Import Protection as Export Destruction

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Abstract

This paper develops a model of heterogeneous firms with both export and import, extending the framework of Melitz (2003). The model highlights mechanisms whereby import policies affect aggregate productivity and export activity. Based on the theoretical model, we develop and structurally estimate an empirical model that incorporates heterogeneity in productivity and shipping costs using Chilean plant-level manufacturing data. The estimated model replicates the key features of plant-level data regarding productivity, exporting, and importing. We perform a variety of counterfactual experiments to assess the positive and normative effects of barriers to trade in import and export markets. These experiments suggest that there are substantial aggregate productivity and welfare gains due to trade. Furthermore, because of import and export complementarities, policies which inhibit the importation of foreign intermediates can have a large adverse effect on the exportation of final goods.

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1 Introduction

This paper develops a stochastic industry model of heterogeneous firms to examine the effects of trade liberalization on resource reallocation, industry productivity, and welfare in the presence of import and export complementarities. We use the theoretical model to develop empirical models which we estimate using Chilean plant-level manufacturing data. The estimated models are then used to perform counterfactual experiments regarding different trading regimes to assess the positive and normative effects of barriers to trade in import and export markets.

Previous empirical work suggests that there is a substantial amount of resource reallocation across firms within an industry following trade liberalization and these shifts in resources contribute to productivity growth. Pavcnik (2002) uses Chilean data and finds such reallocations and productivity effects after trade liberalization in that country. Trefler (2004) estimates these effects in Canadian manufacturing following the U.S.-Canada free trade agreement using plant- and industry-level data and finds significant increases in productivity among both importers and exporters.

Empirical evidence also suggests that relatively more productive firms are more likely to export.[1] In this paper we provide empirical evidence that whether or not a firm is *importing* intermediates for use in production may also be important for explaining differences in plant performance.[2] Our data suggests that firms which are both importing and exporting tend to be larger and more productive than firms that are active in either market, but not both. Hence, the impact of trade on resource reallocation across firms which are importing may be as important as shifts across exporting firms.

Melitz (2003) develops a monopolistic competition model of exporters with different productivities which is motivated by the empirical findings regarding exporters described above.[3] To

[1] See, for example, Aw, Chung, and Roberts (2000), Bernard and Jensen (1999), Bernard, et al. (2003), Clerides, Lack and Tybout (1998), and Eaton, Kortum, and Kramarz (2004). Other observations on firm level exports include: (a) a majority of firms do not export, (b) most exporters only export a small fraction of their output, and (c) most exporters only export to a small number of countries.

[2] See also Kasahara and Rodrigue (2005). Few empirical studies simultaneously examine both exports and imports at micro-level. A notable exception is Bernard, Jensen, and Schott (2005) which provide empirical evidence regarding both importers and exporters in the U.S. while identifying multinational firms separately from domestic firms as well as differentiating between arms length and intra-firm trade.

[3] Several alternative trade theories with heterogeneous firms have been developed in response to these observations on exporters. Eaton and Kortum (2002) develop a Ricardian model of trade with firm-level heterogeneity. Eaton, Kortum, and Kramarz (2005) explore a model that nests both the Richardian framework of Eaton and Kortum and the monopolistic competition approach of Melitz. Helpman, Melitz, and Yeaple (2004) present a monopolistic competition model with heterogeneous firms that focuses on the firm's choice between exports and

simultaneously address the empirical regularities concerning importers, we begin by extending his model to incorporate imported intermediate goods. In the model, the use of foreign intermediates increases a firm's productivity but, due to fixed costs of importing, only inherently highly productive firms import intermediates.

In this environment, trade liberalization which lowers restrictions on the importation of intermediates increases aggregate productivity because some inherently productive firms start importing and achieve within-plant productivity gains. This, in turn, leads to a resource reallocation from less productive to more productive importing firms, enhancing the positive productivity effect. Furthermore, productivity gains from importing intermediates may allow some importers to start exporting, leading to a resource reallocation in addition to that emphasized by Melitz (2003). Similarly, events that encourage exporting will affect a firm's decision to import since newly exporting firms would have a higher incentive to start importing. Thus, the model identifies an important mechanism whereby import tariff policy affects aggregate exports and whereby export subsidies affect aggregate imports.[4]

Based on the theoretical model, we develop and estimate an empirical model of exports and imports using a panel of Chilean manufacturing plants. Motivated by observed differences in the export and import intensities across firms, we also consider an extended model that incorporates firm-level heterogeneity in international shipping costs. The estimated model with heterogeneous productivity and shipping costs captures the basic observed patterns of productivity across firms with different import and export status. It also replicates well the high degree of trade concentration among a small number of plants in our data.

We find that the estimated mean of the productivity distribution at the steady state is substantially higher than the estimated mean at entry, suggesting that the selection through endogenous exiting plays an important role in determining aggregate productivity. Furthermore, the estimated model indicates that firms with high productivity and low shipping costs tend to self-select into exporting and importing; heterogeneity in both productivity and shipping costs plays an important role in determining export and import status.

To examine the effects of trade policies, we perform a variety of counterfactual experiments

foreign direct investment.

[4]It should be noted that in standard trade theory, restrictions on imports of final goods will lower exports of final goods so that balanced trade holds. In this paper, we are studying a different mechanism whereby import restrictions on intermediates decreases exports of final goods through their effect on productivity and the fixed costs of trade in the presence of heterogeneous firms.

that explicitly take into account equilibrium price adjustments. The experiments suggest that the welfare gain due to exposure to trade is substantial. In addition, we find that the equilibrium price response plays an important role in redistributing resources across heterogeneous firms; experiments based on a partial equilibrium model that ignores the equilibrium price response provide substantially different estimates of the impact of trade on aggregate productivity. Another important finding is that because of import and export complementarities, policies which inhibit the importation of foreign intermediates can have a large adverse effect on the exportation of final goods.

The remainder of the paper is organized as follows. Section 2 presents empirical evidence on the distribution of importers and exporters and their performance using Chilean manufacturing plant-level data. Section 3 presents a theoretical model with import and export complementarities. Section 4 provides details and results of the structural estimation of empirical models. Section 5 concludes.

2 Empirical Motivation

In this section we briefly describe Chilean plant-level data and provide summary statistics to characterize patterns and trends of plants which may or may not participate in international markets. Section 4.6 describes the data set in detail.

2.1 Importers and Exporters Distribution and Performance

Table 1 provides several important basic facts about exporters and importers. The fraction of plants that are engaged in trade is relatively small but has increased over time as shown in the first three rows of Table 1. Furthermore, as shown in the fourth through seventh rows of that table, plants that both export and import account for a larger fraction of exports and imports than their counterparts which only export or only import. In addition, the percentage of total output accounted for by firms which were engaged in international trade increased from 73.3% in 1990 to 79.7% in 1996. Plants that both exported and imported became increasingly important in accounting for total output: they constitute only 12.6% of the sample but account for 47.5% of total output in 1996. Overall, this table indicates that plants that engage in both exporting and importing are increasingly common and are important contributors to output and

Table 1: Exporters and Importers in Chile for 1990-1996 (% of Total)

	1990	1991	1992	1993	1994	1995	1996	1990-96 ave.
Exporters	8.4	9.7	9.2	9.2	8.6	9.7	8.8	9.1
Importers	12.6	12.1	13.1	12.9	13.5	11.8	12.0	12.6
Ex/Importers	8.2	9.5	10.7	11.8	13.4	12.5	12.6	11.3
Exports by Exporters	48.4	37.8	49.3	44.9	32.6	38.1	40.5	41.6
Exports by Ex/Importers	51.6	62.2	50.7	55.1	67.4	61.9	59.5	58.4
Imports by Importers	34.8	32.1	31.5	27.8	22.0	20.8	26.7	28.0
Imports by Ex/Importers	65.2	67.9	68.5	72.2	78.0	79.2	73.3	72.0
Output by Exporters	17.4	16.7	23.4	18.9	15.2	20.1	17.8	18.5
Output by Importers	16.8	12.9	14.9	15.0	14.1	13.3	14.4	14.5
Output by Ex/Importers	39.1	44.1	40.5	43.8	50.2	46.3	47.5	44.5
No. of Plants	4584	4764	4937	5041	5081	5110	5464	4997

Notes: Exporters refers to plants that export but do not import. Importers refers to plants that import but do not export. Ex/Importers refers to plants that both export and import.

Table 2: Export and Import Concentration, 1990-1996 average

	Exports		Imports	
	% of Total Exports	% of Ex/Importers	% of Total Imports	% of Ex/Importers
Top 1%	39.8	54.2	25.8	79.6
Top 5%	67.3	66.2	51.3	77.7
Top 10%	80.1	63.2	65.8	72.7

Notes: "Ex/Importers" refers to plants that both export and import while "% of Ex/Importers" refers to a fraction of Ex/Importers in the top 1, 5, and 10% of exporting or importing plants.

the volume of trade.

Exports and imports are highly concentrated among a small number of plants.[5] Tabel 2 reports the shares of total exports and imports in the top 1, 5, and 10 percentiles of exporting and importing plants. As indicated in the first two columns, export concentration is very high, with the top 1 percent of exporting plants accounting for 39.8% of total exports; furthermore, a majority of the top 1% exporters are plants that engage in both exporting and importing. Importers show a similar pattern although the degree of concentration is slightly smaller than exporters while plants that both export and import play a more important role for concentration of imports.

We also examine the degree of exporting and importing for plants by reporting the joint distribution of export and import intensities in Table 3. A plant's export intensity is defined as the ratio of its export sales to total sales while its import intensity is the ratio of expenditures on

[5]Bernard et al. (2005) find U.S. exports and imports to be concentrated among a very small number of firms.

Table 3: Joint Distribution of Export and Import Intensities

	Import Intensity					
Export Intensity	.00	.00-.20	.20-.40	.40-.60	.60-.80	.80-1.00
.00	.000	.175	.096	.053	.037	.020
.00-.20	.132	.100	.068	.049	.029	.008
.20-.40	.033	.015	.007	.002	.003	.002
.40-.60	.030	.016	.001	.002	.002	.001
.60-.80	.041	.018	.002	.001	.001	.001
.80-1.00	.039	.014	.001	.001	.000	.000

Notes: Export and import intensities are reported only for plants which export or import or do both. There are 11,377 observations of such plants over our time series.

imported intermediate inputs to total expenditures on intermediate inputs. The table reports the fraction of observations in our sample of exporting or importing plants in each intensity bin. As the table suggests there is a sizable degree of heterogeneity across plants with regard to export and import intensities. The average export intensity is 25% with a standard deviation of .30 while the average import intensity is 29% with a standard deviation of .25.

We now turn to measures of plant performance and their relationships with export and import status. While the differences in a variety of plant attributes between exporters and non-exporters are well-known (e.g., Bernard and Jensen, 1999), few previous empirical studies have discussed how plant performance measures depend on import status. Table 4 presents estimated premia in various performance measures according to export and import status. Following Bernard and Jensen (1999), columns 1-3 of this table report export and import premia estimated from a pooled ordinary least squares regression using the data from 1990-1996:

$$\ln X_{it} = \alpha_0 + \alpha_1 d_{it}^x (1 - d_{it}^m) + \alpha_2 d_{it}^m (1 - d_{it}^x) + \alpha_3 d_{it}^x d_{it}^m + Z_{it}\beta + \epsilon_{it}, \tag{1}$$

where X_{it} is a vector of plant attributes (employment, sales, labor productivity, wage, non-production worker ratio, and capital per worker). Here, d_{it}^x is a dummy for year t's export status, d_{it}^m is a dummy for year t's import status, Z includes industry dummies at the four-digit ISIC level, year dummies, and total employment to control for size. The export premium α_1 is the average percentage difference between exporters and non-exporters among plants that do not import foreign intermediates. The import premium α_2 is the average percentage difference between importers and non-importers among plants that do not export. Finally, α_3 captures the percentage difference between plants that neither export nor import and plants that both

Table 4: Premia of Exporter and Importer

	Pooled OLS: 1990-1996			Fixed Effects: 1990-1996		
Export/Import Status	Exporters	Importers	Ex/Importers	Exporters	Importers	Ex/Importers
Total Employment	0.889	0.660	1.495	0.101	0.043	0.138
	(0.019)	(0.016)	(0.018)	(0.013)	(0.009)	(0.012)
Total Sales	0.325	0.546	0.756	0.110	0.074	0.158
	(0.018)	(0.013)	(0.016)	(0.013)	(0.010)	(0.013)
Value Added per Worker	0.327	0.490	0.688	0.100	0.053	0.125
	(0.021)	(0.015)	(0.019)	(0.021)	(0.016)	(0.020)
Average Wage	0.210	0.323	0.423	0.055	0.043	0.062
	(0.011)	(0.009)	(0.010)	(0.009)	(0.007)	(0.009)
Non-Production/Total Workers	0.033	0.210	0.345	0.038	0.031	0.056
	(0.014)	(0.011)	(0.012)	(0.014)	(0.011)	(0.015)
Capital per Worker	0.495	0.512	0.866	0.066	0.016	0.134
	(0.026)	(0.019)	(0.024)	(0.016)	(0.012)	(0.017)
No. of Observations	34981			33853		

Notes: Standard errors are in parentheses. "Total Employment" reports the estimates for exporter/importer premia from a regression excluding the logarithm of total employment from the set of regressors. Because they are observed only for one period, 1128 plant observations are dropped from the fixed effects regression.

export and import.

The results show that there are substantial differences not only between exporters and non-exporters but also between importers and non-importers. The export premia among non-importers are positive and significant for all characteristics as shown in column 1. The import premia among non-exporters are positive and significant for all characteristics in column 2, suggesting the importance of import status in explaining plant performance even after controlling for export status. Comparing columns 1-2 with column 3, plants that are both exporting and importing tend to be larger and be more productive than plants that are engaged in either export or import but not both.[6]

We also estimate (1) by the fixed effects regression to control for plant specific effects. The results are reported in columns 4-6. They show the similar patterns to those based on the pooled OLS in columns 1-3. Notably, all the point estimates for column 6 are larger than those reported in columns 4-5, suggesting that plants that are both exporting and importing are larger and more productive than other plants. The point estimates suggest that the magnitude of the performance gap for various characteristics across different export/import status are substantial.

[6]Since export status is positively correlated with import status, the magnitude of the export premia estimated without controlling for import status is likely to be overestimated by capturing the import premia.

3 A Model of Exports and Imports

In this section, motivated by the empirical evidence presented above, we extend the trading environment studied by Melitz (2003) to include importing of intermediates by heterogeneous final goods producers.

3.1 Environment

The world is comprised of $N + 1$ identical countries. Within each country there is a set of final goods producers and a set of intermediate goods producers.

3.1.1 Consumers

In each country there is a representative consumer who supplies labour inelastically at level L. The consumer's preferences over consumption of a continuum of final goods are given by $U = \left[\int_{\omega\in\Omega} q(\omega)^{\frac{\sigma-1}{\sigma}} d\omega\right]^{\frac{\sigma}{\sigma-1}}$, where ω is an index over varieties, and $\sigma > 1$ is the elasticity of substitution between varieties. Letting $p(\omega)$ denote the price of variety ω, we can derive optimal consumption of variety ω to be $q(\omega) = Q\left[\frac{p(\omega)}{P}\right]^{-\sigma}$, where P is a price index given by $P = \left[\int_{\omega\in\Omega} p(\omega)^{1-\sigma} d\omega\right]^{1/(1-\sigma)}$ and Q is a consumption index with $Q = U$. Expenditure on variety ω is given by

$$r(\omega) = R\left[\frac{p(\omega)}{P}\right]^{1-\sigma}, \tag{2}$$

where $R = PQ = \int_{\omega\in\Omega} r(\omega)d\omega$ is aggregate expenditure.

3.1.2 Production

We first describe the final-good sector which is characterized by a continuum of monopolistically competitive firms selling horizontally differentiated goods. Final goods firms sell to domestic consumers and in the trading environment choose whether or not to also export their goods to foreign consumers. In production, final goods producers employ labor, domestically produced intermediates, and choose whether or not to also use imported intermediates.

There is an unbounded measure of ex ante identical potential entrants. Upon entering, an entrant pays a fixed entry cost, f_e. Each new entrant then draws a firm-specific productivity parameter, φ, from a continuous cumulative distribution $G(\varphi)$. A firm's productivity remains at this level throughout its operation. After observing φ, a firm decides whether to immediately exit or stay in the market. All final goods producers must pay a fixed production cost, f, each period to continue in operation. In addition, in each period, a firm is forced to exit with probability ξ.

In the open economy, firms must also pay fixed costs associated with importing intermediates and exporting their product in any period that they choose to be active in those markets. Before making their import and export decisions, firms draw a firm-specific shock to the fixed cost of importing. This shock is denoted ϵ and is identically and independently distributed across firms and across time with a continuous cumulative distribution $H(\epsilon)$ defined over $[\underline{\epsilon}, \bar{\epsilon}]$ with zero mean. The total fixed cost per import market for a firm which is importing but not exporting equals $f_m + \epsilon > 0$. A firm that is exporting but not importing incurs a non-stochastic cost of $f_x > 0$ each period for each export market. Finally, a firm that is both exporting and importing incurs a fixed cost equal to $\zeta(f_x + f_m + \epsilon)$ for each market, where $0 < \zeta \leq 1$ determines the degree of complementarity in fixed costs between exporting and importing.[7]

We let $d^x \in \{0, 1\}$ denote a firm's export decision where $d^x = 0$ implies that a firm does not export their good and let $d^m \in \{0, 1\}$ denote a firm's import decision where $d^m = 0$ implies that a firm does not use imported intermediates. Finally, let $d = (d^x, d^m)$ denote a final good producer's export/import status. With this notation, we can write the total per-period fixed cost of a firm that chooses d and draws ϵ as

$$F(d, \epsilon) = f + N\zeta^{d^x d^m}[d^x f_x + d^m(f_m + \epsilon)]$$

The technology for a firm with productivity level φ and import status d^m is given by:

$$q(\varphi, d^m) = \varphi l^\alpha \left[\int_0^1 x_o(j)^{\frac{\gamma-1}{\gamma}} dj + d^m \int_0^N x(j)^{\frac{\gamma-1}{\gamma}} dj \right]^{\frac{(1-\alpha)\gamma}{\gamma-1}},$$

where l is labor input, $x_o(j)$ is input of domestically-produced intermediate variety j, $x(j)$ is input of imported intermediate variety j, $0 < \alpha < 1$ is the labor share, and $\gamma > 1$ is the elasticity of substitution between any two intermediate inputs. The measure of intermediates produced within any country is fixed at one. We allow for iceberg importing costs so $\tau_m > 1$ units of an

[7] We impose lower bounds on the values for f_x and $f_m + \bar{\epsilon}$ and upper bounds on $f_m + \underline{\epsilon}$ which guarantee that there is a positive measure of firms in each export/import category in the open economy equilibrium. These restrictions are similar to the condition imposed by Melitz (2003) which ensures that his economy is characterized by partitioning of firms by export status. These derivations as well as full derivations of the results below are presented in an appendix which is available upon request.

intermediate good must be shipped abroad for 1 unit to arrive.

In the intermediate goods industry, there is a continuum of firms, each producing a different variety. Anyone can access the blueprints of the intermediate production technology for all varieties and there is free entry. Firms have identical linear technologies in labor input with marginal product equal to one. These conditions imply that domestic intermediates sold in the domestic market will all have price equal to the wage which we normalize to one.

In the symmetric equilibrium, inputs of all domestic intermediates will be equal so $x_o(j) = x_o$ for all j. The cost minimization problem of a final goods producer implies that employment of any imported variety will equal $x(j) = x = \tau_m^{-\gamma} x_o$ for all j. Thus expenditure on imported intermediates and total intermediates respectively are given by

$$X^m = N\tau_m^{1-\gamma} x_o \qquad\qquad X = (1 + N\tau_m^{1-\gamma})x_o \tag{3}$$

Finally, production can be written as

$$q(\varphi, d^m) = a(\varphi, d^m) l^\alpha [x_o + d^m N \tau_m x]^{1-\alpha}, \tag{4}$$

where

$$a(\varphi, d^m) \equiv \varphi \lambda^{d^m}, \tag{5}$$

with $\lambda \equiv (1 + N\tau_m^{1-\gamma})^{\frac{1-\alpha}{\gamma-1}} > 1$. We will refer to this term as a firm's total factor productivity.[8] Note that $a(\varphi, 1) > a(\varphi, 0)$ so a firm which imports intermediates will have higher total factor productivity than if it does not import. This increase in productivity results from increasing returns to variety in the production function. This approach allows us to incorporate an import premium and is motivated by the empirical findings presented in Section 2 and in Kasahara and Rodrigue (2005).[9]

The form of preferences implies that final goods producers will price at a constant markup equal to $\frac{\sigma}{\sigma-1}$ over marginal cost. Hence, using the final goods technology and recalling that all intermediates are priced at the wage which equals one, we have the following pricing rule for

[8] Note that l is a firm's labour input and $x_o + d^m N\tau_m x$ is a firm's gross input of intermediate inputs so $a(\varphi, d^m)$ is a residual measure of productivity.

[9] An alternative approach would include incorporating vertically differentiated inputs with foreign inputs of higher quality to generate an import premium. The approach taken here has the advantage of tractability and is widely used in models of trade with differentiated products (see, for example, Ethier, 1982).

final goods sold in the home market for a producer with productivity φ and import status d^m:

$$p^h(\varphi, d^m) = \left(\frac{\sigma}{\sigma-1}\right)\left(\frac{1}{\Gamma a(\varphi, d^m)}\right),$$

where $\Gamma \equiv \alpha^\alpha(1-\alpha)^{1-\alpha}$.

As in Melitz (2003), we also assume that there are iceberg exporting costs for final goods so that $\tau_x > 1$ units of goods has to be shipped abroad for 1 unit to arrive at its destination. The pricing rule for final goods sold in the foreign market then is given by $p^f(\varphi, d^m) = \tau_x p^h(\varphi, d^m)$.

The total revenue of a final good producer depends on inherent productivity and export/import status. From (2), revenue from domestic sales can be written as $r^h(\varphi, d^m) = R\left(\frac{\sigma-1}{\sigma}P\Gamma a(\varphi, d^m)\right)^{\sigma-1}$ while revenue from foreign sales per country of export is given by

$$r^f(\varphi, d) = d^x \tau_x^{1-\sigma} r^h(\varphi, d^m). \tag{6}$$

Hence, total revenue for a firm with productivity φ and export/import status d is given by $r(\varphi, d) = r^h(\varphi, d^m) + N r^f(\varphi, d)$ or

$$r(\varphi, d) = (1 + d^x N \tau_x^{1-\sigma}) r^h(\varphi, d^m). \tag{7}$$

Thus, using equations (5) and (7), we can determine revenue for a firm with productivity φ and export/import status d relative to a firm with the same productivity who is neither exporting nor importing:

$$r(\varphi, d) = b_x^{d^x} b_m^{d^m} r(\varphi, 0, 0), \tag{8}$$

where $b_x \equiv 1 + N\tau_x^{1-\sigma}$ and $b_m \equiv \lambda^{\sigma-1}$. Turning to profits, we see that the pricing rule of firms implies that profits of a final good producer with inherent productivity φ, export/import status d, and fixed import cost shock ϵ can be written as

$$\pi(\varphi, d, \epsilon) = \frac{r(\varphi, d)}{\sigma} - F(d, \epsilon) \tag{9}$$

In what follows, we explore the equilibria of four economies: the closed economy and three trading economies. Let autarkic equilibrium variables be denoted with a subscript A. We denote equilibrium variables in the full trading equilibrium with a subscript T. Our partial trading economy with $\zeta = b_m = 1$ is equivalent to the open economy studied by Melitz (2003) with exporting of final goods but no importing of intermediates and we denote this economy with an X subscript. We also consider an economy with importing of intermediate goods but no exporting of final goods and denote this economy with an M subscript.

Thus, the equilibrium price index and aggregate revenue in economy $S \in \{A, T, X, M\}$ are denoted P_S and R_S respectively. Evaluating equations (7) and (9) at these equilibrium values allows us to determine equilibrium revenue and profit functions for a final goods producer in each economy.

3.2 Exit, Export, and Import Decisions

3.2.1 Exit Decision

We focus on stationary equilibria in which aggregate variables remain constant over time. Each firm's value function in economy $S \in \{A, T, X, M\}$ is given by the maximum of the exiting value, which is assumed to be zero, and the present value of total sum of expected profits as:

$$V_S(\varphi) = max\left\{0, \sum_{t=0}^{\infty}(1-\xi)^t E_{\epsilon_t}\left(\underset{d_t\in\{0,1\}^2}{max}\pi_S(\varphi, d_t, \epsilon_t)\right)\right\} = max\left\{0, E_\epsilon\left(\underset{d\in\{0,1\}^2}{max}\frac{\pi_S(\varphi, d, \epsilon)}{\xi}\right)\right\},$$

where the second equality follows because ϵ is independently distributed over time. Now since profits are strictly increasing in φ, there exists a cutoff productivity, φ_S^* such that a firm will exit if $\varphi < \varphi_S^*$ where φ_S^* is characterized by $E_\epsilon\left(max_{d\in\{0,1\}^2}\frac{\pi_S(\varphi_S^*, d, \epsilon)}{\xi}\right) = 0$. Using methods similar to those employed by Melitz (2003) we can show that the cutoff productivities for each economy exist, are unique, and satisfy $r_S(\varphi_S^*, 0, 0) = \sigma f$. This also implies that the revenue of a firm can be written as

$$r_S(\varphi, d) = b_x^{d_x} b_m^{d_m}\left(\frac{\varphi}{\varphi_S^*}\right)^{\sigma-1}\sigma f. \tag{10}$$

3.2.2 Export and Import Decisions

For the full trading economy, we now consider the export and import decisions for firms which choose not to exit. Define the following function of inherent productivity:

$$\Phi(\varphi) \equiv \left(\frac{\varphi}{\varphi_T^*}\right)^{\sigma-1}\left(\frac{f}{N}\right).$$

For convenience, we can reference firms of different productivity levels by Φ where the dependence on φ is understood. We refer to this variable as relative productivity. Using equations

(9) and (10), we can write profits in terms of Φ:

$$\hat{\pi}(\Phi, d, \epsilon) = b_x^{d^x} b_m^{d^m} N\sigma\Phi - F(d, \epsilon).$$

To obtain the export and import decision rules as a function of a firm's productivity and fixed import cost, we define the following variables. Let $\Phi_x(d^m, \epsilon)$ be implicitly defined by $\hat{\pi}(\Phi_x(d^m, \epsilon), 1, d^m, \epsilon) = \hat{\pi}(\Phi_x(d^m, \epsilon), 0, d^m, \epsilon)$ or

$$\Phi_x(d^m, \epsilon) = \frac{\zeta^{d^m} f_x + d^m(\zeta^{d^m} - 1)(f_m + \epsilon)}{b_m^{d^m}(b_x - 1)}. \tag{11}$$

So a firm with import status d^m, fixed import cost shock ϵ, and relative productivity $\Phi_x(d^m, \epsilon)$ will be indifferent between exporting and not exporting. Similarly, we have

$$\Phi_m(d^x, \epsilon) = \frac{\zeta^{d^x}(f_m + \epsilon) + d^x(\zeta^{d^x} - 1)f_x}{b_x^{d^x}(b_m - 1)} \tag{12}$$

where a firm with d^x, ϵ, and relative productivity $\Phi_m(d^x, \epsilon)$ will be indifferent between importing and not importing. Finally, let

$$\Phi_{xm}(\epsilon) = \frac{\zeta(f_x + f_m + \epsilon)}{(b_x b_m - 1)}. \tag{13}$$

So a firm with fixed import cost shock ϵ, and relative productivity $\Phi_{xm}(\epsilon)$ will be indifferent between participating in both exporting and importing markets and not participating in either market.

If we let $\theta \equiv f_m + \epsilon$, where $\theta \in (f_m + \underline{\epsilon}, f_m + \bar{\epsilon}) \equiv (\underline{\theta}, \bar{\theta})$, then we can graph each of the variables defined in equations (11)–(13) as a function of θ to determine firms' export and import choices. Figure 1 graphs these cutoff functions for the case with no complementarities in fixed costs, $\zeta = 1$. Note that $\Phi(\varphi_T^*) = \frac{f}{N}$ so active firms are those with $\Phi \geq \frac{f}{N}$. As the figure demonstrates, the space of (Φ, θ) is partitioned into four areas according to firms' export and import choices. Firms with relatively low productivity and low fixed cost of importing will choose to import but not export. Firms with relatively low productivity and higher fixed cost of importing will choose to neither import nor export. Firms with relatively high productivity and high fixed cost of importing will choose to export but not import. Finally, firms with relatively high productivity will choose to both import and export.

We can also demonstrate the effect of complementarities in the fixed costs of importing and exporting. Recall that a decrease in ζ represents an increase in complementarities. Examination of equations (11)-(13) shows that a decrease in ζ will shift down and decrease the slopes of $\Phi_m(1,\cdot)$, $\Phi_x(1,\cdot)$, and $\Phi_{xm}(\cdot)$. As can be seen from Figure 2, each of these changes would serve to increase the measure of firms choosing to both export and import and decrease the measure of firms in each of the other three areas. This is intuitive as an increase in the complementarities should increase the fraction of firms which choose to engage in both activities.

3.3 Autarky and Trading Equilibria

All variables in the stationary equilibrium for each economy can be determined once we determine the cutoff variable for operation, φ_S^*. We now seek to characterize the equations which determine these cutoff variables.

Let $\nu_S(\varphi_S^*, d)$ denote the equilibrium fraction of firms that have export/import status equal to d in economy $S \in \{A, T, X, M\}$. Let average profits within each group of firms according to export/import status be denoted $\tilde{\pi}_S(\varphi_S^*, d)$. Then, average overall profit, $\bar{\pi}_S$, can be expressed as

$$\bar{\pi}_S = \sum_{d \in \{0,1\}^2} \nu_S(\varphi_S^*, d)\tilde{\pi}_S(\varphi_S^*, d). \tag{14}$$

This equation, corresponding to the "zero cutoff profit condition" in Melitz (2003), provides an equilibrium relationship between average overall profit, $\bar{\pi}_S$, and the cutoff productivity, φ_S^*.

The second equilibrium equation is given by the free-entry condition which guarantees that the ex-ante value of an entrant must be equal zero:

$$(1 - G(\varphi_S^*)) \left(\frac{\bar{\pi}_S}{\xi}\right) - f_e = 0. \tag{15}$$

Solving these two equations (14)-(15) for the two unknowns $\bar{\pi}_S$ and φ_S^*, allows us to uniquely determine the equilibrium cutoff productivity in each economy.

3.4 Effects of Trade

We first examine the effects of trade on the decision to operate. Using methods similar to those employed by Melitz (2003), we can demonstrate that either type of trade increases the cutoff productivity for operation, i.e. $\varphi_A^* < \varphi_X^* < \varphi_T^*$ and $\varphi_A^* < \varphi_M^* < \varphi_T^*$. Thus opening trade in either final goods or intermediates or both causes firms with lower inherent productivity to exit. In the economy with no importing, this result is identical to that identified by Melitz (2003) where the exportation of final goods induces a reallocation of labour from less productive firms to more productive firms. We find that allowing firms to import intermediates leads to even more exit of less productive firms.

We also find that when the economy moves from autarky to full trade, market shares are shifted away from firms which do not engage in trade (low productivity firms) to firms which both export and import (high productivity firms). This reallocation of market shares from less productive to more productive firms when an economy opens for full trade increases a productivity average measured using firms revenue shares as weights. This effect was identified by Melitz (2003) in the economy with no importing of intermediates. If the economy also opens to intermediates imports this effect is strengthened because of additional resource reallocation *and* a direct increase in productivity from the use of additional intermediates.

An additional interesting result is that if the returns to importing intermediates, b_m are large enough, then a firm which chooses to export but not import in the open economy will also lose market share. This is because a firm which chooses to only export is at a disadvantage relative to its domestic and foreign competitors who are importing intermediates and such a firm may lose market share when the economy opens to full trade. For similar reasons, when the returns to exporting, b_x are large enough, then a firm which chooses to import but not export in the open economy will also lose market share.

It is also easy to show that the mass of operating firms must fall when an economy opens to either type of trade. This is similar to the findings of Melitz (2003) and is an example of a *selection effect* as discussed in the trade literature with increasing returns and free entry (see, for example, Krugman, 1979). Our environment identifies an additional mechanism arising from the presence of imported intermediates that strengthens this selection effect.

We are also interested in the normative effects of trade and, as in Melitz (2003) use the equilibrium aggregate price index in each equilibrium to obtain a welfare measure: $W_S = \frac{1}{P_S}$. In moving from autarky to an economy with trade in final goods, consumer welfare is impacted by two effects. The number of varieties available to the consumer changes and aggregate productivity increases. In the trading economy with no trade in final goods but trade in intermediates, consumer welfare is only affected by the latter effect and trade in intermediates impacts positively on welfare. In the economies with trade in final goods, the number of varieties available to the consumer in the open economies may be higher or lower than the number of varieties available to the consumer in autarky. If the number of varieties available to the consumer is higher in trade, then welfare is also enhanced by this effect but if it falls then welfare is negatively impacted. However, as in Melitz (2003), we can show the increase in welfare from the productivity gain dominates and welfare is higher in any of the trading economies than in autarky and full trade generates higher welfare than partial trade, i.e. $W_A < W_X < W_T$ and $W_A < W_M < W_T$.

3.5 Restrictions on Trade in Intermediate Goods

We now briefly examine the effects of a restriction on the importation of intermediates on aggregate productivity and export activity. We already argued above that prohibiting the importation of intermediates will have a negative effect on average productivity and welfare. We may also interpret an increase in the transportation costs associated with shipping intermediates, τ_m, as an increase in barriers to trade in those goods and can show that this would also decrease average productivity and welfare.

Furthermore, allowing intermediate imports will allow a larger fraction of firms to enter the export market. This is because the use of imported intermediates increases the productivity of firms through the increasing returns to variety in production. Thus, a restriction on imports decreases export activity and hence, import protection acts as export destruction. Figure 3 demonstrates this effect when imported intermediates are prohibited for the case where there are no fixed cost complementarities. The hatched area in that figure shows the fraction of exporting firms which stop exporting when imports are prohibited, and, hence the export destruction due to import protection. Of course, in the presence of fixed cost complementarities, export destruction due to restrictions on trade in intermediate goods is even more pronounced.

4 Structural Estimation

4.1 The Environment

In this section, we develop an empirical model based on the theoretical model presented in the previous section. The empirical model retains the basic structure of the theoretical model but includes additional cost shocks. With these shocks, the empirical model does not have closed-form characterizations of firms' decisions which complicates the estimation.

We introduce stochastic fixed costs of exporting and importing and cost shocks associated with exiting.[10] Extending the framework developed by Rust (1987), we consider a *nested logit* dynamic programming model in which the set of alternatives are partitioned into subsets, or nests, as follows. [11]

First, a firm draws a cost shock associated with the exiting decision $\chi \in \{0, 1\}$, denoted by $\epsilon_t^\chi \equiv (\epsilon_t^\chi(0), \epsilon_t^\chi(1))$. Here, $\chi = 0$ implies that a firm exits while $\chi = 1$ implies that a firm continues to operate. We assume that ϵ_t^χ is independent of alternatives and randomly drawn from the extreme-value distribution with scale parameter ϱ^χ.

If a firm decides to stay, then it draws stochastic fixed costs associated with its export/import decision. These are similar to the random fixed cost of importing in the theoretical model but here we allow for a stochastic cost for every status. We partition the set of alternative export/import choices into two subsets: $D_0 \equiv \{(0, 0)\}$ and $D_1 \equiv \{(1, 0), (0, 1), (1, 1)\}$. The cost shocks associated with the decision to trade or not trade, denoted by $\epsilon_t^D(D)$ for $D \in \{D_0, D_1\}$, are randomly drawn from the extreme-value distribution with scale parameter ϱ^D. Let $\epsilon_t^D \equiv (\epsilon_t^D(D_0), \epsilon_t^D(D_1))'$. If a firm decides to engage in trade by choosing $D = D_1$, it then draws additional choice-dependent cost shocks associated with its export and import decisions. These are denoted $\epsilon_t^d(d)$ for $d \in D_1$ and are drawn from the extreme-value distribution with scale parameter ϱ^d. Let $\epsilon_t^d \equiv (\epsilon_t^d(1, 0), \epsilon_t^d(0, 1), \epsilon_t^d(1, 1))'$. Figure 4 shows the tree diagram for firm's choice within a period.

An optimization problem for an incumbent firm with productivity φ is then recursively written in terms of the Bellman's equations as

$$
\begin{aligned}
V(\varphi) &= \int \max\{\epsilon^\chi(0), W(\varphi) + \epsilon^\chi(1)\} dH^\chi(\epsilon^\chi), && (16)\\
W(\varphi) &= \int \max\{J(\varphi, D_0) + \epsilon^D(D_0), J(\varphi, D_1) + \epsilon^D(D_1)\} dH^D(\epsilon^D), && (17)\\
J(\varphi, D) &= \begin{cases} \pi(\varphi, 0, 0) + \beta(1-\xi)V(\varphi), & \text{for } D = D_0, \\ \int \left(\max_{d \in D_1} \pi(\varphi, d') + \beta(1-\xi)V(\varphi) + \epsilon^d(d')\right) dH^d(\epsilon^d) & \text{for } D = D_1, \end{cases} && (18)
\end{aligned}
$$

[10] Adding these cost shocks is necessary to explain certain observations in the data. For example, in the absence of exiting cost shocks, the theoretical model predicts that all firms with productivity below the cutoff level will exit. This, however, is inconsistent with the existence of many small firms in our data.

[11] A nested logit model allows for richer substitution patterns across alternatives than does a standard multinomial logit model. See, for example, Ben-Akiva and Lerman (1985).

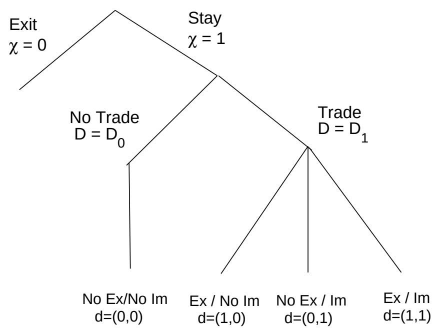

Figure 4: Tree Diagram of Firm's Choice

where H^χ, H^D, and H^d represent the cumulative distribution functions of ϵ^χ, ϵ^D, and ϵ^d, respectively, while $\beta \in (0, 1)$ is the discount factor.

To clarify these modifications, we describe the timing of the decisions of an incumbent using equations (16)-(18). At the beginning of every period, a firm—of which value is denoted by $V(\varphi)$—draws the idiosyncratic cost shocks associated with exiting decisions, ϵ^χ, and decides whether to exit or continue to operate. If the firm decides to exit, it receives the terminal value of $\epsilon^\chi(0)$. If the firm decides to operate with the continuation value of $W(\varphi)$, it will then draw the cost shocks associated with trading decisions, ϵ^D, and decide whether it will engage in trading activities; this trading decision is described in the right hand side of equation (17), where $J(\varphi, D)$ denotes the continuation value under a trading choice $D \in \{D_0, D_1\}$. If the firm decides to trade, it draws the cost shocks, ϵ_t^d, and makes export/import decisions. At the end of the period, a firm faces a possibility of a large negative shock that causes it to exit with probability ξ.

With the solution to the functional equations (16)-(18), and using the properties of the extreme-value distributed random variables (see, for example, Ben-Akiva and Lerman, 1985), the conditional choice probabilities of exiting and export/import decisions are derived as follows. First, taking into account the exogenous exiting probability of ξ, the probability of staying ($\chi = 1$) and exiting ($\chi = 0$) is given by:

$$P(\chi = 1|\varphi) = (1 - \xi)\frac{\exp(W(\varphi)/\varrho^\chi)}{\exp(0) + \exp(W(\varphi)/\varrho^\chi)}, \tag{19}$$

and $P(\chi = 0|\varphi) = 1 - P(\chi = 1|\varphi)$. *Conditional on* $\chi = 1$ (i.e., continuously operating), the choice probabilities of $d \in \{0,1\}^2$ are given by:

$$P(d|\varphi, \chi = 1) = \begin{cases} P(D_0|\varphi, \chi = 1) & \text{for } d \in D_0, \\ P(D_1|\varphi, \chi = 1)P(d|\varphi, \chi = 1, D = D_1), & \text{for } d \in D_1, \end{cases} \tag{20}$$

where

$$\begin{aligned} P(D|\varphi, \chi = 1) &= \frac{\exp(J(\varphi, D)/\varrho^D)}{\sum_{D' \in \{D_0, D_1\}} \exp(J(\varphi, D')/\varrho^D)}, \\ P(d|\varphi, \chi = 1, D = D_1) &= \frac{\exp([\pi(\varphi, d) + \beta(1-\xi)V(\varphi)]/\varrho^d)}{\sum_{d' \in D_1} \exp([\pi(\varphi, d') + \beta(1-\xi)V(\varphi)]/\varrho^d)}. \end{aligned}$$

Equations (19)-(20) define the conditional choice probabilities of exiting and export/import decisions, which follows a familiar nested logit formula (c.f., McFadden, 1978).[12]

We focus on a stationary equilibrium in which the distribution of φ is constant over time. We assume that the logarithm of plant-specific productivity, $\ln \varphi$, is drawn upon entry from $N(0, \sigma_\varphi^2)$, where its density function is denoted by $g_\varphi(\varphi)$. This productivity level is constant after the initial draw. The expected value of an entering firm is then given by $\int V(\varphi) g_\varphi(\varphi) d\varphi$, where $V(\cdot)$ is given in (16). Under free entry, this value must be equal to the fixed entry cost f_e:

$$\int V(\varphi) g_\varphi(\varphi) d\varphi = f_e. \tag{21}$$

We denote the stationary distribution of φ among incumbents by $g_\varphi^*(\varphi)$. Stationarity requires that, for each "type" φ, the number of exiting firms is equal to the number of *successful* new entrants so that

$$\underbrace{MP(\chi = 0|\varphi) g_\varphi^*(\varphi)}_{\text{exits}} = \underbrace{M_e P(\chi = 1|\varphi) g_\varphi(\varphi)}_{\text{entrants}} \qquad \text{for all } \varphi,$$

[12] There are important differences, however, between static nested logit models and the dynamic model we consider here. First, in static models, the property of *independence from irrelevant alternatives* (IIA) holds within each nest but the IIA property no longer holds even within a nest in dynamic models because the continuation value depends on the attributes of other alternatives outside of the nest (c.f., Rust, 1994). Second, while a static model typically has a closed-form specification in parameters (e.g., linear-in-parameters), the conditional choice probabilities (19)-(20) do not have a closed-form expression in parameters; instead, their evaluations require the solution to the functional equations (16)-(18). It is computationally intensive, therefore, to evaluate the conditional choice probabilities in our dynamic model although the extreme-value specification substantially simplifies the computation by avoiding the need for multi-dimensional numerical integrations in (16)-(18).

where M is a total mass of incumbents and M_e is a total mass of plants that attempt to enter into the market. This implies that the stationary distribution $g_\varphi^*(\varphi)$ can be computed as:

$$g_\varphi^*(\varphi) = \frac{M_e}{M}\frac{P(\chi=1|\varphi)}{P(\chi=0|\varphi)}g_\varphi(\varphi), \tag{22}$$

where $\frac{M_e}{M} = 1/\int \frac{P(\chi=1|\varphi)}{P(\chi=0|\varphi)}g_\varphi(\varphi)d\varphi$ since $\int g_\varphi^*(\varphi)d\varphi = 1$.

4.2 The Likelihood Function

We define the following functions of the iceberg shipping costs:

$$z_x \equiv \ln(N\tau_x^{1-\sigma}), \qquad\qquad z_m \equiv \ln(N\tau_m^{1-\gamma}). \tag{23}$$

The basic specification assumes that shipping costs and, therefore, z_x and z_m are the same across plants but later we extend the model to allow for differences in z_x and z_m across plants.

Total revenue, export intensity, and import intensity are assumed to be measured with error. We also allow for labor augmented technological change at the annual rate of α_t. Modifying the revenue functions and the intermediate demand functions by incorporating measurement error and a time trend, we use equations (3), (6), and (7) to specify the logarithm of the *observed* total revenue, export intensity, and import intensity as:

$$\begin{aligned}
\ln r_{it} &= \alpha_0 + \alpha_t t + \ln[1+\exp(z_x)]d_{it}^x + \alpha_m \ln[1+\exp(z_m)]d_{it}^m + \ln\varphi_i + \omega_{1,it}, && (24)\\
\ln N r_{it}^f/r_{it} &= \ln[\exp(z_x)/(1+\exp(z_x))] + \omega_{2,it}, \qquad \text{if } d_{it}^x = 1, && (25)\\
\ln X_{it}^m/X_{it} &= \alpha_m \ln[\exp(z_m)/(1+\exp(z_m)] + \omega_{3,it}, \qquad \text{if } d_{it}^m = 1, && (26)
\end{aligned}$$

where Nr_{it}^f/r_{it} is the observed ratio of export revenue to total revenue; X_{it}^m/X_{it} is the observed ratio of imported intermediate costs to total intermediate costs; and $\omega_{1,it}$, $\omega_{2,it}$, and $\omega_{3,it}$ are measurement errors in the total revenue, export intensity, and import intensity, respectively.

Given these specifications for revenue, (detrended) firm's profit may be expressed in terms of reduced-form parameters as:[13]

$$\pi(\varphi_i, d_{it}) = (1/\sigma)r(\varphi_i, d_{it}) - F(d_{it}), \tag{27}$$

[13] We consider a "detrended" version of firm's problem by using the trend-adjusted discount factor $\beta\exp(\alpha_t)$ in place of the discount factor β in solving the Bellman's equation.

where

$$\begin{aligned} r(\varphi_i, d_{it}) &= \exp(\alpha_0 + \ln[1+\exp(z_x)]d_{it}^x + \alpha_m \ln[1+\exp(z_m)]d_{it}^m + \ln\varphi_i) \\ F(d_{it}) &= f + \zeta^{d_{it}^x d_{it}^m}(f_x d_{it}^x + f_m d_{it}^m). \end{aligned} \tag{28}$$

The conditional choice probabilities (19)-(20) may be evaluated using the solution to the Bellman equations (16)-(18) with the profit function (27).

We assume that, conditional on $(\varphi_i, d_{it}^x, d_{it}^m)$, $\omega_{it} \equiv (\omega_{1,it}, \omega_{2,it}, \omega_{3,it})'$ is randomly drawn from $N(0, \Sigma_\omega)$ and we denote its probability density function by $g_\omega(\cdot)$. We reparametrize Σ_ω using the unique lower triangular Cholesky decomposition as $\Sigma_\omega = \Lambda_\omega \Lambda_\omega'$ and denote the (j,k)-th component of Λ_ω by $\lambda_{j,k}$. Since whether we observe the export/import intensities or not depends on the export/import choices, the likelihood contribution from ω_{it} depends on the decision d_{it}. In the appendix, we derive the conditional density function for *observed* components of ω_{it} conditional on d_{it} and we denote it by $g_\omega(\omega_{it}|d_{it})$.

Denote the parameter to be estimated by

$$\theta = (\alpha_0, \alpha_t, f, f_x, f_m, \zeta, \alpha_m, z_m, z_x, \xi, \varrho^\chi, \varrho^D, \varrho^d, \sigma_\varphi, \lambda_{11}, \lambda_{21}, \lambda_{22}, \lambda_{31}, \lambda_{32}, \lambda_{33})'.$$

The parameter θ is estimated by the method of maximum likelihood.[14]

Let $T_{i,0}$ be the first year in which firm i appears in the data. Conditioning on φ_i, the likelihood contribution from the observation of plant i for $t > T_{i,0}$ is computed as:

$$L_{it}(\theta|\varphi_i) = \begin{cases} P(\chi_{it}=0|\varphi_i) & \text{for } \chi_{it}=0, \\ \underbrace{P(\chi_{it}=1|\varphi_i)}_{\text{Staying}} \underbrace{P(d_{it}|\varphi_i, \chi_{it}=1)}_{\text{Export/Import}} \underbrace{g_\omega(\tilde{\omega}_{it}(\varphi_i)|d_{it})}_{\text{Revenue/Intensity}} & \text{for } \chi_{it}=1, \end{cases}$$

where $g_\omega(\tilde{\omega}_{it}(\varphi_i)|d_{it})$ is the likelihood contribution from the observations of revenues, export intensity, and import intensity (see the appendix). Note that, in estimating the revenue function (24), the endogeneity of export/import decisions as well as the sample selection due to endogenous exiting decisions are dealt with by simultaneously considering the likelihood contribution from export/import/exiting decisions.

For the initial period of $t = T_{i,0}$, we observe a plant that decided to stay in the market so

[14]The discount factor β is not estimated but is set to 0.95. It is difficult to identify the discount factor β in dynamic discrete choice models (c.f., Rust, 1987).

that the likelihood is conditioned on $\chi_{it} = 1$,

$$L_{it}(\theta|\varphi_i) = P(d_{it}|\varphi_i, \chi_{it} = 1)g_\omega(\tilde{\omega}_{it}(\varphi_i)|d_{it}).$$

The likelihood contribution from plant i conditioned on φ_i is

$$L_i(\theta|\varphi_i) = \prod_{t=T_{i,0}}^{T_{i,1}} L_{it}(\theta|\varphi_i),$$

where $T_{i,1}$ is the last year in which firm i appears in the data.

Since we do not observe φ_i, we integrate out the unobserved φ_i to compute the likelihood contribution from plant i observation. The distribution of φ_i crucially depends on whether a plant is observed in the initial sample period or not. If plant i is observed in the initial sample period, we integrate out φ_i using the stationary distribution $g_\varphi^*(\varphi)$ given in (22) while, if plant i enters into the sample after the initial sample period, we use the distribution of initial draws upon successful entry given by $g_e(\varphi) = \frac{P(\chi=1|\varphi)}{\int P(\chi=1|\varphi')g_\varphi(\varphi')d\varphi'} g_\varphi(\varphi)$. Thus, the likelihood contribution from plant i is

$$L_i(\theta) = \begin{cases} \int L_i(\theta|\varphi')g_\varphi^*(\varphi')d\varphi' & \text{for } T_{i,0} = 1990, \\ \int L_i(\theta|\varphi')g_e(\varphi')d\varphi' & \text{for } T_{i,0} > 1990. \end{cases}$$

The parameter vector θ can be estimated by maximizing the logarithm of the likelihood function

$$\mathcal{L}(\theta) = \sum_{i=1}^{N} \ln L_i(\theta). \tag{29}$$

Evaluation of the log-likelihood involves solving the dynamic programming problem that approximates the Bellman equations (16)-(18) by discretization of state space.[15] For each candidate parameter vector θ, we solve the discretized version of (16)-(18) and then obtain the choice probabilities, (19) and (20), as well as the stationary distribution from the associated policy function. Once the choice probabilities and the stationary distribution are obtained for a particular candidate parameter vector θ, we may then evaluate the log-likelihood function (29). Repeating this process, we can maximize (29) over the parameter space of θ to find the estimate.

[15] We use the Gauss-Quadrature method with 30 grid points to approximate the state space of φ.

4.3 Reduced-form vs. Structural Parameters

It is important to note that equations (24)-(26) are *reduced-form* specifications. In particular, we have the following relationships between reduced-form parameters and structural parameters:[16]

$$\begin{aligned}\alpha_0 &= \ln\left[(\Gamma(\sigma-1)/\sigma)^{\sigma-1}RP^{\sigma-1}\right],\\ \alpha_m &= \frac{(\sigma-1)(1-\alpha)}{\gamma-1}.\end{aligned}$$

Since α_0 and α_m are not structural parameters, they could be affected by policy changes. In particular, any policy change that will affect the aggregate price P will lead to a change in α_0. Identifying such a relationship is especially important in conducting counterfactual experiments. As we discuss later, counterfactual policy experiments in this paper explicitly take into account equilibrium price responses using our knowledge of the relationship between the reduced-form parameter α_0 and the aggregate price P.

4.4 Identification

The identification of parameters in revenue function (24) follows from the within-plant variations in d_{it}^x and d_{it}^x together with the moment restriction $E[\omega_{1,it}-\omega_{1,i(t-1)}|d_i^x, d_i^m]=0$ obtained from taking first differences in (24). Furthermore, the moment condition $E[\omega_{3,it}|d_{it}^m=1]=0$ from (26) provides one more restriction on the relationship between α_m and z_m and, thus, α_m and z_m are separately identified.

Having identified the revenue function (24), we may identify the fixed cost of operating f and the scale parameter ϱ^χ for exiting shocks as follows. For simplicity, suppose that the time-dimension is long enough to identify the value of plant-specific productivity φ for each plant from revenue observations using equation (24).[17] Then, since the exiting probabilities are strictly increasing in the fixed cost of operating f, the variation of plant-specific productivity φ and how the values of φ's relate to exiting probabilities identify the parameter f. Furthermore, the elasticities of exiting probabilities with respect to the value of productivity φ tend to decrease as the variance of exiting shocks increases; thus, the variation of φ's and the difference in exiting

[16] Also, with abuse of notation, we replace $(\sigma-1)\ln\varphi$ by $\ln\varphi$ since $(\sigma-1)$ cannot be separately identified from the variance of $\ln\varphi$.

[17] In practice, the time-dimension is short but, under the distributional assumption on φ, we may identify each plant's likelihood for having a particular value of φ.

probabilities across different φ's identify the scale parameter ϱ^{χ} separately from the parameter f.[18] Using the similar identification scheme, we may identify the other fixed cost and scale parameters from the variation of φ's and the variation of export/import probabilities.

In discrete choice models, the scale of profit function cannot be identified because multiplying the profit function of each alternative by a positive constant does not change the optimal choice. For identification, we normalize the profit function (28).[19]

4.5 Extended Model with Heterogeneous Transportation Costs

Shipping costs may differ across plants, depending on where they locate and what kinds of goods they produce and purchase. In this section, we extend the basic model by incorporating heterogeneity in the iceberg shipping costs of exporting and importing.

There are at least two reasons why we are particularly interested in this extension. First, as reported in Section 2, export and import intensities differ substantially across plants in the data but the basic model is unable to explain such differences. Heterogeneity in shipping costs may be part of the reason why different plants choose different export/import intensities.[20] Second, it may provide an additional reason why some plants export or import while others do not; that is, two plants with identical productivity may make different export/import choices because they differ in their transportation costs. If we ignore heterogeneity in transportation costs, we may possibly overestimate the importance of heterogeneity in productivity in explaining heterogeneous export/import choices and its role in resource allocation across plants.

Our assumptions on heterogeneous transportation costs are similar to those on heterogeneous productivity. In particular, we assume that plant-specific transportation costs are drawn upon entry and they are constant after the initial draw. Note from (23) that heterogeneity in transportation costs, τ_x and τ_m, translates into heterogeneity in z_x and z_m. We make distributional assumptions that, conditional on $\ln \varphi$, the random variables z_x and z_m are independent of each other and drawn at the time of entry from normal distributions with the means μ_x and μ_m and the variances σ_x^2 and σ_m^2, respectively.

[18]The variance of exiting shocks is related to the scale parameter ϱ^{χ} as $Var(\epsilon^{\chi}(\chi)) = \frac{(\varrho^{\chi}\pi)^2}{6}$.

[19]Specifically, our normalization is such that, multiplying the profit function by σ, we estimate $\sigma\varrho^{\chi}$, $\sigma\varrho^{D}$, $\sigma\varrho^{d}$, σf, σf_x, and σf_m instead of ϱ^{χ}, ϱ^{D}, ϱ^{d}, f, f_x, and f_x.

[20]Heterogeneity in export and import intensities may also be because plants differ in the number of trading countries as Eaton, Kortum, and Kramarz (2004) find in French data. Unfortunately, due to data limitations, we are unable to determine with which countries a plant is trading.

Thus, a plant's type is characterized by a vector $\eta_i = (\ln \varphi_i, z_{x,i}, z_{m,i})'$ in the extended model. The parameter vector to be estimated in the extended model is

$$\theta = (\alpha_0, \alpha_t, f, f_x, f_m, \zeta_f, \alpha_m, \xi, \varrho^{\chi}, \varrho^{D}, \varrho^{d}, \sigma_{\varphi}, \mu_x, \mu_m, \sigma_x, \sigma_m, \lambda_{11}, \lambda_{21}, \lambda_{22}, \lambda_{31}, \lambda_{32}, \lambda_{33})'.$$

The distributional parameters for z_x and z_m are identified from export/import intensity observations in equations (25)-(26). We omit the details of the estimation procedure for the extended model as it is very similar to that of the basic model.

4.6 Data

We use the Chilean manufacturing census for 1990-1996 which covers all plants with at least 10 employees.[21] Our data set consists of unbalanced panel of 7231 plants, including all plants that have been observed at least one year between 1990 and 1996.[22] The original data set is available from 1979 to 1996 but the value of export sales is reported only after 1990 and, thus, we exclude the period before 1990. A detailed description of the data as well as Chilean industry trade orientation up to 1986 is found in Liu (1993), Tybout (1996), and Pavcnik (2002).

We focus on the following seven observable variables: χ_{it}, r_{it}, Nr^f_{it}, X_{it}, X^m_{it}, d^x_{it}, and d^m_{it}, where i represents plant's identification and t represents the year t. We use the real values of total sales for r_{it}, where the manufacturing output price deflater is used to convert the nominal value into the real value. Our measurement of intermediate inputs, X_{it}, include materials, fuels, and electricity while we use the reported value of imported materials for X^m_{it}. Accordingly, the import intensity X^m_{it}/X_{it} is measured by the ratio of imported materials to total intermediate costs. On the other hand, the export intensity Nr^f_{it}/r_{it} is measured by the ratio of export sales to total sales. The export/import status, (d^m_{it}, d^x_{it}), is identified from the data by checking if the value of export sales and/or the value of imported materials are zero or positive. The entry/exiting decisions, χ_{it}, can be identified in the data by looking at the number of workers across years.

[21]A unit of observation in our sample is a plant not a firm. This is due to limitations of our data set. Unfortunately, we are unable to capture the extent to which multi-plant firms make joint decisions on exporting and importing across different plants they own. Neither are we able to examine whether or not a plant belongs to multinational firm although exporting and importing by multinational firms are important topics (e.g., Helpman et al., 2004; Yi, 2003).

[22]Three plant observations are dropped out of the sample because their values of intermediate inputs are zero at least in one year.

Table 5: Descriptive Statistics

	Total Sales[a]	Intermediate Inputs[a]	Labour	Export Sales[a,b]	Imported Inputs[a,b]	Export Intensity[b]	Import Intensity[b]	Entry Rates[c]	Exiting Rates[d]
1990	5,025	3,082	80.7	5,682	1,622	0.30	0.29	—	—
	(33,443)	(23,613)	(151.5)	(33,770)	(4,599)	(0.33)	(0.25)	—	—
1991	4,974	3,685	80.4	4,115	1,693	0.26	0.29	0.08	0.05
	(29,875)	(24,322)	(153.2)	(20,855)	(4,663)	(0.32)	(0.26)	—	—
1992	5,280	4,250	82.0	4,595	1,655	0.25	0.29	0.07	0.06
	(30,322)	(26,440)	(163.7)	(26,820)	(4,059)	(0.30)	(0.24)	—	—
1993	5,452	4,684	81.9	3,953	1,794	0.25	0.29	0.07	0.07
	(29,744)	(27,337)	(156.3)	(17,142)	(6,474)	(0.30)	(0.24)	—	—
1994	5,613	5,268	81.7	4,274	1,957	0.23	0.29	0.06	0.06
	(29,523)	(30,531)	(156.2)	(19,514)	(13,061)	(0.28)	(0.25)	—	—
1995	5,982	5,981	81.6	4,959	2,298	0.25	0.29	0.08	0.08
	(29,947)	(32,636)	(151.5)	(20,387)	(15,456)	(0.29)	(0.25)	—	—
1996	6,068	6,245	76.9	4,832	1,805	0.25	0.29	0.14	0.08
	(31,367)	(35,738)	(143.0)	(17,205)	(4,912)	(0.29)	(0.25)	—	—
1990-96 ave	5,485	4,742	80.8	4,630	1,832	0.25	0.29	0.08	0.06

Notes: Reported numbers are sample means (standard deviations in parentheses). (a) in the unit of thousand US dollars in 1990. (b) computed using the sample of exporting (importing) plants for export (import) intensity. (c) the number of new entrants divided by the total number of plants. (d) the number of exiting plants divided by the total number of plants.

Descriptive statistics in addition to those presented in Section 2 are provided in Table 5. Examining the standard deviations for total sales, export sales, and various inputs, we note that the production scale varies substantially across plants. Neither export intensity nor import intensity appears to have any trend; from the viewpoint of the model, this suggests no trend in transportation costs during this period. There are substantial plant turnovers every year; on average, 424 plants enter into the market every year while 344 plants exit from the market. Having a large number of entrants and exiting plants in the sample is important for identifying the parameters determining the exiting choice probabilities as well as the distribution of initial productivity draws.

4.7 Estimation Results

Table 6 presents the maximum likelihood estimates of the empirical models and their asymptotic standard errors, which are computed using the outer product of gradients estimator. The parameters are evaluated in units of millions of US dollars in 1990. The standard errors are generally small. We first discuss the results of the basic model in detail and then compare them with those of the extended model.

Table 6: Maximum Likelihood Estimates

Parameters	Basic Model		Extended Model	
α_0	-0.804	(0.003)	-0.456	(0.003)
σf	3.270	(0.132)	7.575	(1.072)
σf_x	1.196	(0.028)	0.127	(0.001)
σf_m	0.881	(0.021)	0.088	(0.001)
ζ	0.740	(0.007)	0.886	(0.005)
$\sigma \varrho^d$	0.209	(0.004)	0.0186	(0.0003)
$\sigma \varrho^D$	0.741	(0.017)	0.0518	(0.0009)
$\sigma \varrho^\chi$	47.998	(1.323)	202.854	(16.061)
α_t	0.040	(0.001)	0.040	(0.001)
ξ	0.0016	(0.0001)	0.0039	(0.0008)
α_m	0.719	(0.006)	0.595	(0.003)
λ_{11}	0.333	(0.001)	0.338	(0.001)
λ_{22}	1.856	(0.014)	1.103	(0.006)
λ_{21}	0.030	(0.023)	0.190	(0.012)
λ_{33}	1.192	(0.007)	0.865	(0.005)
λ_{32}	-0.346	(0.014)	0.098	(0.016)
λ_{31}	-0.130	(0.013)	0.140	(0.009)
σ_φ	0.964	(0.001)	1.061	(0.001)
z_x	-2.534	(0.014)		
z_m	-2.358	(0.020)		
μ_x			-4.439	(0.016)
μ_m			-4.099	(0.020)
σ_x			1.863	(0.009)
σ_m			1.760	(0.013)
σf_e	122.00		540.50	
log-likelihood	-91305.27		-79236.27	
No. of Plants	7231			

Notes: Standard errors are in parentheses. The parameters are evaluated in the unit of million US dollars in 1990.

4.7.1 Results of the Basic Model

In the basic model, the estimated fixed cost of operating in the market is $\hat{f} = 3.27/\sigma$ million US dollars. If, say, $\sigma = 5$, (which implies a mark-up for final goods equal to approximately 25%) then the estimated fixed cost is approximately equal to 622 thousand dollars. The estimated fixed costs for export and import are also substantial: $\hat{f}_x = 1.20/\sigma$ and $\hat{f}_m = 0.88/\sigma$. The parameter determining the degree of complementarity in fixed export and import costs, ζ, is estimated as 0.740, indicating that a firm can save more than 26 percent of per-period fixed cost associated with trade by engaging in both export and import activities.

The estimated magnitudes of the shocks associated with the exiting decision and the export/import decisions are substantial relative to the per-period profit. The estimate of $\rho^d = 0.21/\sigma$ implies the standard error of $\frac{\pi}{\sqrt{6}} \times 0.21/\sigma = 0.27/\sigma$ in export/import cost shocks, which is more than one-sixth of the average incumbent's profit from domestic sales.[23] The estimate of $\rho^D = 0.74/\sigma$ is more than three times as large as that of ρ^d. The estimate of ρ^χ is much larger than ρ^d or ρ^D and implies that the standard error of the shocks associated with the exiting decision is $\frac{\pi}{\sqrt{6}} \times 48.00/\sigma = 61.56/\sigma$, which is more than 50 times as large as the average incumbent's profit from domestic sales.[24]

The estimates of α_m, z_m, and z_x indicate that importing materials from abroad has a substantial impact of a 6.5[$= \hat{\alpha}^m \ln(1 + \exp(\hat{z}_m))$] percent increase on the total revenues while exporting increases the total revenues by 7.6[$= \ln(1 + \exp(\hat{z}_x))$] percent. These estimates are similar in magnitude to the estimates in Table 4 based on the fixed effects regression.[25] In particular, the regression results on total sales in Table 4 suggest that the import premia are 5-7% while the export premia are 8-11%.

These estimates also imply an average export intensity equal to 7.3% and an average import intensity equal to 17.2%. Thus the model is broadly consistent with the relatively low levels of these variables as documented in Section 2 and by other authors for exports (see, for example,

[23] The average productivity at the steady state is $\phi = 2.64$. Then, the average incumbent's profit from domestic sales is computed as $1.18/\sigma[= (1/\sigma)\exp(\hat{\alpha}_0) \times 2.64]$.

[24] The standard error of the exiting shocks is even larger for the extended model. A different source of unobserved heterogeneity, such as permanent heterogeneity in the per-period fixed cost of operating, may be part of the explanation for this large standard error. Other possibilities are to consider more realistic productivity dynamics, such as those based on the first order autoregressive process, as well as to incorporate the sunk costs for exporting and importing. These extensions are the focus of our future work.

[25] The fixed effects regression controls for endogeneity of export/import decisions but does not control for sample selection due to endogenous exiting decisions.

Table 7: Mean of Productivity

	Basic Model	Extended Model
Mean of φ at Entry Trial	1.000	1.000
Mean of φ among All plants at Steady State	2.639	1.387
Mean of φ among Exporters at Steady State	6.567	3.356
Mean of φ among Importers at Steady State	6.071	3.170
Mean of φ among Ex/Importers at Steady State	8.105	4.511

Notes: The reported numbers are relative to the productivity level at entry. In particular, the original numbers are divided by the mean of φ at entry (i.e., $\int \varphi g_\varphi(\varphi)d\varphi$). "Exporters" are plants that export while "Importers" are plants that import. "Ex/Importers" represent plants that both export and import.

Brooks, 2005). However, these values are well below the means of 25% and 29% reported in Section 2.

In the model, firms with higher productivity are more likely to survive than lower productivity firms. Table 7 shows how important such a selection mechanism is.[26] The average productivity among incumbents at the steady state is 2.6 times as high as the average productivity across initial draws in the basic model, indicating that the selection through endogenous exiting plays an important role in determining aggregate productivity. Furthermore, as the last three rows show, higher productivity firms are more likely to export and import. Both exporters and importers are more than twice as productive as the average firm at the steady state while the firms that both export and import are about three times as productive as the average.

4.7.2 Results of the Extended Model

We now discuss the results of the extended model with heterogeneous transportation costs. We focus our discussion on the major differences between the basic and extended models while comparing the predictions of these two models with the actual data.

In Table 6, comparing μ_x and μ_m in the extended model with z_x and z_m in the basic model, we note that the estimated means of transportation costs in the extended model are much larger than those in the basic model. In particular, for an "average" plant with $z_x = \hat{\mu}_x$ and $z_m = \hat{\mu}_m$, exporting increases total revenue by only 1.2$[= \ln(1 + \exp(\hat{\mu}_x))]$ percent while importing has a small impact of a 1.0$[= \hat{\alpha}^m \ln(1 + \exp(\hat{\mu}_m))]$ percent. Thus, for many plants, the gains from exporting and importing are quite low, providing an explanation for why a large fraction of

[26] The numbers reported in Tables 7-12 are directly computed using the approximated stationary density function based on equation (22) rather than simulating the data from the estimated models. The approximation methods are presented in an appendix which is available upon request.

plants are neither exporting nor importing. Nonetheless, because of substantial heterogeneity in transportation costs as indicated by the estimates of σ_x and σ_m, a non-negligible fraction of plants face small transportation costs and are willing to engage in export and import activities.

The estimated fixed costs for export and import, f_x and f_m, in the extended model are approximately one-tenth of the estimates in the basic model. Large fixed costs for export and import are needed in the basic model to explain the fact that only a small fraction of plants export and/or import. On the other hand, as discussed above, the low estimates for μ_x and μ_m in the extended model imply that many plants have little incentive to export or import and, therefore, many plants do not engage in trade even under the small values of fixed costs, f_x and f_m.

In Table 7, the average productivity at the steady state is 1.4 times as high as the average across initial draws in the extended model, which is still substantial but much lower than that of the basic model. In the extended model, some low productivity plants may not exit if their gains from trade is large due to their low transportation costs. As a result, the distribution of productivity at the steady state is more skewed toward the left in the extended model, leading to the lower average productivity.

Table 8 compares the actual and the predicted distribution of export/import status as well as market shares across different export/import states. In the data, while 68.6% of plants are neither exporting nor importing, their market shares account only for a 22.7% of total output. On the other hand, only 10.8% of plants are both exporting and importing but they account for 44.1% of total output. Both empirical models qualitatively replicate these cross-sectional patterns of exporters and importers although there are differences between the actual and predicted magnitudes for market shares.

In Table 9, the extended model performs much better than the basic model in quantitatively capturing the observed high degree of trade concentration. While in the actual data the top 1 percent of exporting plants account for 38.9 percent of total exports, in the basic model they account only for 5.2 percent. On the other hand, the prediction of the extended model matches the actual data quite well, quantitatively replicating the high degree of concentration of total exports. Similarly, in replicating the high degree of import concentration, the extended model substantially outperforms the basic model. The results indicate that the heterogeneity in productivity is not enough to replicate the observed magnitude of trade concentration; the

Table 8: Distribution of Export/Import Status and Market Shares (Actual vs. Predicted)

	Export/Import Status					
	(1) No-Export /No-Import	(2) Export /No-Import	(3) No-Export /Import	(4) Export /Import	(2)+(4) Export	(3)+(4) Import
Actual						
Dist. of Ex/Im Status	0.686	0.086	0.120	0.108	0.194	0.228
Market Share	0.227	0.187	0.145	0.441	0.628	0.586
Basic Model						
Dist. of Ex/Im Status	0.695	0.089	0.129	0.088	0.177	0.216
Market Share	0.060	0.259	0.237	0.444	0.703	0.681
Extended Model						
Dist. of Ex/Im Status	0.713	0.087	0.114	0.087	0.173	0.200
Market Share	0.344	0.144	0.165	0.347	0.490	0.512

Table 9: Export and Import Concentration (Actual vs. Predicted)

	Actual		Basic Model		Extended Model	
	% of Total Exports	% of Total Imports	% of Total Exports	% of Total Imports	% of Total Exports	% of Total Imports
Top 1%	39.8	25.8	5.2	5.4	39.8	19.3
Top 5%	67.3	51.3	19.6	19.7	71.6	41.6
Top 10%	80.1	65.8	30.0	31.1	80.7	54.7

heterogeneity in transportation costs is crucial to quantitatively explain the heavy concentration of exports and imports among a small number of plants in our data.

Table 10 reports the actual and the predicted mean, standard error, and skewness of the distributions for export and import intensities as well as correlation between the export intensity and the import intensity among exporters and/or importers. The extended model replicates the actual mean of export and import intensities better than the basic model although the extended model still under-predicts the actual mean of export intensities.

Looking at the last two columns of Table 10, we notice that the distribution of export/import intensities among all plants are quite different from the distribution among those who engage in export and import activities. For instance, while the mean of export (import) intensities for all plants is only a 4.7 (13.4) percent, the mean of import intensities among importers is a 16.1 (26.9) percent, indicating that plants with high export and import intensities tend to self-select into exporting and importing.

Table 10: Distribution of Export Intensity and Import Intensity (Actual vs. Predicted)

	Actual	Predicted by Basic Model	Predicted by Extended Model	
Export Intensity	Exporters	Exporters	Exporters	All Plants at SS
Mean	0.252	0.073	0.161	0.047
Standard Error	0.302	—	0.188	0.101
Skewness	1.035	—	1.861	4.484
Import Intensity	Importers	Importers	Importers	All Plants at SS
Mean	0.290	0.172	0.269	0.134
Standard Error	0.249	—	0.167	0.138
Skewness	0.963	—	0.949	2.183
Export/Import Intensity	Ex/Importers	Ex/Importers	Ex/Importers	All Plants at SS
$Corr(r_f/r, x_m/x)$	-0.239	—	-0.120	0.005

"All Plants at SS" refers to all plants at the steady state regardless of their export and import status while "Ex/Importers" refers to plants that both export and import.

4.8 Counterfactual Experiments

We now present the results of a series of counterfactual experiments which examine the effect of trade barriers. To determine the full impact of a counterfactual experiment, it is crucial to compute how the equilibrium aggregate price changes as a result of the experiment. This can be done by finding a new equilibrium aggregate price at which the free entry condition (21) holds in the experiment. The appendix provides a detailed description of how we compute the equilibrium aggregate price under a counterfactual experiment; it is shown that we may identify the logarithm of the equilibrium price change up to the parameter $(\sigma - 1)$.

To quantitatively investigate the impact of international trade and export/import complementarities, we conduct four counterfactual experiments with the following counterfactual parameters:

(1) No Trade in Final Goods: $f_x \to \infty$.

(2) No Trade in Intermediate Goods: $f_m \to \infty$.

(3) Autarky: $f_x, f_m \to \infty$.

(4) No Complementarity in Fixed Trading Costs: $\zeta = 1$.

Note that we can investigate the impact of counterfactual experiments on welfare by examining the aggregate price response. This is so because the aggregate price is inversely related to welfare.[27]

Table 11: Counterfactual Experiments (Basic Model)

	Free Trade	Counterfactual Experiments (1) No Trade in Final Goods	(2) No Trade in Intermediates	(3) Autarky	(4) No Comp.
With Equilibrium Price Effect					
$\Delta(\sigma-1)\ln P$	0.000	0.056	0.059	0.061	0.019
ln(Average φ) at Steady State	0.000	-0.017	-0.017	-0.030	-0.002
ln(Average $\varphi(1+exp(z_m)d_m)^{\alpha_m}$)	0.000	-0.036	-0.063	-0.076	-0.009
A Fraction of Exporters	0.177	0.000	0.024	0.000	0.125
A Fraction of Importers	0.216	0.051	0.000	0.000	0.160
Market Shares of Exporters	0.462	0.000	0.146	0.000	0.366
Market Shares of Importers	0.518	0.224	0.000	0.000	0.425
Without Equilibrium Price Effect					
ln(Average φ) at Steady State	0.000	-0.005	-0.004	-0.016	0.002
ln(Average $\varphi(1+exp(z_m)d_m)^{\alpha_m}$)	0.000	-0.024	-0.050	-0.062	-0.004
A Fraction of Exporters	0.177	0.000	0.021	0.000	0.123
A Fraction of Importers	0.216	0.047	0.000	0.000	0.157
Market Shares of Exporters	0.462	0.000	0.134	0.000	0.363
Market Shares of Importers	0.518	0.210	0.000	0.000	0.421

Note: "Average φ" at Steady State is a productivity average using the plants' combined revenues (or market shares) as weights: $\int \sum_d \varphi^{\sigma-1} \frac{r(\varphi,d)P(d|\varphi)}{\int \sum_{d'} r(\varphi',d')P(d'|\varphi')dg^*_\varphi(\varphi')} dg^*_\varphi(\varphi)$.

Table 12: Counterfactual Experiments (Extended Model)

	Free Trade	Counterfactual Experiments (1) No Trade in Final Goods	(2) No Trade in Intermediates	(3) Autarky	(4) No Comp.
With Equilibrium Price Effect					
$\Delta(1-\sigma)\ln P$	0.000	0.062	0.032	0.090	0.001
ln(Average φ) at Steady State	0.000	0.012	-0.008	0.001	0.001
ln(Average $\varphi(1+exp(z_m)d_m)^{\alpha_m}$)	0.000	0.014	-0.090	-0.082	0.001
A Fraction of Exporters	0.173	0.000	0.124	0.000	0.160
A Fraction of Importers	0.200	0.141	0.000	0.000	0.184
Market Shares of Exporters	0.490	0.000	0.421	0.000	0.469
Market Shares of Importers	0.512	0.408	0.000	0.000	0.484
Without Equilibrium Price Effect					
ln(Average φ) at Steady State	0.000	-0.007	-0.016	-0.028	0.000
ln(Average $\varphi(1+exp(z_m)d_m)^{\alpha_m}$)	0.000	-0.005	-0.099	-0.111	0.000
A Fraction of Exporters	0.173	0.000	0.120	0.000	0.160
A Fraction of Importers	0.200	0.133	0.000	0.000	0.184
Market Shares of Exporters	0.490	0.000	0.412	0.000	0.469
Market Shares of Importers	0.512	0.390	0.000	0.000	0.484

Note: "Average φ" at Steady State is a productivity average using the plants' combined revenues (or market shares) as weights: $\int \sum_d \varphi^{\sigma-1} \frac{r(\eta,d)P(d|\eta)}{\int \sum_{d'} r(\eta',d')P(d'|\eta')dg^*_\eta(\eta')} dg^*_\eta(\eta)$.

Table 11 presents the results of counterfactual experiments using the estimated basic model. To examine the importance of the equilibrium price response, we report results both with and without the price response. According to the experiment, moving from autarky to trade decreases the equilibrium aggregate price by $6.1/(\sigma - 1)$ percent. This implies that if $\sigma = 5$, exposure to full trade increases real income by (6.1/4=)1.52%, leading to a substantial increase in welfare. This positive welfare effects occurs because under trade, more productive firms start exporting and importing, which in turn increases aggregate labor demand and the real wage.

The impact of trade on aggregate inherent productivity—measured by a productivity average using the plants' market shares as weights—can be understood by comparing "ln(Average φ) at Steady State" between trade and autarky. Moving from trade to autarky leads to a 3.0% decrease in this measure of aggregate productivity at the steady state. We also see a fall in productivity under partial trade barriers. In the fourth and eleventh rows of Table 11, we also report the effect of trade on a measure of aggregate productivity which includes the positive productivity effect from importing intermediates. Finally, by comparing between the experiments with and without equilibrium price responses, we clearly see the importance of the equilibrium price response to quantitatively explain the impact of trade on aggregate productivity.

The counterfactual experiments under no trade in final goods or no trade in intermediates (but not both) highlight the interaction between exporting and importing in the presence of heterogeneous firms. According to the estimated basic model, when the economy moves from full trade to no trade in intermediates, the fraction of *exporters* declines from a 17.7% to 2.4%. Similarly, when the economy moves from full trade to no trade in final goods, the fraction of *importers* declines from a 21.6% to 5.1%. In terms of market shares, moving from trade to no intermediate trade leads to a decrease in the total market shares of *exporters* from 46.2% to 14.6% while moving from trade to no trade in final goods leads to a decrease in the total market shares of *importers* from 51.8% to 22.4%. Thus, policies that prohibit the import of foreign materials could have a large negative impact on the export of final consumption goods, and vice-versa.

To examine the role of complementarities between export and import fixed costs relative to the role played by the complementarities in the revenue function, we conducted an experiment

[27] Recall that aggregate income is constant at the level of L. From the budget constraint $PQ = L$ we have that aggregate utility is given by $U = Q = P^{-1}L$.

to determine what would happen to the fraction of importers and/or the fraction of exporters had there been no complementarity between export and import in the fixed cost function. Eliminating the fixed cost complementarity also lowers the fraction of exporters and importers, as expected, but the impact is less than under trade restrictions. These results suggest that both forms of complementarities are present.

We now examine the results from the extended model, reported in Table 12, and compare them with the results from the basic model. The estimated welfare effect of exposure to trade in the extended model is larger than in the basic model; the experiment implies that, if $\sigma = 5$, then moving from autarky to trade increases real income by (9.0/4=)2.25% in the extended model as opposed to 1.52% in the basic model. Unobserved heterogeneity in transportation costs provides an additional source of gains from trade; plants with low transportation costs self-select into export and import activities and, as a result, resource are reallocated toward exporters and importers who have advantages in exporting and importing.

The equilibrium impact of trade on aggregate productivity reported in "ln(Average φ)" is almost zero in the extended model. Note that the impact of trade on aggregate productivity without an equilibrium price effect is a 2.8% but the equilibrium price response has a negative impact on aggregate productivity, offsetting the "partial equilibrium" effect of trade on aggregate productivity in the extended model.[28] This result qualitatively contrasts with the result from the basic model.

Once we take into account the additional productivity effect from importing, however, the equilibrium impact of trade on aggregate productivity is 8.2% in the extended model while it is 7.6% in the basic model, as reported in the fourth row of Tables 11-12. In the extended model, heterogeneity in productivity gains from importing plays a major role in redistributing resources and determining aggregate productivity. Moving from autarky to trade causes plants who have higher productivity gains from importing to self-select into importing; as a result, resources are reallocated toward importing plants who achieved higher productivity gains from importing, leading to an increase in aggregate productivity.

Moving from free trade to no trade in intermediate goods, the fraction of exporters declines

[28]When the aggregate price decreases (or the real wage increases) as a result of moving from autarky to trade, resource are reallocated toward not only highly productive plants but also toward plants with low transportation costs. Since plants with low transportation costs are not necessarily the ones with high productivity, it is not clear ex-ante whether the impact of a decrease in the aggregate price on aggregate productivity is positive or negative.

from 17.3% to 12.4 % while the market shares of exporters decline from 49.0% to 42.1%. Thus, shutting down intermediate goods trade has a negative impact on exporting in the extended model but its magnitude is much smaller than in the basic model. Similarly, when the economy moves from free trade to no trade in final goods, the fraction of importers as well as the market shares of importers decline in the extended model but by a smaller magnitude than in the basic model.

In the extended model, eliminating the complementarity in the fixed cost function lowers the fraction of exporters or importers but not as much as in the case of no trade in intermediate goods or no trade in final goods. Thus, as in the basic model, both the complementarities in the revenue function and the complementarities in the fixed cost function are important for capturing the interaction between exporting and importing.

To briefly summarize the results of the counterfactual experiments, we find that trade barriers have a substantial negative effect on aggregate welfare and aggregate productivity. Furthermore, the experiments suggest that there are significant revenue and cost complementarities between the exportation of final goods and the importation of intermediate goods. Thus, policies which restrict imports of intermediates harm exporters of final goods and restricting exports of those goods decreases the ability of firms to use productivity-enhancing imported intermediates.

5 Conclusions and Extensions

We have developed and estimated a stochastic industry model of importing and exporting with heterogeneous firms. The analysis highlights interactions between imports of intermediate goods and exports of final goods. In doing so, we have identified a potential mechanism whereby import policy can affect exports and export policy can affect imports.

Our model has a simple parsimonious structure and, yet, is able to replicate the basic features of the plant-level data. To maintain its parsimony, and also because of data limitations and computational complexity, the model ignores several important features. In estimation, we treat manufacturing as a single industry although there are possibly differences across more narrowly defined industries in some of the parameter values. Because we mainly focus on the cross-sectional steady state implications, we do not distinguish between per-period fixed costs and the one time sunk costs despite empirical evidence of sunk costs for exporting and importing (e.g., Roberts and Tybout, 1997; Kasahara and Rodrigue, 2005). We also do not address the important issue of how multi-plant and multinational firms make joint decisions on exporting and importing across different plants. Finally, we ignore plant capital investment decisions. These features could be incorporated into our theoretical and empirical framework and such extensions are important topics for our future research.

A Appendix

A.1 Estimation of the Density Function

Conditioning on φ_i, we may compute the estimate of $\omega_{it} = (\omega_{1,it}, \omega_{2,it}, \omega_{3,it})'$ from (24)-(26) as

$$\begin{aligned}
\tilde{\omega}_{1,it}(\varphi_i) &= \ln r_{it} - \alpha_0 - \alpha_t - \ln[1+\exp(z_x)]d^x_{it} - \alpha_m \ln[1+\exp(z_m)]d^m_{it} - \ln \varphi_i, \\
\tilde{\omega}_{2,it}(\varphi_i) &= \ln r^f_{it}/r_{it} - \ln[\exp(z_x)/(1+\exp(z_x))], \\
\tilde{\omega}_{3,it}(\varphi_i) &= \ln x^m_{it}/x_{it} - \alpha_m \ln[\exp(z_m)/(1+\exp(z_m)].
\end{aligned}$$

Since whether we may observe $\tilde{\omega}_{2,it}$ and $\tilde{\omega}_{3,it}$ or not depends on the export/import choices, we use the following conditional density function to compute the likelihood contribution from revenues and export/import intensities:

$$g_\omega(\tilde{\omega}_{it}|d_{it}) = \begin{cases} g_{\omega_1}(\tilde{\omega}_{1,it}) & \text{for } d_{it} = (0,0), \\ g_{\omega_1}(\tilde{\omega}_{1,it}) g_{\omega_2|\omega_1}(\tilde{\omega}_{2,it}|\omega_{1,it}) & \text{for } d_{it} = (1,0), \\ g_{\omega_1}(\tilde{\omega}_{1,it}) g_{\omega_3|\omega_1}(\tilde{\omega}_{3,it}|\omega_{1,it}) & \text{for } d_{it} = (0,1), \\ g_\omega(\tilde{\omega}_{it}) & \text{for } d_{it} = (1,1), \end{cases}$$

where $g_{\omega_1}(\cdot)$ is a marginal distribution of $\omega_{1,it}$ while $g_{\omega_j|\omega_1}(\cdot|\omega_{1,it})$ is a conditional distribution of $\omega_{j,it}$ given $\omega_{1,it}$ for $j = 2, 3$. Specifically, given the lower triangular Cholesky decomposition of Σ_ω, we may write $(\omega_{1,it}, \omega_{2,it}, \omega_{3,it})' \equiv (\lambda_{11}\zeta_{1,it}, \lambda_{21}\zeta_{1,it} + \lambda_{22}\zeta_{2,it}, \lambda_{31}\zeta_{1,it} + \lambda_{32}\zeta_{2,it} + \lambda_{33}\zeta_{3,it})'$, where $\lambda_{m,n}$ is the (m,n)-th element of Λ_ω, and $\zeta_{j,it}$ is independently distributed $N(0,1)$ for all j, i, t. Then, $g_{\omega_j|\omega_1}(\tilde{\omega}_{j,it}|\tilde{\omega}_{1,it}) = \frac{1}{\sqrt{2\pi}\lambda_{jj}} \exp\left(-\frac{1}{2}\left(\frac{\tilde{\omega}_{j,it} - (\lambda_{j1}/\lambda_{11})\tilde{\omega}_{1,it}}{\lambda_{jj}}\right)^2\right)$ for $j = 2, 3$.

A.2 Counterfactual Experiments

Denote the equilibrium aggregate price under the parameter θ by $P(\theta)$. Suppose that we are interested in a counterfactual experiment characterized by a counterfactual parameter vector $\tilde{\theta}$ that is different from the estimated parameter vector $\hat{\theta}$. Recall that we have the following relationship between α_0 and the equilibrium price P:

$$\hat{\alpha}_0 = \ln\left[(\Gamma(\sigma-1)/\sigma)^{\sigma-1}R\right] + (\sigma-1)\ln P(\hat{\theta}),$$

where the aggregate price is explicitly written as a function of θ. At the counterfactual aggregate price $P(\tilde{\theta})$, the coefficient α_0 takes a value of

$$\tilde{\alpha}_0 = \ln\left[(\Gamma(\sigma-1)/\sigma)^{\sigma-1}R\right] + (\sigma-1)\ln P(\tilde{\theta}) = \hat{\alpha}_0 + k(\tilde{\theta},\hat{\theta}),$$

where

$$k(\tilde{\theta},\hat{\theta}) \equiv (\sigma-1)\ln\left(P(\tilde{\theta})/P(\hat{\theta})\right)$$

represents the equilibrium price change (up to the parameter $(\sigma-1)$).

Thus, replacing $\hat{\alpha}_0$ with $\tilde{\alpha}_0$, we may evaluate the revenue function (28) at the *counterfactual* aggregate price $P(\tilde{\theta})$ (i.e. at the counterfactual value of α_0):

$$r(\varphi_i, d_{it}; k(\tilde{\theta},\hat{\theta})) = \exp\left(k(\tilde{\theta},\hat{\theta}) + \hat{\alpha}_0 + \ln[1+\exp(z_x)]d_{it}^x + \hat{\alpha}_m \ln[1+\exp(z_m)]d_{it}^m + \ln\varphi_i\right). \quad (30)$$

The equilibrium price change, $k(\tilde{\theta},\hat{\theta})$, is then determined so that the following equilibrium free entry condition holds:

$$\hat{f}_e = \int V\left(\varphi'; \tilde{\theta}, k(\tilde{\theta},\hat{\theta})\right) g(\varphi';\tilde{\theta})d\varphi'.$$

Here $V\left(\varphi'; \tilde{\theta}, k(\tilde{\theta},\hat{\theta})\right)$ is the solution to the Bellman equations (16)-(18) when the revenue function (30) is used to compute profits and $g(\varphi';\tilde{\theta})$ is the normal probability density function from which the initial productivity is drawn.[29]

[29] For every pair $(\tilde{\theta},\hat{\theta})$, there exists a unique value of $k(\tilde{\theta},\hat{\theta})$ that satisfies the free entry condition because the value function $V(\varphi';\tilde{\theta},k(\tilde{\theta},\hat{\theta}))$ is strictly increasing in $k(\tilde{\theta},\hat{\theta})$.

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