Productivity and the Decision to Import and Export: Theory and Evidence*

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Abstract

This paper develops an open economy model with heterogeneous final goods producers who simultaneously choose whether to export their output and whether to use imported intermediates. Using the theoretical model, we develop and estimate a structural empirical model that incorporates heterogeneity in productivity, transport costs, and other costs using Chilean plant-level data for a set of manufacturing industries. The estimated model is consistent with many key features of the data regarding productivity, exporting, and importing. We perform a variety of counterfactual experiments to assess quantitatively the positive and normative effects of barriers to trade in import and export markets. These experiments suggest that there are substantial gains in aggregate productivity and welfare 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.

Keywords: exporting, importing, firm heterogeneity, aggregate productivity, resource allocation

JEL Classification Numbers: O40, F12, E23, C23.

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1 Introduction

This paper develops and estimates a stochastic industry model of heterogeneous firms which may export output and import inputs. We use Chilean plant-level data for a set of manufacturing industries to estimate the model. The estimated models are used to perform counterfactual experiments regarding different trading regimes to assess the effects of barriers to trade in import and export markets on prices, productivity, resource allocation, and welfare.

Previous empirical work suggests that there is a substantial degree 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 reallocation 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 consistent with this observation and additional evidence suggesting that whether or not a firm is *importing* intermediates for use in production is also important for explaining differences in plant performance.[2] In particular, our data suggests that firms which both import intermediates and export their output 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), motivated by the empirical findings regarding exporters described above, develops a monopolistic competition model of exporters with different productivities and examines the effect of trade liberalization.[3] To address simultaneously the empirical regularities concern-

[1]See, for example, Alvarez and Lopez (2005), 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 Amiti and Konings (2007), Halpern, Korn, and Szeidl (2006), and Kasahara and Rodrigue (2008) for evidence of a positive relationship between importing inputs and productivity. Few empirical studies simultaneously examine both exports and imports at the micro-level. A notable exception is Bernard, Jensen, and Schott (2005) who provide empirical evidence regarding both importers and exporters in the U.S.

[3]Several alternative trade theories with heterogeneous firms have been developed as well. Eaton and Kortum (2002) develop a Ricardian model of trade with firm-level heterogeneity. Eaton, Kortum, and Kramarz (2011) 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 foreign direct investment. Bernard, Redding, and Schott (2007) develop a model of endowment-driven comparative advantage with heterogeneous

ing firms which import intermediates, we extend his model to incorporate imported intermediate goods. In the model, the use of foreign intermediates increases a firm's productivity (because of increasing returns) but, due to fixed costs of importing, only inherently highly productive firms import intermediates. Thus, a firm's productivity affects its participation decision in international markets (i.e. importing inputs and/or exporting output) and, conversely, this participation decision (i.e. importing inputs) affects its productivity. We also extend Melitz' (2003) model to allow for sunk costs of trade, differences across firms in international transportation costs, and plant-specific cost and trade shocks.

We then provide a structural estimation of the stationary equilibrium of the model using a panel of Chilean plants for six manufacturing industries (Wearing Apparel, Plastic Products, Food Products, Textiles, Wood Products, and Fabricated Metals). The data is well-suited for our study as Chile underwent a significant trade liberalization from 1974-1979 but had fairly stable trade policies, and savings, investment, and growth rates during our sample period from 1990-1996.[4] Furthermore, a significant portion of Chilean imports are in chemicals, electrical machinery, and heavy industrial machinery which is consistent with our focus on imported intermediate inputs.

We find that the estimated model replicates the observed patterns of productivity across plants with different import and export status as well as the observed distribution of export and import intensities. It is also consistent with the high degree of trade concentration among a small number of plants in our data. We also include serially uncorrelated transitory firm-level cost and trade shocks which causes firms to exit and change their trade status, consistent with the data. Furthermore, the inclusion of sunk costs and permanent unobserved firm-level shocks in the model allows us to capture the high degree of persistence in a plant's export and import status apparent in the data. We note, however, that we do not include serially correlated transitory shocks in the model and this exclusion affects the role of sunk costs in explaining this

firms to examine both across and within industry reallocations in response to trade liberalization. Atkeson and Burstein (2007) examine firms' decisions to export and innovate in a dynamic, general equilibrium model.

[4]For example, using the data for Chile from Fuentes, Larrain, and Schmidt-Hebbel (2006), we calculate that the standard deviations of the growth rate of real GDP in 1970-1979, 1980-1989, and 1990-1999 are equal to 0.072, 0.072 and 0.035, respectively, while the standard deviations of the growth rate of TFP for those sub-periods are 0.056, 0.049, and 0.030. In addition, using data from the International Financial Statistics database, we found that the corresponding decade averages and standard deviations (in parentheses) of Chilean exports relative to GDP were .18(.060), .26(.063), and .29(.027). The analogous statistics for imports were .59(.602), .26(.030), and .28(.015). Furthermore, Fuentes et al. report indexes of macroeconomic instability for Chile of .34 for 1960-1974, .28 for 1975-1989, and .08 for 1990-2005. Hence, the Chilean macroeconomic environment in the 1990's was stable, especially relative to the macroeconomic environment in 1970's and 1980's, and there was no major change in tariff rates between 1990 and 1996.

observed persistence.

Regarding productivity, we find that the estimated mean of the productivity distribution at the steady state is significantly higher than the estimated mean at entry for each of our industries, suggesting that selection through endogenous exit plays an important role in determining industry productivity. Furthermore, the estimated model indicates that firms with high productivity and low international transportation costs tend to self-select into exporting and importing. Hence, heterogeneity in *both* productivity and shipping costs are significant in determining export and import status.

To examine the effects of trade policies, we perform a variety of counterfactual experiments that explicitly take into account equilibrium price adjustments. The experiments suggest that goods' prices fall significantly in moving from autarky to trade, resulting in increases in consumers' real purchasing power ranging from 3-32 percent across the industries in our study. Furthermore, we estimate that industry total factor productivity increases between 5-21 percent when trade is liberalized. Another important finding from these experiments is that because of importing and exporting complementarities, policies that prohibit the importation of foreign intermediates can have a large adverse effect on the exportation of final goods, causing exports to fall significantly in each of the industries we study.

Our paper is a contribution to the recent empirical literature which seeks to provide structural estimation of international models with heterogeneous firms using plant-level data to examine the quantitative implications of trade policies. For instance, Das, Roberts, and Tybout (2007) use Columbian plant-level data for three manufacturing industries to examine the effects of trade liberalization and export subsidies on exports. Halpern, Koren, and Szeidl (2006) use a panel of Hungarian firms to explore relationships between importing and plant productivity. Using Indonesian data, Rodrigue (2008) estimates a model with foreign direct investment and exporting. Our results complement these papers but include analysis on the interaction between importing and exporting, sunk costs, and plant-specific shocks.

The remainder of the paper is organized as follows. Section 2 describes the Chilean manufacturing plant-level data we use and presents statistics from the industries regarding exporting and importing behavior. Section 3 presents the model while Section 4 provides details and results of the structural estimation of the model. Section 5 concludes.

2 The Data

Our data set is based on the Chilean manufacturing census for 1990-1996 which covers all plants with at least 10 employees.[5] We examine two 4-digit level and four 3-digit level manufacturing industries. The list of industries and some descriptive statistics are given in Tables 1 and 2.[6] As can be seen from Table 1, these industries are relatively large in sample size and include many plants that export and/or import. This table also demonstrates that a relatively large fraction of industry output is accounted for by firms which engage in international trade. Furthermore, among the firms that trade, those which both export goods and import intermediate inputs account for a significant fraction of trade volume and output.

Table 1: Descriptive Statistics for Exporters and Importers

% of Industry Total (1990-1996 Average)	**Wearing Apparel**	**Plastic Products**	**Food Products**	**Textiles**	**Wood Products**	**Fabricated Metals**
Number of Exporters	5.1	5.1	28.2	7.0	17.8	4.4
Number of Importers	14.9	24.7	11.0	21.4	2.2	15.0
Number of Ex&Importers	7.7	19.2	12.9	14.0	4.9	9.0
Exports by Exporters	10.0	16.0	51.6	17.1	58.2	16.1
Exports by Ex&Importers	90.0	84.0	48.4	82.9	41.8	83.9
Imports by Importers	36.5	39.2	55.4	29.3	20.2	36.6
Imports by Ex&Importers	63.5	60.8	44.6	70.7	79.8	63.4
Output by Exporters	8.7	5.0	6.2	9.3	35.8	6.2
Output by Importers	18.6	29.9	22.6	20.4	2.6	22.8
Output by Ex&Importers	39.9	45.9	34.4	49.1	31.1	39.3
Number of Plants	534	369	857	530	561	642

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

Turning to Table 2, we note that the standard deviations across plants for total sales and

[5] 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). 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. The unit of observation in the data is a plant not a firm. There are a few important limitations in our data set. First, data for plants with fewer than 10 employees is not available. As a result, plants that shrink to fewer than 10 employees will be listed as exiting in our data set and small existing plants that expand beyond 10 employees will be counted as entrants. This data limitation is likely to bias our results. Furthermore, 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 a multinational firm although exporting and importing by multinational firms are important topics (e.g., Helpman et al., 2004; Yi, 2003). Pavcnik (2002) reports that over 90 percent of manufacturing firms had only one plant for 1979-1986.

[6] The first two industries in Table 1 are 4-digit level industries while the last four industries are 3-digit level. In the data set, we observe the number of blue-collar workers and white-collar workers, the value of total sales, the value of export sales, the value of intermediate inputs, and the value of imported intermediate inputs for each plant (among other variables.) We deflate sales and expenditure on inputs by the industry-level output price deflator to convert nominal series into real terms. A plant's export and import status is identified from the data by checking if the value of export sales and the value of imported materials, respectively, are zero or positive.

inputs suggests well-known heterogeneity across plants within a narrowly defined industry. Furthermore, export and import intensities differ across trading plants within an industry. These findings motivate us to include elements in our model below which generate heterogeneities across plants with respect these characteristics. Finally, we note that this table indicates that average gross profit margins were relatively stable between 1990 and 1996, consistent with the constant mark-ups we incorporate into our model.

Table 2: Descriptive Statistics in 1990 and 1996

Industry		Total Sales[a]	Intermediate Inputs[a]	Labour	Export Intensity[b]	Import Intensity[b]	Gross Profit Margin[c]
Wearing Apparel	1990	1.33	0.83	73.1	0.21	0.28	0.21
		(3.62)	(2.47)	(155.8)	(0.32)	(0.26)	(0.18)
	1996	2.63	1.48	62.8	0.09	0.29	0.21
		(13.90)	(7.82)	(190.6)	(0.19)	(0.24)	(0.21)
Plastic Products	1990	2.76	1.71	73.6	0.05	0.35	0.23
		(5.50)	(3.86)	(81.3)	(0.10)	(0.23)	(0.22)
	1996	6.87	4.03	69.2	0.08	0.42	0.23
		(14.11)	(9.00)	(84.5)	(0.12)	(0.26)	(0.40)
Food Products	1990	6.91	4.60	128.9	0.58	0.11	0.18
		(13.11)	(9.07)	(172.6)	(0.33)	(0.12)	(0.23)
	1996	9.37	5.86	135.0	0.51	0.17	0.20
		(18.52)	(11.32)	(178.7)	(0.31)	(0.18)	(0.21)
Textiles	1990	2.21	1.23	87.4	0.11	0.37	0.23
		(4.95)	(2.56)	(185.2)	(0.19)	(0.26)	(0.25)
	1996	2.40	1.39	69.4	0.14	0.36	0.23
		(4.76)	(2.79)	(126.6)	(0.21)	(0.23)	(0.20)
Wood Products	1990	2.21	1.39	80.0	0.35	0.20	0.20
		(5.26)	(3.54)	(136.7)	(0.28)	(0.28)	(0.25)
	1996	3.21	1.84	71.6	0.37	0.20	0.17
		(9.51)	(4.72)	(101.1)	(0.29)	(0.33)	(0.38)
Fabricated Metals	1990	2.62	1.53	74.0	0.11	0.36	0.26
		(6.30)	(3.80)	(99.7)	(0.17)	(0.27)	(0.17)
	1996	3.33	1.91	63.1	0.10	0.30	0.26
		(7.80)	(4.95)	(81.9)	(0.15)	(0.25)	(0.19)

Notes: Table entries are sample means with standard deviations in parentheses. (*a*) In units of billions of US dollars in 1990. (*b*) Computed using the sample of exporting (importing) plants for export (import) intensity . Export intensity is the ratio of export sales to total sales. Import intensity is the ratio of real expenditure on imported inputs to real expenditure on total inputs. (*c*) Computed as (revenue - variable cost)/revenue.

Table 3 reports the number of plants in each industry that change their export and/or import status and the number of firms which enter and exit on average over our sample period. The table demonstrates that a substantial number of plants change their export/import status in each industry. This observed within-plant variation in export and import status is important in our estimation for identifying the sunk costs of exporting or importing separately from ongoing fixed costs of trade in our model. We also note that there were substantial plant turnovers in the industries in our study. Having a number of entrants and exiting plants in the sample is important for identifying parameters in our model which affect the decision to exit and the distribution of productivity across plants.

Although firms change their trade status, this status is generally persistent as demonstrated in Table 4. The observed persistence suggests the possibility of sunk costs for exporting and importing, which we include in our model below.[7]

Table 3: Number of Changes in Export/Import Status and Entry and Exit

	Wearing Apparel			**Plastic Products**			**Food Products**		
	Exp or Imp	Exp	Imp	Exp or Imp	Exp	Imp	Exp or Imp	Exp	Imp
No. of Changes ≥ 1	141	65	108	158	80	122	312	136	209
No. of Changes ≥ 2	81	33	50	87	35	59	174	60	116
No. of Changes ≥ 3	31	6	15	42	11	21	65	22	39
Avg. No. of Entrants per Year	37			30			53		
Avg. No. of Exiters per Year	30			17			45		
	Textiles			**Wood Products**			**Fabricated Metals**		
	Exp or Imp	Exp	Imp	Exp or Imp	Exp	Imp	Exp or Imp	Exp	Imp
No. of Changes ≥ 1	207	104	152	106	82	41	170	87	132
No. of Changes ≥ 2	113	50	68	53	37	20	106	34	73
No. of Changes ≥ 3	54	20	22	25	13	7	40	11	22
Avg. No. of Entrants per Year	27			39			48		
Avg. No. of Exiters per Year	29			30			25		

We end this section by examining relationships between measures of plants' performance and their export and import status.[8] While differences in a variety of plant attributes between exporters and non-exporters are well-known (e.g. Bernard and Jensen, 1999), few empirical studies have discussed how plant performance depends on import status. Following Bernard and Jensen (1999), we report export and import premia estimated from a pooled ordinary least squares regression using data from 1990-1996 for each industry separately:

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

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, year dummies, and employment to control for size when the dependent variable is not employment. The export premium, α_1, is the average percentage difference between exporters and non-exporters among

[7] In our robustness exercises presented in the appendix, we evaluate a model without sunk costs and find that such a model generates much less persistence in trade status.

[8] Differences in a variety of plant attributes between exporters and non-exporters are well-known (e.g. Clerides et al., 1998; Bernard and Jensen, 1999; Bernard et al., 2003). Kasahara and Rodrigue (2008), Ferenandes (2007), and Muendler (2004) discuss how plant performance depends on import status.

Table 4: Transition Probabilities and Distributions of Export and Import Status

	Wearing Apparel				**Plastic Products**			
	No Exp/ No Imp	Exp/ No Imp	No Exp/ Imp	Exp/ Imp	No Exp/ No Imp	Exp/ No Imp	No Exp/ Imp	Exp/ Imp
No Exp/No Imp	0.911	0.025	0.060	0.004	0.845	0.029	0.108	0.018
Exp/No Imp	0.255	0.553	0.032	0.160	0.162	0.412	0.118	0.309
No Exp/Imp	0.244	0.015	0.676	0.065	0.193	0.021	0.661	0.125
Exp/Imp	0.028	0.063	0.113	0.796	0.030	0.068	0.091	0.810
Entrants Dist.	0.794	0.049	0.081	0.076	0.626	0.050	0.268	0.056
Steady State Dist.	0.742	0.048	0.137	0.073	0.532	0.049	0.234	0.184
	Food Products				**Textiles**			
	No Exp/ No Imp	Exp/ No Imp	No Exp/ Imp	Exp/ Imp	No Exp/ No Imp	Exp/ No Imp	No Exp/ Imp	Exp/ Imp
No Exp/No Imp	0.876	0.056	0.062	0.006	0.857	0.043	0.090	0.010
Exp/No Imp	0.091	0.784	0.002	0.123	0.277	0.532	0.014	0.177
No Exp/Imp	0.189	0.014	0.732	0.066	0.166	0.020	0.723	0.092
Exp/Imp	0.009	0.206	0.038	0.746	0.024	0.065	0.061	0.850
Entrants Dist.	0.794	0.049	0.081	0.076	0.762	0.044	0.163	0.031
Steady State Dist.	0.742	0.048	0.137	0.073	0.602	0.064	0.200	0.133
	Wood Products				**Fabricated Metals**			
	No Exp/ No Imp	Exp/ No Imp	No Exp/ Imp	Exp/ Imp	No Exp/ No Imp	Exp/ No Imp	No Exp/ Imp	Exp/ Imp
No Exp/No Imp	0.951	0.038	0.007	0.004	0.916	0.021	0.055	0.008
Exp/No Imp	0.159	0.775	0.003	0.064	0.274	0.415	0.019	0.292
No Exp/Imp	0.295	0.023	0.545	0.136	0.185	0.014	0.721	0.080
Exp/Imp	0.029	0.184	0.096	0.692	0.037	0.112	0.093	0.758
Entrants Dist.	0.785	0.167	0.013	0.034	0.849	0.028	0.098	0.025
Incumbents Dist.	0.767	0.166	0.021	0.047	0.725	0.041	0.145	0.088

Notes: The first four rows for each industry are the probabilities of moving from the trade status listed in the row to the trade status listed in the column in the next period.

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 do both.

Table 5 presents our estimates and demonstrates 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 for each industry. The import premia among non-exporters are also positive and significant, suggesting the importance of import status in explaining plant performance even after controlling for export status. Comparing columns 1-2 with column 3 for each industry, we note that plants that are both exporting and importing tend to be larger and have higher value added per worker than plants that are engaged in either exporting or importing but not both.[9]

[9] 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.

Table 5: Premia of Exporter and Importer: Pooled OLS, 1990-1996

	Wearing Apparel			**Plastic Products**			**Food Products**		
Export/Import Status	Exp	Imp	Exp&Imp	Exp	Imp	Exp&Imp	Exp	Imp	Exp&Imp
Total Employment	0.79 (0.09)	0.57 (0.05)	1.76 (0.08)	0.67 (0.09)	0.64 (0.05)	1.13 (0.06)	0.97 (0.04)	0.85 (0.05)	1.63 (0.04)
Total Sales	1.27 (0.10)	1.16 (0.06)	2.42 (0.09)	1.08 (0.11)	1.08 (0.07)	1.90 (0.07)	0.91 (0.05)	1.94 (0.07)	2.46 (0.05)
Value Added per Worker	0.46 0.08)	0.56 (0.04)	0.53 (0.07)	0.46 (0.10)	0.41 (0.05)	0.77 (0.05)	0.09 (0.05)	0.92 (0.06)	0.88 (0.06)
No. of Observations		2332			1706			4040	
	Textiles			**Wood Products**			**Fabricated Metals**		
Export/Import Status	Exp	Imp	Exp&Imp	Exp	Imp	Exp&Imp	Exp	Imp	Exp&Imp
Total Employment	0.78 (0.07)	0.44 (0.04)	1.56 (0.06)	1.05 (0.04)	0.39 (0.12)	1.76 (0.09)	0.62 (0.08)	0.59 (0.04)	1.38 (0.06)
Total Sales	1.22 (0.09)	1.16 (0.05)	2.24 (0.07)	1.35 (0.07)	0.92 (0.16)	2.95 (0.11)	0.95 (0.12)	1.31 (0.06)	2.28 (0.05)
Value Added per Worker	0.48 (0.07)	0.67 (0.04)	0.60 (0.05)	0.22 (0.06)	0.76 (0.07)	0.83 (0.10)	0.30 (0.07)	0.53 (0.04)	0.64 (0.05)
No. of Observations		2604			2523			2985	

Notes: Standard errors are in parentheses.

3 A Model of Exports and Imports

The empirical results of the last section motivate us to extend the model of Melitz (2003) to incorporate exporting, importing, and differences across plants with respect to productivity, exporting and importing costs, and other characteristics. We use the model to further explore the relationships suggested above between plant productivity and export and import status. The model also provides an empirical framework for estimating the positive and normative effects of trade in final goods and intermediates.

Consider a country which produces an intermediate good and final goods and trades with the rest of the world. The final goods sector is characterized by a continuum of monopolistically competitive firms producing horizontally differentiated goods using labor and intermediate goods. We index firms in this sector by i and let the (endogenous) measure of final goods producers be denoted by M. There is an unbounded measure of ex ante identical potential entrants into this sector. Upon entering, an entrant pays a fixed entry cost, f_e, and then draws its type, $\eta_i \equiv (\varphi_i, \tau_i^x, \tau_i^m)'$. Here φ_i is a productivity parameter and τ_i^x and τ_i^m are transport costs of exporting output and importing intermediates respectively. A firm's type is fixed throughout its lifetime.

We consider an environment with firm-level shocks but no aggregate shocks. At the beginning of period t, both entrants and incumbents draw idiosyncratic shocks, $\epsilon_{it}^{\chi} \equiv (\epsilon_{it}^{\chi}(0), \epsilon_{it}^{\chi}(1))$, which we refer to as exit cost shocks. Here $\epsilon_{it}^{\chi}(0)$ is the return if the firm chooses to exit and $\epsilon_{it}^{\chi}(1)$

plus the continuation value (specified below) is the return from continuing to produce. After observing these shocks, a firm decides whether to exit or to continue to operate. We assume that ϵ_{it}^{χ} is i.i.d., is independent of alternatives and is drawn from the extreme-value distribution with scale parameter ϱ^{χ} with c.d.f. H^{χ}.[10]

Firms that stay in the market in period t draw firm-specific i.i.d. shocks associated with each export/import status given by $\epsilon_{it}^{d} \equiv \left\{\epsilon_{it}^{d}(d)\right\}_{d\in\mathcal{D}}$, where $\mathcal{D} \equiv \{(0,0),(1,0),(0,1),(1,1)\}$ is the set of potential export/import status with the first element denoting export status, d^{x}, and the second denoting import status, d^{m}. A firm receives the continuation value associated with its export/import status choice plus the relevant export/import shock. The export/import shocks are drawn from the extreme-value distribution with scale parameter ϱ^{d} and c.d.f. H^{d}. These shocks are incorporated to capture observed changes in firms' trade status over time in the data. Let $d_{it} \equiv (d_{it}^{x}, d_{it}^{m}) \in \mathcal{D}$ denote firm $i's$ export/import status at time t.

Finally, each continuing firm faces the possibility of a large negative i.i.d. shock with probability ξ that forces the firm to exit. Continuing firms, then, differ with respect to their type and their past and current export/import status. New entrants have past export/import status equal to $(0,0)$.

The technology for a final good producer of type η_i with import status d_{it}^{m} is given by:

$$q(\eta_i, d_{it}^{m}) = \varphi_i l_{it}^{\alpha}\left[x_{it}^{o\,\frac{\gamma-1}{\gamma}} + d_{it}^{m} x_{it}^{m\,\frac{\gamma-1}{\gamma}}\right]^{\frac{(1-\alpha)\gamma}{\gamma-1}}, \tag{2}$$

where l_{it} is labor input, x_{it}^{o} is input of the domestically-produced intermediate, x_{it}^{m} is input of the imported intermediate, $0 < \alpha < 1$ is labor share, and $\gamma > 1$ is the elasticity of substitution between intermediate inputs. This production function incorporates increasing returns to variety in intermediate inputs using an approach similar to that used in many applications in macroeconomics, growth, and international economics.[11] This feature implies that firms which use multiple varieties of intermediates through importing, will have higher total factor productivity. Thus, our environment is consistent with the empirical evidence presented in Section 2 of this paper and in Amiti and Konings (2005), Halpern, Koren, and Szeidl (2006), and Kasahara and Rodrigue (2008) which suggest that the use of foreign intermediate goods is associated with higher plant productivity.[12]

[10] Without these shocks, the model predicts that all firms with productivity below a certain level will exit which is inconsistent with the existence of many small firms in our data.

[11] See, for example, Devereux, Head, and Lapham (1996a, 1996b), Ethier (1982), Grossman and Helpman (1991), and Romer (1987).

[12] An alternative approach would be to incorporate vertically differentiated inputs with foreign inputs of higher

Firms must pay non-stochastic per-period fixed costs of operating as well as per-period fixed and sunk costs of trading. Total fixed and sunk costs in period t for firm i with past export/import status equal to d_{it-1} and current status equal to d_{it} is given by:

$$F(d_{it-1}, d_{it}) = \begin{cases} f & \text{for } (d^x_{it}, d^m_{it}) = (0,0), \\ f + f^x + c^x(1 - d^x_{it-1}) & \text{for } (d^x_{it}, d^m_{it}) = (1,0), \\ f + f^m + c^m(1 - d^m_{it-1}) & \text{for } (d^x_{it}, d^m_{it}) = (0,1), \\ f + \zeta[f^x + f^m + c^x(1 - d^x_{it-1}) + c^m(1 - d^m_{it-1})] & \text{for } (d^x_{it}, d^m_{it}) = (1,1). \end{cases} \tag{3}$$

Here f is the per-period cost of operating in the market while f^x and f^m are non-stochastic per-period fixed costs of exporting and importing, respectively. The parameter c^x represents the sunk cost of exporting for a plant to begin exporting while the parameter c^m represents the sunk cost of importing. The parameter ζ captures the degree of fixed and sunk cost complementarity between exporting and importing. The inclusion of sunk costs of exporting and importing is motivated by empirical evidence on the existence of such costs and improves the model's ability to match observed transition patterns for export and import status.[13]

The intermediate good is produced under perfect competition using a linear technology in labor with marginal product equal to one. Thus, the domestic intermediate sold in the domestic market will have price equal to the wage

which we normalize to one.

Finally, there is a representative consumer who supplies labor inelastically at level L in each period. There is also a representative consumer in the rest of the world. The consumers' preferences over consumption of the continuum of final goods available for consumption are given by $U_t = \left[\int_{i\in\Omega_t} c_{it}^{\frac{\sigma-1}{\sigma}} di\right]^{\frac{\sigma}{\sigma-1}}$, where Ω_t is the set of final goods available to the consumer, and $\sigma > 1$ is the elasticity of substitution between varieties. Letting p_{it} denote the price of variety i, we can define a price index given by $P_t = \left[\int_{i\in\Omega_t} p_{it}^{1-\sigma} di\right]^{1/(1-\sigma)}$ giving expenditure on variety $i \in \Omega_t$ as

$$e_{it} = R_t \left[\frac{p_{it}}{P_t}\right]^{1-\sigma}, \tag{4}$$

where $R_t = P_t U_t$ is aggregate expenditure.

quality to generate a positive relationship between importing and plant productivity. Halpern, Koren, and Szeidl (2006) use Hungarian plant data and find that approximately two-thirds of the increase in plant productivity due to importing is attributable to an increase in the variety of intermediates used in production while the remaining one-third is due to an increase in quality.

[13] See Roberts and Tybout (1998), Bernard and Jensen (2004), and Das et al. (2007) for evidence of sunk costs of exporting, and Kasahara and Rodrigue (2005) for sunk costs of importing.

We begin by examining the end-of-period static production and pricing decision of a final good producer of type η_i with export/import status d_{it}. If the firm is using an imported intermediate at time t, the firm must purchase $\tau_i^m > 1$ units of the imported intermediate for one unit to arrive for use in production. Thus, solving the cost minimization problem of a final goods producer gives the following cost function:

$$C(q;\varphi_i, d_{it}) = \left[\frac{q}{\Gamma \varphi_i (1+z_i^m)^{d_{it}^m \left(\frac{1-\alpha}{\gamma-1}\right)}} \right], \tag{5}$$

where $\Gamma \equiv \alpha^\alpha (1-\alpha)^{1-\alpha}$ and $z_i^m \equiv \tau_i^{m\,1-\gamma}$.

The form of preferences implies that a final goods producer will price goods sold in the domestic market at a constant markup over marginal cost:

$$p_{it}^h = \left(\frac{\sigma}{\sigma-1}\right) \left(\frac{1}{\Gamma \varphi_i (1+z_i^m)^{d_{it}^m \left(\frac{1-\alpha}{\gamma-1}\right)}} \right). \tag{6}$$

Recalling that firms face firm-specific iceberg transport cost for exporting their output equal to $\tau_i^x > 1$, the price of a final good sold in foreign markets by domestic producer i equals

$$p_{it}^f = \tau_i^x p_{it}^h. \tag{7}$$

Using (4), (6) and (7), we can derive total revenue from domestic and foreign sales for domestic final goods producer i:

$$r_{it} = r_{it}^h + r_{it}^f = (1 + d_{it}^x z_i^x) r_{it}^h = (1 + d_{it}^x z_i^x) R_t \left[\left(\frac{\sigma-1}{\sigma}\right) \Gamma P_t \varphi_i \left(1+z_i^m\right)^{d_{it}^m \left(\frac{1-\alpha}{\gamma-1}\right)} \right]^{\sigma-1}, \tag{8}$$

where $z_i^x \equiv \tau_i^{x\,1-\sigma}$. Profits, net of shocks, are given by

$$\pi(\eta_i, d_{it-1}, d_{it}) = \frac{r_{it}}{\sigma} - F(d_{it-1}, d_{it}). \tag{9}$$

We now turn to the dynamic component of a final good producer's optimization problem. The Bellman equations which characterize the optimization problem for final good producer i

with $(\eta_i, d_{it-1}, \epsilon_{it}^{\chi}, \epsilon_{it}^{d})$ are:

$$V(\eta_i, d_{it-1}, \epsilon_{it}^{\chi}) = \max\left\{\epsilon_{it}^{\chi}(0),\ \epsilon_{it}^{\chi}(1) + \int W(\eta_i, d_{it-1}, \epsilon^d) dH^d(\epsilon^d)\right\}, \tag{10}$$

$$W(\eta_i, d_{it-1}, \epsilon_{it}^{d}) = \max_{d' \in \mathcal{D}} \left(\epsilon^d(d') + \pi(\eta_i, d_{it-1}, d') + \beta(1-\xi)\int V(\eta_i, d', \epsilon^{\chi}) dH^{\chi}(\epsilon^{\chi})\right), \tag{11}$$

where $\beta \in (0,1)$ is the discount factor. Now $V(\cdot,\cdot,\cdot)$ represents the value of a firm at the beginning of the period and equation (10) characterizes the decision to exit or remain after observing the exit cost shock. Equation (11) characterizes the firm's export and import decision after observing export/import cost shocks and recursively defines the value of a firm with state variable (η_i, d_{it-1}) and cost shock ϵ_{it}^{d}.

In what follows, it is useful to define *expected* value functions as:

$$\bar{V}(\eta_i, d_{it-1}) = \int V(\eta_i, d_{it-1}, \epsilon^{\chi}) dH^{\chi}(\epsilon^{\chi}), \tag{12}$$

$$\bar{W}(\eta_i, d_{it-1}) = \int W(\eta_i, d_{it-1}, \epsilon^{d}) dH^{d}(\epsilon^{d}). \tag{13}$$

We focus on stationary equilibria in which aggregate variables such as the aggregate price index, P, aggregate revenue, R, the measure of final goods producers, and the distribution of those producers by type and by export/import status is constant. We denote the stationary equilibrium distribution of these variables across operating firms by $\mu^*(\eta, d)$. Of course, individual firms enter, exit, and change their export/import status over time as they receive the idiosyncratic shocks described above. We drop the time subscript and denote the state for final good producer i as (η_i, d_i).

In the stationary equilibrium, free entry into final goods production implies that the expected value of an entering firm must equal the fixed entry cost:

$$\int \bar{V}(\eta, (0,0)) g_{\eta}(\eta) d\eta = f_e. \tag{14}$$

Stationarity also requires that the number of firms which exit equals the number of successful entrants:

$$M \int \Big(\sum_{d \in \mathcal{D}} P^{\chi}(0|\eta, d)\mu^*(\eta, d)\Big) g_{\eta}(\eta) d\eta = M_e \int \Big(P^{\chi}(1|\eta, (0,0))\Big) g_{\eta}(\eta) d\eta, \tag{15}$$

where M is the mass of incumbents, M_e is the mass of firms that attempt to enter, $P^{\chi}(0|\eta, d)$ is the probability of exit for a firm with state (η, d) and $P^{\chi}(1|\eta, d) = 1 - P^{\chi}(0|\eta, d)$ is the probability of not exiting for such a firm. Now, using the properties of extreme-value distributed random variables (see, for example, Ben-Akiva and Lerman, 1985), we can derive the latter probability as:

$$P^{\chi}(1|\eta, d) = (1-\xi)\left(\frac{\exp(\bar{W}(\eta, d)/\varrho^{\chi})}{\exp(0) + \exp(\bar{W}(\eta, d)/\varrho^{\chi})}\right), \tag{16}$$

where $\bar{W}(\cdot,\cdot)$ is defined in equation (13).

The final condition that the stationary equilibrium must satisfy is that the measure of firms with state (η, d) is constant. To write that condition, we first derive the choice probabilities for all possible current export/import statuses conditional on continuing to operate and the firm's state, (η, d). These follow the familiar logit formula (see, for example, McFadden, 1978) and are as follows:

$$P^{d}(d'|\eta, d) = \frac{\exp([\pi(\eta, d, d') + \beta(1-\xi)\bar{V}(\eta, d')]/\varrho^{d})}{\sum_{\tilde{d}\in\mathcal{D}} \exp([\pi(\eta, d, \tilde{d}) + \beta(1-\xi)\bar{V}(\eta, \tilde{d})]/\varrho^{d})} \tag{17}$$

for $d' \in \mathcal{D}$. Hence, the equilibrium condition is written

$$M\mu^{*}(\eta, d) = M\sum_{d'\in\mathcal{D}} P^{d}(d|\eta, d')P^{\chi}(1|\eta, d')\mu^{*}(\eta, d') + M_{e}P^{d}(d|\eta, (0,0))P^{\chi}(1|\eta, (0,0))g_{\eta}(\eta), \tag{18}$$

for all states (η, d). The first term on the right-hand side is the measure of survivors from last period with state (η, d) while the second term represents the measure of new entrants with that state.

4 Structural Estimation

4.1 Empirical Methodology

We begin by placing distributional assumptions on the parameters which determine plant $i's$ type, η_i. Let $(\sigma-1)\ln(\varphi_i)$ be drawn from $N(0, (\sigma^{\varphi})^2)$. We also assume that, conditional on φ_i, that z_i^x and z_i^m are independent of each other and are drawn at the time of entry from log normal distributions with means μ^x and μ^m and standard deviations σ^x and σ^m, respectively. Henceforth, we let plant $i's$ type be designated by $\tilde{\eta}_i \equiv ((\sigma-1)\ln(\varphi_i), \ln(z_i^x), \ln(z_i^m))'$.

We assume that plant revenue, export intensity, and import intensity are measured with error. Export and import intensities in the stationary equilibrium for a plant i at time t that engages in these activities are given by:

$$\kappa_{it}^x \equiv \frac{r_{it}^f}{r_{it}} = \frac{z_i^x}{1+z_i^x} \quad \text{if} \quad d_{it}^x = 1, \quad \text{and} \quad \kappa_{it}^m \equiv \frac{\tau_i^m x_{it}^m}{x_{it}^o + \tau_i^m x_{it}^m} = \frac{z_i^m}{1+z_i^m} \quad \text{if} \quad d_{it}^m = 1. \tag{19}$$

We also allow for labor augmented technological change at an annual rate of α_t. With these assumptions, we use the stationary version of equation (8), and equation (19) to specify the logarithm of *observed* total revenue, export intensity, and import intensity for plant i in period t as follows:

$$\ln(r_{it}) = \alpha_0 + \alpha_t t + (\sigma-1)\ln(\varphi_i) + \ln(1+z_i^x)d_{it}^x + \alpha_m \ln(1+z_i^m)d_{it}^m + \omega_{it}^r, \tag{20}$$

$$\ln(\kappa_{it}^x) = \ln(z_i^x/(1+z_i^x)) + \omega_{it}^x \text{ if } d_{it}^x = 1, \tag{21}$$

$$\ln(\kappa_{it}^m) = \ln(z_i^m/(1+z_i^m)) + \omega_{it}^m \text{ if } d_{it}^m = 1, \tag{22}$$

where ω_{it}^r, ω_{it}^x, and ω_{it}^m are measurement errors while

$$\alpha_0 = \ln(R) + (\sigma-1)\ln\left(\left(\frac{\sigma-1}{\sigma}\right)\Gamma P\right) \quad \text{and} \quad \alpha_m = \frac{(1-\alpha)(\sigma-1)}{\gamma-1}. \tag{23}$$

We also assume that the gross profit margin is measured with error. Thus, using (6), we have

$$\frac{r_{it} - vc_{it}}{r_{it}} = \frac{1}{\sigma} + \omega_{it}^\sigma \tag{24}$$

where vc_{it} is observed variable cost and ω_{it}^σ is measurement error. Finally, conditional on $(\tilde{\eta}_i, d_{it}^x, d_{it}^m)$, $\omega_{it} \equiv (\omega_{it}^r, \omega_{it}^x, \omega_{it}^m, \omega_{it}^\sigma)'$ 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 $\lambda_{j,k}$.[14]

Given these assumptions, we can use equation (9) and the revenue function given in equation (20) to derive profits for plant i at time t, $\pi(\tilde{\eta}_i, d_{it-1}, d_{it})$. We then use these profit functions to construct the Bellman equations for each plant using equations (10)-(13).

[14] We note that the normality assumption is restrictive. In particular, since the measurement error enters in the revenue function (20) in terms of the logarithm, the measurement error in (24) may not be normally distributed. Thus, the normal distribution should be viewed as an approximation to the true underlying joint distribution of measurement errors in order to parsimoniously capture the correlation of measurement errors across equations.

Finally, we use maximum likelihood to estimate the following parameter vector θ:[15]

$$\theta \equiv (\sigma, f, f^x, f^m, c^x, c^m, \zeta, \alpha_0, \alpha_t, \alpha_m, \mu^x, \mu^m, \sigma^\varphi, \sigma^x, \sigma^m, \xi, \varrho^\chi, \varrho^d, vec(\Lambda_\omega)', \tilde{\theta}_0')', \tag{25}$$

where $vec(\Lambda_\omega) = (\lambda_{11}, \lambda_{21}, \lambda_{22}, \lambda_{31}, \lambda_{32}, \lambda_{33}, \lambda_{41}, \lambda_{42}, \lambda_{43}, \lambda_{44})'$ is the parameter vector determining the measurement error distribution while the set of parameters that specify the initial distribution in 1990 is given by $\tilde{\theta}_0 = (\mu_0^\varphi, \mu_0^x, \mu_0^m, \sigma_0^\varphi, \sigma_0^x, \sigma_0^m, \alpha_0^x, \alpha_1^x, \alpha_2^x, \alpha_3^x, \alpha_0^m, \alpha_1^m, \alpha_2^m, \alpha_3^m)'$. In what follows, we briefly describe the estimation methodology we use to estimate θ and provide full details in the appendix.

Recalling that ϵ^χ and ϵ^d are type I extreme-value distributed random variables, we can write the Bellman's equations given by (12)-(13) for plant i as follows (see the appendix):

$$\bar{V}(\tilde{\eta}_i, d_{it-1}) = \varrho^\chi \ln\left(\exp(0) + \exp(\bar{W}(\tilde{\eta}_i, d_{it-1})/\varrho^\chi)\right), \tag{26}$$

$$\bar{W}(\tilde{\eta}_i, d_{it-1}) = \varrho^d \ln\left(\sum_{d' \in \mathcal{D}} \exp\left([\pi(\tilde{\eta}_i, d_{it-1}, d') + \beta\exp(\alpha_t)(1-\xi)\bar{V}(\tilde{\eta}_i, d')]/\varrho^d\right)\right), \tag{27}$$

where we have "detrended" firms' problems by using the trend-adjusted discount factor $\beta\exp(\alpha_t)$ in place of the discount factor β.[16]

Given a value for θ, we can solve the approximated model with a finite number of grid points over firms' types, $\tilde{\eta} = ((\sigma-1)\ln(\varphi), \ln(z^x), \ln(z^m))'$. The continuous state space of $(\sigma-1)\ln(\varphi)$ is approximated by n_φ grid points uniformly distributed between $\underline{\varphi}$ and $\bar{\varphi}$ while the continuous state space of $\ln(z^x)$ and $\ln(z^m)$ is approximated by n_z grid points so that $\ln(z^x/(1+z^x))$ and $\ln(z^m/(1+z^m))$ are uniformly distributed between 0 and 1 together with two additional end points at 0.0001 and 0.9999. Thus, the continuous state space of $\tilde{\eta}$ is approximated by $n_\eta = n_\varphi \times n_z \times n_z$ points. The distribution function of $\tilde{\eta}$ is accordingly approximated by a multinomial distribution. In practice, we choose $\underline{\varphi} = -5$, $\bar{\varphi} = 5$, $n_\varphi = 20$, and $n_z = 22$.

Let $\tilde{\eta}^k$ and ω^k for $k = 1, ..., n_\eta$ be the grid points and weights associated with the multinomial distribution, respectively. Given a θ, we can find the fixed point of the Bellman's equations for each $\tilde{\eta}^k$ by iterating on (26)-(27) starting from an initial guess of $W^o(\tilde{\eta}^k, d) = 0\ \forall d \in \mathcal{D}$, until convergence. Once the fixed point is computed, we evaluate the conditional choice probabilities in equations (16)-(17) for each $\tilde{\eta}^k$. We denote these probabilities as $P_\theta^\chi(\cdot|\tilde{\eta}^k, d)$ for the exit choice

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

[16]In estimation, we restrict the value of $\beta\exp(\alpha_t)(1-\xi)$ to be no more than 0.99 so that the value function iteration does not diverge.

and as $P^d_\theta(\cdot|\tilde{\eta}^k, d)$ for the export/import choice. The stationary distribution, $\mu^*_\theta(\tilde{\eta}, d)$ is then computed using the conditions for a stationary equilibrium given by equations (15) and (18).

The density of initial draws upon successful entry, $g^e_\theta(\tilde{\eta})$ is evaluated at $\tilde{\eta}^k$ as

$$g^e_\theta(\tilde{\eta}^k) = \frac{\omega^k P^\chi_\theta(1|\tilde{\eta}^k, (0,0))}{\sum_{j=1}^{n_\eta} \omega^j P^\chi_\theta(1|\tilde{\eta}^j, (0,0))}. \tag{28}$$

Finally, we need to derive the conditional density function for observed components of ω_{it}, conditional on $(\tilde{\eta}_i, d_{it})$. Conditioning on $\tilde{\eta}_i$, we can compute an estimate of ω_{it}, $\tilde{\omega}_{it}(\tilde{\eta}_i)$ using (20)-(22). We can then derive the following conditional density function:

$$g_{\omega,\theta}(\omega_{it}|\tilde{\eta}_i, d_{it}) = \begin{cases} g_{\omega^r}(\tilde{\omega}^r_{it}(\tilde{\eta}_i)) g_{\omega^\sigma|\omega^r}(\tilde{\omega}^\sigma_{it}(\tilde{\eta}_i)|\tilde{\omega}^r_{it}(\tilde{\eta}_i)) & \text{for } d_{it} = (0,0), \\ g_{\omega^r}(\tilde{\omega}^r_{it}(\tilde{\eta}_i)) g_{\omega^x|\omega^r}(\tilde{\omega}^x_{it}(\tilde{\eta}_i)|\tilde{\omega}^r_{it}(\tilde{\eta}_i)) g_{\omega^\sigma|\omega^r,\omega^x}(\tilde{\omega}^\sigma_{it}(\tilde{\eta}_i)|\tilde{\omega}^r_{it}(\tilde{\eta}_i), \tilde{\omega}^x_{it}(\tilde{\eta}_i)) & \text{for } d_{it} = (1,0), \\ g_{\omega^r}(\tilde{\omega}^r_{it}(\tilde{\eta}_i)) g_{\omega^m|\omega^r}(\tilde{\omega}^m_{it}(\tilde{\eta}_i)|\tilde{\omega}^r_{it}(\tilde{\eta}_i)) g_{\omega^\sigma|\omega^r,\omega^m}(\tilde{\omega}^\sigma_{it}(\tilde{\eta}_i)|\tilde{\omega}^r_{it}(\tilde{\eta}_i), \tilde{\omega}^m_{it}(\tilde{\eta}_i)) & \text{for } d_{it} = (0,1), \\ g_\omega(\tilde{\omega}_{it}(\tilde{\eta}_i)) & \text{for } d_{it} = (1,1), \end{cases}$$

where $g_{\omega^r}(\cdot)$ is the marginal distribution of ω^r_{it}, $g_{\omega^j|\omega^r}(\omega^j_{it}|\omega^r_{it})$ is the conditional distribution of ω^j_{it} given ω^r_{it} for $j \in \{x, m, \sigma\}$, and $g_{\omega^\sigma|\omega^r,\omega^k}(\omega^\sigma_{it}|\omega^r_{it}, \omega^k_{it})$ is the conditional distribution of ω^σ_{it} given ω^r_{it} and ω^k_{it} for $k \in \{x, m\}$.

We now discuss the construction of the likelihood function for plant i. Let t_{io} denote the first year in which plant i appears in the data. Conditioning on $\tilde{\eta}_i$, the likelihood contribution from the observation for plant i in period $t > t_{io}$ is computed as:

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

For the initial period of operation for plant i, t_{io}, the likelihood is given by $L_{it_{io}}(\theta|\tilde{\eta}_i, (0,0)) = P^d_\theta(d_{it_{io}}|\tilde{\eta}_i, (0,0)) g_{\omega,\theta}(\omega_{it_{io}}|\tilde{\eta}_i, d_{it_{io}})$. With these, we can write the likelihood contribution from plant i *conditioned* on $(\tilde{\eta}_i, d_{it_{io}})$ as

$$L_i(\theta|\tilde{\eta}_i, d_{it_{io}}) = \prod_{t=t_{io}+1}^{T_i} L_{it}(\theta|\tilde{\eta}_i, d_{it-1}), \tag{29}$$

where T_i is the last year in which plant i appears in the data.

To compute the likelihood contribution from plant i, we integrate out $\tilde{\eta}$ from the conditional likelihood (29) using appropriate distributions of $\tilde{\eta}$ as implied by the model. In particular, we assume that η is drawn from $g^e_\theta(\tilde{\eta})$ defined in (28) for a plant that enters during the sample period. For a plant observed in the first year of the sample period, 1990, we could assume that $\tilde{\eta}$ is distributed according to the stationary distribution $\mu^*_\theta(\tilde{\eta}, d)$ defined in (18). In the mid 1980's, however, Chile experienced aggregate shocks, which may have caused deviations from the steady state in 1990 and the stationarity assumption may not be appropriate for the initial year. For this reason, we use a "flexible" but parsimonious initial conditions distribution in the spirit of Heckman (1981) to determine the distribution of $\tilde{\eta}$ in 1990 which we denote as $\mu_{0,\theta}(\tilde{\eta}, d)$. Details of this procedure are given in the appendix.

The likelihood contribution from plant i is determined as:

$$L_i(\theta) = \begin{cases} \sum_{k=1}^{n_\eta} L_i(\theta|\tilde{\eta}^k, d_{it_{io}})\mu_{0,\theta}(\tilde{\eta}^k, d_{it_{io}}) & \text{for } t_{io} = 1990 \\ \sum_{k=1}^{n_\eta} L_i(\theta|\tilde{\eta}^k, d_{it_{io}})P^d_\theta(d_{it_{io}}|\tilde{\eta}^k, (0,0))g_{\omega,\theta}(\omega_{it_{io}}|\tilde{\eta}^k, d_{it_{io}})g^e_\theta(\tilde{\eta}^k) & \text{for } t_{io} > 1990. \end{cases}$$

Finally, the parameter vector θ is estimated by maximizing the following log-likelihood function:

$$\mathcal{L}(\theta) \equiv \sum_{i=1}^{\mathcal{N}} L_i(\theta), \tag{30}$$

where $\mathcal{N}$ is the number of plants in the data.

In summary, for each candidate parameter vector, θ, we solve the discretized versions of (26)-(27) and then use those solutions to obtain the choice probabilities using (16)-(17), the stationary distribution for $(\tilde{\eta}, d)$, the conditional distributions for ω, and the distribution of $\tilde{\eta}$ upon entry. We then use these to evaluate the log-likelihood function given by (30). We repeat this process to maximize $\mathcal{L}(\theta)$ over the parameter space of θ to determine our estimate of θ.

4.2 Identification

In this section, we briefly discuss which features of the data allow our estimation procedure to estimate particular parameters within θ. First, given the short panel data of seven periods, it is not possible to identify plant-specific productivities and transport costs for each plant due to the incidental parameters problem. For this reason, we follow the random effects approach by imposing parametric distributional assumptions as described in the previous section.[17] Specifi-

[17]Nonparametric identification of unobserved heterogeneity is difficult especially in the presence of state dependence as in our model. Kasahara and Shimotsu (2009) show that it is possible to nonparametrically identify the distribution of unobserved heterogeneity when the length of panel data is sufficiently long and the covariates

cally, we assume that the distribution of $((\sigma - 1)\ln\varphi_i, \ln(z_i^x), \ln(z_i^m))$ is normally distributed at the time of entry and we identify their means and standard deviations, $(\mu^x, \mu^m, \sigma^\varphi, \sigma^x, \sigma^m)$, by exploiting variation in productivities and export/import intensities among new entrants.

The per-period fixed cost of exporting, f^x, is identified from the frequency with which exporters become non-exporters. The sunk cost of exporting, c^x, can be separately identified from the per-period fixed cost, f^x, by examining the extent to which past exporting status matters for current exporting frequencies, after controlling for other plant characteristics. Once we control for plant characteristics, whether a plant exported last year or not should not affect the probability of exporting when the sunk cost of exporting is zero. On the other hand, if a plant faces large sunk costs of exporting, then a plant that exported last year is more likely to export this year than a plant that did not export last year. Similarly the fixed and sunk costs associated with importing, f^m and c^m, may be identified from the frequencies of importing and the extent to which past importing status affects the probability of importing.

The fixed cost of operating, f, is identified from the frequencies of exiting across plants with similar plant characteristics. The cost complementarity parameter, ζ, is identified by comparing the frequencies of exporting among non-importers with the frequencies of exporting among importers across plants after controlling for plant characteristics.

The scale parameters for exit shocks and export/import cost shocks, ϱ^χ and ϱ^d, are important determinants of the elasticities of the different choice probabilities with respect to payoff relevant state variables. Consequently, the scale parameter for exit shocks, ϱ^χ, is identified by differences in exiting frequencies across plants with different plant characteristics while we may identify scale parameters for shocks associated with export/import choices, ϱ^d, by differences in exporting and importing frequencies across plants with different plant characteristics. The elasticity of substitution in consumption, σ, is identified from average gross profit margins as specified in equation (24).

Finally, we note that our estimate of θ alone does not allow us to identify the parameters of the technology for producing final goods given in equation (2) including labor's share, α, and the elasticity of substitution between intermediates, γ. Instead, we compute the average material shares in variable cost as our estimate of $1 - \alpha$ and then use this estimate, our estimates of σ and α_m, and the second equation in (23) to derive an estimate of γ.

provide sufficient variation across different types.

Table 6: Maximum Likelihood Estimates

Params.	Apparel		Plastics		Food		Textiles		Wood		Metals	
σ	4.459	(0.055)	3.750	(0.039)	5.249	(0.065)	4.231	(0.042)	4.974	(0.077)	3.849	(0.033)
α_0	-0.791	(0.012)	-0.528	(0.017)	-0.466	(0.016)	-0.673	(0.010)	-0.869	(0.020)	-0.753	(0.011)
α_t	0.063	(0.003)	0.172	(0.003)	0.033	(0.002)	0.016	(0.002)	0.031	(0.003)	0.073	(0.002)
α_m	0.249	(0.058)	0.201	(0.030)	0.757	(0.086)	0.297	(0.034)	0.314	(0.133)	0.234	(0.035)
f	0.044	(0.008)	0.123	(0.016)	0.087	(0.014)	0.092	(0.017)	0.027	(0.003)	0.056	(0.005)
f^x	0.051	(0.012)	0.036	(0.009)	0.078	(0.009)	0.037	(0.009)	0.055	(0.006)	0.083	(0.014)
f^m	0.037	(0.009)	0.030	(0.009)	0.117	(0.014)	0.028	(0.009)	0.061	(0.013)	0.055	(0.011)
c^x	0.549	(0.138)	0.710	(0.125)	0.998	(0.101)	0.790	(0.146)	0.363	(0.068)	0.790	(0.136)
c^m	0.478	(0.116)	0.459	(0.076)	0.874	(0.081)	0.665	(0.121)	0.496	(0.088)	0.643	(0.108)
ζ	0.796	(0.031)	0.814	(0.041)	0.930	(0.025)	0.885	(0.034)	0.742	(0.035)	0.762	(0.029)
μ^x	-3.704	(0.354)	-3.519	(0.772)	-0.834	(0.149)	-3.651	(1.024)	-2.520	(0.396)	-4.178	(0.745)
μ^m	-1.539	(0.207)	-0.988	(0.206)	-3.168	(0.267)	-1.570	(0.229)	-4.004	(1.205)	-1.924	(0.221)
σ^x	1.350	(0.285)	1.128	(0.717)	1.682	(0.162)	1.233	(0.739)	2.063	(0.368)	1.334	(0.434)
σ^m	1.196	(0.189)	1.635	(0.219)	1.209	(0.210)	1.109	(0.224)	1.644	(0.717)	1.462	(0.237)
σ^φ	1.220	(0.076)	1.069	(0.074)	1.240	(0.068)	1.064	(0.080)	1.276	(0.082)	1.066	(0.049)
γ	11.321		11.071		5.262		8.558		9.996		8.795	
log-likelihood	-3800.59		-3776.13		-10466.13		-5339.84		-4604.60		-4879.97	
No. of Plants	534		369		857		530		561		642	

Notes: Standard errors are in parentheses. The parameters are evaluated units of millions of US dollars in 1990. We compute $\gamma = (\sigma - 1)(1 - \alpha)/\alpha_m + 1$ where $(1 - \alpha)$ is computed as the mean of the material share in total variable cost.

4.3 Estimation Results

Table 6 presents a subset of the maximum likelihood estimates for each industry.[18] The table also reports 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 estimated elasticity of substitution in consumption across differentiated final products, σ, ranges from 3.75 for Plastic Products to 5.25 for Food Products, implying markups of price over marginal cost ranging between 24% and 37%. Our estimate of the elasticity of substitution in production across differentiated intermediate products, γ, ranges from 5.26 to 11.32.[19]

4.3.1 Sunk and Fixed Costs

Our approach allows us to quantify the magnitude of sunk and fixed costs of exporting and importing. The average sunk cost of exporting ranges from 363 thousand 1990 US dollars for Wood Products to 998 thousand 1990 US dollars for Food Products. The sunk costs of importing range from 459 thousand 1990 US dollars for Plastic Products to 874 thousand 1990 US dollars

[18] Estimates for the remaining parameters are presented in the appendix.

[19] Our estimates for the elasticity of substitution in production across differentiated intermediate products are higher than those found by Feenstra, Markusen, and Zeile (1992) and Halpern et al. (2006). For instance, the latter study finds that the elasticity of substitution between domestic and foreign intermediate goods is 5.4.

for food products. Thus, both exporting and importing requires high start-up costs, which may arise because starting to import requires establishing a network with foreign suppliers, learning government regulations, or implementing new materials. It is important to note that the exporting and importing costs *actually incurred* are lower than these estimates since plants start exporting and/or importing when they get lower cost shocks. Furthermore, as we discuss below, plants that both export and import pay considerably less of the sunk costs because of cost complementarities.

We note that controlling for permanent unobserved heterogeneities in productivity and transportation costs is important for estimation of the sunk costs. Without controlling for permanent unobserved heterogeneities, the sunk costs will be overestimated.[20] Our specification has a limitation, however, in that it does not allow for serially correlated transitory shocks, which could lead to an upward bias in our sunk cost estimates.[21]

The fixed costs of exporting range from 36 to 83 thousand 1990 US dollars while the fixed costs of importing range from 28 to 117 thousand 1990 US dollars, indicating that both exporters and importers also pay substantial per-period fixed costs to continue to export and import. The parameter determining the degree of complementarity in exporting and importing sunk and fixed costs, ζ, ranges from 0.74 to 0.93, indicating that a firm can save between 7 and 26 percent of the per-period fixed costs and sunk costs associated with trade by simultaneously engaging in both export and import activities. Hence, the estimated total fixed costs of trading for a plant that both exports and imports range from 54 thousand 1990 US dollars for Plastic Products to 181 thousand 1990 US dollars for Food Products.

4.3.2 Importing and Exporting

The estimates of α_m, μ^x, μ^m, σ^x, and σ^m indicate that the effects of exporting and importing on total revenue differ across plants but, on average, their impact is large. In particular, for the "average" plant in an industry with $z_i^x = \exp(\mu^x)$ and $z_i^m = \exp(\mu^m)$, the revenue premium from exporting ranges from 1.5% for Metals to 36.1% for Food Products while the revenue premium

[20]For instance, when we re-estimate the model for Apparel industry by fixing the standard deviations of permanent unobserved heterogeneities at one-half of the original maximum likelihood estimates, the sunk cost estimate for exporting increases from 0.549 to 2.423.

[21]To the best of our knowledge, the only previous study that estimates the magnitude of sunk costs of exporting is Das et al. (2007) while there is no previous study that estimates importing sunk costs. Despite using different empirical specifications and looking at different countries and industries, our estimates of exporting sunk costs are similar in magnitude, although larger, to the estimates of Das, Roberts, and Tybout, especially given our relatively large standard errors. Their estimates range from 344 thousand 1986 US dollars to 430 thousand 1986 US dollars for leather products, basic chemicals, and knitted fabrics industries in Columbia.

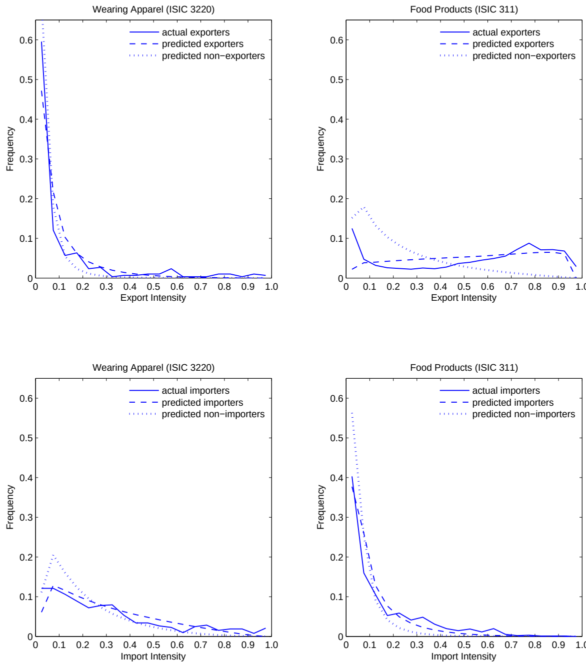

Figure 1: Export and Import Intensities (Actual vs. Predicted)

from importing intermediates varies from 0.6% for Wood Products to 6.4% for Plastics.[22] Furthermore, the estimates of σ^x and σ^m suggest substantial heterogeneity in gains from exporting and importing. Note that since plants with larger gains from exporting and importing are more likely to self-select into those activities, the average revenue gains from exporting and importing among *actual* exporters and importers is even larger than the gain for the "average" plant.

Figure 1 compares the actual and predicted distribution of export and import intensities for one of our four digit industries, Wearing Apparel, and one of our three digit industries, Food Products. In the top panels, the solid line indicates the actual export intensities while the dashed line indicates the predicted export intensities. The empirical models quantitatively replicate the observed pattern of export intensities. The figure also plots the distribution of latent export intensities among non-exporters if they had exported. The distribution of non-exporters (dotted line) is skewed left relative to that of exporters (dashed line). This is because, in the model, plants with lower transportation costs are more likely to export than plants with

[22]The revenue premium from exporting is derived from the coefficient on d_{it}^x in equation (20): $\ln(1+z_i^x)$ while the revenue increase from importing intermediates is derived from the coefficient on d_{it}^m in that equation: $\alpha_m \ln(1+z_i^m)$.

Table 7: Export and Import Concentration (Actual vs. Predicted)

Exports	**Apparel**		**Plastics**		**Food**		**Textiles**		**Wood**		**Metals**	
	% of Total Exports		% of Total Exports		% of Total Exports		% of Total Exports		% of Total Exports		% of Total Exports	
	Actual	Pred.	Actual	Pred.	Actual	Pred.	Actual	Pred.	Actual	Pred.	Actual	Pred.
Top 5%	55.43	40.68	46.79	34.79	24.94	50.99	51.02	37.01	42.57	58.49	34.98	41.10
Top 10%	71.03	54.96	64.46	48.58	41.28	59.95	68.35	51.59	62.63	69.60	54.16	57.41
Imports	% of Total Imports		% of Total Imports		% of Total Imports		% of Total Imports		% of Total Imports		% of Total Imports	
	Actual	Pred.	Actual	Pred.	Actual	Pred.	Actual	Pred.	Actual	Pred.	Actual	Pred.
Top 5%	35.13	37.19	38.58	50.05	44.45	42.29	40.93	32.31	39.03	46.11	42.53	35.20
Top 10%	54.70	46.57	57.63	57.56	59.70	55.75	58.13	41.08	52.50	59.10	60.12	45.86

higher transportation costs. Similarly, in the bottom panels, the estimated model replicates the distribution of import intensities well and the predicted import intensities among non-importers tend to be lower than those among importers.[23]

Table 7 shows that exports and imports are highly concentrated in all of our industries in the data and that the estimated model performs reasonably well in capturing the observed high degree of trade concentration. For instance, in Wearing Apparel, the top 5 percent of exporting (importing) plants account for 55.4 (35.1) percent of total exports (imports) in the actual data, while the prediction of the empirical model is 40.7 (37.2) percent.[24]

4.3.3 Productivity

We now examine differences in productivity distributions between incumbents and entrants and across firms with different trade status.[25] In the model, plants with higher productivity are more likely to survive than lower productivity plants. Figure 2 shows the importance of such

[23]The predicted distribution of import intensities is hump-shaped while the actual distribution is not. This is because we assume that transportation costs are normally distributed.

[24]In our preliminary investigation, we estimated a model without heterogeneity in transportation costs and found that the degree of trade concentration predicted by the model without heterogeneous transportation costs is far less than observed. Hence, not only heterogeneity in productivities but also heterogeneity in transportation costs are crucial to quantitatively explain the heavy concentration of exports and imports among a small number of plants in our data.

[25]There is a substantial literature on issues associated with measuring productivity using deflated sales measures of output. We note that when output is proxied by deflated sales based on an industry-wide producer price index as in our case, productivity may be mismeasured due to product differentiation and different product mixes (cf., Klette and Griliches, 1996; Katayama, Lu, and Tybout, 2003; De Loecker, 2007). Different methodologies have been developed in the literature to deal with simultaneity and selection biases in estimating production functions (Olley and Pakes, 1996; Blundel and Bond, 2000; Levinsohn and Petrin, 2002). A positive feature of our analysis here is that we extract an underlying unobserved plant efficiency from observables while controlling for the endogenous decisions to export and import using a structural model.

Table 8: Mean of Predicted Productivity

Relative Mean of φ for	**Apparel**	**Plastics**	**Food**	**Textiles**	**Wood**	**Metals**
Incumbents	1.288	1.456	1.349	1.534	1.165	1.225
Exporters	2.492	2.092	1.788	2.238	2.018	2.106
Importers	2.154	1.807	2.239	2.075	2.869	1.772
Ex&Importers	3.257	2.373	2.631	2.758	3.284	2.569

Notes: The reported numbers are relative to the productivity level at entry in the estimated model. 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.

a selection mechanism for Wearing Apparel and Food Products. In the top panels, the actual productivity distribution among incumbents (solid line) is skewed right relative to the actual productivity distribution among new entrants.[26] The bottom panels show that the empirical models qualitatively capture the observed difference in the productivity distributions between incumbents and new entrants.[27] In Table 8, the predicted average productivity advantage of incumbents relative to that of plants attempting to enter ranges from 17% in Wood Products to 53% for Textiles, indicating that selection through endogenous exiting may play an important role in determining aggregate productivity.

Exporters and importers tend to have higher productivities than domestic plants that do not engage in any trading activities because higher productivity plants are more likely to export and import and because importing increases productivity. This is shown in Figure 3 for Apparel and Food. In the top panels of the figure, the actual productivity distributions among plants that export, plants that import and plants that do both are skewed right relative to the actual distribution among plants that do neither. As the bottom panels show, the estimated models replicate the basic patterns of the differences in productivity distributions across plants with different trading status. This is also demonstrated in Table 8 for all the industries in our sample. The average productivity advantage of exporters and importers relative to the average incumbent is large, ranging from 54% for exporters in Plastic Products to 170% for importers in Wood Products. The table also shows that plants which both export and import are even more productive on average.

[26] To construct the actual productivity distribution, we first compute a revenue residual, $\ln \varphi_i + \omega_{it}^r$, for each plant-time observation as our measure of "actual productivity," and then plot a histogram of these residuals.

[27] The numbers used to construct Figures 1-3 as well as those reported in Tables 8-12 are directly computed using the approximated distribution function rather than simulating the data from the estimated models. The approximation methods are presented in a supplementary appendix which is available upon request.

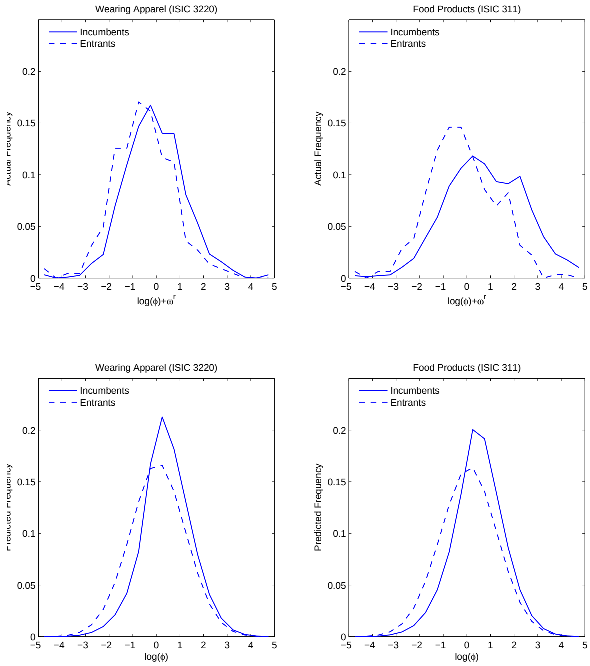

Figure 2: Productivity Distribution of Incumbents and New Entrants (Actual vs. Predicted)

4.3.4 Dynamics

Table 9 shows predicted transition probabilities of export/import status conditional on not exiting from the market. The table also reports the distribution of entrants as well as the steady state distribution of plants according to export/import status. Comparing these results to those from the actual data in Table 4, we see that the estimated models are able to replicate the observed persistence in export/import status. The model also captures the new entrants' distribution and the steady state distribution of export/import status reasonably well.

The empirical models generate the observed persistence in export/import status for the following two reasons. First, the presence of sunk costs of exporting and importing generates "true state dependence" in export/import decisions. Second, unobserved heterogeneity may lead to "spurious state dependence" even without sunk costs because, for instance, highly productive plants are likely to keep exporting while less productive plants do not export. We note that in our specification, plant-specific shocks have a permanent unobserved component and serially uncorrelated transitory component. If the transitory component is actually serially correlated, our estimated effects of permanent unobserved heterogeneity and/or sunk costs could be exag-

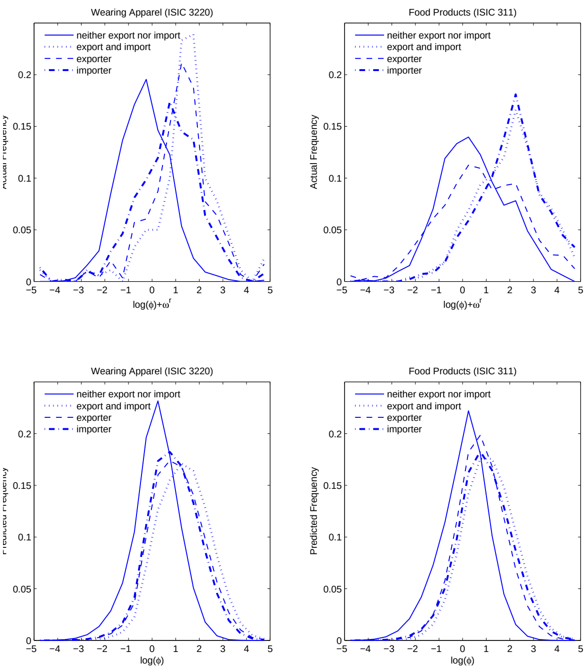

Figure 3: Productivity Distribution across Import/Export Status (Actual vs. Predicted)

gerated.

4.3.5 Sources of Variation Across Firms

In our model, variation across firms in export and import decisions as well as in total revenues and export revenues reflects differences both in their permanent unobserved heterogeneities, $(\varphi, \tau^x, \tau^m)$, and in other idiosyncratic shocks, such as ξ^d and ξ^χ. In this section we examine how much of the variation in export and import decisions and in revenues can be explained by the differences in permanent productivity and transportation costs.

Following Eaton, Kortum, and Kramarz (2011), we measure the explanatory power of the firm's permanent productivity for export and import decisions at the steady state as $R^x_\varphi = 1 - E[Var(d^x|\varphi)]/Var(d^x)$ and $R^m_\varphi = 1 - E[Var(d^m|\varphi)]/Var(d^m)$, respectively, where $Var(d^x)$ and $Var(d^m)$ are the variances of export and import decisions while $E[Var(d^x|\varphi)]$ and $E[Var(d^m|\varphi)]$ are the expected variances of export and import decisions given the firm's productivity φ. For each of six industries, we compute R^x_φ and R^m_φ by using the estimated steady state joint distribution of (φ, z^x, z^m, d). The results indicate that, on average across the six industries, 52.2

Table 9: Predicted Transition Probabilities and Distributions of Export and Import Status

	Wearing Apparel				**Plastic Products**			
	No Exp/ No Imp	Exp/ No Imp	No Exp/ Imp	Exp/ Imp	No Exp/ No Imp	Exp/ No Imp	No Exp/ Imp	Exp/ Imp
No Exp/No Imp	0.887	0.032	0.067	0.014	0.780	0.042	0.148	0.031
Exp/No Imp	0.206	0.641	0.017	0.136	0.123	0.629	0.025	0.223
No Exp/Imp	0.196	0.007	0.716	0.081	0.178	0.010	0.715	0.096
Exp/Imp	0.036	0.122	0.145	0.697	0.027	0.143	0.118	0.713
Entrants Dist.	0.859	0.037	0.076	0.027	0.748	0.043	0.162	0.047
Steady State Dist.	0.633	0.085	0.181	0.101	0.393	0.121	0.279	0.207
	Food Products				**Textiles**			
	No Exp/ No Imp	Exp/ No Imp	No Exp/ Imp	Exp/ Imp	No Exp/ No Imp	Exp/ No Imp	No Exp/ Imp	Exp/ Imp
No Exp/No Imp	0.845	0.090	0.053	0.011	0.835	0.050	0.099	0.015
Exp/No Imp	0.069	0.832	0.005	0.095	0.163	0.679	0.021	0.137
No Exp/Imp	0.319	0.035	0.552	0.093	0.169	0.011	0.738	0.081
Exp/Imp	0.014	0.201	0.027	0.758	0.029	0.130	0.137	0.704
Entrants Dist.	0.686	0.213	0.044	0.056	0.828	0.051	0.102	0.019
Steady State Dist.	0.402	0.376	0.058	0.164	0.499	0.128	0.240	0.133
	Wood Products				**Fabricated Metals**			
	No Exp/ No Imp	Exp/ No Imp	No Exp/ Imp	Exp/ Imp	No Exp/ No Imp	Exp/ No Imp	No Exp/ Imp	Exp/ Imp
No Exp/No Imp	0.938	0.048	0.008	0.006	0.906	0.021	0.062	0.012
Exp/No Imp	0.128	0.820	0.001	0.050	0.263	0.593	0.019	0.125
No Exp/Imp	0.329	0.018	0.528	0.125	0.237	0.006	0.697	0.060
Exp/Imp	0.028	0.190	0.049	0.733	0.062	0.144	0.191	0.603
Entrants Dist.	0.833	0.129	0.008	0.030	0.895	0.022	0.067	0.016
Steady State Dist.	0.708	0.217	0.017	0.058	0.712	0.056	0.172	0.060

Notes: The first four rows for each industry are the probabilities of moving from the trade status listed in the row to the trade status listed in the column in the next period.

percent of the variation in export decisions can be attributable to permanent productivity differences while 50.9 percent of the variation in import decisions can be attributable to permanent productivity differences. These numbers are similar in magnitude to those of Eaton et al. (2011) who find that on average 57 percent of the variation in entry in a market is attributable to the variation in the firm's cost draw.

From (20), we note that $Var(\ln r) = Var((\sigma-1)\ln\varphi) + Var(\ln(1+z_i^x)d_{it}^x) + Var(\alpha_m \ln(1+z^m)d^m) + 2Cov((\sigma-1)\ln\varphi, \ln(1+z_i^x)d_{it}^x) + 2Cov((\sigma-1)\ln\varphi, \alpha_m\ln(1+z^m)d^m) + 2Cov(\ln(1+z_i^x)d_{it}^x, \alpha_m\ln(1+z^m)d^m) + Var(\omega^r)$. Hence, the variance of the log of revenues is decomposed into the variance attributable to the variances of $\ln\varphi$, $\ln z^x d^x$, $\alpha_m \ln(1+z^m)d^m$, and ω^r, and other covariance terms. Panel A of Table 10 reports the result of a revenue decomposition. On average across six industries, permanent unobserved heterogeneity in productivity and transportation costs explain more than 90 percent of variation in the log of revenues. Among the three sources of permanent unobserved heterogeneity, the variation in unobserved productivity differences contributes 77.7 percent of the variation in the log of revenues while the variations in export and import intensities contribute 4.7 percent and 1.5 percent, respectively. These results suggest that permanent productivity differences are quite important in explaining variation in total revenues.

For exporting plants, the variance of the log of export revenues is decomposed into the variance attributable to the variances of $\ln\varphi$, $\ln z^x$, $\alpha_m \ln(1+z^m)d^m$, $\omega^x+\omega^r$, and other covariance terms. Panel B of Table 10 reports the result of the variance decomposition of export revenues. On average, 71.0 percent of the variation in export revenues is explained by three sources of permanent unobserved heterogeneity. The variation in export intensities contributes 49.9 percent of the variation in export revenues while the variation in permanent productivity contributes 26.7 percent of the variation in export revenues. On the other hand, variation in the import decision and import intensities contributes very little to the variation in export revenues.

Table 10: Variation in Total and Export Revenues

(A) *Fraction of Variance in Total Revenues*

Industry	$Var(\ln(r))$	Permanent Unobserved Heterogeneity (φ,τ^x,τ^m)	φ	τ^x	τ^m	Idiosyncratic Errors: ω^r
Apparel	1.0000	0.9235	0.8713	0.0038	0.0008	0.0765
Plastic	1.0000	0.8829	0.8090	0.0036	0.0008	0.1171
Food	1.0000	0.9254	0.5792	0.1776	0.0745	0.0746
Textiles	1.0000	0.9169	0.8607	0.0037	0.0010	0.0831
Wood	1.0000	0.8942	0.7002	0.0911	0.0133	0.1058
Metals	1.0000	0.8804	0.8440	0.0018	0.0004	0.1196

(B) *Fraction of Variance in Export Revenues*

Industry	$Var(\ln(r^f))$	Permanent Unobserved Heterogeneity (φ,τ^x,τ^m)	φ	τ^x	τ^m	Idiosyncratic Errors: $\omega^x+\omega^r$
Apparel	1.0000	0.7077	0.2851	0.3892	0.0012	0.2923
Plastic	1.0000	0.4659	0.1972	0.2642	0.0041	0.5341
Food	1.0000	0.7345	0.3319	0.6899	0.0014	0.2655
Textiles	1.0000	0.6313	0.2338	0.3646	0.0015	0.3687
Wood	1.0000	0.8747	0.2996	0.7798	0.0003	0.1253
Metals	1.0000	0.8458	0.2526	0.5057	0.0017	0.1542

Notes: In Panel A, the columns "φ," "τ^x," "τ^m," and "Idiosyncratic Errors ω^r" report the fraction of variance in total revenues explained by the terms $Var((\sigma-1)\ln\varphi)$, $Var(\ln(1+z_i^x)d_{it}^x)$, $Var(\alpha_m \ln(1+z^m)d^m)$, and $Var(\omega^r)$, respectively; the column "(φ,τ^x,τ^m)" reports the fraction of variance in total revenues explained by φ, τ^x, and τ^m including their covariance terms. Panel B reports the fraction of variance in export revenues explained by the different components similarly defined as those in Panel A.

4.4 Counterfactual Experiments

We now present the results of a series of counterfactual experiments which quantify the effects of trade barriers on trading activity, productivity, and prices in the stationary equilibria of our model economy, given the parameter estimates above. To quantitatively investigate the impact of trade barriers and export/import complementarities, we conduct the following six counterfactual experiments: (1) Autarky ($f^x, f^m \to \infty$); (2) No Trade in Final Goods ($f^x \to \infty$); (3) No Trade in Intermediates ($f^m \to \infty$); (4) No Complementarity in Fixed Trading Costs ($\zeta = 1$); (5) The transportation cost of exporting, τ_x, increases by 10%; and (6) The transportation cost of importing, τ_m, increases by 10%.

To determine the full impact of a counterfactual experiment, it is necessary to compute how the equilibrium aggregate price changes as a result of the experiment because the "reduced-form" parameter α_0 in the revenue function given by (20) depends on the aggregate price, (see (23)). This can be achieved by finding a new equilibrium aggregate price at which the free entry condition (14) holds in the experiments. The appendix provides a detailed description of our approach.

Table 11 presents the results of the counterfactual experiments using the estimated models. According to these experiments, moving from autarky to trade decreases the industry price-index by between 2.6% for Wood Products to 31.9% for Plastic Products, suggesting that there are substantial increases in consumers' purchasing power for these goods due to trade. This increases consumer welfare and this positive welfare effect occurs because under trade, more productive firms start exporting and importing, which in turn increases aggregate labor demand and the real wage.[28] The impact of trade on aggregate productivity, measured by a productivity average using the plants' market shares as weights, can be understood by comparing "ln(Average φ)" at the steady state between trade and autarky. Moving from trade to autarky decreases this measure of aggregate productivity at the steady state by between 1.7% for Food Products and 8.4% for Plastic Products. Note that once we take into account the additional productivity effect arising from importing intermediates, the impact of trade on total factor productivity (TFP) is much larger at 8.6% and 21.4% for those two industries. Comparing these effects, we

[28]In our industry-level counterfactual experiments, the change in P is an estimate of the effect of trade restrictions on the industry-level price index so its inverse is a measure of the change in real purchasing power of a consumer for goods in that industry. If these were the only goods in the consumer's consumption basket, the change in the industry price index would capture the effect of trade liberalization on aggregate consumer welfare. This is a standard result in the literature (see Arkolakis, Costinot, and Rodriguez-Clare (2012, ACR-C hereafter), for example) and can be seen from the aggregate budget constraint, $PQ = L$, which implies that aggregate utility is given by $U = Q = \frac{L}{P}$. Now, since L is constant, changes in aggregate welfare are measured by the inverse of changes in the aggregate price index. Of course, if there are other goods in consumers' consumption baskets, changes in industry-level price indexes would be weighted by expenditure share in calculating the effect of changes in the trading environment on consumers' overall welfare. We also note that compared to the relatively modest aggregate welfare gains from trade discussed in ACR-C for the U.S., we would expect larger estimated welfare gains in our study because: (1) The import penetration ratio for Chile is approximately 30% which is much larger than the U.S. ratio of 7%; and (2) The industries we study are very active in trade so we would expect fairly sizable price effects from prohibiting trade.

Table 11: Counterfactual Experiments

		Counterfactual Experiments					
	Free Trade	Autarky	No Trade in Final Goods	No Trade in Intermediates	No Complementarities	10% inc. in τ_x	10% inc. in τ_m
Wearing Apparel							
$\Delta \ln P$	0.000	0.092	0.086	0.089	0.005	0.001	0.053
Δ ln(Average φ)	0.000	-0.040	-0.027	-0.026	0.004	-0.002	-0.019
Δ ln(Average TFP)	0.000	-0.116	-0.027	-0.102	0.003	-0.002	-0.065
Fraction of Exporters	0.186	0.000	0.000	0.139	0.123	0.169	0.188
Fraction of Importers	0.281	0.000	0.252	0.000	0.229	0.278	0.233
Aggregate Exports	1.000	0.000	0.000	0.878	0.893	0.685	0.949
Aggregate Imports	1.000	0.000	0.893	0.000	0.924	0.971	0.398
Exiting Rates at Low φ	11.183	10.422	9.735	10.097	11.383	11.192	9.898
Exiting Rates at High φ	5.957	5.945	5.945	5.945	5.958	5.957	5.946
Plastic Products							
$\Delta \ln P$	0.000	0.319	0.298	0.314	0.005	0.000	0.160
Δ ln(Average φ)	0.000	-0.084	-0.081	-0.076	0.007	-0.001	-0.053
Δ ln(Average TFP)	0.000	-0.214	-0.077	-0.206	0.006	-0.001	-0.117
Fraction of Exporters	0.328	0.000	0.000	0.313	0.225	0.307	0.363
Fraction of Importers	0.486	0.000	0.520	0.000	0.442	0.484	0.450
Aggregate Exports	1.000	0.000	0.000	0.824	0.895	0.749	0.907
Aggregate Imports	1.000	0.000	0.841	0.000	0.975	0.983	0.494
Exiting Rates at Low φ	12.617	6.293	5.739	6.129	13.219	12.668	7.338
Exiting Rates at High φ	3.857	3.752	3.752	3.752	3.877	3.859	3.753
Food Products							
$\Delta \ln P$	0.000	0.154	0.148	0.149	0.002	0.034	0.005
Δ ln(Average φ)	0.000	-0.017	-0.006	-0.035	0.002	0.004	-0.003
Δ ln(Average TFP)	0.000	-0.086	-0.012	-0.104	0.001	0.004	-0.027
Fraction of Exporters	0.540	0.000	0.000	0.605	0.530	0.490	0.540
Fraction of Importers	0.222	0.000	0.178	0.000	0.195	0.216	0.201
Aggregate Exports	1.000	0.000	0.000	0.855	1.002	0.647	0.978
Aggregate Imports	1.000	0.000	0.136	0.000	0.985	0.622	0.672
Exiting Rates at Low φ	11.805	11.677	10.657	8.914	11.927	11.520	11.703
Exiting Rates at High φ	5.760	5.582	5.578	5.574	5.767	5.674	5.746
Textiles							
$\Delta \ln P$	0.000	0.099	0.086	0.092	0.004	0.001	0.041
Δ ln(Average φ)	0.000	-0.035	-0.039	-0.033	0.004	-0.001	-0.025
Δ ln(Average TFP)	0.000	-0.116	-0.038	-0.114	0.003	-0.001	-0.066
Fraction of Exporters	0.261	0.000	0.000	0.233	0.212	0.243	0.267
Fraction of Importers	0.374	0.000	0.367	0.000	0.341	0.372	0.333
Aggregate Exports	1.000	0.000	0.000	0.907	0.932	0.704	0.952
Aggregate Imports	1.000	0.000	0.921	0.000	0.964	0.980	0.494
Exiting Rates at Low φ	13.222	13.925	12.260	13.074	13.428	13.242	12.295
Exiting Rates at High φ	4.360	4.197	4.053	4.122	4.383	4.366	4.160
Wood Products							
$\Delta \ln P$	0.000	0.026	0.026	0.023	0.002	0.004	0.006
Δ ln(Average φ)	0.000	-0.021	-0.015	-0.006	0.001	0.002	-0.003
Δ ln(Average TFP)	0.000	-0.040	-0.020	-0.024	-0.001	0.001	-0.013
Fraction of Exporters	0.275	0.000	0.000	0.266	0.257	0.237	0.275
Fraction of Importers	0.075	0.000	0.023	0.000	0.029	0.067	0.063
Aggregate Exports	1.000	0.000	0.000	0.978	0.996	0.661	0.988
Aggregate Imports	1.000	0.000	0.132	0.000	0.884	0.628	0.507
Exiting Rates at Low φ	9.375	9.659	9.612	9.269	9.409	9.389	9.316
Exiting Rates at High φ	7.154	7.154	7.154	7.154	7.154	7.154	7.154
Fabricated Metals							
$\Delta \ln P$	0.000	0.104	0.095	0.101	0.007	0.000	0.050
Δ ln(Average φ)	0.000	-0.027	-0.021	-0.019	0.002	-0.002	-0.014
Δ ln(Average TFP)	0.000	-0.086	-0.021	-0.078	0.000	-0.002	-0.044
Fraction of Exporters	0.117	0.000	0.000	0.068	0.061	0.110	0.116
Fraction of Importers	0.232	0.000	0.198	0.000	0.185	0.230	0.207
Aggregate Exports	1.000	0.000	0.000	0.808	0.768	0.721	0.965
Aggregate Imports	1.000	0.000	0.908	0.000	0.898	0.984	0.510
Exiting Rates at Low φ	6.345	6.135	5.556	5.933	6.473	6.346	5.720
Exiting Rates at High φ	3.958	3.958	3.958	3.958	3.958	3.958	3.958

see that the majority of TFP effect of trade is induced by importing intermediates.[29]

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 models, when the economy moves from full trade to no trade in final goods, both the fraction of importers of intermediates and the level of imported intermediates declines in all of our industries. Furthermore, when the economy moves from full trade to no trade in intermediates, the fraction of exporters of final goods falls in all industries except Food Products while total exports of final goods decline in all industries.[30] Thus, generally policies that prohibit the import of foreign materials could have a large negative impact on the exporting of final

consumption goods – that is, import protection can lead to export destruction.

We now briefly examine the role of complementarities between export and import fixed and sunk costs relative to the role played by the complementarities in the revenue function. To do so we conduct an experiment to determine what would happen to the fraction of importers and the fraction of exporters if there was no complementarity between exporting and importing in the fixed and sunk cost functions. We find that eliminating cost complementarities lowers the fraction of exporters and importers as well as aggregate exports and imports for all of our industries, providing evidence that the cost complementarities play a role in inducing plants to both export and import simultaneously.

We conduct additional (less extreme) experiments to examine what would happen to prices and productivity if the transportation cost parameters, τ_x and τ_m, were 10% higher than the actual estimates. The results are presented in columns (5) and (6) of Table 11. A 10 percent increase in transportation costs of either form have a relatively small impact on the fraction of exporters and importers but a substantial impact on aggregate exports and imports. This implies that the impact of an increase in transportation costs (or tariffs) on aggregate exports and imports operates mainly through the intensive margin rather than through the extensive margin. This finding is consistent with the findings of Das et al. (2007). We also note that a

[29]We remind the reader that our assumption of an exogenously fixed measure of intermediate goods blueprints implies that our model does not capture the full general equilibrium effects on welfare, resource allocation, and productivity of trade liberalization. In particular, if the measure of intermediate goods were endogenously determined, increased trade would presumably induce resource allocations within intermediate goods producers as well as additional reallocations between intermediate and final good producers. However, since we assume that the measure of intermediates produced within a country is fixed and in our estimation we treat all producers as final good suppliers, we miss some of these resource reallocations that might affect our measures of productivity and consumer purchasing power gains.

[30]For Food Products, the fraction of exporters rises slightly when trade in intermediates is restricted because of the relatively large price effect.

10 percent increase in import tariffs has a substantial effect on the average TFP ranging from 1.3 percent in Wood Products to 11.7 percent in Plastic Products.

The last two rows in each panel of Table 11 report average exit rates at the steady state for low productivity firms ($\varphi < 1$) and for high productivity firms ($\varphi \geq 1$).[31] When the economy moves from autarky to trade, an increase in profitability from exporting and importing lowers exiting rates while an increase in the real wage tends to increase exiting rates, especially for the least productive firms.For all industries except for Wood Products, the latter effect dominates, and moving from autarky to trade induces a substantial increase in exit rates for the less productive firms and, hence, a resource reallocation from less to more efficient firms. [32]

To examine the distributional effects of trade policies, Table 12 reports the effect of alternative policies on average revenues across different values of φ, z^x, and z^m. We classify the firm's state space into eight categories by classifying each of φ, z^x, and z^m into two categories; "H" and "L."[33] Recall that high transport costs is associated with low levels of z^j so, for example, a firm with $(\varphi, z^x, z^m) = (L, L, L)$ is a low productivity firm with high transport costs for both exporting and importing. For all six industries, moving from free trade to autarky increases the size of firms with low productivity and high transportation costs while it decreases the size of firms with high productivity and low transportation costs. Thus, an increase in trade barriers leads to resource allocation from efficient to inefficient firms.

Because changes in trade policies affect both extensive and intensive margins, different trade regimes will lead to different size distributions. Figure 4 shows the distribution of revenues across different trade policies. Trade regimes closer to free trade tend to have a size distribution that stochastically dominates the distribution under regimes with trade barriers, especially for Plastic Products and Food Products industries.

5 Conclusions and Extensions

We have developed and estimated a stochastic industry model of importing and exporting with heterogeneous firms. The estimated model is consistent with many key features of the data regarding productivity, exporting, and importing. The results of our counterfactual experiments

[31] Recall that the distribution of $\ln \varphi$ is normalized so that its expectation is equal to zero at the time of entry.

[32] In the model of Melitz (2003), the latter effect dominates the former for a set of parametric productivity distributions he considers. On the other hand, in our model with additional stochastic elements such as iid cost shocks, the effect of moving from autarky to trade on exit rates is ambiguous in general, and it depends on the parameter values.

[33] We define φ to be "L" if $\ln \varphi < 0$ and "H" if $\ln \varphi \geq 0$ while we let z^j for $j = x, m$ to be "L" if $z^j/(1+z^j) < 0.2$ and "H" if $z^j/(1+z^j) \geq 0.2$.

Table 12: Counterfactual Experiments: Change in Average Revenues across Different States

States	Free Trade	% Change From Free Trade					
	Log of Revenue	Autarky	No Trade in Final Goods	No Trade in Intermediates	No Complementarities	10% inc. in τ_x	10% inc. in τ_m
Wearing Apparel							
$(\varphi, z^x, z^m) = (L, L, L)$	-0.7044	0.0411	0.0307	0.0381	-0.0010	-0.0005	0.0215
$(\varphi, z^x, z^m) = (L, L, H)$	-0.6756	0.0123	0.0252	0.0093	-0.0067	-0.0007	0.0121
$(\varphi, z^x, z^m) = (L, H, L)$	-0.5726	-0.0908	-0.1012	0.0293	-0.0280	-0.0147	0.0262
$(\varphi, z^x, z^m) = (L, H, H)$	-0.5285	-0.1349	-0.1219	-0.0148	-0.0443	-0.0155	0.0131
$(\varphi, z^x, z^m) = (H, L, L)$	1.0086	-0.0213	-0.0155	-0.0098	-0.0049	-0.0027	-0.0021
$(\varphi, z^x, z^m) = (H, L, H)$	1.0751	-0.0878	-0.0133	-0.0762	-0.0116	-0.0033	-0.0185
$(\varphi, z^x, z^m) = (H, H, L)$	1.3013	-0.3140	-0.3082	0.0061	-0.0197	-0.0173	0.0150
$(\varphi, z^x, z^m) = (H, H, H)$	1.3902	-0.4029	-0.3285	-0.0828	-0.0330	-0.0175	-0.0062
Plastic Products							
$(\varphi, z^x, z^m) = (L, L, L)$	-0.6209	0.1111	0.0885	0.1120	-0.0086	-0.0013	0.1175
$(\varphi, z^x, z^m) = (L, L, H)$	-0.5184	0.0086	0.0668	0.0095	-0.0202	-0.0018	0.0792
$(\varphi, z^x, z^m) = (L, H, L)$	-0.4120	-0.0979	-0.1205	0.1149	-0.0508	-0.0166	0.1219
$(\varphi, z^x, z^m) = (L, H, H)$	-0.2759	-0.2340	-0.1758	-0.0212	-0.0654	-0.0158	0.0558
$(\varphi, z^x, z^m) = (H, L, L)$	0.9235	-0.0549	-0.0465	-0.0278	-0.0025	-0.0038	-0.0214
$(\varphi, z^x, z^m) = (H, L, H)$	1.0331	-0.1645	-0.0188	-0.1374	-0.0067	-0.0043	-0.0366
$(\varphi, z^x, z^m) = (H, H, L)$	1.1859	-0.3173	-0.3090	0.0195	-0.0068	-0.0107	0.0162
$(\varphi, z^x, z^m) = (H, H, H)$	1.3154	-0.4469	-0.3011	-0.1100	-0.0093	-0.0108	-0.0115
Food Products							
$(\varphi, z^x, z^m) = (L, L, L)$	-0.8050	0.1177	0.1174	0.1309	-0.0013	0.0306	0.0030
$(\varphi, z^x, z^m) = (L, L, H)$	-0.7557	0.0684	0.1341	0.0816	-0.0051	0.0373	-0.0015
$(\varphi, z^x, z^m) = (L, H, L)$	0.0462	-0.7335	-0.7338	0.0578	-0.0052	-0.1185	0.0011
$(\varphi, z^x, z^m) = (L, H, H)$	0.1562	-0.8436	-0.7778	-0.0522	-0.0150	-0.1214	-0.0094
$(\varphi, z^x, z^m) = (H, L, L)$	1.0965	-0.0920	-0.0817	-0.0491	-0.0019	-0.0266	-0.0057
$(\varphi, z^x, z^m) = (H, L, H)$	1.2257	-0.2212	-0.0364	-0.1783	-0.0072	-0.0135	-0.0162
$(\varphi, z^x, z^m) = (H, H, L)$	1.8721	-0.8676	-0.8574	0.0067	-0.0031	-0.1079	-0.0045
$(\varphi, z^x, z^m) = (H, H, H)$	2.0684	-1.0639	-0.8791	-0.1895	-0.0090	-0.1003	-0.0159
Textiles							
$(\varphi, z^x, z^m) = (L, L, L)$	-0.7143	0.0200	0.0332	0.0296	-0.0025	-0.0009	0.0224
$(\varphi, z^x, z^m) = (L, L, H)$	-0.6768	-0.0175	0.0380	-0.0078	-0.0065	-0.0010	0.0172
$(\varphi, z^x, z^m) = (L, H, L)$	-0.5742	-0.1201	-0.1069	0.0592	-0.0203	-0.0161	0.0474
$(\varphi, z^x, z^m) = (L, H, H)$	-0.5158	-0.1785	-0.1230	0.0009	-0.0307	-0.0176	0.0386
$(\varphi, z^x, z^m) = (H, L, L)$	1.0055	-0.0628	-0.0705	-0.0578	-0.0009	-0.0032	-0.0385
$(\varphi, z^x, z^m) = (H, L, H)$	1.0691	-0.1265	-0.0647	-0.1215	-0.0027	-0.0035	-0.0509
$(\varphi, z^x, z^m) = (H, H, L)$	1.2372	-0.2946	-0.3022	-0.0367	-0.0013	-0.0130	-0.0251
$(\varphi, z^x, z^m) = (H, H, H)$	1.3147	-0.3721	-0.3103	-0.1142	-0.0030	-0.0134	-0.0376
Wood Products							
$(\varphi, z^x, z^m) = (L, L, L)$	-0.6486	0.0151	0.0090	-0.0102	0.0018	-0.0037	-0.0058
$(\varphi, z^x, z^m) = (L, L, H)$	-0.6437	0.0102	0.0069	-0.0150	-0.0005	-0.0037	-0.0070
$(\varphi, z^x, z^m) = (L, H, L)$	-0.2070	-0.4265	-0.4327	-0.0096	-0.0058	-0.0606	-0.0047
$(\varphi, z^x, z^m) = (L, H, H)$	-0.1727	-0.4608	-0.4641	-0.0438	-0.0271	-0.0628	-0.0111
$(\varphi, z^x, z^m) = (H, L, L)$	1.0479	-0.0170	-0.0166	-0.0014	-0.0021	-0.0018	-0.0001
$(\varphi, z^x, z^m) = (H, L, H)$	1.1014	-0.0705	-0.0291	-0.0549	-0.0165	-0.0021	-0.0099
$(\varphi, z^x, z^m) = (H, H, L)$	1.7276	-0.6967	-0.6963	0.0007	-0.0068	-0.0562	0.0011
$(\varphi, z^x, z^m) = (H, H, H)$	1.8283	-0.7975	-0.7561	-0.1001	-0.0369	-0.0570	-0.0120
Fabricated Metals							
$(\varphi, z^x, z^m) = (L, L, L)$	-0.5011	-0.0061	-0.0438	-0.0183	0.0060	-0.0005	-0.0367
$(\varphi, z^x, z^m) = (L, L, H)$	-0.4792	-0.0280	-0.0452	-0.0402	0.0016	-0.0005	-0.0408
$(\varphi, z^x, z^m) = (L, H, L)$	-0.4306	-0.0766	-0.1144	-0.0253	-0.0165	-0.0071	-0.0288
$(\varphi, z^x, z^m) = (L, H, H)$	-0.3941	-0.1131	-0.1303	-0.0618	-0.0324	-0.0079	-0.0339
$(\varphi, z^x, z^m) = (H, L, L)$	0.8765	-0.0104	-0.0069	-0.0058	-0.0035	-0.0012	-0.0002
$(\varphi, z^x, z^m) = (H, L, H)$	0.9411	-0.0750	-0.0061	-0.0704	-0.0110	-0.0016	-0.0121
$(\varphi, z^x, z^m) = (H, H, L)$	1.1173	-0.2513	-0.2478	0.0034	-0.0308	-0.0116	0.0164
$(\varphi, z^x, z^m) = (H, H, H)$	1.2125	-0.3465	-0.2776	-0.0919	-0.0522	-0.0118	0.0005

Notes: We classify the firm's state space into eight categories based on the values of (φ, z^x, z^m) by classifying each of φ, z^x, and z^m into two categories based on the threshold value. We define φ to be "L" if $\ln \varphi < 0$ and "H" if $\ln \varphi \geq 0$ while we let z^j for $j = x, m$ be "L" if $z^j/(1 + z^j) < 0.2$ and "H" if $z^j/(1 + z^j) \geq 0.2$. Within each category of states, the second column reports the average value of log(revenue) under free trade while the third to the eighth columns report the percentage difference in average revenue between free trade and alternative policies in counterfactual experiments.

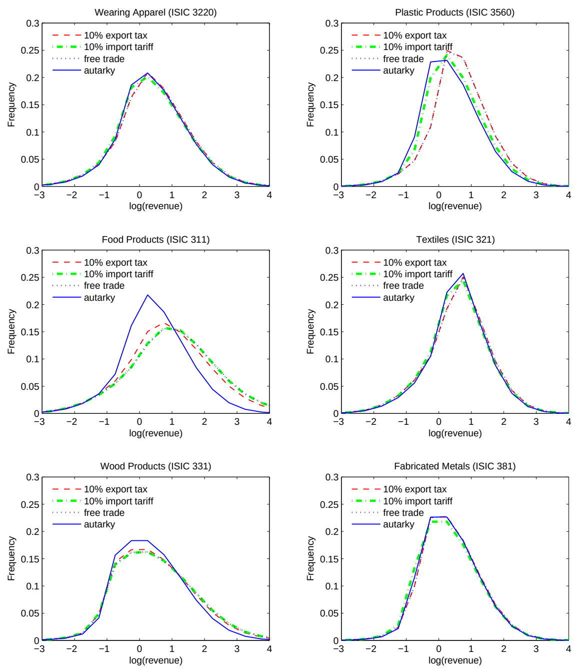

Figure 4: Counterfactual Size Distributions

imply that there are substantial aggregate productivity and welfare gains due to trade in both final goods and intermediates. 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. Hence, 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.[34] To maintain its parsimony, and also because of data limitations and computational complexity, the model ignores several important features. Estimating a more realistic model with shocks that have serially correlated transitory components, such as first-order autoregressive process, is an important future research topic. We do not address the important issue of how multi-plant and multinational firms make joint decisions on exporting and importing across different plants. We also ignore plant capital investment decisions. Finally, we do not allow adjustment in the measure of varieties of intermediates produced within a country

[34] The supplemental appendix contains additional robustness exercises regarding the specification of trade shocks and the sensitivity of the results to the inclusion of sunk costs and aggregate shocks. Our basic findings continue to hold in those exercises.

in response to changes in the trading environment. These features could be incorporated into our theoretical and empirical framework and such extensions are important topics for our future research.

References

[1] Alvarez, R. and R.A. Lopez (2005) "Exporting and Performance: Evidence from Chilean Plants," *Canadian Journal of Economics*, 38(4), 1384-400.

[2] Amiti, M. and J. Konings (2007) "Trade Liberalization, Intermediate Inputs, and Productivity: Evidence from Indonesia," *American Economic Review*, 97(5), 1611-163.

[3] Arkolakis, Costas, Arnaud Costinot, and Andrés Rodríguez-Clare (2012) "New Trade Models, Same Old Gains?" *American Economic Review*, 102(1), 94-130.

[4] Atkeson, A. and A. Burstein (2007) "Innovation, Firm Dynamics, and International Trade," NBER Working Paper No. 13326.

[5] Aw, B.Y., S. Chung, and M.J. Roberts (2000) "Productivity and Turnover in the Export Market: Micro-level Evidence from the Republic of Korea and Taiwan(China)," *World Bank Economic Review*, 14, 65-90.

[6] Ben-Akiva, M. and M. Lerman (1985) *Discrete Choice Analysis: Theory and Application to Travel Demand*, MIT Press, Cambridge, MA.

[7] Bernard, A.B. and J.B. Jensen (1999) "Exceptional Exporter Performance: Cause, Effect, and or Both?" *Journal of International Economics*, 47, 1-25.

[8] Bernard, A.B. and J.B. Jensen (2004) "Why Some Firms Export?" *Review of Economics and Statistics*, 86(2), 561-569.

[9] Bernard, A.B., J. Eaton, J.B. Jensen, and S. Kortum (2003) "Plants and Productivity in International Trade," *American Economic Review*, 93(4), 1268-1290.

[10] Bernard, Andrew B., J. Bradford Jensen, and Peter K. Schott (2005) "Importers, Exporters, and Multinationals: A Portrait of Firms in the U.S. that Trade Goods," NBER Working Paper No. 11404.

[11] Bernard, A.B., S. Redding, and P. Schott (2007) "Comparative Advantage and Heterogeneous Firms," *Review of Economic Studies*, 74(1), 31-66.

[12] Blundell, R.W. and S.R. Bond (2000) "GMM Estimation with Persistent Panel Data: an Application to Production Functions," *Econometric Reviews*, 19(3), 321-340.

[13] Clerides, S., Lach, S., and J.R. Tybout (1998) "Is Learning by Exporting Important? Micro-Dynamic Evidence from Colombia, Mexico, and Morocco," *Quarterly Journal of Economics*, 113, 903-947.

[14] De Loecker, J. (2007) "Product Differentiation, Multi-Product Firms and Estimating the Impact of Trade Liberalization on Productivity," NBER Working Paper No. 13155.

[15] Das, S. M. Roberts, and J. Tybout (2007) "Market Entry Costs, Producer Heterogeneity, and Export Dynamics," *Econometrica*, 75(3), 837-873.

[16] Devereux, M., A. Head, and B. Lapham (1996a) "Monopolistic Competition, Increasing Returns, and the Effects of Government Spending," *Journal of Money, Credit, and Banking*, 28(2), 233-254.

[17] Devereux, M., A. Head, and B. Lapham (1996b) "Aggregate Fluctuations with Increasing Returns to Specialization and Scale," *Journal of Economic Dynamics and Control*, 20, 627-656.

[18] Eaton, J., and S. Kortum (2002) "Technology, Geography, and Trade," *Econometrica*, 70(5), 1741-79.

[19] Eaton, J., S. Kortum, and F. Kramarz (2004) "Dissecting Trade: Firms, Industries, and Export Destinations," *American Economic Review, Papers and Proceedings*, 94(2), 150-154.

[20] Eaton, J., S. Kortum, and F. Kramarz (2011) "An Anatomy of International Trade: Evidence from French Firms," *Econometrica*, 79(5), 1453-1498.

[21] Ethier, W.J. (1982) "National and International Returns to Scale in the Modern Theory of International Trade," *American Economic Review*, 72(3), 389-405.

[22] Feenstra, Robert C., J.R. Markusen, and W. Zeile (1992) "Accounting for Growth with New Inputs: Theory and Evidence," *American Economic Review*, 82(2), 415-421.

[23] Fernandes, A. (2007) "Trade policy, Trade Volumes and Plant-level Productivity in Colombian Manufacturing Industries," *Journal of International Economics*, 71(1), 52-71.

[24] Fuentes, R., M. Larrain K. Schmidt-Hebbel (2006) "Sources of Growth and Behavior of TFP in Chile," *Cuadernos de Economia* 43(127), 113-142.

[25] Grossman, G.M. and E. Helpman (1991) *Innovation and Growth in the Global Economy*, Cambridge, MA: The MIT Press.

[26] Halpern, L. M. Koren, and A. Szeidl (2006) "Imports and Productivity," mimeo, Federal Reserve Bank of New York.

[27] Heckman, J. J. (1981) "The Incidental Parameters Problem and the Problem of Initial Conditions in Estimating a Discrete Time-Discrete Data Stochastic Process," in C. F. Manski and D. McFadden (eds), *Structural Analysis of Discrete Data with Econometric Applications,* MIT Press, Cambridge, MA, 114-178.

[28] Helpman, E., M.J. Melitz, and S.R. Yeaple (2004) "Export versus FDI with Heterogeneous Firms" *American Economic Review*, 94, 300-316.

[29] Kasahara, Hiroyuki, and Joel Rodrigue (2005) "Does the Use of Imported Intermediates Increase Productivity? Plant-Level Evidence," EPRI Working Paper # 2005-7.

[30] Kasahara, H., and J. Rodrigue (2008) "Does the Use of Imported Intermediates Increase Productivity? Plant-Level Evidence," *Journal of Development Economics*, 87(1), 106-118.

[31] Kasahara, H., and K. Shimotsu (2008) "Nonparametric Identification of Finite Mixture Models of Dynamic Discrete Choices," *Econometrica*, 77(1), 135-175.

[32] Katayama, H., S. Lu, and J.R. Tybout (2003) "Why Plant-level Productivity Studies are often Misleading, and an Alternative Approach to Inference," NBER Working Paper No. 9617.

[33] Klette, T.J., and Z. Griliches (1996) "The Inconsistency of Common Scale Estimators When Output Prices are Unobserved and Endogenous," *Journal of Applied Econometrics*, 11, 343-361.

[34] Levinsohn, J. and A. Petrin (2003) "Estimating Production Functions Using Inputs to Control for Unobservables," *Review of Economic Studies*, 70: 317-341.

[35] Liu, L. (1993) "Entry-Exit, Learning and Productivity Change: Evidence from Chile," *Journal of Development Economics*, 42: 217-242.

[36] McFadden, D. (1978) "Modeling the Choice of Residential Location," in A. Karlquist et al. (eds.), *Spatial Interaction Theory and Residential Location*, Amsterdam: North-Holland.

[37] Melitz, M.J.(2003) "The Impact of Trade on Intra-Industry Reallocations and Aggregate Industry Productivity," *Econometrica*, 71: 1695-1725.

[38] Muendler, M-A.(2004) "Trade, Technology and Productivity: A Study of Brazilian Manufacturers 1986-1998," CESifo Working Paper Series No. 1148.

[39] Olley, S. and Pakes, A. (1996) "The Dynamics of Productivity in the Telecommunications Equipment Industry," *Econometrica*, 65(1): 292-332.

[40] Pavcnik, N. (2002) "Trade Liberalization, Exit, and Productivity Improvements: Evidence From Chilean Plants," *Review of Economic Studies*, 69(1): 245-276.

[41] Roberts, M. and J.R. Tybout (1997) "Decision to Export in Columbia: An Empirical Model of Entry with Sunk Costs" *American Economic Review*, 87: 545-564.

[42] Rodrigue, J. (2007) "FDI and Exports: An Empirical Framework," mimeo, Queen's University.

[43] Romer, P. (1987) "Growth Based on Increasing Returns Due to Specialization," *American Economic Review*, 77(2), 56-62.

[44] Rust, J. (1987) "Optimal replacement of GMC bus engines: an empirical model of Harold Zurcher." *Econometrica* 55(5): 999-1033.

[45] Tybout, J.R. (1996) "Chile, 1979-1986: Trade Liberalization and its Aftermath," in M. Roberts and J. Tybout (eds.), *Industrial Evolution in Developing Countries*, Oxford: Oxford University Press.

[46] Trefler, D. (2004) "The Long and Short of the Canada-U.S. Free Trade Agreement," *American Economic Review*, 94(4): 870-895.

[47] Yi, K-M. (2003)"Can Vertical Specialization Explain the Growth of World Trade?" *Journal of Political Economy*, 111(1): 52-102.

A Appendix

A.1 Estimation Procedure

A.1.1 Type I Extreme-Value Distributions

Here, we briefly discuss the properties of Type I extreme-value distributed random variables (cf., Ben-Akiva and Lerman (1985)). Assume that $\epsilon(0)$ and $\epsilon(1)$ are independently drawn from identical extreme-value distributions with mean zero and variance $\frac{\varrho^2\pi^2}{6}$, where ϱ is the shape parameter.[35] Let $V(0)$ and $V(1)$ be real numbers. We use the following two properties for our estimation. The first property is: $E[\max(V(0)+\epsilon(0), V(1)+\epsilon(1)] = \varrho\ln[\exp(V(0)/\varrho)+\exp(V(1)/\varrho)]$, where the expectation is taken with respect to the distribution of $\epsilon(0)$ and $\epsilon(1)$. The second property is: $P(V(0)+\epsilon(0) > V(1)+\epsilon(1)) = \frac{\exp(V(0)/\varrho)}{\exp(V(0)/\varrho)+\exp(V(1)/\varrho)}$. In the multivariate case, when we have $\epsilon(d)$ for $d = 0, 1, 2, ..., J$, the first property is $E[\max_{j=0,1,...,J} V(j) + \epsilon(j)] = \varrho\ln[\sum_{j=0}^{J}\exp(V(j)/\varrho)]$ while the second property is $P[V(d)+\epsilon(d) > V(j)+\epsilon(j) \text{ for all } j \neq d] = \frac{\exp(V(d)/\varrho)}{\sum_{j'=0}^{J}\exp(V(j')/\varrho)}$.

A.1.2 Initial Distribution Specification

Following Heckman (1981), we specify the distribution of $\tilde{\eta}$ in 1990 as $\mu_{0,\theta}(\tilde{\eta}, d) = P_0^x(d^x|\tilde{\eta})P_0^x(d^m|\tilde{\eta})g_{\tilde{\eta},0}(\tilde{\eta})$, where $(\sigma-1)\ln\varphi$, $\ln z^x$, $\ln z^m$ are independently normally distributed with means μ_0^φ, μ_0^x, and μ_0^m, and standard deviations σ_0^φ, σ_0^x, and σ_0^m so that $g_{\tilde{\eta},0}(\tilde{\eta}) = \frac{1}{\sigma_0^\varphi\sigma_0^x\sigma_0^m}\phi\left(\frac{(\sigma-1)\ln\varphi-\mu_0^\varphi}{\sigma_0^\varphi}\right)\phi\left(\frac{\ln z^x-\mu_0^x}{\sigma_0^x}\right)\times \phi\left(\frac{\ln z^m-\mu_0^m}{\sigma_0^m}\right)$, while $P_0^x(d^x|\tilde{\eta})$ and $P_0^x(d^m|\tilde{\eta})$ are specified under logit formulas:

$$\begin{aligned} P_0^x(d^x|\eta) &= \frac{\exp(\alpha_0^x+\alpha_1^x(\sigma-1)\ln\varphi+\alpha_2^x\ln z^x+\alpha_3^x\ln z^m)}{1+\exp(\alpha_0^x+\alpha_1^x(\sigma-1)\ln\varphi+\alpha_2^x\ln z^x+\alpha_3^x\ln z^m)}, \\ P_0^m(d^m|\eta) &= \frac{\exp(\alpha_0^m+\alpha_1^m(\sigma-1)\ln\varphi+\alpha_2^m\ln z^x+\alpha_3^m\ln z^m)}{1+\exp(\alpha_0^m+\alpha_1^m(\sigma-1)\ln\varphi+\alpha_2^m\ln z^x+\alpha_3^m\ln z^m)}. \end{aligned}$$

A.1.3 Counterfactual Experiments Procedure

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

[35] The cumulative distribution function of $\epsilon(d)$ for $d = 0, 1$ is $\exp(-\exp(-(\epsilon(d)-\gamma)))$, where γ is Euler's constant.

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 at the *counterfactual* aggregate price $P(\tilde{\theta})$ (i.e. at the counterfactual value of α_0):

$$r(\eta_i, d_{it}; k(\tilde{\theta}, \hat{\theta})) = \exp\left(k(\tilde{\theta}, \hat{\theta}) + \hat{\alpha}_0 + \alpha_t t + \ln[1 + z_i^x] d_{it}^x + \hat{\alpha}_m \ln[1 + z_i^m] d_{it}^m + (\sigma - 1) \ln \varphi_i \right). \quad (31)$$

The equilibrium price change, $k(\tilde{\theta}, \hat{\theta})$, is then determined so that the following equilibrium free entry condition holds: $\hat{f}_e = \int \bar{V} \left(\eta', d_{it} = (0,0); \tilde{\theta}, k(\tilde{\theta}, \hat{\theta}) \right) g_\eta(\eta'; \tilde{\theta}) d\eta'$. Here $\bar{V} \left(\eta', d_{it}; \tilde{\theta}, k(\tilde{\theta}, \hat{\theta}) \right)$ is the solution to the Bellman equations (10)-(13) when the revenue function (31) is used to compute profits and $g_\eta(\eta'; \tilde{\theta})$ is the probability density function from which the initial plant characteristic vector is drawn.[36]

A.2 Additional Maximum Likelihood Estimates

Table 13 presents the maximum likelihood estimates for the remaining parameters.

Table 13: Remaining Maximum Likelihood Estimates

Params	**Apparel**		**Plastics**		**Food**		**Textiles**		**Wood**		**Metals**	
ϱ^d	0.131	(0.031)	0.165	(0.026)	0.272	(0.022)	0.195	(0.033)	0.099	(0.016)	0.179	(0.028)
ϱ^χ	0.269	(0.084)	0.450	(0.149)	0.517	(0.147)	0.639	(0.163)	0.044	(0.021)	0.130	(0.032)
ξ	0.059	(0.009)	0.038	(0.007)	0.056	(0.005)	0.037	(0.007)	0.072	(0.006)	0.040	(0.005)
λ_{11}	0.314	(0.003)	0.331	(0.005)	0.394	(0.002)	0.294	(0.003)	0.416	(0.004)	0.328	(0.003)
λ_{22}	1.321	(0.059)	1.404	(0.037)	0.844	(0.007)	1.281	(0.031)	0.905	(0.020)	1.190	(0.037)
λ_{21}	-0.253	(0.108)	-0.069	(0.089)	0.000	(0.022)	-0.198	(0.070)	-0.166	(0.032)	-0.406	(0.080)
λ_{33}	0.676	(0.017)	0.571	(0.007)	0.936	(0.011)	0.638	(0.009)	0.881	(0.056)	0.699	(0.015)
λ_{32}	0.076	(0.073)	0.042	(0.047)	-0.021	(0.052)	-0.021	(0.053)	0.065	(0.125)	-0.025	(0.059)
λ_{31}	-0.041	(0.059)	0.039	(0.025)	-0.184	(0.033)	-0.017	(0.029)	-0.460	(0.080)	0.012	(0.032)
λ_{44}	0.170	(0.002)	0.159	(0.002)	0.198	(0.001)	0.181	(0.002)	0.186	(0.002)	0.172	(0.002)
λ_{43}	0.023	(0.011)	0.009	(0.010)	0.013	(0.008)	0.009	(0.009)	0.018	(0.019)	0.016	(0.009)
λ_{42}	-0.043	(0.010)	-0.018	(0.012)	-0.020	(0.005)	-0.031	(0.009)	-0.007	(0.009)	-0.011	(0.010)
λ_{41}	0.049	(0.003)	0.060	(0.004)	0.080	(0.003)	0.046	(0.003)	0.091	(0.004)	0.078	(0.003)
μ_0^φ	0.057	(0.081)	0.687	(0.112)	0.974	(0.079)	0.450	(0.077)	0.345	(0.083)	0.539	(0.085)
μ_0^x	-4.080	(0.540)	-4.765	(0.288)	-2.737	(0.200)	-3.936	(0.331)	-3.238	(0.344)	-3.970	(0.375)
μ_0^m	-1.646	(0.147)	-1.047	(0.161)	-3.110	(0.142)	-1.439	(0.117)	-3.963	(0.726)	-1.875	(0.149)
σ_0^φ	1.233	(0.065)	1.267	(0.089)	1.518	(0.061)	1.284	(0.058)	1.258	(0.065)	1.361	(0.064)
σ_0^x	1.387	(0.345)	1.390	(0.135)	2.771	(0.244)	1.342	(0.196)	1.936	(0.270)	1.094	(0.268)
σ_0^m	1.154	(0.117)	1.340	(0.132)	1.309	(0.140)	1.240	(0.108)	1.831	(0.467)	1.281	(0.119)
a_0^x	-0.744	(1.610)	1.500	(2.461)	1.761	(0.810)	0.197	(1.185)	2.529	(2.271)	2.367	(1.771)
a_1^x	1.549	(0.368)	0.836	(0.256)	0.602	(0.117)	1.218	(0.188)	1.069	(0.297)	0.802	(0.203)
a_2^x	1.206	(0.569)	1.045	(0.750)	1.353	(0.148)	1.101	(0.360)	1.560	(0.438)	1.438	(0.548)
a_3^x	-0.336	(0.399)	0.059	(0.223)	0.130	(0.237)	-0.035	(0.211)	0.254	(0.506)	0.448	(0.245)
a_0^m	-1.203	(1.259)	1.978	(2.833)	-1.586	(0.552)	0.065	(0.942)	-0.348	(1.300)	0.994	(1.786)
a_1^m	0.906	(0.186)	1.331	(0.295)	1.188	(0.155)	1.008	(0.160)	0.866	(0.318)	0.949	(0.163)
a_2^m	0.175	(0.354)	0.850	(0.825)	0.278	(0.083)	0.251	(0.271)	0.355	(0.268)	0.579	(0.502)
a_3^m	0.123	(0.217)	0.281	(0.227)	0.395	(0.174)	0.674	(0.154)	0.847	(0.393)	0.810	(0.197)
f_e	4.194		4.995		13.036		4.103		5.730		3.792	

Notes: Standard errors are in parentheses. The parameters are evaluated units of millions of US dollars in 1990.

[36] 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 $\bar{V} \left(\eta', d_{it}; \tilde{\theta}, k(\tilde{\theta}, \hat{\theta}) \right)$ is strictly increasing in $k(\tilde{\theta}, \hat{\theta})$.