', d_{t-1}) g_a(a') da'} g_a(a). \tag{15}$$

where $d_{t-1} = (0, 0)$ in the plant's initial year of entry for all domestic plants. Equation (15) is used along with the choice probabilities (9)-(11) to build the likelihood function.

The likelihood contribution from each plant i is calculated by numerically integrating out unobserved plant-specific productivity a_i as

$$L_i(\theta) = \begin{cases} \int L_i(\theta|a', d_{i,T_{i,0}})\mu(a', d_{i,T_{i,0}})da' & \text{for } T_{i,0} = 1993, \\ \int L_i(\theta|a', d_{i,T_{i,0}})P_\theta^d(d_{i,T_{i,0}}|a', d_{i,T_{i,0}-1})g_a^e(a')da' & \text{for } T_{i,0} > 1993, \end{cases}$$

where the starred distributions are used in place of the unstarred distributions for foreign firms and the stationary distribution of foreign plants is conditional on entering Indonesia, $\mu^*(a', d_{i,T_{i,0}}|d_{i,T_{i,0}}^{fdi} = 1)$. The parameter vector θ can then be estimated by maximizing the logarithm of the likelihood function

$$\mathcal{L}(\theta) = \sum_{i=1}^{N} \ln L_i(\theta). \tag{16}$$

The evaluation of the log-likelihood function involves solving the dynamic programming problem that approximates the Bellman equations (3)-(6) by discretization of the state space. The fixed and sunk export costs in the foreign country are first set as a fraction of the costs in Indonesia. Then for each candidate choice of parameter vector, the discretized dynamic programming problem (3)-(6) is solved and used to calculate the conditional choice probabilities (9)-(11) and the stationary distributions. Using the conditional choice probabilities and the stationary distributions, it is possible to evaluate the log-likelihood function (16). Searching over the parameter space of θ, the estimates are found by maximizing (16).

4.3 Reduced-Form and Structural Parameters

It is not possible to identify all of the parameters of the model. Equation (13) is a reduced-form specification where the reduced-form parameters represent the following structural parameters:

$$\varphi_B = \left(\frac{wB}{w^*B^*}\right)^{1-\varepsilon} \qquad \varphi_W = \left(\frac{w}{w^*}\right)^{1-\varepsilon}.$$

It is important to note that policy changes may affect the value of reduced-form parameters if the underlying structural parameters change. For instance, any change to the aggregate price level P will lead to a change in $B = [(1-\alpha)\gamma E]^{1/(1-\varepsilon)}/(\alpha P)$ and φ_B. The counterfactual experiments in this paper explicitly account for equilibrium price changes on the reduced-form coefficients using our knowledge of the relationship between the reduced-form coefficients and the aggregate prices.

4.4 Identification

The identification of the revenue function (13) parameters follows from the within-plant variation in revenue and export status. It is assumed that the panel is long enough that, given the parameters identified in the revenue function, the value of plant-specific productivity a is identified for each plant.[23]

Since the exiting probabilities are strictly increasing in the fixed cost, f, it can be identified by relating the probability of exit to the variation in a. At the same time, the elasticities of the exiting probabilities tend to decrease as the variance of the exiting shocks increases. The variation in the differences between different a's across firms and the difference in exiting probabilities identify the scale parameter ϱ_χ separately from f. The fixed cost and scale parameters are similarly identified by relating the variation in a to the variation in export and FDI probabilities.

The sunk cost parameters are identified from two different sources of variation. The sunk export cost is identified from the differences in export frequencies across plants with similar productivity levels but different export histories. The sunk FDI costs are identified off of the entry and exit dynamics of foreign firms, given the parametric assumption on the distribution of productivity. Specifically, a model without sunk costs cannot match the distribution of productivity among foreign owned firms in Indonesia, because high fixed costs and low cost shocks are both required to match the higher productivity and low exit rates across foreign owned plants. This results in too few low productivity, foreign owned plants. A model with sunk costs can do a better job of simultaneously matching these features since the previous investment in Indonesia will encourage low productivity foreign plants to stay in Indonesia even in the presence of large cost shocks.[24]

Lastly, the scale of the profit function cannot be identified because multiplying the profit function by a constant leads to the same optimal choice. Thus, for identification the profit functions (14) are normalize by $\kappa = \varepsilon/(w^* B^*)^{1-\varepsilon}$.[25]

[23]Even though only four years of data are employed in this exercise, the distributional assumptions on a allow me to identify each plant's likelihood of having a particular value of a.

[24]See the Supplemental Appendix for a brief description of the results from the estimation of a model without sunk costs.

[25]Specifically, the parameters κf, κf_x, κf_{fdi}, $\kappa \varrho_\chi$, $\kappa \varrho_{fdi}$ $\kappa \varrho_x$ and $\kappa \varrho_x^*$ are estimated instead of f, f_{fdi}, f_x, f_{x^*},

Due to limitations of the data it is not possible to identify the parameters φ_w, f^*, f_x^*, and c_x^*. The first parameter represents differences in wages across countries. It is calibrated using cross-country manufacturing wage data from International Labour Organization Bureau of Statistics. The foreign wage is constructed as a weighted average of foreign wages using the share of FDI in Indonesia as weights. The last three parameters are fixed and sunk cost parameters in the foreign country and are calibrated using data from the World Bank's *Doing Business Report*. The fixed cost of operating in a foreign country, f^* is calibrated using an index of labour rigidity to estimate that $f^* = 0.51f$. Similarly, the fixed and sunk costs of exporting from the foreign country, $f_x^* = 0.38 f_x$ and $c_x^* = 0.38 c_x$, are calibrated using the number of days needed to process export applications across countries. To test for possible misspecification around the fixed cost parameters, the robustness of the results with regards to this calibration is checked by estimating the model under various alternative fixed cost assumptions. In particular, the model is re-estimated assuming that the fixed operation costs are equal across countries and that fixed costs are much higher in Indonesia. The robustness results are presented in the Appendix.

5 Estimation Results

Table 7 presents the maximum likelihood parameter estimates of the model along with the associated asymptotic standard errors. The standard errors are computed using the outer product of gradients estimator. The parameters are evaluated in millions of Indonesian rupiahs in 1983.

5.1 Sunk and Fixed Costs

The estimates of sunk export and FDI costs across industries are large. The estimated sunk cost of export for a domestic exporter ranges from 104 thousand 1983 US dollars in the textiles industry to 153 and 171 thousand US dollars in the manufactured metals and food industries, respectively. Across industries, the sunk costs are greater than one year's worth of export revenue. In contrast, foreign plants are estimated to only pay less than 2% of the sunk export costs faced by their domestic counterparts. Sunk FDI costs, however, are estimated to be even larger. Across industries the sunk FDI costs range from 228 thousand 1983 US dollars (metals) to 242 thousand 1983 US dollars (food). However, these costs also account for a substantial

ϱ_X, ϱ_{fdi}, ϱ_x and ϱ_x^*.

Table 7: Structural Estimates

Industry	Food		Metals		Textiles	
$\kappa\varrho_\chi$	74.924	(4.592)	74.935	(7.2e-06)	80.406	(2.2e-06)
$\kappa\varrho_x$	6.142	(0.177)	6.741	(0.366)	6.634	(0.542)
$\kappa\varrho_{x^*}$	0.181	(0.181)	0.095	(0.389)	0.220	(0.116)
$\kappa\varrho_{fdi}$	1.694	(0.150)	3.303	(0.131)	3.337	(0.186)
κc_x	29.154	(1.026)	26.963	(1.731)	20.921	(1.802)
κc_{fdi}	41.108	(1.817)	40.236	(1.942)	47.054	(3.044)
κf	0.507	(0.443)	0.368	(0.917)	5.749	(0.880)
κf_x	0.296	(0.516)	0.337	(0.762)	1.166	(0.376)
κf_{fdi}	2.132	(0.777)	1.977	(1.149)	0.048	(2.242)
ζ_{f_x}	0.004	(0.232)	0.105	(1.104)	0.051	(1.394)
ζ_{c_x}	0.015	(0.014)	0.010	(0.040)	0.006	(0.006)
ρ	0.0003	(0.003)	0.004	(0.004)	4.7e-06	(0.003)
φ_B	1.072	(0.013)	1.828	(0.037)	1.692	(0.024)
φ_τ	-5.313	(0.001)	-3.795	(0.002)	-5.437	(0.070)
σ_a	0.795	(0.005)	0.751	(0.007)	0.779	(0.004)
σ_{a^*}	1.319	(0.017)	0.967	(0.012)	0.829	(0.015)
ξ	0.001	(0.0001)	0.001	(0.0002)	0.001	(0.0001)
$\varepsilon = 1/\text{mark-up}$	3.8		3.0		3.8	
log-likelihood	-34799.059		-15978.675		-31431.706	
No. of Obs.	17,786		7,549		13,287	

Notes: Standard errors are in parentheses. The parameters are evaluated in units of millions of Indonesian Rupiahs in 1983. Metals refers to manufactured metals.

percentage of total revenue; across industries the sunk FDI costs account for 70% (food) to 134% (metals) of total revenue earned by foreign plants in Indonesia. Although the average sunk costs are typically a large percentage revenue it is important to recall that the sunk costs *incurred* are substantially lower since the estimated model predicts many plants only export or invest abroad when they receive beneficial cost shocks.

While fixed costs are typically much smaller than the estimated sunk costs, they are still substantial relative to total revenue. The average fixed cost of operation in Indonesia ranges from 2 and 3 thousand 1983 US dollars in the manufactured metals and food industries, respectively, to 28 thousand 1983 US dollars for the textiles industry. The average fixed export cost ranges from 2 thousand 1983 US dollars in the food manufactured metals, respectively, to 6 thousand 1983 US dollars in the textiles industry. As with the sunk costs, foreign firms are estimated to only pay a small percentage of the fixed export costs (1 to 10% across industries). The fixed FDI costs range from less than 1 thousand dollars in the textiles industry, to 11 thousand dollars in the manufactured metals industry and 12 thousand 1983 US dollars in the food industry. It is important to note that there exists substantial uncertainty in the estimates of most fixed costs since the standard are usually large and the estimates are often insignificant. Government policy

Table 8: Distribution of Plants by Ownership/Export Status

Actual	Domestic Non-Exporters	Domestic Exporters	Foreign Non-Exporters	Foreign Exporters
Food	0.931	0.046	0.016	0.008
Metals	0.824	0.071	0.058	0.047
Textiles	0.839	0.114	0.025	0.023
Predicted				
Food	0.923	0.053	0.014	0.010
Metals	0.826	0.069	0.047	0.058
Textiles	0.832	0.120	0.018	0.030

Note: Metals refers to manufactured metals.

may also drive differences in the estimates across industries. For example, it is well known that the manufactured metals industry received large subsidies during this period.

5.2 Exports and FDI

The parameters φ_T and φ_B jointly capture the impact of exporting at the plant-level. These estimates imply that the average plant can increase their revenues by 52, 55 and 93 percent in the textiles, manufactured metals, and food industries. These numbers are particularly large in light of the fact that the transport cost is estimated to be approximately 6.7 to 7.0 across industries. The large increase in revenues reflect the substantial productivity differences between exporting and non-exporting firms and the small size of Indonesian economy relative to that of the rest of the world.[26] The estimates also imply that on average 34 and 35 percent of a domestic exporters' revenues are from export sales in the textiles and manufactured industries, while exporters in the food industry receive 48 percent of revenues from export sales. Relative to the data, the model underpredicts the average percentage of revenues from exports in the food, manufactured metals and textiles industries by 1, 6 and 19 percent, respectively.

One can further examine the fit of the model by comparing its predictions of the actual distribution to plants in the data. Table 8 documents the predicted distribution of plants export and ownership status for all industries.[27] The model's predictions match the distribution of plants across export and ownership status very closely in all industries. Table 9 reports the models predicted domestic market and export shares across export and ownership status. While

[26]The parameters ϕ_B and ϕ_W jointly imply that Indonesia's economy is roughly 0.5 to 4.1 percent of the world economy.

[27]The estimated model does not provide a prediction in terms of the total number of foreign firms relative to the total number of domestic firms. As such, the percentage of foreign firms in the data is taken as given.

Table 9: **Export/Domestic Market Share by Ownership/Export Ownership**

	Export Share		Domestic Market Share			
Actual	Domestic	Foreign	Domestic Non-Exp.	Domestic Exp.	Foreign Non-Exp.	Foreign Exp.
Food	0.837	0.163	0.551	0.289	0.126	0.032
Metals	0.458	0.542	0.462	0.099	0.300	0.138
Textiles	0.717	0.283	0.602	0.238	0.097	0.062
Predicted						
Food	0.568	0432	0.458	0.180	0.226	0.137
Metals	0.328	0.672	0.467	0.112	0.193	0.229
Textiles	0.643	0.357	0.450	0.274	0.125	0.152

Note: Metals refers to manufactured metals.

one would expect the model to predict the dominant role of foreign plants in the domestic and export markets, Table 9 demonstrates that it often overstates their importance in both domestic and export markets. Because of the large productivity differences between foreign and domestic plants, small differences in the distribution of plants or the predicted productivity differences can have large impacts at the aggregate level.

5.3 Productivity

The model predicts that only the most productive domestic firms are able to produce profitably in Indonesia. Figure 1 shows the importance of survival selection among domestic plants in Indonesia. The actual productivity distribution for incumbents in the top three panels is skewed to the right relative to the distribution of new entrants for all three industries. The bottom three panels of Figure 1 show that the model's predicted productivity distributions for entrants and incumbents capture this selection mechanism. Similarly, Table 10 confirms that domestic incumbents are on average 12 to 32 percent more productive than new domestic entrants across industries.

It is important to note that in all 3 industries there is a second smaller peak to the right of the highest peak in the incumbent distributions of Figure 1. This second peak exists in the predicted distributions due to the substantial benefit firms receive when they export. Because exporters receive such a large increase in total revenues from exporting they become substantially less vulnerable to the exit cost shocks. It is likely, however, that the benefit to exporting is much more heterogeneous across plants than our simple model captures. In particular, allowing the

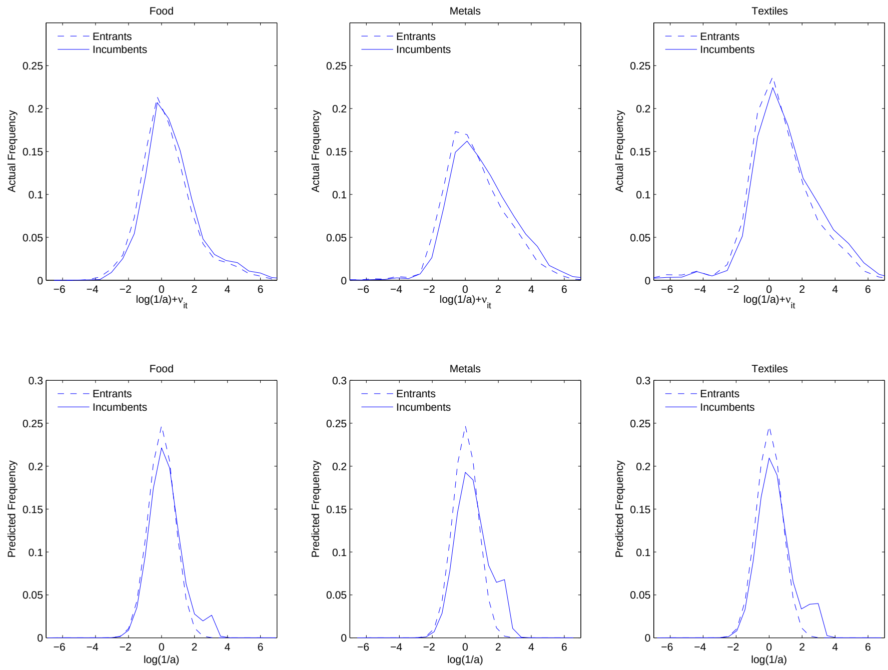

Figure 1: Productivity Distributions of Domestic Entrants and Incumbents (Actual vs. Predicted)

transport cost to vary across plants[28] would improve the fit of the predicted distribution.

Figure 2 shows the productivity distributions for foreign entrants and incumbents. One striking difference with their domestic counterparts is that the model predicts that foreign entrants will be more productive than foreign incumbents. This is due to the sunk cost feature of the model. Low productivity foreign plants are less willing to leave Indonesia when they receive a negative cost shock since they expect much higher future returns from the plant. Moreover, because they are low productivity plants they are unlikely to receive another cost shock in the future that will make re-investment in Indonesia profitable if they leave. As such, there is an accumulation of lower productivity foreign plants. It is also noteworthy that the distribution of foreign plants is much more concentrated in the model than it is in the data. One potential explanation for this result is that there exists other forms of heterogeneity across plants that is not well captured by the variation in productivity alone.

[28]See Kasahara and Lapham (2007) for an example.

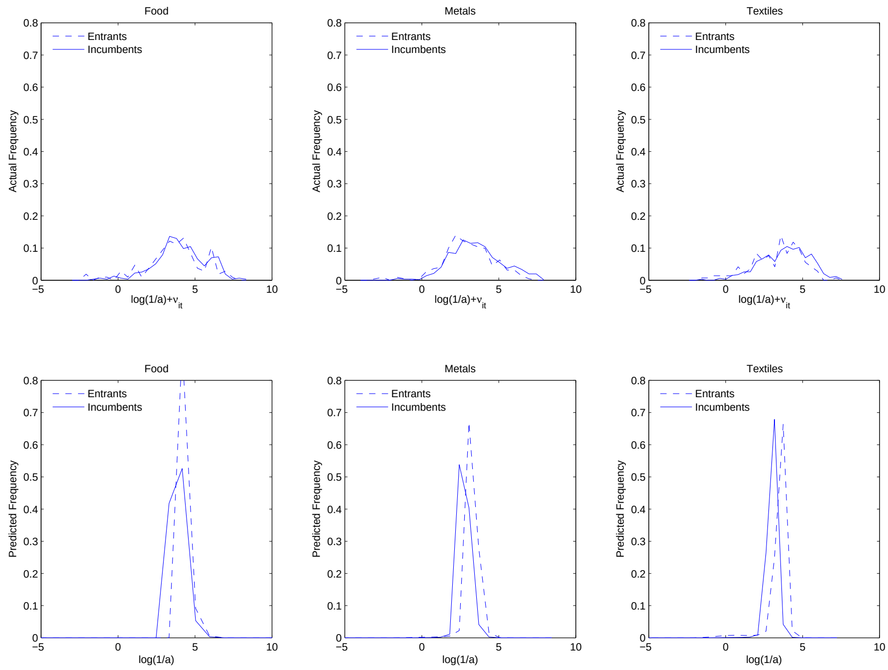

Figure 2: Productivity Distributions of Foreign Entrants and Incumbents (Actual vs. Predicted)

Table 10: Average Productivity

	Food		Metals		Textiles	
	Indonesian	Foreign	Indonesian	Foreign	Indonesian	Foreign
Mean at entry trial	1.000	1.000	1.000	1.000	1.000	1.000
Mean at successful entry in Indonesia	1.003	4.578	1.006	4.994	1.005	3.429
Mean at steady state in Indonesia	1.095	3.977	1.252	3.915	1.139	2.950
Non-Exporters	1.059	4.082	1.205	3.929	1.081	3.178
Exporters	1.959	3.841	1.969	3.904	1.642	2.820

Note: Metals refers to manufactured metals.

As shown in Section 2 domestic exporters tend to have higher productivity than domestic non-exporters, while the opposite is true for foreign plants. Also, foreign plants tend to be more productive than domestic plants. Figure 3 shows the actual and predicted productivity distributions for domestic non-exporters, domestic exporters, foreign non-exporters and foreign exporters, while Table 10 reports their average productivities. The top panel shows that in all three industries the plants follow the same productivity ranking that we observed in the Section 2. In particular, it is notable that the productivity distribution of foreign non-exporters is skewed

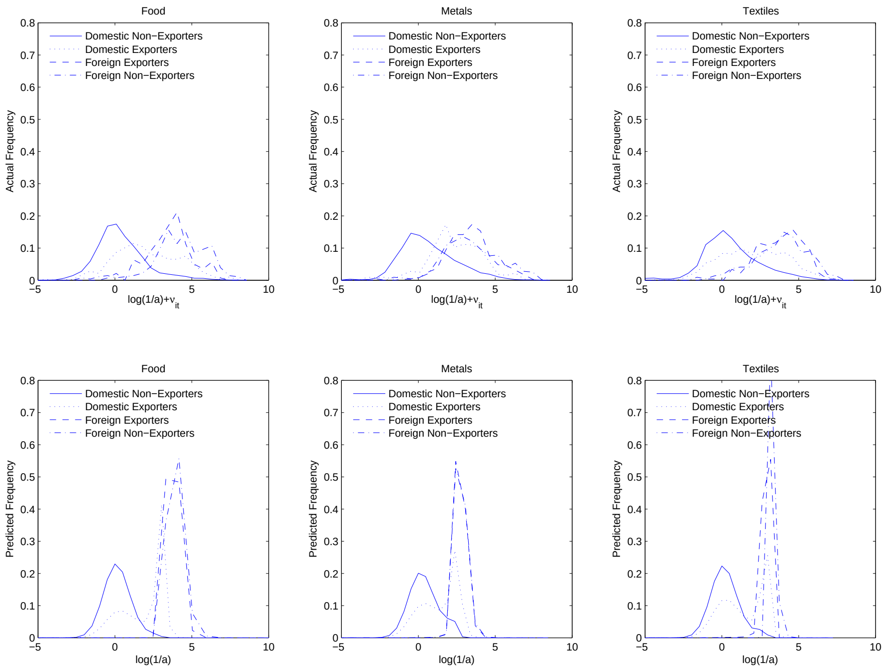

Figure 3: Productivity Distributions of Domestic and Foreign Firms by Export Status (Actual vs. Predicted)

to the right of the productivity distribution of foreign exporters, though the differences across foreign plants are less clear. However, the large difference between foreign and domestic firms is quite evident. The predicted distribution matches these rankings and Table 10 confirms that on average foreign non-exporters are the most productive plants, followed by foreign exporters, domestic exporters and domestic non-exporters. It is important to note, however, that the variance on the productivity distribution for foreign plants is smaller than that observed in the data.

5.4 Dynamics

Table 11 documents the actual and predicted transition probabilities of FDI, export and exit in the textiles industry.[29] It is noteworthy that despite the model's restriction that no domestic plant can become a foreign plant, the model captures many of the transition probabilities across

[29]Similar tables can be found in the Supplemental Appendix for the food and manufactured metals industries.

Table 11: Transition Probabilities - Textiles

Actual	Dom. Non-Exporters	Dom. Exporters	For. Non-Exporters	For. Exporters	Exit
Dom. Non-Exporters at t	0.945	0.051	0.003	0.001	0.088
Dom. Exporters at t	0.309	0.679	0.001	0.011	0.068
For. Non-Exporters at t	0.138	0.031	0.581	0.256	0.030
For. Exporters at t	0.027	0.066	0.178	0.732	0.016
Predicted					
Dom. Non-Exporters at t	0.927	0.073	—	—	0.110
Dom. Exporters at t	0.479	0.521	—	—	0.054
For. Non-Exporters at t	—	—	0.556	0.444	0.001
For. Exporters at t	—	—	0.272	0.728	0.011

FDI and export status relatively well. The data indicates that foreign ownership and export status are quite persistent. Although the model captures much of the persistence in export and ownership status, it still underpredicts the degree persistence for domestic exporters.[30] Since there are a substantial number of low productivity plants that export, the model requires relatively large export cost shocks in order to explain their existence.

5.5 Counterfactual Experiments

This section presents the results from a series of counterfactual experiments intended to examine the effect of trade and FDI barriers for the textiles industry. The counterfactual results for the food and manufactured metals industries are presented in the Appendix. In particular, to determine the quantitative implications of barriers to trade and FDI, the following three counterfactual experiments are conducted by manipulating three parameters:

1. Autarky: $f_x, f_{x^*}, f_{fdi} \to \infty$,

2. No Trade: $f_x, f_{x^*} \to \infty$,

3. No FDI in Indonesia: $f_{fdi} \to \infty$,

To determine the full impact of trade or FDI barriers on the Indonesian economy it is important to consider the effect policy changes have on the aggregate price level. The experiments impose the free entry conditions (7) and solve for the new price levels in Indonesia and the rest of the world which satisfies (7) under the policy change.[31]

[30] Das, Roberts and Tryout (2007), Kasahara and Lapham (2007) and Ruhl and Willis (2007) all find that sunk costs are necessary in order to capture the dynamic behaviour of entry and exit in international trade markets.

[31] See the Supplementary Appendix for details.

Table 12: Counterfactual Experiments - Textiles

	Base	Autarky	No Trade	No FDI
Avg. Productivity[a]	2.404	1.865	2.251	1.949
$-(\varepsilon-1)\delta\Delta\ln P$	—	$-\delta 0.048$	$-\delta 0.014$	$-\delta 0.008$
Exit/Entry Rate of Foreign Firms in Indonesia	—	-1	-0.021	-1
% of For. Non-Exporters	0.018	0	0.051	0
% of Dom. Exporters	0.120	0	0	0.107
%Δ in Exports	—	-1	-1	-0.615
Dom. Mkt. Shr. of Dom. Non-Exp.	0.450	1	0.655	0.715
Dom. Mkt. Shr. of Dom. Exp.	0.274	0	0	0.285
Dom. Mkt. Shr. of For. Non-Exp.	0.125	0	0.345	0
Dom. Mkt. Shr. of For. Exp.	0.152	0	0	0

Notes: a) Average productivity of all plants located in Indonesia in the steady state and is calculated using plant-level revenue shares as weights.

Table 12 presents the results from the counterfactual experiments in the textiles industry.[32] The effect of trade and FDI on average productivity can be best understood by comparing the steady state level of average productivity between the estimated (base) model and that of the counterfactual experiments in the first row. The second row compares welfare across the experiments and will be left to the end.

Eliminating trade and FDI reduces average productivity in the textiles industry by 22.4 percent, while restricting FDI alone causes a 18.9 percent fall in average productivity. In contrast, trade barriers cause a smaller 6.4 percent fall in average productivity. The widely different impacts on the average productivity with FDI and trade restrictions is largely attributable to differences in the substitutability of trade and FDI and the exit decisions of highly productive foreign firms.

Column 3 suggests that the number of foreign plants located in Indonesia falls by only 2.1 percent when trade restrictions are raised. The economic implication is that the Indonesian market, though small relative to the rest of the world, is large and profitable enough that existing multinational firms would continue serving Indonesian consumers even if they were unable to continue using Indonesia as an export platform. Moreover, failing to account for the presence of foreign firms after the policy change would cause one overestimate the impact of trade restrictions on aggregate productivity.

[32] Results for the manufactured metals and food industries are presented in the Appendix.

The fourth column presents the results from a counterfactual experiment where trade is allowed but FDI is not permitted. The fall in productivity is almost as large as that under autarky it is largely attributed to two features of the model. First, the fall is partly due the removal of the top 5% of the most productive firms, the foreign firms, in the industry. When these firms leave it is assumed they take all of their knowledge and technology with them so their are no spillovers to the domestic industry. Second, average productivity is constructed by weighting plant level productivity by revenue shares. Thus, while foreign plants might only account for less than 5% of all plants in the textile industry, their productivity levels receive almost one quarter of the total weight in the average productivity calculation. Due to the direct impact that FDI restrictions have on the entry decision of foreign firms it is clear that FDI policy can have a much larger impact on aggregate productivity in Indonesia than trade. The estimates imply that the impact of FDI on aggregate productivity is 3 times that of international trade.

The welfare results are reported in the second row of Table 12. Welfare is measured as the change in the inverse price level since increases in prices reduce the purchasing power of consumers. The parameter δ captures the size of the textiles sector in the Indonesian economy. Blalock and Gertler (2005) estimate that manufacturing composes approximately one quarter of the Indonesian and the textiles industry accounts for almost one quarter of manufacturing which implies $\delta \approx 0.055$. Although this will greatly reduce the size of the welfare impact it is clear from Table 12 that if similar changes occur across all Indonesian manufacturing sectors there would be significant drop in overall welfare.

Table 12 documents a relatively large fall in welfare under autarky, but smaller changes to welfare when there are restrictions to trade or FDI. The intuition behind this result is that trade (FDI) flows partially "insure" FDI (trade) flows in the presence of FDI (trade) restrictions. For instance, a restriction to FDI is insured by the trade flows into Indonesia so that Indonesian consumers can continue to access foreign goods through trade. Similarly, trade restrictions are insured by foreign firms that enter and continue to produce in Indonesia. Since the foreign firms tend to be much larger and more productive they tend to greatly reduce the fall in welfare.

In sum, the estimates imply that the model's predictions broadly match the features of the Indonesian manufacturing data. Moreover, the estimates confirm the ranking of productivity across plants with different ownership and export status as shown in Section 2. The counterfactual experiments indicate that FDI restrictions have a much larger impact on aggregate productivity than international trade. The additional results in the Appendix document the same qualitative results across industries and very similar quantitative results across estimation assumptions. Last, these results suggest that policies which induce inwards flows of FDI will have a much larger impact on aggregate productivity relative to those that encourage exports.

6 Conclusions

This paper presents and estimates a model of foreign direct investment and exports with heterogeneous firms. The model is structurally estimated using a panel of Indonesian manufacturing plants. Counterfactual policy experiments are employed to assess the impact of a change in FDI or trade policy on aggregate productivity.

The model's empirical predictions broadly match the features of the Indonesian manufacturing data. The model captures export decisions at the plant level and documents the differential export behaviour across foreign and domestic firms. Moreover, the estimates confirm the ranking of productivity across plants with different ownership and export status as shown in Section 2. The model emphasizes that accounting for FDI flows is essential to recovering accurate estimates of the impact of trade on aggregate productivity. In particular, the counterfactual experiments imply that the impact of trade on productivity is greatly mitigated by FDI flows.

The counterfactual experiments imply that FDI restrictions can reduce aggregate productivity by 3 to 11 times more than trade restrictions across FDI-intensive industries in Indonesia. FDI restrictions account for a fall in average total factor productivity between 19 and 36 percent across industries. Trade restrictions, in contrast, are estimated to cause total factor productivity to fall by less than 7 percent across industries.

The results suggest that policies which induce inwards flows of FDI will have a much larger impact on aggregate productivity relative to those that encourage exports. Moreover, the results imply that the differential impact international policies have on foreign and domestic firms can lead to drastically different results. These results are particularly important for policymakers in developing countries where the interaction between trade and foreign direct investment policy has been largely unexamined.

The welfare implications differ substantially across international integration policies. Autarky causes substantial reductions in welfare, while trade and FDI restrictions cause much smaller welfare impacts on an economy such as Indonesia. The model suggests that trade and FDI act as substitutes for each other and reduce the welfare impact of trade or FDI restrictions.

The results suggest a number of extensions and interesting questions for future work. The data demonstrates that manufacturing plants in Indonesia demonstrate substantial heterogeneity across export intensity and import behaviour. Amiti and Konings (2007) find that Indonesian manufacturing plants can substantially improve plant-level productivity by importing foreign inputs. Allowing for richer export and import patterns may uncover further dimensions of interaction across FDI, export and import decisions.

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Appendix

Table 13: Counterfactual Experiments - Food and Metals Industries

	Food				Metals[a]			
	Base	Autarky	No Trade	No FDI	Base	Autarky	No Trade	No FDI
Avg. Productivity[a]	3.001	1.676	2.898	1.916	3.336	2.333	3.250	2.452
$-(\varepsilon-1)\delta\Delta\ln P$	—	$-\delta 0.010$	0	-δ0.010	—	$-\delta 0.010$	$-\delta 0.00001$	-δ0.001
Exit/Entry Rate of Foreign Firms in Indonesia	—	-1	0.021	-1	—	-1	0.027	-1
% of For. Non-Exporters	0.014	0	0.026	0	0.047	0	0.114	0
% of Dom. Exporters	0.053	0	0	0.044	0.069	0	0	0.077
%Δ in Exports	—	-1	-1	-0.646	—	-1	-1	-0.670
Mkt. Shr. of Dom. Non-Exp.	0.458	1	0.567	0.800	0.467	1	0.544	0.807
Mkt. Shr. of Dom. Exp.	0.180	0	0	0.200	0.112	0	0	0.193
Mkt. Shr. of For. Non-Exp.	0.26	0	0.433	0	0.196	0	0.456	0
Mkt. Shr. of For. Exp.	0.137	0	0	0	0.229	0	0	0

Notes: a) Metals refers to manufactured metals. b) Average productivity of all plants located in Indonesia in the steady state and is calculated using plant-level revenue shares as weights.

Table 14: Counterfactual Experiments - Robustness

Industry	Food								
Experiment	Autarky			No Trade			No FDI		
Assumption	A1	A2	A3	A1	A2	A3	A1	A2	A3
% Δ Avg. Productivity[a]	-0.441	-0.580	-0.401	-0.034	-0.023	-0.018	-0.362	-0.555	-0.336
$-(\varepsilon-1)\Delta\ln P^b$	-0.010	-0.010	-0.010	0	-0.004	-0.005	-0.010	-0.010	-0.010
Industry	Metals								
Experiment	Autarky			No Trade			No FDI		
Assumption	A1	A2	A3	A1	A2	A3	A1	A2	A3
% Δ Avg. Productivity[a]	-0.441	-0.580	-0.401	-0.034	-0.023	-0.018	-0.362	-0.555	-0.336
$-(\varepsilon-1)\Delta\ln P^b$	-0.010	-0.010	-0.010	0	-0.004	-0.005	-0.010	-0.010	-0.010
Industry	Textiles								
Experiment	Autarky			No Trade			No FDI		
Assumption	A1	A2	A3	A1	A2	A3	A1	A2	A3
% Δ Avg. Productivity[a]	-0.224	-0.467	-0.301	-0.064	-0.018	-0.015	-0.189	-0.468	-0.269
$-(\varepsilon-1)\Delta\ln P^b$	-0.048	-0.048	-0.037	-0.014	-0.00001	-0.011	-0.008	-0.001	-0.008

Notes: a) The percentage change in average productivity for all plants in the steady state. Calculated using plant-level revenue shares as weights and evaluated relative to the estimated model. b) The welfare impact must be multiplied by industry share δ.

The parameter estimates that generated these results are available in the Supplementary Appendix.