THE STRUCTURE AND EVOLUTION OF ENTRY COSTS IN TRADE

by

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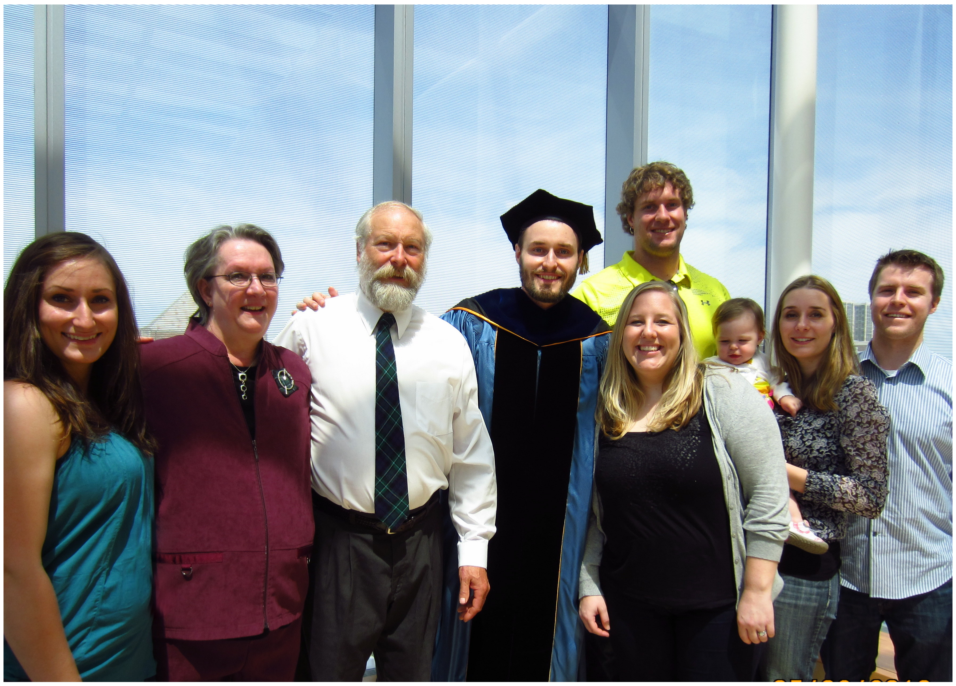

To my first teachers; Mom and Dad. To my first classmates; T, P, and tc. And to the McCallum dining room table.

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PREFACE

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CHAPTER I

Introduction

Understanding the frictions that make it difficult for U.S. firms to conduct trade with consumers and firms in foreign countries is the theme of this dissertation. It is well known that U.S. firms interact with economic agents in other counties infrequently relative to their U.S. counterparts. This basic observation implies the existence of significant barriers between national markets. Discerning how these frictions shape the global flow of goods, business opportunities for U.S. firms, and the welfare of foreign and U.S. consumers is at the heart of international economics.

The first essay focuses on uncovering the structure of export entry barriers faced by U.S. firms. I look for evidence of complementaries in entry costs that would generate increasing returns in the number of foreign destinations served. Perfect complimentary, or a global sunk export entry cost, is one the firm must pay to access any foreign market. Imperfect complimentarities might be geographic so that entering Germany reduces the cost of entering France, or linguistic so exporting to Mexico lowers barriers to entry into Spain. I discover that export status is hardly affected by past experience exporting to other countries, even when those other countries are similar to a potential export destination. In contrast, past experience exporting to a particular country is very helpful to accessing that destination again. This implies sunk entry barriers are mostly country specific.

I also provide the first dollar value estimates of up-front costs that fully account for the choice to access different markets and allow for a global entry cost. I find that the global cost is \$20 thousand while the cost to enter each country is \$3.7 million for Canada, \$4.16 million for Japan, \$3.58 million for Mexico, \$4.22 million for the United Kingdom, and \$3.63 million for Germany. These results are consistent with the descriptive statistics and reduced form results and again provide evidence that entry costs are mainly country specific.

The second essay explores the rise of worldwide trade since 1987. In particular, we look at the growth in the number of goods varieties traded internationally from the perspective of the U.S. manufacturing firms. Using data from the U.S. Census, we find that the percentage of plants that export rose from 21 percent in 1987 to 39 percent in 2006. In discussing the causes of similar documented trends in other countries, prior authors have suggested the natural explanation that the up-front costs of entering foreign markets has declined over time. We consider this hypothesis and find little evidence that these trends have been driven by substantial declines in entry costs. We instead make the case that increased participation was driven not by a decline in the cost of entering foreign markets but by an increase in the benefits of exporting. Specifically, the documented growth in foreign income over our time period is sufficient to account for the rise in U.S. export participation.

The final essay explicitly considers the process by which producers and consumers find one another. It embeds search and matching frictions in a general equilibrium international trade model with heterogeneous firms. The search friction at the heart of the model arises because it takes time and expense for U.S. importers to find suitable foreign varieties. Search implies that the price paid for an imported good lies between the domestic final sales price and the foreign affiliate's average cost of production. Largely due to profit maximizing conditions that survive the addition of search, many of the standard trade results remain intact. In particular, search frictions do not affect the quantity traded, the productivity threshold necessary to export or the domestic price. Nevertheless, the search friction enters the standard gravity equation, and the total value of imports falls as search frictions rise with the magnitude of the search friction having a first order effect on the value of imports. We argue ignoring these frictions will lead to biased estimates of the effect of variable and fixed trade costs and that quantifying the importance of search frictions requires using disaggregated data.

CHAPTER II

The Structure of Export Entry Costs

2.1 Introduction

Sunk export entry costs are a fundamental determinant of whether firms export; a fact which has been highlighted by modern firm level models of international trade in the style of Melitz (2003). Despite the important role sunk costs play, we understand little about their structure. In particular, we do not know if entry costs are country specific, global or something in between. A global sunk export entry cost is one the firm must pay to access any foreign market. An example of this is finding a transport company that ships to any location. Country specific sunk costs could be paid in addition to this cost in order to access a specific foreign market. These might include satisfying product safety requirements or establishing a distribution network at a national level. The true structure of entry costs could be something between purely global or country specific. In this case, entry costs could exhibit significant complementarities among destinations. Examples might be geographic so that entering Germany reduces the cost of entering France, or linguistic so exporting to Mexico lowers barriers to entry into Spain.

This paper makes two main contributions to understanding sunk export entry costs. First, it seeks to understand destination complementarity for firms' entry decisions and finds that entry costs are mostly country specific. Descriptive statistics show that U.S. firms only enter one destination when they start exporting and as such do not appear to be benefiting from returns to scale with regard to the number of destinations served. Reduced form results show export status exhibits tremendous country specific conditional persistence and is hardly affected by past experience exporting to other countries. In particular, if a firm exports to country c last year, the probability it exports to c this year increases by 26.19 percentage points. If they export to one location other than c, the probability they export to c this year increases by only 0.73 percentage points.

The second main contribution of the paper is to provide dollar value estimates of the up-front costs firms face when entering major U.S. export destinations. To my knowledge this is the only paper that provides estimates that fully account for the choice to access different markets and allow for a global entry cost. Using the Metal Forgings and Stampings (SIC 346) industry and the top 5 U.S. export destinations, I find that the global cost is \$20 thousand while the costs to enter each country are \$3.7 million for Canada, \$4.16 million for Japan, \$3.58 million for Mexico, \$4.22 million for the United Kingdom, and \$3.63 million for Germany. These results are consistent with the descriptive statistics and reduced form results and again provide evidence that entry costs are mainly country specific.

This paper also provides an important empirical test of the country specific entry cost assumption currently made by most heterogeneous trade models. Some standard results from these models rely on the assumption of country specific export entry costs. For example, in Melitz-style models, and Broda and Weinstein (2006) in particular, larger markets have higher welfare because they have access to more varieties. This result, however, is driven by the assumption of country specific sunk entry costs. If the sunk export entry costs is incurred in getting goods out of the domestic country instead of getting them into a foreign market, then the number of imported varieties is uncorrelated with market size. While purely global entry costs are the extreme case, any entry cost complementarities work towards separating the relationship between importer market size and welfare.

Additional motivation comes from Anderson and van Wincoop (2003) who showed that accounting for multilateral resistance dramatically attenuates estimates of the trade retarding effect of national borders. To date, however, analogous relationships along the participation margin of trade have received little attention. Large complementarities in entry costs could change the nature of firm participation in trade by introducing "hub" participation countries that share similarities to other potential destinations. These hubs would attract more varieties, and have higher welfare, than predicted by trade models that do not allow for complementarities in entry costs.

Any complementarities will also link the firm participation decision across export destinations. For example, if a European Union entry cost is large relative to country specific entry costs for the countries in the EU, then changes to market size, variable trade costs, and other country specific factors that increase the profitability of exporting to Germany will also raise the probability firms export to France. This simple mechanism links export participation across destinations in a novel and complex way. The existence of these linkages would have important policy implications since a reduction of bilateral tariffs will make a country more attractive but could also induce entry into other countries that share similar entry barriers.

It should be noted that throughout this paper I do not take a stand on the fundamental determinant of these sunk entry costs. In this respect, my paper differs from those that seek to introduce micro founded sources of sunk costs based on learning as in Ruhl and Willis (2009) and Eaton, Eslava, Krizan, Kugler and Tybout (2012), or search as in Chaney (2011), or reaching additional consumers as in Arkolakis (2010). With that said, the fact that I find entry costs to be mainly country specific and of similar magnitudes across destinations, is generally consistent with interpreting them as being mainly due to market penetration. This reinforces a report by the consulting firm First Washington Associates (1991) conducted for the World Bank which argues that the majority of foreign market entry cost is related to marketing. It also matches more closely the theoretical framework and results of Arkolakis (2010).

Nearly all canonical heterogeneous firm trade models assume entry costs are purely country specific as in Melitz (2003), Chaney (2008) and Eaton, Kortum and Kramarz (2011). Recently, three papers have shown that this assumption is suspect and argue there are significant complementarities among export participation decisions for different destinations. In particular, Hanson and Xiang (2011) consider two versions of the Melitz model. One version is standard and has only country specific entry costs. The second has both bilateral and global costs. The two versions lead to estimation equations that make opposing predictions about the sign of the coefficient on variable trade costs. They estimate these coefficients using U.S. movie sales and reject the model of only country specific sunk costs in favor of the model that includes global and country specific costs.

Allowing for a more nuanced relationship between destinations Morales, Sheu and Zahler (2011) study sunk costs for one Chilean chemicals industry 1995-2005 using a moment inequality approach. The authors find sunk export entry costs contain "gravity" and "extended gravity" components. The gravity component is such that Chilean firms find it less expensive to start exporting to countries that are more similar to Chile. The "extended gravity" component means Chilean firms find it less expensive to start exporting to countries that are more similar to countries the firm has exported to in the past. Their model also includes a basic cost that firms pay if they have no exporting experience. This basic cost is estimated to be approximately 70,000 year 2000 U.S. dollars. Overall their paper finds evidence that there is a global entry cost and significant complementarities to the up-front cost of exporting.

Using a panel of Norwegian manufacturers, Moxnes (2010) argues that both bilateral and global costs exist and that country specific costs are three times as large as global. The reduced form model includes two equations and does not provide estimates of entry costs but only of the persistence they introduce. One equation describes the decision to export to a specific country and the second equation captures the decision to export at all. A normally distributed firm-destination effect helps control for unobserved heterogeneity in this random effects framework. Joint estimation of the two choices is accomplished via dynamic mixed logit/probit models for panel data following Train (2003).

My results are largely consistent with Moxnes (2010) but stand in contrast to Morales, Sheu and Zhaler (2011) and Hanson and Xiang (2011). There are likely two explanations for this. First, like this paper, Moxnes (2010) relies on all Norwegian manufacturing sectors, whereas Morales, Sheu and Zhaler (2011) and Hanson and Xiang (2011) focus on individual industries, specifically a Chilean chemicals industry and U.S. movie producers, respectively. These specific industries may exhibit entry costs complementarities while most sectors do not. Second, as will be discussed in more detail in the reduced form section, identification of sunk costs relies on careful identification of state dependence which can be conflated with heterogeneity. Moxnes (2010) controls for unobserved heterogeneity while Morales, Sheu and Zhaler (2011) do not.

Lastly, Lincoln and McCallum (2012) use the two country model and Bayesian estimation strategy developed by Das, Roberts and Tybout (2007) to estimate entry costs that range from \$2 million to \$5.5 million year 1987 USD for four U.S. manufacturing industries. I estimate my model on the exact data used by Lincoln and McCallum (2012) for the 1992-2003 panel of the Metal Forgings and Stampings (SIC 346) industry. While their model and estimation method differ dramatically from the one presented here, my results are remarkably similar.

The next section presents stylized facts that shed light on the basic nature of up-front costs facing U.S. firms. Section three presents a dynamic panel linear probability model that utilizes all of the data. We learn about entry cost from this model because if there is a large global entry cost, then exporting somewhere in the past will raise the probability of exporting anywhere else in the present. Similarly, if there are significant complementarities among export destinations, exporting somewhere in the past will raise the probability of exporting to a similar country in the present. The results in both specifications imply entry costs are mainly country specific. Section four details the structural model which provides dollar value estimates of entry costs. In the model, each firm chooses the set of destinations to serve each period given the set of destinations they served last period. Firms are forward-looking and form a forecast of the expected profit stream they expect to earn based on a measure of their productivity and market demand. They then choose to pay the sunk entry cost if the discounted value of profits minus the sunk entry cost will result in positive net profit. I employ recent econometric advances discussed in Su and Judd (2012) in the estimation of the structural parameters of this dynamic discrete choice (DDC) model. Section five summarizes the results of the structural model showing again that entry costs are mostly country specific. Finally, the last section presents conclusions and avenues for further research.

2.2 Data and stylized facts

The data are from the Center of Economics Studies at the U.S. Census. The primary data sets are the Longitudinal Foreign Trade Transaction Database (LFTTD) which I match to the Business Registry (BR). The LFTTD provides the universe of U.S. firm export transactions 1992-2007 and the BR provides firm characteristics such as total employment, total wage bill and primary industry, among others. I observe about 40,000 U.S. manufacturing firms' exporting behavior to the top 50 export destinations over 16 years. I restrict the sample to firms with 20 or more employees and utilize only arms length export revenue. All export revenues are converted to

2000 USD using sector level producer price indexes from the NBER productivity database. Table 2.1 includes the top 50 countries along with the average number of U.S. firms exporting to each and average value of exports per firm over 1992-2007.

Throughout the paper I will define foreign market entry as a U.S. firm exporting a positive amount to a given country. Recent work by Bernard, Redding and Schott (2010) and Bernard, Redding and Schott (2011) highlight the importance of the product participation margin in addition to the firm participation margin. I abstract from the product dimension throughout this paper for two reasons. First, over longer time horizons, which will be the focus of this paper, the product space itself is endogenous since firms can choose to invent or abandon products. Likewise, natural attrition and uptake using any classification of products obscures the definition of export entry and exit at the product level. The second reason is that including products would increase firms' state space and quickly make my model intractable. As such, I focus on entry at the country-firm-year level and assume the set of countries a firm can choose to serve is exogenous.

A few descriptive statistics quickly shed light on the structure of export entry costs. If there is one global cost or significant complementarities in entry costs, then entry behavior benefits from returns to scale in the number of destinations entered. Table 2.2 shows that firms start exporting to only one market regardless of firm size. Furthermore, firms do not dramatically increase the number of foreign markets served after their first exporting experience. This is true across all employment size categories looking up to five years after a firm's initial entry into international markets. These numerical results are robust to a number of alternative definitions of foreign market entry and are remarkably similar when Canada is not considered a foreign market. Foreign market entry here is defined as exporting in the present year after not exporting for any of the past three years. Defining entry as exporting in the present year after having not exported in the past two years or not exporting in the past year also gives the same result.

Table 2.3 presents a similar message; firms only enter a few destinations when they start exporting. In fact, 99.1% of firms enter three or fewer destinations. Bernard, Jensen and Schott (2009) have a similar result using the cross section to report the number of destinations served by all exporters in 1993 and 2000. They do not restrict to new entrants as I do here and as such report a higher fraction of firms serving more destinations. Their higher fraction is likely driven by the fact that exporting firms are typically larger than new entrants and that these larger firms serve more destinations. Like Table 2.2, the results of Table 2.3 do not depend on length of export history used to define entry or if Canada is treated as a foreign market.

Looking at the destinations where firms begin exporting shows they are the same destinations that receive the most U.S. export volume. For example, firms start exporting to Canada, Mexico, the United Kingdom, Germany, Japan, Australia, Hong Kong, Singapore, China, Italy, France, The Netherlands, Ireland, Taiwan and South Korea. These entry destinations do not exhibit a striking pattern beyond what a standard gravity equation would suggest. In other words, there do not seem to be strong complementarities among the unconditional choice of entry destination.

Table 2.4 presents basic statistics regarding the first year of exporting. The vast majority of new exporters have fewer than 150 employees and have typical first year sales between $60,000 and $95,000 year 2000 USD per country served. These measures will be helpful for interpreting the entry cost estimates provided by the structural model.

Figure 2.1 provides more evidence that the main entry barriers firms face are country specific. As the value of exporting to a specific destination c increases, the probability that a firm exports there also increases. This relationship is evident in the data when using employment to proxy for the value of exporting. Furthermore, conditioning on firms exporting experience should shift this schedule up or down depending on the structure of entry barriers. As can be seen, the probability of exporting to a given destination is essentially unchanged for firms that have experience exporting to at least one other country and those that have no exporting experience. This stands in contrast to the dramatic increase in the fraction of firms that export to a specific country conditional on having exported there last year. The fact that country specific experience raises the probability of exporting to that country while general exporting experience does not suggests the magnitude of country specific entry costs is much larger than any global cost that might exist.

Understanding the determinants of the number of firms that export to a particular market, of which entry costs are certainly one, is important if we want to know why the U.S. exports a lot to some countries and not much to others. This fact has been known since Eaton, Kortum and Kramarz (2004) pointed out that the variation in the number of firms that export to different markets explains a large portion of the variation in total export flows. Figure 2.2 graphs the contributions of the log number of firms and log average exports to the total variance in U.S. exports across destination markets in each year 1992-2007. Firm participation contributes more than average exports in each year 1992-2007 and averages 41% of the total variance in export flows over that period. Removing Canada, or both Canada and Mexico, leaves each component with one third of the total variance. Summing both contributions does not add to 100 percent since the remaining portion in each year is from the covariance between the number of firms and average exports per firm.

2.3 Reduced form

This section presents a preliminary view of the geographic structure of entry costs using a reduced form model. The logic behind the specification comes from the seminal work of Dixit (1989) and Baldwin and Krugman (1989) and similar models have been employed to study export entry costs by Roberts and Tybout (1997), Bernard and Wagner (2001), Bernard and Jensen (2004) and Lincoln and McCallum (2012), among others. I use it because existence of country specific sunk entry costs will induce persistence in a firm's export status to that country. Additionally, existence of a global sunk entry cost implies that the probability of serving any destination increases if the firm has prior experience exporting anywhere else. Likewise, components of entry cost that depend on similarities between countries would lead prior exporting experience to a destination that shares some characteristic, for example, legal origin or common border, to increase the probability of exporting to a similar destination. The specification here has a few advantages. First, its simple linear structure allows consideration of 50 countries and all U.S. firms. Second, it exploits the panel structure of the data to control for unobserved heterogeneity which can confound identification of state dependence induced by entry costs. And third, it provides a way to check the basic framework and assumptions of the structural model put forward in the next section.

2.3.1 State dependence vs. heterogeneity

To explain how sunk export entry costs map to persistence, consider the following basic process

$$y_{cit} = \rho y_{cit-1} + \varepsilon_{cit} \tag{2.1}$$

where $y_{cit} = \{0, 1\}$ denotes if firm i exports to country c in year t and ε_{cit} is $i.i.d.$ mean zero with a finite second moment. This example abstracts from any other covariates that might cause a firm to export in order to explain the link between sunk costs and persistence as clearly as possible. Absent estimation issues, the persistence coefficient in the regression is $P\left[y_{cit} = 1 \mid y_{cit-1} = 1\right] - P\left[y_{cit} = 1 \mid y_{cit-1} = 0\right] = \rho$. Hence, if the firm exported last period, the probability it exports this period increases by ρ. Each probability that comprises persistence has a straightforward linkage to sunk costs. The term $P\left[y_{cit} = 1 \mid y_{cit-1} = 1\right]$ is the probability that a firm continues to serve a destination. Higher sunk entry cost will increase the real option value of remaining an exporter despite temporary shocks to ε_{cit} and in turn increase this probability. The second term, $P\left[y_{cit}=1 \mid y_{cit-1}=0\right]$ is the probability of entry which is decreasing in the magnitude of the sunk entry cost. Therefore, greater persistence implies higher sunk entry costs and vise versa. If there are any sunk costs so that $\rho > 0$, the state of exporting last period raises the probability of exporting this period and the process exhibits state dependence.

One of the seminal papers to study sunk export entry costs, Roberts and Tybout (1997), highlights the fact that identifying export entry costs requires separating persistence generated by sunk entry costs from any other sources of persistence in exporting status. The fact that state dependence can be conflated with heterogeneity has been well known since Heckman (1981) and Chamberlain (1985). Estimated persistence may be due to "true" state dependence or due to either observed or unobserved heterogeneity. In particular, time invariant error components and persistent errors are two important types of unobserved heterogeneity. Persistence due to permanent heterogeneity simply reflects underlying differences in firms and their propensity to export to a given destination. Such "spurious" state dependence would lead to incorrect conclusions about the nature of sunk export entry costs and must therefore be carefully controlled for in any empirical specification.

The importance of firms' lasting differences has received considerable attention following Melitz (2003). That trading and non-trading firms differ has been documented many times and a good survey is provided by Redding and Melitz (forthcoming). However, trading firms also differ from other trading firms. Bernard, Jensen, Redding and Schott (2010) document substantial heterogeneity among trading firms that contributes to deviations from standard gravity model predictions. In short, there is significant heterogeneity among firms that needs to be properly conditioned out of any regression that seeks to identify state dependence. Including observable firm and destination specific variables will be important but inevitably some unobserved heterogeneity will remain. For example, we have little hope of observing variables that measure managerial ability, product quality or foreign consumers' affinity towards an American brand. As such, both in the reduced form and structural models, controlling for unobserved heterogeneity will be a prerequisite for identifying entry costs.

2.3.2 Specification

The specification is a dynamic panel linear probability model (LPM)

$$y_{cit} = \sum_{h=1}^{p} \beta_h y_{cit-h} + \sum_{h=1}^{p} \gamma_h n_{it-h} + \sum_{h=1}^{p} \lambda_h X_{cit-h} + \delta_t + \delta_{ci} + \epsilon_{cit} \tag{2.2}$$

where i , c, and t index firms, countries, and years respectively. The dependent binary variable $y_{cit} = \{0, 1\}$ is on if firm i exports to country c in year t and off otherwise. The coefficients on the lagged country specific export variables, β_h, are the marginal increase in the probability of exporting to a country this year if the firm exported there last year. The variable, $n_{it-h} \equiv \sum_{k \neq c} y_{kit-h}$, is the number of other destinations, not including the dependent variable destination, to which the firm exported in period $t-h$. The relative magnitude of coefficients β and γ captures the relative importance of the country specific (bilateral) and global entry costs. The controls in X_{cit-h} include both firm specific and country specific variables. Among the firm specific variables, X_{it-h}, are the log of the average real wage (to proxy for labor productivity) and the log of the number of employees (which proxies for other sources of productivity). The foreign market specific covariates, X_{ct-h}, include the log of average real exports per firm to that market (to control for foreign market size, tariffs faced by U.S. exporters, and transport costs), the log of the number of U.S. manufacturing firms that export to that market (to control for general market attractiveness and potential network effects) and the log of the real exchange rate defined so an increase corresponds to a depreciation of the foreign currency relative to the U.S. dollar.

The baseline specification above allows comparison of the country specific and global sunk entry cost but extensions are readily available. In particular, testing the impact of other entry cost complementarities is now possible. Consider the specification

$$y_{cit} = \sum_{h=1}^{p} \beta_h y_{cit-h} + \sum_{h=1}^{p} \gamma_h^{legl} n_{it-h}^{legl} + \sum_{h=1}^{p} \gamma_h^{ctig} n_{it-h}^{ctig} + \sum_{h=1}^{p} \lambda_h X_{cit-h} + \delta_t + \delta_{ci} + \epsilon_{cit} \quad (2.3)$$

where n_{it-h}^{legl} and n_{it-h}^{ctig} are the number of countries, other than the dependent variable country, to which the firm exports in period $t-h$ that share common legal origin or a contiguous border with country c. For brevity I use only legal origin and contiguous border as examples here but the regression results in Table 2.6 include common colonial relationship, contiguous border, common currency, similar distance from the U.S., common language, common legal origin, similar per capita GDP, common region, and common memberships in regional trade agreements.

Identification of the country specific or other components of entry costs is achieved by exploiting the dynamic panel structure of the model. Shocks to X_{cit-h} will change the value of exporting to specific locations and therefore induce changes in export status to that country, y_{cit-h}, and the number of other destinations, n_{it-h}, as well. The variation in y_{cit-h} and n_{it-h} then allows identification of their respective coefficients and the nature of entry costs. Hence, shocks to X_{cit-h} induce variation in the lagged dependent variables where the magnitude of these relative responses then allows distinguishing between types of entry costs.

Finally, since this is a paper about firm participation, often called the extensive margin of trade, the work of Armenter and Koren (2012) will be particularly useful in considering what I can hope to learn from the micro data. Their main point is to carefully choose the null hypothesis for any moment calculated in the data. Sparsity makes it difficult to distinguish zeros that occur in the data at random from zeros generated by structural features. Their "Balls-and-Bins" model of trade, however, provides a guide for which moments can be used to identify structural models of trade. They suggest the fraction of firms that export is a particularly useful moment. The expected value of the dependent variable in my specification is precisely the fraction of firms that export to country c in year t and likewise should be informative according to their reasoning.

2.3.3 Estimation issues

As outlined above, the way I learn about sunk entry costs is by carefully decomposing country specific state dependence from other sources of export status state dependence. I need to use a dynamic model to identify state dependence but omitting unobserved heterogeneity will lead to upwards biased estimates of the persistence coefficients. Intuition for this upwards bias in the present context can be developed by considering the possibility that some firms are "good" at exporting and some are "bad" at exporting. Firms that are "good" at exporting will likely always export and firms that are "bad" will likely export less often. In this way, the "good" and "bad" heterogeneity will cause observed export status to appear more persistent than if it is properly conditioned out. In particular, if there is any unobservable heterogeneity simple OLS will lead to an over estimate of persistence.

I can exploit the panel structure of the data and use fixed effects to control for unobserved heterogeneity. However, well known work on dynamic panel estimation where unobserved individual heterogeneity is removed by first differences (FD) was shown by Nickell (1981) to give persistence estimates that are biased downwards when the true coefficient is positive. The explicit functional form of the bias using the within-group (WG) transformation and WG with time dummies are provided by Hahn and Kursteiner (2002) and Hahn and Moon (2006), respectively. These two papers show that WG (with or without time effects), like FD, is asymptotically biased if the ratio N/T goes to a constant even as N and T individually go to infinity. For fixed N, the asymptotic bias is order $O\left(T^{-1}\right)$ in each of these papers. As such, without the constraint on the ratio of N/T the asymptotic bias eventually disappears. The asymptotic bias is also a function of the error variance-covariance matrix so the absolute size of the bias depends on an unobserved quantity. Using Monte Carlo experiments, Arellano (2003) argues that if the number of periods is at least 10 then the downward bias caused by the within-group estimator is likely small.

In summary, OLS will provide an over estimate of the importance of country specific exporting experience, and within-group estimation that includes fixed effects will provide an underestimate. In order to consistently estimate the parameters for fixed T I employ the unbiased GMM based estimator developed by Arellano and Bond (1991). The assumptions of this estimation technique are valid in the linear probability model context despite the assured heteroskedasticity of the model. As a reminder, linear probabilities models are assured to be heteroskedastic since the estimated errors can only take two values. Standard errors are clustered at the firm level and I rely on at least 1.5 million cross section firm-country observations to deal with any remaining heteroskedasticity. Using weak instruments or specifying a large number of moment restrictions relative to the cross section sample size has been shown to lead to considerable finite sample bias in Monte Carlo studies of the dynamic panel GMM estimators. Among others, see Arellano and Bond (1991), Kiviet (1995), Ziliak (1997), Blundell and Bond (1998) for details. The large number of cross section observations relative the number of moments I employ reduce any worries on this score.

2.3.4 Reduce form results

The baseline results presented in Table 2.5 suggest that sunk export entry costs are largely country specific. The first column presents the OLS based estimates that do not control for unobserved heterogeneity and will overestimate the importance of country specific sunk costs. The second column presents the consistent Arellano and Bond (1991) estimation results where firm-country and time fixed effects are included. The third column presents within-group estimation that allows firm-country and time fixed effects and will underestimate the importance of country specific sunk entry costs. In short, columns one and three present upper and lower bounds of the country specific effects and column two presents a consistent estimate. Finally, column four includes all possible interacted fixed effects; firm-time, country-firm, and country-time using the within-group estimator. The fact that columns three and four give similar estimates of country specific persistence suggests the controls in columns two and three do a good job of controlling for heterogeneity.

Since the model is an LPM, the coefficients are interpreted as marginal changes in probability. Considering the second column and holding all else constant, if a firm exported to country c last year, the probability it exports to c this year increases by 26.19 percentage points. If they export to one location other than c, the probability they export to c this year increases by 0.73 percentage points. The export status process exhibits tremendous country specific conditional persistence and is hardly affected by exporting to other countries. Even if a firm exported to 10 other locations last year, the probability they export to country c increases by only 7.3 percentage points which is less than the effect of exporting to country c two years ago. These results are remarkably similar across estimation techniques denoted by each column. The number of other countries served in the past is collinear with the interacted fixed effects included in column four and is therefore omitted.

While Table 2.5 results are consistent with the definition of a global sunk entry cost, the true nature of entry costs may be determined by similarities between countries instead of exporting experience to any destination. As such, Table 2.6 includes the second specification. This regression allows for many different sources of complementarities but the message is the same as the baseline regression. Looking again at the second column and holding all else constant, if a firm exports to c last year, the probability they export to c this period increases by 26.08 percentage points. If last year they exported to one location other than c that at some time in the past had a colonial relationship with c, the probability they export to c this year increases by 1.64 percentage points. This is the largest complimentary effect that can be seen in Table 2.6 and is likely due to the historical colonial relationship between the United Kingdom and Canada which are both common export destinations for U.S. firms. The marginal effect of each of the complementarities is small relative to the country specific effect. Even if a country c shares many similarities with a destination, the sum of the effects will be small relative to country specific exporting experience. Again, these results are not sensitive to the estimation methodology presented in each of the columns.

As mentioned in the introduction, I do not take a stand on the fundamental source of these sunk entry costs. With this agnosticism in mind the specifications above includes three lags on all variables. The coefficients on these lags can be interpreted as demand accumulation, learning, market penetration or decay in a true sunk entry cost. They can also account for the well documented increased survival rate of firms that remain in a market. For example, the baseline results of Table 2.5 column two implies that a firm that has three continuous years of exporting experience to a market will have a $26.19 + 9.10 + 3.16 = 38.45$ percentage point increase in the probability they export to that market this year. In contrast, one year of export experience only raises the probability by 26.19 percentage points. My results suggest any meaningful effect of demand accumulation, learning or decay in entry costs is largely experienced in the first year and completely realized after three years.

I present a few robustness checks for these baseline specifications. In particular, I use an indicator variable that is on if the firm exported elsewhere in the past instead of using the number of other destinations. I do this for both the regression that tests for global entry costs and the one with gravity similarities. I also change the sample for both specifications. The baseline sample follows the literature, and Roberts and Tybout (1997) in particular, in allowing for firms to enter production but not to exit. This ensures any exit from exporting is a true exit from exporting and not a firm shutting down. To check that this assumption is not driving the results I also estimate the model on a balanced panel and a panel that allows for firm birth and firm death and get the same results. Finally, much of the international trade literature makes a significant distinction between the behavior of firms of different sizes. To check this, I restrict the firms in the sample by firm size categories and still find that the magnitude of the country specific experience is much larger than other sources of persistence.

2.4 Dynamic structural model

This section presents a structural model of the decision firms make to enter foreign markets. Firms are forward looking and have pricing power once they enter a foreign market. Each period they consider all possible combinations of destinations they could serve and choose the set that maximizes value. The model is partial equilibrium in that firms' choices do not have an effect on the macroeconomic environment but the structure I employ allows each sector to be nested in a familiar general equilibrium model in the spirit of Melitz (2003). I also abstract from strategic behavior among firms.

Intuitively, firms solve the entry decision using backwards induction. First they decide what price to charge if they export to a country, then given this behavior they form an estimate of the future profit stream of serving each market and enter the set of markets that will result in positive profits net of any entry costs. The operating profit generated by each firm is a simple function of expected revenue. Expected revenue, however, cannot be calculated simply using observed revenue in each market because revenue is only observed when the firm exports to that market. This commonly seen problem is often referred to as Heckman selection after Heckman (1979) but is also known as a type II probit model. I resolve this problem by jointly estimating the determinants of revenue and export participation.

2.4.1 Optimal static pricing decision (intensive margin)

There are C countries indexed by c, and $S+1$ sectors indexed by s. The representative consumer in country c has Cobb-Douglas utility over the goods produced by each sector

$$U_{ct} \equiv q_{0ct}^{\mu_{ct}^{0}} \prod_{s=1}^{S} q_{sct}^{\mu_{ct}^{s}} \tag{2.4}$$

where q_{sct} is consumption of differentiated goods sector s in country c in calendar year t. q_{0ct} is consumption of a freely traded homogeneous good that will serve as the numeraire. It is produced under constant returns to scale with one unit of labor. The exponent μ_{ct}^{s} can be interpreted as a country and sector specific demand shock that varies by year. Since the utility function is Cobb-Douglas, the expenditure on goods from sector s is $Y_{ct}^{s} = \mu_{ct}^{s} Y_{ct}$ where Y_{ct} is aggregate expenditure in country c.

Each sector is an aggregate of Ω_{ct}^{s} varieties, one produced by each firm i. The aggregator is CES with country and sector specific elasticity of substitution ε_{cs} across varieties

$$q_{ct}^{s} = \left[\sum_{i \in \Omega_{ct}^{s}} \omega_{cit}^{1/\varepsilon_{cs}} \left(q_{cit}\right)^{\frac{\varepsilon_{cs}-1}{\varepsilon_{cs}}} \right]^{\frac{\varepsilon_{cs}}{\varepsilon_{cs}-1}} \tag{2.5}$$

where each firm faces a demand shock ω_{cit} to it's own variety. Firms are monopolistically competitive so they set prices equal to a markup times the marginal cost of exporting to country c

$$p_{cit}^{s} = m_{cs} \tau_{ct}^{s} c_{t}^{s} a_{it} \tag{2.6}$$

where the markup is $m_{cs} = \frac{\varepsilon_{cs}}{\varepsilon_{cs}-1}$, $\tau_{ct}^{s} \geq 1$ is a sector specific iceberg cost, c_{t}^{s} is the cost of an input bundle and a_{it} is a firm's efficiency. The c_{t}^{s} input bundle can include any input costs as long as the firm can flexibly adjust that input within the period and as long as the production function is constant returns to scale. Including this optimal price gives a firm's export revenue as

$$R_{cit}^{s} = \omega_{cit} \frac{\mu_{ct}^{s} Y_{ct} \left(m_{cs} \tau_{ct}^{s} c_{t}^{s} a_{it}\right)^{1-\varepsilon_{cs}}}{\left(P_{ct}^{s}\right)^{1-\varepsilon_{cs}}} \tag{2.7}$$

From here on suppress the sector superscript and subscript s since I will estimate the structural model sector-by-sector. Taking the log of (2.7) gives

$$r_{cit} = (1-\varepsilon_{c}) \ln m_{c} + (1-\varepsilon_{c}) \ln (c_{t} a_{it}) + \ln \mu_{ct} Y_{ct} + (1-\varepsilon_{c}) \ln \left(\frac{\tau_{ct}}{P_{ct}}\right) + \ln \omega_{cit} \tag{2.8}$$

I will not observe all the variables in this expression and I need to keep the state space parsimonious so I parametrize log revenue as

$$r_{cit} = \alpha_{c} + \beta_{c} w_{it} + \gamma_{c} x_{t} + \eta_{cit} \tag{2.9}$$

where w_{it} is the log number of full-time employees at firm i in year t and x_{t} is the log of U.S. manufacturing exports. Notice that each term has a straightforward mapping to the constant, marginal cost, and market size and tariff measures in the full revenue expression. I assume the demand shock $\eta_{cit} \sim N\left(0, \sigma_{c\eta}^{2}\right)$ *i.i.d.* so log revenue is distributed according to

$$f\left(r_{cit} \mid w_{it}, x_t\right) = \sigma_{c\eta}^{-1}\phi\left(\frac{r_{cit} - \alpha_c - \beta_c w_{it} - \gamma_c x_t}{\sigma_{c\eta}}\right) \tag{2.10}$$

where $\phi(\cdot)$ denotes the standard normal probability density function. The *i.i.d.* assumption implies that, while firms know their specific distribution of revenue in a market, they do not know their revenue realization until after making the entry decision. I assume firms make their decision to enter the market using the properties of the log normal distribution to calculate expected revenue

$$E\left[R_{cit} \mid w_{it}, x_t\right] = \exp\left(\alpha_c + \beta_c w_{it} + \gamma_c x_t + \frac{1}{2}\sigma_{c\eta}^2\right) \tag{2.11}$$

Before accounting for sunk entry cost, define gross operating profits as

$$\pi_{cit}^g = \varepsilon_c^{-1} E\left[R_{cit} \mid w_{it}, x_t\right] - f_c \tag{2.12}$$

This expression for gross profit nests the standard result for monopolistic competition and CES demand when there is no uncertainty and no period fixed costs (i.e. $\sigma_{c\eta}^2 = 0,\ f_c = 0$). Export revenue cannot be negative in the model, which is consistent with monopolistic competition, but gross operating profits may be. Also, uncertainty in the level of revenue will unambiguously increase expected revenue but will not guarantee positive gross operating profits.

2.4.2 Dynamic destination choice (extensive margin)

I characterize the entry decision of the firm taking optimal pricing behavior once they enter as determined by the assumptions in the previous section. As such, period net profit takes the sum of gross operating profit across countries and subtracts country specific and global entry cost

$$\pi\left(\mathbf{y_{it}},\mathbf{y_{it-1}},w_{it},x_t\right)=\sum_c\left(\varepsilon_c^{-1}E\left[R_{cit}\mid w_{it},x_t\right]-f_c\right)y_{cit}-\mathbf{b}\cdot\mathbf{e_{it}}-g\cdot e_{it}^g+\epsilon_{it}\left(\mathbf{y_{it}}\right) \tag{2.13}$$

where $\mathbf{y_{it}}$ is a $C\times 1$ vector of indicator variables. Each element of this vector defines the binary exporting status of firm i in year t to a particular country c. For example, if I restricted the set of countries under consideration to Canada and Mexico, the status vector would be $\mathbf{y_{it}}=(y_{CANit},y_{MEXit})'$ and exporting to only Canada would make the vector $(y_{CANit},y_{MEXit})'=(1,0)'$. Notice that if $\mathbf{y_{it}}$ is a vector of zeros, the firm only serves the U.S. market. I do not allow firms to enter or exit production entirely since they must at least always serve the U.S. market. Country specific export entry costs $\mathbf{b}$ are also in a $1\times C$ vector. Entry is captured by the vector of entry indicators $\mathbf{e_{it}}=\mathbf{e_{it}}\left(\mathbf{y_{it}},\mathbf{y_{it-1}}\right)$ which is $C\times 1$ and has the same structure as $\mathbf{y_{it}}$. Each element of $\mathbf{e_{it}}$ is an indicator where firm i entered market c in year t if current export status $y_{cit}=1$ but last year's export status was $y_{cit-1}=0$. The parameter g is the scalar global entry cost if the firm did not serve any foreign market last period but exports today. The scalar $e_{it}^g=e_{it}^g\left(\mathbf{y_{it}},\mathbf{y_{it-1}}\right)$ is a scalar indicator equal to one if the firm exports somewhere this year and did not serve any foreign destination last period. There is one scalar structural error draw $\epsilon_{it}=\epsilon_{it}\left(\mathbf{y_{it}}\right)$ for each combination of $\mathbf{y_{it}}$ destinations. This is an unobserved error for the econometrician but an observed state variable for the firm. Given their current state $(\mathbf{y_{it-1}},w_{it},x_t,\epsilon_{it})$, the firm chooses the current and future set of countries that maximizes the expected present discounted value of future period profits where the expectation is taken over the future evolution of states and δ is the discount rate. I will assume that all stochastic states have Markov transition densities so the value function can be written using Bellman's equation

$$V\left(\mathbf{y_{it-1}},w_{it},x_t,\epsilon_{it}\right)=\max_{\mathbf{y_{it}}}\left\{\pi\left(\mathbf{y_{it}},\mathbf{y_{it-1}},w_{it},x_t\right)+\epsilon_{it}\left(\mathbf{y_{it}}\right)+\delta E\left[V\left(\mathbf{y_{it}},w_{it+1},x_{t+1},\epsilon_{it+1}\right)\right]\right\} \tag{2.14}$$

where the expectation $E\left[\cdot\right]$ is against the joint transition density denoted by

$$p\left(w_{it+1}, x_{t+1}, \epsilon_{it+1} \mid \mathbf{y_{it-1}}, w_{it}, x_t, \epsilon_{it}\right) = p_x\left(x_{t+1} \mid x_t\right) p_w\left(w_{it+1} \mid w_{it}\right) p_\epsilon\left(\epsilon_{it+1} \mid \mathbf{y_{it}}\right) \tag{2.15}$$

Here I have assumed $(x_{t+1}, w_{it+1}, \epsilon_{it+1})$ are independent of one another and that $\mathbf{y_{it}}$ is conditionally independent of ϵ_{it+1} which is *i.i.d.* over time. The independence of these three transition densities allows computation of the three integrals in the continuation value sequentially instead of simultaneously. As can be seen, the transition densities for total U.S. exports, x_t, and firm level employment, w_{it}, do not depend on the export decision, $\mathbf{y_{it-1}}$. This assumption is not very restrictive for U.S. exports but may be more so for firm level employment. Given the relative importance of domestic sales versus exports, however, U.S. firms likely make their employment decisions independently of their export profile. Therefore, I think it is a reasonable assumption that goes a long way towards making the model tractable.

The transition for firm employment is

$$p_w\left(w_{it+1} \mid w_t\right) = \tau_w^{-1} \phi^{TR}\left(\frac{w_{it+1} - \lambda_w - \rho_w w_{it}}{\tau_w}\right) \tag{2.16}$$

where I assume the same form for $p_x\left(x_{t+1} \mid x_t\right)$ and $\phi^{TR}(\cdot)$ denotes the truncated normal distribution. Truncating the possible shocks to the state variables is a prerequisite for using Chebyshev functional approximation which I use to get the expected value function. With that said, I truncate to within 6 standard deviations of the observed shocks. Since these processes are independent of the export decision, I can estimate their parameters using OLS prior to solving the structural model. This trades statistical efficiency in the estimation of the parameters governing these transitions for a reduction in the computational burden of the structural model.

Assuming that $\epsilon_{it}(\mathbf{y_{it}})$ is distributed type-one extreme value (T1EV) [1] *i.i.d.* across

[1] The type-one extreme value distribution, also known as the Gumbel distribution, is governed by

choices, time and firms allows me to invoke McFadden (1974) and Rust (1987) and obtain a contraction mapping that defines the expected value function in closed form

$$V\left(\mathbf{y_{it-1}}, w_{it}, x_t\right) = \ln\left(\sum_{\mathbf{y^*_{it}}} \exp\left[\pi\left(\mathbf{y^*_{it}}, \mathbf{y_{it-1}}, w_{it}, x_t\right) + \delta E_{t+1}\left[V\left(\mathbf{y^*_{it}}, w_{it+1}, x_{t+1}\right)\right]\right]\right) + \gamma \tag{2.17}$$

where $\mathbf{y^*_{it}}$ indexes all 2^C combinations of the destination vector $\mathbf{y_{it}}$ that the firm could choose this period, $E_{t+1}\left[\cdot\right]$ is the expectation against the remaining state variables (w_{it+1}, x_{t+1}) and $V\left(\mathbf{y_{it-1}}, w_{it}, x_t\right) \equiv E_\epsilon\left[V\left(\mathbf{y_{it-1}}, w_{it}, x_t, \epsilon_{it}\right)\right]$ defines the expected value function. The T1EV assumption on the error also implies the familiar multinomial logit form for the conditional choice probability

$$P\left[\mathbf{\tilde{y}_{it}} \mid \mathbf{y_{it-1}}, w_{it}, x_t\right] = \frac{\exp\left[\pi\left(\mathbf{\tilde{y}_{it}}, \mathbf{y_{it-1}}, w_{it}, x_t\right) + \delta E_{t+1}\left[V\left(\mathbf{\tilde{y}_{it}}, w_{it+1}, x_{t+1}\right)\right]\right]}{\sum_{\mathbf{y^*_{it}}} \exp\left[\pi\left(\mathbf{y^*_{it}}, \mathbf{y_{it-1}}, w_{it}, x_t\right) + \delta E_{t+1}\left[V\left(\mathbf{y^*_{it}}, w_{it+1}, x_{t+1}\right)\right]\right]} \tag{2.18}$$

This is the probability the set of destinations $\mathbf{\tilde{y}_{it}}$ is selected given the equations in the model, structural parameters, transition densities, and firm's observable state $(\mathbf{y_{it-1}}, w_{it}, x_t)$.

2.4.3 Likelihood

The likelihood contribution of each firm in each time period is determined by the probability of observing the export destinations $\mathbf{y_{it}}$ and log revenues r_{cit} from each market

$$l_{it}\left(\theta \mid \mathbf{y_{it}}, \mathbf{y_{it-1}}, x_t, w_{it}, \mathbf{r_{it}}\right) = \left(P\left[\mathbf{\tilde{y}_{it}} \mid \mathbf{y_{it-1}}, x_t, w_{it}\right] \prod_c f\left(r_{cit} \mid y_{cit} = 1, x_t, w_{it}\right)\right)^{1(\mathbf{\tilde{y}_{it}} = \mathbf{y_{it}})} \tag{2.19}$$

the location parameter μ and scale parameter σ. If an i.i.d. random variable $\epsilon \sim T1EV\left(\mu, \sigma\right)$, then $mode\left(\epsilon\right) = \mu$, $V\left[\epsilon\right] = \frac{\pi^2}{6}\sigma^2$, and $E\left[\epsilon\right] = \mu + \sigma\gamma$ where $\gamma \approx 0.5772$ is the Euler-Mascheroni constant.

where $P[\cdot]$ is the conditional choice probability from (2.18) and $f(\cdot)$ is the distribution of log revenue given in expression (2.10). The variable $\mathbf{\tilde{y}_{it}}$ is a set of destinations for which the probability is defined by the model and the indicator $1(\mathbf{\tilde{y}_{it}} = \mathbf{y_{it}})$ is on when that same set is observed in the data as being selected by firm i in period t.

The time series observations run from $t = 1, \ldots T$ and as such I do not observe the export destination set served prior to the start of the sample, $\mathbf{y_{i0}}$. The key here will be to define a new expression for $P[\mathbf{\tilde{y}_{i1}} \mid \mathbf{y_{i0}}, x_1, w_{i1}]$ that does not depend on $\mathbf{y_{i0}}$. I will retain the same assumptions that the unobserved state variables are T1EV and employ a flexible functional form of the log of total employment at the firm, w_{i1} in the first observed period

$$P[\mathbf{\tilde{y}_{i1}} \mid w_{i1}] = \frac{\exp\left[\sum_c (\psi_c + \xi_c w_{i1}) \tilde{y}_{ci1}\right]}{\sum_{\mathbf{y^*_{it}}} \exp\left[\sum_c (\psi_c + \xi_c w_{i1}) y^*_{ci1}\right]} \tag{2.20}$$

The contribution to the likelihood provided by the level of revenue is not needed in this initial period. Since participation in (2.18) is not a function of revenue, I bypass the selection issue in the initial period. Furthermore, the revenue distribution is independent over time so specifying an initial condition for revenue is unnecessary.

The likelihood accounting for the initial conditions correction is

$$L(\theta \mid \mathbf{y}, \mathbf{w}, \mathbf{x}, \mathbf{r}) = \prod_{i=1}^{N} \prod_{t=2}^{T} \left(P[\mathbf{\tilde{y}_{it}} \mid \mathbf{y_{it-1}}, x_t, w_{it}] \prod_c f(r_{cit} \mid y_{cit} = 1, w_{it}, x_t) \right)^{1(\mathbf{\tilde{y}_{it}} = \mathbf{y_{it}})} P[\mathbf{\tilde{y}_{i1}} \mid w_{i1}]^{1(\mathbf{\tilde{y}_{i1}} = \mathbf{y_{i1}})} \tag{2.21}$$

Let the vector $\theta = (g, b_c, f_c, \varepsilon_c, \alpha_c, \beta_c, \gamma_c, \sigma_c, \psi_c, \xi_c)$ collect all the parameters of the model that will be estimated in the structural routine. The likelihood is the probability of observing the initial set of destinations and then the sequence of country choices and revenue levels over time for all the firms in the sample.

2.4.4 Estimation

Maximizing the likelihood itself is not sufficient since I need to ensure any parameters are also consistent with the forward looking behavior of the firm defined by the value function above. To estimate the parameters of the model and ensure they satisfy the model I employ Mathematical Programing with Equilibrium Constraints (MPEC). This method allows maximization of the likelihood function subject to the constraints that define the value function. First introduced in the economics literature by Su and Judd (2012), MPEC has been shown to be an important improvement when parameter estimation implies solving an additional optimization problem.

There are two key benefits to MPEC over the nested fixed point (NFP) method introduced by Rust (1987). First, MPEC is more numerically stable than NFP according to Dubé, Fox and Su (2012). The intuition for this result is quite simple. Since NFP requires using a parameter vector selected in an outer loop as an input to solving the model in an inner loop, the likelihood value for that parameter vector depends on the parameters and on quality of the solution to the model in the inner loop. Imprecise solutions to the model can give incorrect inference regarding the most likely parameter vector. The second benefit of MPEC is a reduction in computation time by exploiting recent developments from operations research and computer science in the area of robust constrained optimization. Given the potential size of the state space, being able to provide the solver with analytical gradients of the likelihood and using Chebyshev function approximation to search over Chebyshev coefficients instead of value function points on a grid also provides significant computational savings.

The MPEC constraint is a functional equation defined by the expected value function in (2.17). In order to solve this problem on a computer, it needs to be discretized. Finding the expected value function on a grid is a common approach. However, a priori definition of a grid for the state variables is restrictive and could possibly lead to incorrect inference. I want to allow the data to inform the estimates as much as possible without forcing these variables onto a grid. Additionally, as the number of grid points grows the quality of approximation increases but so too does the computation time.

Instead of searching for the value function at each point in a discrete state space I search for the Chebyshev coefficients that approximate the expected value function. I employ the methods outlined in Judd (1998) and Judd (1992) to construct the Chebyshev approximation to the expected value function as

$$V\left(\mathbf{y_{it-1}}, w_{it}, x_t\right) \approx r_{\mathbf{y_{it-1}}} \Lambda\left(w_{it}, x_t\right) \tag{2.22}$$

where $r_{\mathbf{y_{it-1}}}$ is a $1 \times R$ vector of Chebyshev coefficients and $\Lambda\left(w_{it}, x_t\right)$ is an $R \times 1$ vector of Chebyshev polynomials evaluated at the continuous state variables. Chebyshev polynomial approximation is not well suited to the approximation of discontinuous functions and I want to allow the state variable $\mathbf{y_{it-1}}$ to possibly result in discrete jumps in the expected value function. Therefore, I allow the coefficients $r_{\mathbf{y_{it-1}}}$ to differ for each possible set of destinations $\mathbf{y_{it-1}}$ that might be selected.

Using the Chebyshev approximation, the final MPEC problem searches for the structural parameters θ and the Chebyshev coefficients r that define the approximate expected value function

$$\max_{\theta, r} \quad \ln\left[L\left(\theta \mid \mathbf{y_{it}}, \mathbf{y_{it-1}}, w_{it}, x_t\right)\right]$$

subject to

$$r_{\mathbf{y_{it-1}}} \Lambda\left(w_{it}, x_t\right) = \ln\left(\sum_{\mathbf{y^*_{it}}} \exp\left[\pi\left(\mathbf{y^*_{it}}, \mathbf{y_{it-1}}, w_{it}, x_t\right) + \delta E_{t+1}\left[r_{\mathbf{y_{it}}} \Lambda\left(w_{it+1}, x_{t+1}\right)\right]\right]\right)$$

where the objective function is defined in (2.21) and the constraint defining the functional equation version of the expected value function is from (2.17). The two integrals in $E_{t+1}[\cdot]$ are against $p_w\left(w_{it+1} \mid w_t\right)$ and $p_x\left(x_{t+1} \mid x_t\right)$. They are computed sequentially using Gauss-Legendre quadrature and the truncated normal transition densities from above.

2.5 Structural results

The only other paper that has estimated the up-front cost of exporting for the U.S. is Lincoln and McCallum (2012). They use a two country model so there is no distinction between country specific and global entry costs. Altering my model to match their two country framework and using the same sample of manufacturing plants from the Metal Forgings and Stampings (SIC 346) industry provides the estimates presented in Table 2.7. Entry costs in my model are \$3.84 million and \$5.35 million in their paper. Given that the estimation techniques in these two papers differ dramatically, the similarity of these estimates suggests my model captures the fundamental features of the exporting decision well.

The next set of results in Table 2.8 employes the country specific export data for the same industry and restricts the set of countries to Canada and Mexico. To be explicit, in each period the firm can choose among four options: not to export, to export to Canada, to export to Mexico or to export to both. The global entry cost for this sample is estimated to be zero and the country specific entry costs are \$3.71 and \$3.59 million year 2000 USD for Canada and Mexico, respectively. The remaining structural parameters of the model are also reported in Table 2.8 along with measures of model performance. These performance measures are calculated using the structural parameter estimates and assumptions on the error terms to simulate a dataset and then calculate moments of the simulated data. The first moment is the fraction of firms that export to each country. Armenter and Koren (2012) argue that the fraction of firms that export can be a particularly informative moment for distinguishing between models of the participation margin of trade. As can be seen in the table, the model matches the data quite well. The second moment measures how often country-firm-year export status predictions in the model match the observed data. In other words, this is the fraction of observations where the model correctly predicts export status. It should be noted that this is the most restrictive moment for export status since the model is only counted as correct when it gets the country-firm-year prediction right. The final set of moments are means and standard deviations of the expected revenue in the model and observed revenue in the data. Only positive revenue observations are used to calculate these. Both the mean and standard deviation of the simulated revenue match the data and suggest the simple revenue process I use performs well.

Table 2.9 presents estimates using the same sample of firms in the Metal Forgings and Stampings (SIC 346) industry over 1992-2007 but expanding the set of countries from Canada and Mexico to the top 5 U.S. export destinations. I define the top 5 destinations using the average fraction of total manufactured goods exported from the U.S. to these countries over the years 1992-2007. The global entry cost estimate in this case is \$20 thousand and the country specific entry costs are are \$3.7 million for Canada, \$4.16 million for Japan, \$3.58 million for Mexico, \$4.22 million for the United Kingdom, and \$3.63 million for Germany where all values are in year 2000 USD. I report the same measures of model performance and again conclude the model fits well.

Tables 2.10 and 2.11 attempt to test for Asian and European regional complementarities in entry costs. In this case, the regional entry cost is paid if the firm exported to a country in the region this period but did not export to any country in the region last period. In both of these tables, there is evidence that regional entry costs are about one third the size of country specific entry costs. In particular, the model estimates that it costs \$1.64 million to access the first Asian country and then \$3.28 million for Japan, \$3.47 million for China, \$3.67 million for Korea, and \$3.61 million for Taiwan thereafter. A similar pattern emerges for Europe where the first European country costs \$1.27 million and adding the United Kingdom costs \$3.65 million, accessing Germany costs \$3.09 million, entering France costs \$4.47 million and adding The Netherlands costs \$3.82 million. As in the previous cases, the model simulated moments match the data well. At first glance the size of regional entry costs may contrast with the reduced form results. These estimates, however, are for one industry and do not presently control for unobserved heterogeneity.

2.6 Extensions and conclusions

I plan to make a few improvements to the reduced form and structural model in order to solidify the main result that entry costs are mostly country specific. These improvements will focus on controlling for unobserved heterogeneity and serially correlated errors. For the reduced form, I plan to employ the Butler and Moffit (1982) random effects quadrature based estimator which allows for both initial conditions and serially correlated errors. Additionally, I will employ the Geweke-Hajivassiliou-Keane (GHK) multivariate normal random effects simulations based estimator. Each of these estimators makes a number of strong assumptions, namely that unobserved heterogeneity is normally distributed and uncorrelated with other regressors, but provides explicit solutions for initial conditions and serially correlated errors. Finally, since the dependent variable is binary I will also employ the probit and logit bias reduced modified maximum likelihood technique developed by Carro (2007). While this estimator requires assuming the error term is *i.i.d.* normal or logistically distributed it can handle fixed effects, lagged dependent variables, time fixed effects and reduces the Nickell bias from order $O\left(T^{-1}\right)$ to $O\left(T^{-2}\right)$. This reduction in the bias order could be quite significant for my relatively long time span of 13 years.

The structural model will be extended by adding non-parametric firm types that do not vary over time in a discrete mixture model framework. By allowing all parameters of the model to vary by permanent firm type, I will be able to control for a significant amount of unobserved heterogeneity not currently accounted for in the structural model.

This paper provides a first step towards uncovering the structure of export entry costs. I show that entry costs are mostly country specfic and estimate that it costs U.S. firms in the Metal Forgings and Stampings (SIC 346) industry $20 thousand to get started exporting anywhere and between $3.5 and $4.25 million to break into each of the five main U.S. export destinations.

Table 2.1: Number of firms and average exports per firm

Country	Number of firms	Exports per firm ($m)
Canada	25,427	1.28
United Kingdom	10,837	1.10
Mexico	8,678	1.87
Germany	8,206	1.18
Japan	7,721	2.32
Australia	7,297	0.65
France	6,085	1.02
Hong Kong	5,729	0.80
Singapore	5,594	1.05
Taiwan	5,488	1.45
Italy	5,374	0.67
South Korea	5,194	1.63
Netherlands	5,156	1.14
China	4,667	2.12
Brazil	4,014	1.09
Israel	3,922	0.49
Spain	3,912	0.57
Belgium	3,609	1.25
Sweden	3,509	0.41
Switzerland	3,436	0.50
Thailand	3,213	0.81
New Zealand	3,174	0.24
South Africa	3,164	0.42
Malaysia	3,077	1.16
India	3,041	0.56
Ireland	2,890	0.74
Chile	2,865	0.48
Argentina	2,687	0.49
Colombia	2,329	0.61
Saudi Arabia	2,304	1.15
Denmark	2,287	0.31
Philippines	2,287	1.11
Venezuela	2,245	0.72
United Arab Emirates	2,220	0.72
Norway	2,071	0.32
Turkey	2,048	0.76
Finland	2,013	0.32
Austria	1,883	0.36
Costa Rica	1,671	0.45
Peru	1,596	0.33
Indonesia	1,560	0.73
Guatemala	1,431	0.42
Panama	1,389	0.33
Poland	1,334	0.32
Dominican Republic	1,334	0.85
Egypt	1,302	0.89
Kuwait	1,084	0.50
El Salvador	1,011	0.47
Russia	925	1.18
Honduras	899	0.72

These are the 50 most common destinations for U.S. exports. The number of firms and average exports per firm are calculated in each year then averaged over the sample 1992-2007. Exports are in millions of year 2000 USD.

Table 2.2: Number of countries entered by firm size

Employees	Mean entered	St. Dev. entered
$[20, 50)$	1.11	0.43
$[50, 150)$	1.18	0.69
$[150, 500)$	1.24	0.93
$[500, 1000)$	1.34	0.98
≥ 1000	1.30	0.83

Firms enter one destination when they start exporting. Mean and standard deviation are of the number of destinations entered when a firm starts exporting. Rows define firm size categories by number of employees. The results are the same when Canada is not treated as a foreign market. Entry here is defined as exporting in the present year after not exporting for any of the past three years. Having not exported in the past two years or not exporting in the past year also gives the same result. Firms do not dramatically increase the number of destinations served up to five years after their initial entry into international markets.

Table 2.3: Number of countries entered

Number entered	Percent	Cumulative
1	89.42	89.42
2	8.26	97.67
3	1.46	99.13
4	0.48	99.62
5+	0.38	100.00

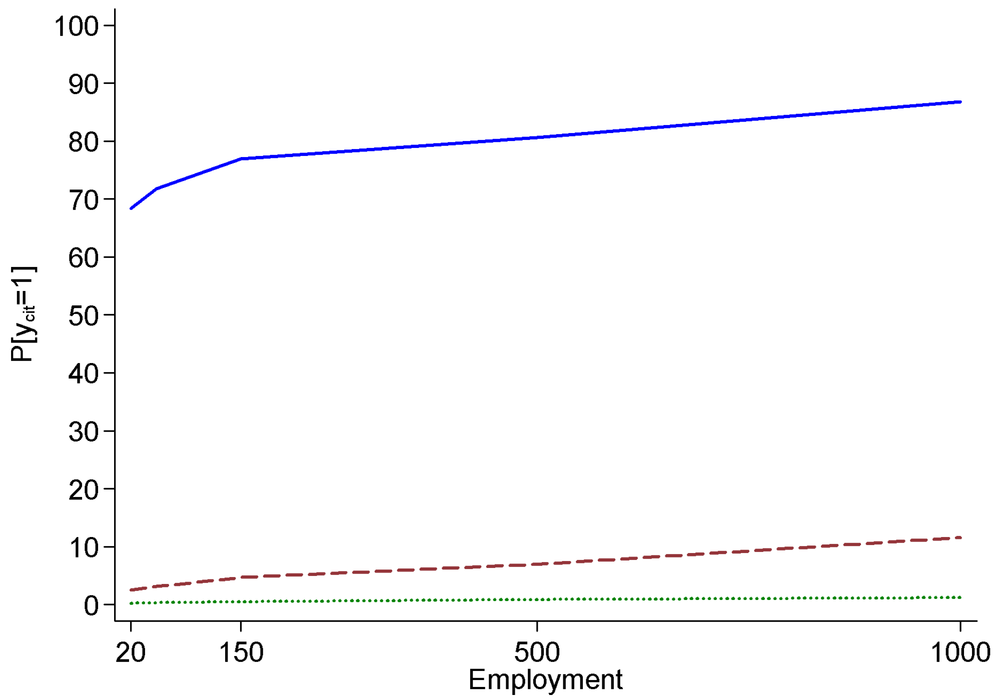
An overwhelming majority of firms enter only a few markets when they start exporting. The columns provides the percent of firms and the cumulative percent that entered 1, 2, 3, 4, and 5 or more destinations when they started exporting. Like table 2.2, these results do not depend on length of export history used to define entry or if Canada is treated as a foreign market. Neither do firms dramatically increase the number of destinations served up to five years after initial entry into international markets.

Table 2.4: Entry measures by firm size

Employees	Exp./Emp.	Exp.	Exp./Dest.	Firms
$[20, 50)$	2,181	69,042	63,316	11,410
$[50, 150)$	1,043	83,535	66,149	8,558
$[150, 500)$	503	116,281	94,380	1,816
$[500, 1000)$	369	270,565	135,614	233
≥ 1000	164	360,552	232,371	133

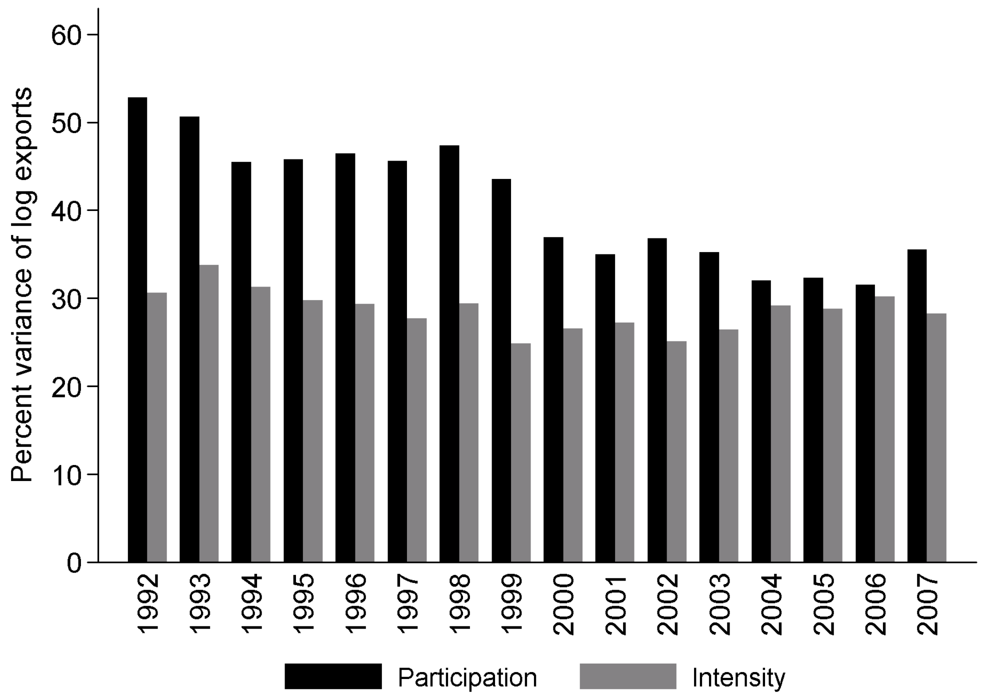
Each column is calculated by taking the mean across firms in each employee category in the first year of exporting experience. Exports per employee, total firm exports, and exports per destination are in year 2000 USD deflated using NBER revenue price deflators at the four digit SIC industry level. The final column is the number of firms in that employment category. Entry here is defined as exporting in the present year after not exporting for any of the past three years. Having not exported in the past two years or in the past year gives similar results. Treating Canada as the U.S. domestic market also gives similar results.

Figure 2.1: The effect of exporting experience



As firm size increases, the probablity of exporting anywhere increases (all lines). The probability of exporting to a given destination is essentially unchanged for firms that have experience exporting to at least one other country (dash) and those that have no exporting experience (dot). Country specific experience, however, dramatically increases the probability of exporting to that country again (solid). The fact that country specific experience raises the probability of exporting to a country while general exporting experience does not suggests the magnitude of country specific entry costs are much larger than any global cost that might exist.

Figure 2.2: US export variance decomposition for top 50 countries



Variation in total U.S. exports across destinations in a given year is mainly determined by variation in the number of firms that export to each destination. On average, the participation margin contributed 41 percent of the total variance over 1992-2007. Removing Canada, or both Canada and Mexico leaves each component with one third of the total variance. The remaining portion in each year is from the covariance between the number of firms and average exports per firm.

To be more explicit about the construction of this figure denote total exports from the U.S. to country c in a given year t as $X_{ct} \equiv N_{ct}\bar{x}_{ct}$ where N_{ct} is the number of firms exporting to c and $\bar{x}_{ct}$ is average exports per firm. Take logs to get $\ln(X_{ct}) \equiv \ln(N_{ct}) + \ln(\bar{x}_{ct})$. Next compute the variance across countries of both sides holding the year fixed to get $V_t[\ln(X_{ct})] \equiv V_t[\ln(N_{ct})] + V_t[\ln(\bar{x}_{ct})] + 2COV_t[\ln(N_{ct}), \ln(\bar{x}_{ct})]$. Finally, divide both sides by $V_t[\ln(X_{ct})]$ so each term is expressed as a fraction of the total variance of U.S. exports across destinations.

Table 2.5: dependent variable y_{cit}

	OLS	AB	WG2	WG3
y_{cit-1}	41.40***	26.19***	19.50***	18.75***
	(0.09)	(0.14)	(0.12)	(0.12)
y_{cit-2}	20.33***	9.10***	4.54***	4.36***
	(0.08)	(0.10)	(0.08)	(0.08)
y_{cit-3}	15.30***	3.16***	-0.78***	-0.98***
	(0.07)	(0.10)	(0.07)	(0.08)
n_{it-1}	0.68***	0.73***	0.69***	
	(0.01)	(0.02)	(0.01)	
n_{it-2}	-0.07***	0.08***	0.11***	
	(0.01)	(0.01)	(0.01)	
n_{it-3}	-0.15***	0.06***	0.09***	
	(0.01)	(0.01)	(0.01)	
controls	x_{it-1}, x_{ct-1}	x_{it-1}, x_{ct-1}	x_{it-1}, x_{ct-1}	
controls	x_{it-2}, x_{ct-2}	x_{it-2}, x_{ct-2}	x_{it-2}, x_{ct-2}	
controls	x_{it-3}, x_{ct-3}	x_{it-3}, x_{ct-3}	x_{it-3}, x_{ct-3}	
FE	δ_t	δ_t, δ_{ci}	δ_t, δ_{ci}	$\delta_{it}, \delta_{ci}, \delta_{ct}$
Observations	19,696,400	19,696,400	19,696,400	19,696,400
Overall R^2	0.611	-	0.525	0.564

Firm clustered standard errors in parentheses.
Significant at 1% *** 5% ** and 10% *

This linear probability model gives coefficients that are interpreted as marginal changes in probability. Considering column AB and holding all else constant, if a firm exported to country c last year, the probability they export to c this year increases by 26.19 percentage points. If they exported to one location other than c, the probability they export to c this year increases by 0.73 percentage points. The magnitude of the country specific effect, y_{cit-h}, is much larger than the effect of the number of other countries served, n_{it-h}, implying that sunk export entry costs are mainly country specific. The columns use OLS, Arellano and Bond (1991) (AB) and within-group (WG) estimation methods. Columns OLS and WG2 provide upper and lower bounds on the country specific effect while AB provides a consistent estimate. WG3 includes all possible interacted fixed effects which are collinear with the number of other countries served. The fact that WG2 and WG3 give similar estimates of country specific persistence suggests that x_{it-h} and x_{ct-h} control for essentially the same variables as the fixed effects δ_{it} and δ_{ct}. Consistency of the AB estimator relies on zero serial correlation in the first differenced errors. The Arellano and Bond AR(2) test has a null of no autocorrelation in the second lag of the first differenced errors and returns $p - value = 0.356$ in the model above.

Table 2.6: dependent variable y_{cit}

	OLS	AB	WG2	WG3
y_{cit-1}	41.08***	26.08***	19.33***	18.76***
	(0.093)	(0.132)	(0.115)	(0.122)
y_{cit-2}	20.02***	9.04***	4.36***	4.22***
	(0.079)	(0.103)	(0.077)	(0.082)
y_{cit-3}	14.95***	3.13***	-0.94***	-1.11***
	(0.070)	(0.103)	(0.072)	(0.076)
n_{it-1}^{coly}	0.11***	1.64***	-0.13***	-0.08**
	(0.032)	(0.172)	(0.038)	(0.041)
n_{it-2}^{coly}	0.11***	0.83***	-0.10***	-0.10**
	(0.037)	(0.093)	(0.037)	(0.041)
n_{it-3}^{coly}	0.14***	0.44***	-0.09**	-0.11***
	(0.032)	(0.069)	(0.036)	(0.040)
n_{it-1}^{ctig}	0.51***	-0.08	0.51***	0.73***
	(0.038)	(0.132)	(0.045)	(0.047)
n_{it-2}^{ctig}	0.21***	0.04	0.31***	0.36***
	(0.043)	(0.083)	(0.042)	(0.044)
n_{it-3}^{ctig}	0.11***	0.12*	0.22***	0.27***
	(0.038)	(0.073)	(0.042)	(0.045)
n_{it-1}^{curr}	-0.69***	-0.42***	-0.26***	-0.21***
	(0.035)	(0.045)	(0.037)	(0.038)
n_{it-2}^{curr}	-0.08*	-0.12***	-0.06	-0.14***
	(0.045)	(0.039)	(0.040)	(0.040)
n_{it-3}^{curr}	0	-0.34***	-0.12***	-0.16***
	(0.036)	(0.035)	(0.035)	(0.037)
n_{it-1}^{dist}	0.40***	0.82***	0.49***	0.21***
	(0.018)	(0.079)	(0.021)	(0.021)
n_{it-2}^{dist}	-0.03	0.29***	0.12***	0.07***
	(0.020)	(0.042)	(0.019)	(0.020)
n_{it-3}^{dist}	-0.10***	0.19***	0.08***	0.05**
	(0.017)	(0.032)	(0.019)	(0.020)
n_{it-1}^{lang}	0.36***	0.55***	0.38***	0.28***
	(0.018)	(0.130)	(0.021)	(0.022)
n_{it-2}^{lang}	0.05**	0.17***	0.15***	0.13***
	(0.021)	(0.061)	(0.020)	(0.022)
n_{it-3}^{lang}	-0.07***	0	0.11***	0.08***
	(0.017)	(0.038)	(0.019)	(0.021)
n_{it-1}^{legl}	0.44***	0.22***	0.45***	0.09***
	(0.016)	(0.072)	(0.018)	(0.018)
n_{it-2}^{legl}	-0.01	-0.04	0.10***	0.05***
	(0.017)	(0.036)	(0.017)	(0.018)
n_{it-3}^{legl}	-0.04***	0	0.09***	0.06***
	(0.015)	(0.026)	(0.016)	(0.017)
n_{it-1}^{pcap}	0.38***	0.49***	0.24***	0.12***
	(0.012)	(0.030)	(0.013)	(0.014)
n_{it-2}^{pcap}	-0.03**	0.07***	-0.01	0
	(0.014)	(0.017)	(0.013)	(0.014)
n_{it-3}^{pcap}	0.04***	0.10***	0.03***	0
	(0.012)	(0.017)	(0.012)	(0.014)
n_{it-1}^{regn}	0.73***	-0.41***	0.72***	0.66***
	(0.021)	(0.113)	(0.025)	(0.026)
n_{it-2}^{regn}	0	-0.34***	0.18***	0.21***
	(0.025)	(0.055)	(0.024)	(0.025)
n_{it-3}^{regn}	-0.13***	-0.21***	0.06**	0.14***
	(0.021)	(0.040)	(0.023)	(0.025)
n_{it-1}^{rtag}	0.08***	0.57***	0.10***	-0.02
	(0.017)	(0.039)	(0.018)	(0.019)
n_{it-2}^{rtag}	-0.06***	0.11***	0.02	-0.04*
	(0.022)	(0.021)	(0.020)	(0.021)
n_{it-3}^{rtag}	-0.15***	0.02	0.08***	-0.04*
	(0.018)	(0.020)	(0.019)	(0.020)
controls	x_{it-1}, x_{ct-1}	x_{it-1}, x_{ct-1}	x_{it-1}, x_{ct-1}	
controls	x_{it-2}, x_{ct-2}	x_{it-2}, x_{ct-2}	x_{it-2}, x_{ct-2}	
controls	x_{it-3}, x_{ct-3}	x_{it-3}, x_{ct-3}	x_{it-3}, x_{ct-3}	
FE	δ_t	δ_t, δ_{ci}	δ_t, δ_{ci}	$\delta_{it}, \delta_{ci}, \delta_{ct}$
Observations	19,696,400	19,696,400	19,696,400	19,696,400
Overall R^2	0.611	-	0.530	0.565

Firm clustered standard errors in parentheses.
Significant at 1% *** 5% ** and 10% *

Sunk entry costs do not exhibit large complimentarities since exporting to similar countries in the past does not much increase the probability of exporting to a country. The covariates n_{it-h} count the number of countries other than c to which firm i exported in year $t-h$ that share a common, colonial relationship (coly), contiguous border (ctig), currency (curr), distance from the U.S. (dist), language (lang), legal origin (legl), per capita GDP (pcap), region (regn), and memberships in regional trade agreements (rtag). The columns use OLS, Arellano and Bond (1991) (AB) and within-group (WG) estimation methods. Consistency of the AB estimator relies on zero serial correlation in the first differenced errors. The Arellano and Bond AR(2) test has a null of no autocorrelation in the second lag of the first differenced errors and returns $p - value = 0.153$ in the model above.

Table 2.7: Structural estimates: data from Lincoln and McCallum (2012)
Metal Forgings and Stampings (SIC 346)

	estimate (standard error)
Net profit parameters	
global entry cost (g)	3.84 (0.03)
period fixed cost (f)	0.15 (0.08)
elasticity of substitution (ε)	482.96 (26.60)
Revenue parameters	
constant (α)	-12.95 (0.33)
employment elasticity (β)	1.84 (0.01)
total exports elasticity (γ)	0.25 (0.03)
error standard deviation (σ)	1.27 (0.01)
Initial conditions	
constant (ψ)	-3.78 (0.00)
firm size elasticity (ξ)	0.91 (0.00)
Percent of firms that export	
data	82.56
model	82.25
Model correctly predicts export status	
percent	71.91
Export revenue, mean (standard deviation)	
data	43.06 (62.18)
model	69.92 (86.72)

These estimates use the model in this paper and the data employed in Lincoln and McCallum (2012) over 1992-2003. Parameters g and f are in millions of year 1987 USD. The remaining parameters, other than constants, are elasticities. Firm clustered standard errors using 20 bootstrapped samples are in parentheses.

Table 2.8: Structural estimates: Canada and Mexico
Metal Forgings and Stampings (SIC 346)

	Canada	Mexico
Net profit parameters		
global entry cost (g)	0.00 (0.00)	
country entry cost (b)	3.71 (0.09)	3.59 (0.01)
period fixed cost (f)	0.36 (0.42)	2.02 (0.02)
elasticity of substitution (ε)	5.27 (254.4)	1.00 (0.00)
Revenue parameters		
constant (α)	-12.76 (0.91)	-38.31 (0.17)
employment elasticity (β)	0.97 (0.03)	0.60 (0.01)
total exports elasticity (γ)	0.5 (0.06)	2.64 (0.01)
error standard deviation (σ)	1.81 (0.01)	1.91 (0.01)
Initial conditions		
constant (ψ)	-5.65 (0.00)	-6.77 (0.00)
firm size elasticity (ξ)	1.25 (0.00)	0.84 (0.00)
Percent of firms that export		
data	58.76	21.55
model	58.07	21.24
Model correctly predicts export status		
percent	57.75	72.81
Export revenue, mean (standard deviation)		
data	0.94 (2.76)	0.55 (1.85)
model	1.31 (2.90)	0.64 (0.73)

Firms are only able to choose to export to these countries. The sample includes 351 firms over 16 years from 1992 to 2007. Parameters g, b and f are in millions of year 2000 USD. The remaining parameters, other than constants, are elasticities. Firm clustered standard errors using 20 bootstrapped samples are in parentheses.

Table 2.9: Structural estimates: top 5 destinations

Metal Forgings and Stampings (SIC 346)

	Canada	Japan	Mexico	U.K.	Germany
			Net profit parameters		
global entry cost (g)			0.02		
country entry cost (b)	3.70	4.16	3.58	4.22	3.63
period fixed cost (f)	0.36	1.48	2.02	1.11	1.09
elasticity of substitution (ε)	5.22	1.00	1.02	1.00	1.00
			Revenue parameters		
constant (α)	-12.75	-14.88	-38.20	-12.26	-10.37
employment elasticity (β)	0.97	0.59	0.60	0.50	0.47
total exports elasticity (γ)	0.50	0.73	2.63	0.57	0.42
error standard deviation (σ)	1.81	1.94	1.91	1.88	1.95
			Initial conditions		
constant (ψ)	-5.65	-8.74	-6.77	-6.19	-6.22
firm size elasticity (ξ)	1.25	1.21	0.84	1.02	0.89
			Percent of firms that export		
data	58.76	9.94	21.55	21.47	16.77
model	58.07	10.06	20.82	19.94	16.45
			Model correctly predicts export status		
percent	57.75	84.74	71.99	72.72	74.72
			Export revenue, mean (standard deviation)		
data	0.94 (2.76)	0.60 (1.92)	0.55 (1.85)	0.61 (3.44)	0.41 (1.10)
model	1.31 (2.90)	0.57 (0.58)	0.63 (0.74)	0.51 (0.39)	0.50 (0.36)

Firms are only able to choose to export to these countries. The sample includes 351 firms over 16 years from 1992 to 2007. Parameters g, b and f are in millions of year 2000 USD. The remaining parameters, other than constants, are elasticities. Standard errors are forthcoming.

Table 2.10: Structural estimates: top Asian destinations

Metal Forgings and Stampings (SIC 346)

	Japan	China	Korea	Taiwan
	Net profit parameters			
global entry cost (g)		1.64 (0.02)		
country entry cost (b)	3.28 (0.05)	3.47 (0.01)	3.67 (0.01)	3.61 (0.03)
period fixed cost (f)	1.09 (0.18)	0.97 (0.01)	1.10 (0.02)	1.03 (0.12)
elasticity of substitution (ε)	1.00 (150.1)	1.47 (0.01)	1.00 (0.00)	1.00 (150.1)
	Revenue parameters			
constant (α)	-2.67 (8.27)	-15.14 (0.05)	-8.43 (0.65)	-9.36 (7.74)
employment elasticity (β)	0.51 (0.06)	0.41 (0.01)	0.48 (0.01)	0.47 (0.04)
total exports elasticity (γ)	-0.22 (0.64)	0.83 (0.01)	0.24 (0.05)	0.31 (0.61)
error standard deviation (σ)	1.96 (0.04)	1.92 (0.01)	1.91 (0.01)	1.85 (0.04)
	Initial conditions			
constant (ψ)	-8.74 (0.00)	-7.98 (0.00)	-8.73 (0.00)	-7.33 (0.00)
firm size elasticity (ξ)	1.21 (0.00)	0.87 (0.00)	1.14 (0.00)	0.89 (0.00)
	Percent of firms that export			
data	9.94	8.85	6.55	6.04
model	9.56	11.36	6.34	5.98
	Model correctly predicts export status			
percent	85.42	83.00	89.92	88.84
	Export revenue, mean (standard deviation)			
data	0.60 (1.92)	0.41 (0.96)	0.34 (0.86)	0.36 (1.00)
model	0.61 (0.47)	0.42 (0.25)	0.45 (0.35)	0.28 (0.24)

Firms are only able to choose to export to these countries. The sample includes 351 firms over 16 years from 1992 to 2007. Parameters g, b and f are in millions of year 2000 USD. The remaining parameters, other than constants, are elasticities. Firm clustered standard errors using 20 bootstrapped samples are in parentheses.

Table 2.11: Structural estimates: top European destinations
Metal Forgings and Stampings (SIC 346)

	U.K.	Germany	France	the Netherlands
	Net profit parameters			
global entry cost (g)			1.27	
country entry cost (b)	3.65	3.09	4.47	3.82
period fixed cost (f)	0.64	0.80	0.58	0.69
elasticity of substitution (ε)	1.55	1.00	4.69	1.00
	Revenue parameters			
constant (α)	-5.34	-0.95	-16.00	-11.16
employment elasticity (β)	0.47	0.41	0.57	0.55
total exports elasticity (γ)	0.02	-0.32	0.84	0.41
error standard deviation (σ)	1.89	1.95	1.96	1.55
	Initial conditions			
constant (ψ)	-6.19	-6.22	-7.09	-6.54
firm size elasticity (ξ)	1.02	0.89	0.97	0.79
	Percent of firms that export			
data	21.47	16.77	10.86	8.19
model	20.90	17.74	11.18	7.83
	Model correctly predicts export status			
percent	69.98	73.97	82.37	86.36
	Export revenue, mean (standard deviation)			
data	0.61 (3.44)	0.41 (1.10)	0.59 (1.61)	0.15 (0.33)
model	0.48 (0.34)	0.46 (0.26)	0.56 (0.57)	0.15 (0.12)

Firms are only able to choose to export to these countries. The sample includes 351 firms over 16 years from 1992 to 2007. Parameters g, b and f are in millions of year 2000 USD. The remaining parameters, other than constants, are elasticities. Standard errors are forthcoming.

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CHAPTER III

Entry Costs and Increasing Trade

3.1 Introduction

A common feature of the rise in aggregate exports from several countries across the world is a significant expansion in the number of firms that export. A natural explanation that has been suggested by prior authors (e.g., Melitz 2003) is that the up-front costs of entering foreign markets have declined.[1] We test this idea for the first time using plant level data from the United States Census. We find that the U.S. also saw significant foreign market entry over the period, with the fraction of plants that export rising from 21% in 1987 to 39% in 2006.[2] Across a number of different estimation approaches, however, we find little evidence for the idea that declines in the costs of entering foreign markets played a significant role in driving these trends. We instead argue that changes in other factors that govern export status, specifically foreign income, were of a sufficient magnitude to explain the level of foreign market entry that we see in the data, without the need to appeal to falling entry costs.

Our analysis begins by presenting a number of descriptive statistics that provide new insight into the U.S. experience. We find that the rise in the fraction of plants selling abroad mentioned above was broad-based; it was experienced across a broad

[1] See also Roberts and Tybout (1997a).

[2] We discuss our data and how these and other figures are calculated in Section 3.2.

range of industries as well as geographic regions. These extensive margin adjustments were matched with strong intensive margin adjustments, with average foreign sales per exporter also increasing substantially. Over time, changes along both of these margins had a large influence on aggregate trade volumes. Finally, at the same time that more plants began to sell abroad, the level of persistence in export market status remained quite stable.

We next turn to understanding how much declines in the costs of entering foreign markets contributed to these trends. As these costs cannot be directly observed with current data sources, we need to use models of firm behavior to estimate their magnitude. Thus, to get a comprehensive perspective we consider both reduced form and structural estimation approaches. Our reduced form analyses provide a tractable way of addressing this question for U.S. manufacturing as a whole and allow for a wide variety of robustness checks. This approach does not provide direct estimates of the magnitude of changes in these costs but coefficients in the regressions are directly related to them. We let these coefficients differ across the earlier and later parts of the sample to look at how the costs compare. The estimated parameters have similar magnitudes in the two different periods. These findings suggest minimal changes in the barriers to entry in foreign markets.

We then turn to a set of structural estimations that use the methodology developed by Das, Roberts, and Tybout (2007). This approach allows us to estimate the average foreign market entry costs in dollars that plants face in a given period. The methodology is attractive in that it provides numerical estimates of how these costs have changed and can flexibly account for plant and time specific unobservable factors that determine exporting behavior. Estimations require the use of computationally intensive Bayesian Monte Carlo Markov Chain methods, however. We are thus constrained to a set of four industries. We estimate these costs across 1987-1997 and 1992-2003 and compare the results for these two time periods. Three of the four industries that we consider experienced roughly similar or rising costs across the two different panels and the fourth saw a moderate decline. Taken together, the results from the reduced form and structural estimations are evidence that declines in the costs of entering foreign markets have been modest at best. The level of responsiveness of export market participation to changes in the costs of entering foreign markets predicted by recent models of international trade suggest that these changes are unlikely to have played a large role in the changes that we see in the data.

We conclude with an analysis of whether changes in other factors that determine export status were of a sufficient magnitude to cause the large increase in export particpiation. Specifically, we investigate whether a calibrated model of plant heterogeneity and international trade akin to that of Chaney (2008) can match the extensive margin adjustments we see in the data. Keeping other factors such as the costs of entering foreign markets as well as trade-related variable costs stable, we find that growth in foreign income is sufficient to explain the rise in the fraction of exporters. Our accounting exercise demonstrates that a reduction in the costs of entering foreign markets is not needed to account for these trends in a standard model. These calculations lend credibility to our estimation results and point to a significant role for foreign economic growth in explaining the rise of trade.

Our work addresses an issue that is relevant for a number of other countries in addition to the U.S. Several other studies have suggested that large-scale foreign market entry was experienced worldwide during this period. Indeed, of the studies that have used plant or firm level data to study the rise in exports from other nations, many have found that entry into foreign markets played a significant role in the expansion of trade. This work includes studies on the experiences of Chile, Colombia, Mexico, and Morocco.[3] Although there is little plant-level evidence on this question outside

[3]These papers include Bergoeing, Micco, and Repetto (2011), Roberts, Sullivan, and Tybout (1995), and Clerides, Lach and Tybout (1996). Roberts and Tybout (1997a) provide a survey of several of these papers. A notable exception here is China; see Amiti and Freund (2010). In the U.S. context, Bernard and Jensen (2004a) have also previously documented a significant increase in the

of these countries, we also see dramatic increases in the number of goods sold across countries in disaggregated industry-level trade data. These results are consistent with substantial foreign market entry by firms in different sectors for a wide range of countries. Papers documenting these trends include Evenett and Venables (2002), Broda and Weinstein (2006), and Harris, Kónya, and Mátyás (2011). Particularly notable is an acceleration in the growth of varieties traded during 1987-2006. Taken together, these studies suggest that our estimations address a question of first-order importance for understanding the recent growth of worldwide trade.

Our analysis also fills a significant gap in the international trade literature. A large number of studies have looked at the effect of changes in variable trade costs on export and import patterns. While there has been some work on other factors such as transportation costs, this work has primarily focused on understanding the effects of changes in tariffs. Yet these costs are only one, albeit important, piece of the puzzle. Changes in the barriers to entry in foreign markets also can have significant effects on trade patterns. One reason why these changes have not yet been studied is that methods to estimate their magnitude have only been developed relatively recently. Another is that the data requirements for looking at how they have changed are quite high. This study represents an initial effort to address this issue.

In the next section, we discuss our data sources and document several new stylized facts about U.S. plants' exporting behavior from 1987 to 2006. Section 3.3 uses a model of export behavior to motivate reduced form estimations on the evolving nature of these costs. In Section 3.4 we describe the structural model that we use to estimate changes in these costs and the results that we get from our estimations. Section 3.5 performs an accounting exercise that looks at the contribution of other factors to the rise in export market participation such as increases in foreign income.

fraction of manufacturing plants that export over the period 1987-1992. Bernard, Jensen, and Schott (2009) additionally report significant extensive margin entry for U.S. firms in goods (agriculture, manufacturing, and mining) sectors across the two years 1993 and 2000.

Section 3.6 concludes.

3.2 Data and Stylized Facts

We use data from a number of different sources. Our data on aggregate industry exports come from two sources (i) the United Nations' Commodity Trade Statistics Database (Comtrade) and (ii) data from the U.S. Census that was concorded to the 1987 U.S. SIC classification system using the approach described in Pierce and Schott (2012). Information on price deflators is obtained from the NBER manufacturing productivity database (Bartelsman and Gray, 1996). The primary microdata for our analyses come from the Annual Survey of Manufacturers (ASM) and Census of Manufacturers (CMF) from the U.S. Census. Both data sets contain information on the operations of U.S. manufacturing plants. The CMF is conducted in every year ending in 2 or 7 (e.g. 1987, 1992, etc.) and contains data on the universe of manufacturing establishments. The ASM is a survey of plants that is conducted in each intervening year. The sampling frames for these surveys are chosen two years after the most recent CMF.[4] These establishments are then followed over time for five years until the next ASM sampling frame is implemented. Not all plants within a firm are sampled with certainty during each ASM wave so we treat the plant as the unit of analysis. This is consistent with the literature that has used this data as well as a number of other trade-related studies on other countries. Wherever possible, however, we perform robustness checks on our analysis at the level of the firm, finding similar results. We begin our analyses in 1987, the first year that comprehensive data on export revenues was collected.

[4]Over the period 1987-1998 plants with more than 250 employees were sampled with certainty in the ASM. In the 1999-2003 ASM this threshold was increased to 500 employees and was further raised to 1000 in the 2004-2008 ASM. As the sampling probability is inversely related to a plant's contribution to output, plants between 250 and 500 employees are still sampled with a high degree of certainty 1999-2003, however. In our estimations that span these years, we reweight the plants accordingly.

The sample designs of these data sets impose some structure on our analysis. The ASM includes large plants with certainty but samples smaller plants according to their contribution to output. Due to the loss of non-certainty cases across different ASM panels, we limit our sample for panel analyses to plants with 250 or more employees. This avoids a number of challenges involved in following smaller plants over time and allows for comparability with previous studies that have used a similar approach. Despite this restriction, however, our data covers a significant portion of economic activity and the great majority of export volume.[5] Arkolakis (2010) has also suggested that small firms may only partially enter a foreign market making the assumption of binary export status undergirding our analyses more appropriate for large producers.

With these data we develop a number of new stylized facts regarding the pace and character of trade growth since 1987. Figure 3.1 plots the percentage of plants with 20 or more employees that export in each year from 1987 to 2003.[6] The overall upward trend is unmistakable; 21% of plants exported in 1987 and 35% exported in 2003. Although we focus our analyses on the 1987-2003 period, this percentage rises steadily after 2003 to 39% in 2006. A number of different aspects of these trends are of note. Firstly, given the secular declines in U.S. manufacturing, it is important to know if these trends were driven by increases in the number of exporting plants or declines in the number of manufacturing establishments in operation. Over 1987-2003, the raw number of exporting plants increased by 34% while the total number of plants decreased by 20%. These figures imply exporters and non-exporters largely face the same entry and exit probabilities. We can also test this directly. Taking the 21% participation rate from 1987 as a baseline, new plants that entered the

[5]Bernard and Jensen (2004a) use a similar sample and note that it accounts for 41% of employment, 52% of shipments, and 70% of exports in 1987.

[6]Similar to several other studies, we focus on plants with 20 or more employees. In all of our analyses we drop administrative records, which are essentially imputed data for small employers and new businesses. Due to disclosure concerns, estimates for 1987 and 1992 are from Bernard and Jensen (2004b).

sample and remained in business until 2002 were somewhat more apt to sell abroad. Those that exited were only slightly less likely to be exporters. Finally, we can abstract from entry and exit to understand how exporting status changed for existing establishments. Amongst plants that had 20 or more employees in both the 1987 and 2002 Census of Manufacturers, 29% export in 1987 and 39% export in 2002. This suggest that a large part of these trends were due to adjustments by plants that were in operation in 1987 but only sold domestically. In summary, more plants export than ever before, exporters exit at the same rate as non-exporters, entrants are slightly more likely to export, and continuing plants are more likely to export.

Figures 3.2 and 3.3 look at the sectoral and geographic dimensions of the rise in export market participation. Figure 3.2 plots the percentage of plants that export in each industry in 1987 and 2003. While some industries saw larger changes than others, there has been a significant expansion in foreign market participation across nearly all sectors of the economy. Figure 3.3 similarly demonstrates that the results in Figure 3.1 were experienced broadly across different regions of the U.S. These results hold generally across states as well. In Tables 3.1 and 3.2 we document the time path of each of these trends across 5-6 year intervals, mostly using the CMF. While we find similar patterns to the overall trend by region, there is more heterogeneity in the timing and magnitude of foreign market entry across industries. The fact that the expansion in the fraction of plants that export has been pervasive across these two dimensions suggests that these trends were not driven by idiosyncratic factors such as the rise of high-tech industries.

In a similar vein, we also looked at how the composition of the destinations of aggregate exports changed over time. We find that although export volumes rose sharply over the period, with a few exceptions trade shares have remained quite stable. For example, Germany accounted for 5.4% of total U.S. exports in 1987 and accounted for 5.8% in 2003. Among the top 40 export destinations in 1987, the rank correlation between export shares in 1987 and 2003 is 88%. These countries account for 92% of total U.S. exports in 1987. We present the shares for the top 20 export destinations in 1987 and their corresponding shares in 2003 in Table 3.4.

Although we focus on the determinants of changes in export status, it is clear that there have also been significant expansions in total exports through the intensive margin of trade. These changes suggest that the incentives to sell abroad have increased significantly over time. In the aggregate, manufacturing exports as a percentage of GDP rose by 35% over the 1987-2003. In Figure 3.4 we graph the average level of real foreign sales across exporting plants by year. Estimates are for plants with 20 or more employees and exclude the computer and semiconductor industries due to the strong decline in prices over time; estimates including all industries show a significantly stronger increase over time. In order to look at percentage changes we normalize these figures such that the average in 1987 is set equal to one. We find that average foreign sales increased steadily by 49% over the time period. These results are robust to limiting the sample to plants with at least 10 employees, plants with at least 250 employees, and single plant firms. They also hold when looking at firms in different Census of Manufacturers samples. Thus, even though both the number and fraction of plants that export increased significantly, the average level of foreign sales for each of these plants has also increased. Eaton, Kortum and Kramarz (2011) suggest that decreases in the costs of entering foreign markets should lower average foreign sales; these figures thus suggest that either these costs have increased or that other factors were important in determining export trends.

To get a sense of how changes in the extensive margin have affected overall trade volumes, we use information from each year in which we have data from the Census of Manufacturers. This allows us to track the universe of small as well as large plants over time. The fact that the intensive margin dominates trade volumes in the short-run has been documented by, among others, di Giovanni and Levchenko (2009) and

Bernard, Jensen, Redding, and Schott (2009). Authors have only recently begun to focus on the relative importance of the extensive margin for aggregate trade volumes over longer time horizons, however. Table 3.5 reports the contribution to Census year aggregate exports by plants that exported in a given prior Census year. When the time horizon is greater than five years we limit these figures to plants that exported in each intervening Census year. Thus, only 46% of aggregate exports in 2002 came from plants that exported in 1987, 1992, and 1997. These numbers underestimate the importance of changes along the extensive margin since they are not restricted to plants that exported continuously in all prior years.[7] Removing any continuous exporting restriction, we find that 57% of trade in 2002 is from plants that export in both 1987 and 2002.

In Figure 3.5 we look at annual rates of entry, exit, and export status persistence. Plants that persist are those who continue exporting or only selling to the domestic market. In each year we limit the sample to plants that existed in the previous year, such that the percent of plants that enter, exit, and keep the same export market status adds up to 100% in each year. Due to changes in the plants included across different ASM sampling frames, we limit the graph to plants with 250 or more employees. We find similar trends, however, within and across different ASM sampling frames for plants with 20 or more employees. In order to make the changes in the series clear we use two different axes, with entry and exit rates depicted using the scale on the right axis and persistence levels on the left axis.

It is our expectation that if the barriers to entry in foreign markets fell dramatically, we should see significantly less persistence in export market status over time. Indeed, if they fell to zero, plants would be able to enter without cost. They would

[7] We are unable to calculate year-to-year statistics based on continuously exporting plants due to the breaks between ASM panels. These figures echo related results reported in Bergoeing, Micco, and Repetto (2011) for Chile 1990-2007, Bernard, Jensen, Redding and Schott (2009) for the aggregate U.S. economy (including non-manufacturing sectors) for 1993-2003, and Eaton, Eslava, Kugler and Tybout (2007) for Colombia 1996-2005. The analysis in Table 3.5 is done with the plant identifier lbdnum. The results from using the alternative plant identifier ppn are similar.

also be more likely to exit since re-entry would also be free. This intuition is developed more formally in Sections 3 and 4. We instead find that the level of persistence stayed roughly constant over time, with a mean of 85% and a standard deviation of less than 3%. The level of persistence amongst exporters, which can be denoted as $E[y_{it} \mid y_{it-1} = 1]$ where y_{it} is a 0/1 indicator for export status, also remained stable over time. Thus, export market participation increased at the same time that export status persistence remained stable. The rise in the number of exporters documented in Figures 3.1-3.3 was driven by entry rates regularly outpacing exit rates, rather than changes in the frequency of entry and exit. These results suggest that dramatic declines in the costs of entering foreign markets are unlikely.

3.3 Reduced Form Estimations

In this section we consider reduced form evidence on how the costs of entering foreign markets have changed over time. While our structural estimations in the following section will allow us to study a number of different industries in depth, the reduced form will give us a sense of how these costs have changed for the manufacturing sector as a whole. Drawing upon the seminal work of Dixit (1989) and Baldwin and Krugman (1989), several prior studies have used a simple binary choice model of whether or not to export to test for the existence of barriers to entry in foreign markets.[8] Here, we use this approach to get a sense of how these costs have changed over time. The basic premise of the model is that a plant will sell abroad if the benefits from exporting exceed the additional costs of doing so. The benefits include the extra gross revenues that it could make as well as any option value associated with being an exporter in the future. In addition to the extra expenses associated with increased production, the costs include barriers to entry for plants that did not export previously. Specifically, a plant that has not exported for more than two years

[8]See Roberts and Tybout (1997b), Bernard and Wagner (2001), and Bernard and Jensen (2004a).

must pay a sunk cost F_0 to enter the foreign market and a re-entry cost F_R if it last exported two years ago.[9] The model can be reduced to a simple decision rule where

$$y_{it} = \begin{cases} 1 & \text{if } p^*_{it} - F_0 + F_0 \cdot y_{it-1} + (F_0 - F_R) \cdot \tilde{y}_{it-2} \geq 0 \\ 0 & \text{otherwise} \end{cases} \tag{3.1}$$

Here y_{it} is plant $i's$ export status in year t and $\tilde{y}_{it-2} = y_{it-2}(1 - y_{it-1})$ is an indicator function for whether the plant last exported two years prior to year t. The term p^*_{it} can be written as

$$p^*_{it} = p_{it} + \delta \left(E_t \left[V_{it+1} \mid y_{it} = 1 \right] - E_t \left[V_{it+1} \mid y_{it} = 0 \right] \right)$$

It is determined by the extra gross profit that the plant could make by exporting this year p_{it} plus the option value associated with being an exporter next period. This option value, in turn, is given by the difference in the discounted future expected value of being an exporter today relative to only selling domestically. In the model if there are no costs to entering the foreign market, the condition for exporting in equation (3.1) collapses to $p_{it} \geq 0$. In this case, the plant decides whether or not to export based solely on what is most profitable today and ignores dynamic considerations. Thus, once controlling for factors that account for changes in p_{it}, if there are no costs to entering foreign markets we should see a lack of state dependence in exporting status.

To obtain an estimating equation that will allow us to look at changes in F_0 and F_R we need to parameterize $p^*_{it} - F_0$. A number of factors likely influence this term, such as changes in plant productivity and fluctuations in foreign income. We use the

[9] Prior studies have found little difference between the costs of entering foreign markets anew and entering after three years of not exporting. They have also found a small difference between F_0 and F_R above. The model can be extended to include a cost of exiting L, which makes the coefficient α_1 in equation (3.2) a function of $F_0 + L$. We think these costs are likely to be small. See Heckman (1981a) and Chamberlain (1985) for lucid discussions of econometric issues relating to identifying true state dependence.

following functional form

$$p^*_{it} - F_0 \approx \mu_i + X'_{it}\beta + \phi_t + \varepsilon_{it}$$

to develop the specification

$$y_{it} = \mu_i + X'_{it}\beta + \alpha_1 \cdot y_{it-1} + \alpha_2 \cdot \tilde{y}_{it-2} + \phi_t + \varepsilon_{it} \tag{3.2}$$

This equation provides the basis for our estimations. The vector X_{it} contains a number of covariates that predict export market participation. These include the ratio of nonproduction to total employment, an indicator function for change of product and the logarithms of employment, total factor productivity, and average wages. Productivity is estimated with the approach of Levinsohn and Petrin (2003). We also include an industry-level trade-weighted exchange rate series.[10] Unobserved plant specific factors that influence p^*_{it} are captured in the term μ_i. Business cycle effects and other time varying factors are absorbed into the year fixed effects ϕ_t. The coefficients $\alpha_1 = F_0$ and $\alpha_2 = (F_0 - F_R)$ parameterize the importance of barriers to entry in foreign markets. Larger estimates of α_1, for example, suggest higher sunk costs F_0.

Table 3.6 presents the results from estimating the specification in (3.2) over the period 1989-2003. Standard errors in parentheses are clustered at the plant level and plant-specific characteristics in X_{it} are lagged by one period in order to avoid issues of simultaneity. Column (1) presents our baseline results. We include terms that interact the variables y_{it-1} and $\tilde{y}_{it-2}$ with an indicator function for the post-1995 period $Post_{95}$. The coefficient estimates on these interaction terms indicate how the costs F_0 and F_R compare in the second half of the period to those in the first. We find a small decline for the coefficient α_1 in the second part of the panel and a

[10]Each exchange rate is a geometric export-weighted average of bilateral real exchange rates where the weights are constructed using 3 digit SIC export data. We follow the aggregation method used by the U.S. Federal Reserve, as detailed in Loretan (2005). We use the same industry-level exchange rate series for both our reduced form estimations and structural analysis.

somewhat larger decrease in α_2. Controlling for other factors, exporting last year raises a plant's probability of exporting by 44% over the period 1989-1995 and by 40% over 1996-2003. These results suggest a relatively small decline in the cost F_0 and an increase in the costs of re-entering foreign markets F_R. The size of each of these coefficients, however, suggests that the changes in these costs are unlikely to have been significant enough to have played a determinative role in the large export participation increase. In column (2) we consider the same approach as in column (1) but drop several plant-specific covariates. The comparable results suggest that our baseline estimations do a good job accounting for the plant heterogeneity and time-varying factors that drive differences in p^*_{it} across plants and time.

In our estimations in columns (1) and (2) we allow entry into the sample but drop plants that died during the sample period. This approach allows us to abstract from plant death, which is not explicitly a part of the model. We present the results from alternatively considering a fully balanced panel with no entry or exit into the sample over the 1989-2003 period in column (3). We find similar estimates to those shown in columns (1) and (2). This is reassuring not only for the validity of our reduced form approach but also for our structural estimations, where the model constrains us to use a balanced panel of observations. We also considered a sample that contained no restrictions in terms of entry and exit into the sample. We find similar results with this sample definition as well.

In column (4) we estimate our baseline specification on a sample limited to plants in the industries that we consider for our structural analyses. These industries are the Preserved Fruits and Vegetables (SIC 203), Metal Forgings and Stampings (SIC 346), Aircraft and Parts (SIC 372), and Measuring and Controlling Devices (SIC 382) industries. We discuss how these sectors were chosen in Section 3.4. Due to concerns about disclosure, we pool the plants from different industries and consider a panel in which both entry and exit are allowed. We find similar results to the overall trend for these industries. Both the magnitudes and changes in the coefficients α_1 and α_2 are similar to those found in columns (1) – (3). These results suggest that the industries that we consider for our structural analyses are representative of aggregate trends.

In addition to the results presented in Table 3.6, we come to similar conclusions when considering alternative approaches to our baseline specification. These include using different definitions of the post-period indicator function $Post$, only considering plants with 350 or more employees, dropping the computer and semiconductor industries, using current values of plant-specific characteristics in the vector X_{it}, adding the variable "Last exported three years ago" and its interaction with $Post_{95}$, and limiting the analysis to single-plant firms.[11] This last robustness check is especially reassuring as it alleviates concerns related to multi-plant firms. Standard errors are similar when clustering by firm or by industry at the 3 digit SIC level. The estimations using a balanced panel were also robust to these alternative estimation approaches.

3.4 Structural Estimation

3.4.1 Model

In this section, we turn to a structural approach to address how the costs of entering foreign markets have evolved. The extra structure afforded by the model allows us to provide numerical estimates of the costs of entering foreign markets in different time periods. Specifically, we use the estimation methodology developed by Das, Roberts, and Tybout (2007) to look at the average level of foreign market entry costs facing plants over the 1987-1997 and 1992-2003 periods. Comparing these cost estimates across the two panels will then give us a sense of how they have changed. In addition to addressing the question of the determinants of the rise in

[11] Specifically we alternately considered defining the post period as the years after 1993, 1994, 1996 or 1997. We define the computer and semiconductor industries as the SIC87 sector codes 357 and 3674 over 1987-1997 and the NAICS sector code 334 over 1997-2003.

export intensity, our results contribute to the emerging literature on estimating the magnitude of these barriers. Indeed, these costs have not been estimated with panel data outside of Colombia and Chile.

Here we lay out the basics of the model underlying the estimation approach; further details are contained in the appendix. All plants in the model serve the domestic market and face the choice of whether or not to sell their goods abroad. The foreign and domestic markets are segmented from one another and are both monopolistically competitive. We abstract from entry and exit into production in the domestic market, requiring the use of a balanced panel in our estimations. We assume that plants' marginal costs do not respond to output shocks, simplifying the model significantly by isolating the decision to serve foreign markets from domestic concerns. Plants are forward-looking in the sense that, although they do not know what their future realizations of marginal costs, foreign demand, and the exchange rate will be, they know the Markov processes by which these factors evolve and set their expectations accordingly.

The log potential profits from selling in the foreign market π^*_{it} for plant i in year t is defined as

$$\ln\left(\pi^*_{it}\right) = \psi_0 z_i + \psi_1 e_t + v_{it} \tag{3.3}$$

where z_i indexes time-invariant plant characteristics including a constant and e_t is the exchange rate. v_{it} is a stationary, serially correlated disturbance term that captures shifts in factors that determine potential export profits. Examples of these factors include changes in productivity, factor input prices, tariffs, transportation costs, and demand. Although this general form is quite parsimonious, it allows for significant flexibility in accounting for many of the other potential explanations for changes in export status. We assume that v_{it} is the sum of m stationary and independent $AR(1)$ processes. Formally, we have $v_{it} = \sum_{j=1}^{m} x_{jit}$ where i indexes plants, t the time period, and j the type of potential shock. Each of these potential shocks can be written $x_{jit} = \lambda_x^j x_{jit} + w_{xjt}$, where w_{xjt} is normally distributed with mean zero and variance σ_{wj}^2. The composite term v_{it} therefore follows an $ARMA\,(m, m-1)$ process. The exchange rate e_t follows the AR(1) process $e_t = \lambda_0 + \lambda_e e_{t-1} + w_{et}$ where w_{et} is normally distributed with mean zero and variance σ_w^2. The parameters λ_0, λ_e, σ_w and the distribution of w_{et} are known to all plants. For ease of exposition, we denote $\Psi = (\psi_{01}, ..., \psi_{0k}, \psi_1) = (\psi_0, \psi_1)$ and collect the parameters λ_x^j and σ_{wj} into the diagonal matrices Λ_x and $\sum_\omega$.

The relevant variable for the empirical analysis of a plant's decision of whether or not to export is the level of foreign profits that it could make. Our data, however, only contain information on total revenues and export revenues. In order to make estimation possible we draw upon two aspects of the model mentioned above: first, markets are monopolistically competitive, and second, foreign and domestic markets are segmented. We further denote c_{it} as the marginal cost of production, $\eta_i > 1$ as a plant-specific foreign demand elasticity, and P_{it}^f as the domestic currency price of exports. If the plant exports, it would optimally choose to price its goods such that $c_{it}^f = P_{it}^f \left(1 - \eta_i^{-1}\right)$. This implies that potential foreign revenues R_{it}^{f*} and variable costs C_{it}^{f*} to exporting can be written as $C_{it}^{f*} = R_{it}^{f*} \left(1 - \eta_i^{-1}\right)$ if we multiply both sides of this expression by the optimal quantity of exports. Using the fact that $\pi_{it}^* = R_{it}^{f*} - C_{it}^{f*}$, this condition implies that potential export profits are given by

$$\pi_{it}^* = \eta_i^{-1} R_{it}^{f^*} \tag{3.4}$$

which is the standard relationship between gross profit and revenue under monopolistic competition. Taking logs and substituting this expression into (3.3) yields

$$\ln\left(R_{it}^{f^*}\right) = \ln\left(\eta_i\right) + \psi_0 z_i + \psi_1 e_t + v_{it} \tag{3.5}$$

This relationship provides a way to estimate the parameters that determine export profits and allows us to account for a significant amount of plant heterogeneity in our estimations to follow. It does, however, create an incidental parameters problem with the introduction of the parameters $\eta = \{\eta_i\}_{i=1}^n$. As the number of plants in the sample grows, so too does the number of parameters.

To solve this problem we explicitly use data on costs and revenues. This information can be used to identify η. We begin by assuming that the ratio of foreign demand elasticities to domestic demand elasticities is $1+\upsilon$ for all plants in the industry. By steps analogous to those used to derive (4), profit maximization and segmented markets imply that we should observe $C_{it}^d = R_{it}^d \left(1 - \eta_i^{-1}[1+\upsilon]\right)$ in the domestic market. Combining this with (4) and invoking the assumption of segmented markets, optimally selected production for all markets must satisfy

$$C_{it} = C_{it}^f + C_{it}^d = R_{it}^f \left(1 - \eta_i^{-1}\right) + R_{it}^d \left(1 - \eta_i^{-1}\left(1+\upsilon\right)\right) \tag{3.6}$$

Dividing this expression by $R_{it} = R_{it}^f + R_{it}^d$, rearranging, replacing optimal with realized values, and including an error term ξ_{it} yields

$$1 - \frac{C_{it}}{R_{it}} = \eta_i^{-1}\left(1 + \upsilon\frac{R_{it}^d}{R_{it}}\right) + \xi_{it} \tag{3.7}$$

Here R_{it}^d, R_{it}, and C_{it} are the plant's realized domestic revenue, total revenue, and total variable cost. We assume that the error term ξ_{it} comes from measurement error in the costs C_{it} and follows the AR(1) process $\xi_{it} = \lambda_\xi \xi_{it-1} + w_{\varsigma t}$, where $w_{\varsigma t}$ is normally distributed with variance σ_ς^2. We can then use this expression to form the density $f_c\left(C_{i0}^T \mid R_{i0}^{fT}, R_{i0}^{dT}, \theta\right)$.

The equation (3.3) gives us an expression for the baseline level of profits that plants earn from foreign markets in each period. In looking at the plant's dynamic problem of whether or not to export, we further allow each plant to receive a shock to profits each period of $\kappa + \varepsilon_{1it}$. κ is common to all plants and ε_{1it} is allowed to vary across plants

i and years t. Plants must also pay an up-front, sunk cost to enter foreign markets $\gamma_s z_i + \varepsilon_{2it} - \varepsilon_{1it}$. These one-time costs γ_s depend on time invariant plant characteristics z_i, are paid fully in the first year of exporting, and are allowed to vary across plants and time. Examples of these costs include market research, setting up distribution channels, learning about foreign regulations and documentation requirements, and a number of other non-tariff barriers. We are most interested in the parameters γ_s. Note that γ_s parameterizes the typical costs that plants face and not necessarily the costs that are paid by plants that begin to sell abroad. Indeed, all else equal, the plants that enter are those that are likely to have drawn a favorable shock of $\varepsilon_{2it} - \varepsilon_{1it}$. We assume that ε_{jit} are serially uncorrelated, normally distributed with mean zero and variance $\sigma^2_{\varepsilon j}$, and are uncorrelated with v_{it} and e_t for each $j = 1, 2$. For the sake of exposition, we let $\sum_\varepsilon = diag\left(\varepsilon_{1it}, \varepsilon_{2it}\right)$ and $\Gamma = (\gamma_{s1}, \gamma_{s2}, ..., \gamma_{sk}, \kappa) = (\gamma_s, \kappa)$. We also define x_{it} as the $m \times 1$ vector of shocks to variable profits so $v_{it} = \iota' x_{it}$ where ι is a vector of ones.

We are now in a position to describe the plant's decision of whether or not to export. Let y_{it} be an indicator variable for whether plant i exported in year t. Using the expression for gross potential export profits π^*_{it} from (3), we can write

$$u\left(\cdot\right) = \begin{cases} \pi^*_{it}\left(e_t, x_{it}, z_i\right) + \kappa + \varepsilon_{1it} & \text{if } y_{it} = 1 \text{ and } y_{it-1} = 1 \\ \pi^*_{it}\left(e_t, x_{it}, z_i\right) + \kappa - \gamma_s z_i + \varepsilon_{2it} & \text{if } y_{it} = 1 \text{ and } y_{it-1} = 0 \\ 0 & \text{if } y_{it} = 0 \end{cases} \tag{3.8}$$

The plant's potential net export profits depend on its prior export status, since we assume that sunk costs have to be paid if the plant did not export in the previous year.

In each period t, the plant observes the state variables e_t, x_{it}, z_i, ε_{jit}, and y_{it-1} and forms its expectations about the future using the fact that it knows the processes by which these terms evolve. The plant then determines the decision rule of whether or not to export $y_{it} = y(e_t, x_{it}, z_i, \varepsilon_{jit}, y_{it-1} \mid \theta)$ which maximizes its net discounted expected profit stream over a 30 year horizon. Formally, we have the Bellman equation

$$V_{it} = \max_{y_{it} \in \{0,1\}} \{u(e_t, x_{it}, z_i, \varepsilon_{jit}, y_{it-1}, y_{it} \mid \theta) + \delta E_t V_{it+1}\} \tag{3.9}$$

where

$$E_t V_{it+1} = \int_{e'} \int_{x'} \int_{\varepsilon'} V_{it+1} \cdot f_e(e' \mid e_t, \theta) \cdot f_x(x' \mid x_t, \theta) \cdot f_\varepsilon(\varepsilon' \mid \varepsilon_t, \theta)\, d\varepsilon' dx' de'$$

and θ collects all the parameters

$$\theta = (\Psi, \eta, \upsilon, \Lambda_x, \Sigma_\omega, \Gamma, \Sigma_\varepsilon, \lambda_0, \lambda_e, \sigma_w, \lambda_\xi, \sigma_\varsigma)$$

The decision rule of whether or not to export implied by this Bellman can be written as a binary choice problem $y_{it} = I(y_{it}^* > 0)$. Here $I(\cdot)$ is an indicator function and y_{it}^* is a comparison of the benefits from exporting and from not exporting

$$y_{it}^* = u(e_t, x_{it}, z_i, \varepsilon_{it}, 1, y_{it-1} \mid \theta) + \delta \Delta E_t V_{it+1}(e_t, x_{it}, z_i \mid \theta) \tag{3.10}$$

where

$$\Delta E_t V_{it+1}(e_t, x_{it}, z_i \mid \theta) = E_t[V_{it+1} \mid y_{it} = 1] - E_t[V_{it+1} \mid y_{it} = 0]$$

The first term in (3.10) reflects the direct benefits today from exporting, whereas the second term reflects the option value of being an exporter tomorrow.

3.4.2 Estimation

Using the expressions developed above to describe a plant's intensive and extensive margin exporting decisions, we then develop a likelihood function that allows us to estimate the parameters in one step

$$L\left(D \mid \theta\right) = \prod\nolimits_{i=1}^{n} f_c\left(C_{i0}^{T} \mid R_{i0}^{fT}, R_{i0}^{dT}, \theta\right) \cdot P\left(y_{i0}^{T}, R_{i0}^{fT} \mid e_0^{T}, z_i, \theta\right) \qquad (3.11)$$

Here $D = \{D_i\}_{i=1}^{n}$ denotes the data for all firms. $f_c\left(C_{i0}^{T} \mid R_{i0}^{fT}, R_{i0}^{dT}, \theta\right)$ is determined by the expression in (7) and the likelihood $P\left(y_{i0}^{T}, R_{i0}^{fT} \mid e_0^{T}, z_i, \theta\right)$ is formed from the relationships implied by the extensive margin decision in (8). We provide more details about the construction of $P\left(y_{i0}^{T}, R_{i0}^{fT} \mid e_0^{T}, z_i, \theta\right)$ in the appendix. Estimating the likelihood function $L\left(D \mid \theta\right)$ with classical methods presents two problems. First, while allowing each plant to face its own demand elasticity controls for a significant amount of plant heterogeneity, it also presents us with an incidental parameters problem in that we need to estimate $\eta = \{\eta_i\}_{i=1}^{n}$. To add to this, the likelihood function is highly non-standard and unlikely to be globally concave in θ. To circumvent these issues, we use a Bayesian approach and write the posterior distribution of the parameters with $P\left(\theta \mid D\right) \propto q\left(\theta\right) L\left(D \mid \theta\right)$, where $q\left(\theta\right)$ gives our prior beliefs about the parameters. To characterize the posterior distribution $P\left(\theta \mid D\right)$, we then use the random walk Metropolis-Hastings algorithm. This algorithm essentially allows us to estimate $E\left(\theta \mid D\right)$ by performing Monte Carlo integration using a Markov chain.

Computational constraints place some restrictions on the level of heterogeneity for which these estimates can account. To characterize the time invariant plant characteristics that affect sunk costs and export profits, we let z_i equal an indicator function based on plant size. The threshold for z_i is set to be equal to the median level of sales in 1987, such that half of the plants are considered large in the first panel for each industry. We keep this threshold for the second panel, capturing changes in plant sales over time. The number of $AR(1)$ processes additively included in the profit function disturbance term is set to two so $v_{it} = \iota' x_{it} = x_{1it} + x_{2it}$. Among other interpretations, these two shocks capture cost and demand shock processes that can evolve independently. We set the discount rate δ to 0.9. In order to ease computational costs, we do not estimate the parameters for the exchange rate process simultaneously with the rest of the model. Instead, we estimate them separately using export-weighted industry real exchange rates constructed with the same approach as those described in Section 3.3. We fit each of these series to an $AR(1)$ process from 1972 until the last year of each panel to give estimates of $\hat{\lambda}_0$, $\hat{\lambda}_e$, and $\hat{\sigma}_w$. These parameters are then treated as fixed for the purposes of the estimation of the model.

For the rest of our parameters, we have to specify a prior distribution. With a few exceptions, we make these distributions reasonably diffuse to let the data speak for itself. To impose non-negativity on the variance parameters, our priors are that they are distributed log normally with a mean of zero and a variance of 2. Our priors on the root of each AR(1) process are that they are distributed uniformly on $(-1, 1)$. This ensures that these processes are stationary. We also set a more restrictive prior for η_i due to the incidental parameters problem. Following the empirical literature, we set the prior such that $\ln(\eta_i - 1) \sim N(2, 1)$. This implies a mean and standard deviation for η_i of 12.2 and 16.0, respectively. It also ensures that $\eta_i > 1$, which is a necessary condition for the model. The prior for υ, the parameter that determines the ratio of foreign and domestic demand elasticities, is also assumed to be uniform on $[-5, 5]$. The priors for other parameters are given in Table 3.6.

Given these preliminaries, it is possible to provide intuition about the main sources of variation used to identify the sunk cost parameters. First note that for any type of plant the probability of exporting is an increasing function of the gross potential profit stream that it could earn in foreign markets. If there are no barriers to entry, the probability that a plant exports today should not depend on whether it exported yesterday. Plants with similar gross potential profit streams should have the same probability of exporting regardless of their exporting history. If there are significant up-front costs, however, plants that previously exported should have a higher probability of exporting than previously non-exporting plants since they do not need to pay the sunk cost to export. The higher these costs are, the bigger should be the difference between the export probabilities of plants that exported previously and those that did not. Thus, differences in the exporting frequencies of plants with similar gross potential export profit streams but different exporting histories in our data provide significant identifying variance for the sunk cost parameters.

3.4.3 Results

In choosing the industries that we focused on, we used several criteria to narrow down our choices (i) there were enough plants in each panel to allow for identification (ii) the industry was sufficiently export oriented (iii) it did not experience large, idiosyncratic shocks that would make our results unrepresentative (iv) like aggregate exports, the overall destination composition of industry exports was relatively stable and (v) the industries were in different 2 digit SIC sectors in order to get a broad view.[12] As mentioned above, these criteria led us to consider four 1987 SIC industries: Preserved Fruits and Vegetables (SIC 203), Metal Forgings and Stampings (SIC 346), Aircraft and Parts (SIC 372), and Measuring and Controlling Devices (SIC 382). Table 3.13 lists the 4 digit subindustries that comprise these 3 digit sectors. We use two panels, 1987-1997 and 1992-2003, and estimate the level of sunk costs γ_s in each period.

Tables 3.8-3.12 present the results. In Table 3.8 we present the estimates for our main sunk cost parameters by industry. All figures are in 1987 dollars. Tables 3.9

[12]Due to data constraints, we are limited in considering a model with only two countries. This assumption has advantages as well as drawbacks. This noted, we limit our structural analyses to industries where the destination of industry exports have remained stable over time by region. Considering a number of industries further alleviates concerns related to this modeling choice.

-3.12 present the full estimation results for each industry and time period. For each parameter we report the estimated mean and standard deviation, although median values give similar results. For each panel we consider 50k draws from the posterior distribution to construct our estimates.[13] Despite generally using highly diffuse prior distributions, the posterior distributions for most of our parameters are fairly concentrated. This suggests that the estimates are primarily informed by the data itself rather than the values that we chose for our priors. We looked at the results from several different levels of thinning the chain. Here we alternately constructed our estimates by dropping every 2nd, 5th, 10th, 50th, or 100th draw. This standard robustness check for Monte Carlo Markov Chain (MCMC) methods is often used to diagnose a lack of convergence of the chain to the posterior distribution $P(\theta \mid D)$ or slow movement of the chain across the parameter space ("slow mixing"). These different levels of thinning all give comparable results.

Consistent with the small changes that we see in the reduced form estimations, we generally find comparable results for γ_s across the two different time periods. The Aircraft and Parts (SIC 372) and Measuring and Controlling Devices (SIC 382) industries experienced little change in the costs that they faced while the Preserved Fruits and Vegetables (SIC 203) sector experienced a decrease and the Metal Forgings and Stampings (SIC 346) industry saw a rise in the costs. Using the elasticity estimates for each plant suggests that the magnitude of the sunk costs are equal to a few years of the average level of exporting profits. Interestingly, we find similar estimates for γ_s for larger and smaller plants across each of the panels. These results suggest that differences in plant size do not alter the costs that plants face in our samples. Elasticity estimates are also consistent with the values suggested by the literature. In concert with our estimates from Section 3.3, we interpret these results

[13] Acceptance rates are kept within the range suggested by the literature and we use a burn-in period of at least 50k iterations. We looked at a number of diagnostic statistics to check for convergence. These tests are reviewed at length in Brooks and Roberts (1998). See the appendix for further details about the MCMC estimation methods.

to suggest that declines in these costs are unlikely to have been a major factor for the level of entry that we see in the data.

One interesting aspect of our results is that we find that the costs increased over time for the Metal Forgings and Stampings (SIC 346) industry. There are a number of factors that may have acted to raise the costs for this industry as well as kept the barriers to entry for other industries higher than they otherwise would have been. In what little survey evidence we have on these costs, firms list market research and redesigning their products for foreign markets as two of the primary costs that they face in beginning to sell abroad.[14] With the increasing integration of the world economy, market research costs may have increased substantially due to the need to identify and study competition from a greatly expanded number of source countries. Secondly, while most types of nontariff barriers have decreased in the last 25 years, technical barriers to trade have increased significantly. These include product specification, testing, and information disclosure requirements. These changes are seen in the data on nontariff barriers as well as in the rising concerns of policy makers in recent years. It is also consistent with the idea of "regulatory protectionism" that has been the subject of significant prior research. Table 3.14 presents results from a United Nations Conference on Trade and Development (2005) report that argues that these barriers to trade have expanded significantly over time. Finally, as the use of antidumping measures have grown significantly, the costs of developing an optimal strategy for entering foreign markets may have increased due to the need to spend more on market research and legal fees.[15] While beyond the scope of this study, we consider the effects of these factors to be an open area for future research.

[14]See the study conducted for the World Bank by First Washington Associates (1991).

[15]For evidence on changes in the technical barriers to trade, see UNCTAD (2005), Henson and Wilson (2005), USTR (2011), U.S. Department of Commerce (2004), Maskus, Wilson, and Otsuki (2000), and Beghin (2008). Baldwin (2000) and Sykes (1999) provide discussions of regulatory protectionism and Blonigen and Prusa (2008) and Finger, Ng, and Wangchuk (2001) document the rise in antidumping cases.

3.5 Discussion

In this section we perform back-of-the-envelope calculations to better understand the determinants of the increase in the percentage of plants that export. With 21% exporting in 1987 and 35% in 2003 the fraction of plants that export rose by 67% over the period. Our intent is to investigate whether a standard model can match this rise without changes in the costs of entering foreign markets. This exercise will give us a sense of whether or not our estimates are reasonable. We find that the model can easily account for the patterns that we see in the data using standard calibrations of the parameters. Here we provide one particular accounting, although other approaches are also sufficient to match the data. We consider a two-country version of the model of Chaney (2008) and assume as he does that the distribution of productivity is Pareto. Given this distribution, the model implied fraction of plants that export in each period can be written as

$$P\left(\phi > \phi_x^{87} \mid \phi > \phi_p^{87}\right) = \left(\frac{\phi_p^{87}}{\phi_x^{87}}\right)^{\theta} = frac^{87} \tag{3.12}$$

and

$$P\left(\phi > \phi_x^{03} \mid \phi > \phi_p^{03}\right) = \left(\frac{\phi_p^{03}}{\phi_x^{03}}\right)^{\theta} = frac^{03} \tag{3.13}$$

Here ϕ_p is the minimum level of productivity ϕ needed to produce which we will assume is stable $\phi_p^{87} = \phi_p^{03}$. ϕ_x is the threshold level needed to access foreign markets profitably and is given in the model as

$$\phi_x = \left(\frac{f_x}{Y_j}\right)^{1/(\sigma-1)} \frac{w_i \tau_{ij}}{P_j}$$

If we divide the expression in (3.13) by that in (3.12) and use the exporting threshold from the model, the ratio of the fraction of plants that export in these two years is

$$\frac{frac^{03}}{frac^{87}} = \left(\frac{\phi_x^{87}}{\phi_x^{03}}\right)^{\theta} = \left(\frac{f_x^{87}}{f_x^{03}}\frac{Y_j^{03}}{Y_j^{87}}\right)^{\frac{\theta}{\sigma-1}} \left(\frac{w_i^{87}}{w_i^{03}}\frac{P_j^{03}}{P_j^{87}}\frac{\tau_{ij}^{87}}{\tau_{ij}^{03}}\right)^{\theta} \tag{3.14}$$

The parameter $\tau_{ij} > 1$ is the level of iceberg transportation costs, w_i is the home country wage, P_j is the foreign price index, f_x is the cost of entering the foreign market, and Y_j is the level of foreign income. From the ASM, we know that real wage growth in U.S. manufacturing has been quite stagnant. Furthermore, U.S. manufacturing competitiveness $\dfrac{w_i}{P_j}$ is also stable or declining over the period. As discussed by several authors, with the exception of NAFTA, tariffs on U.S. goods also did not change significantly over the period; they were in general quite low and stayed that way. Hummels (2007) in turn notes modest reductions in the ad valorem air and ocean freight rates on U.S. goods over 1987-2003. Using a gravity equation framework that accounts for other important factors besides tariffs and transportation costs, Jacks, Meissner, and Novy (2008) also find little change in τ_{ij} for the U.S. 1987-2000. Debaere and Mostashari (2010) further look at imports into the U.S. over 1989-1999 and argue that changes in τ_{ij} have played a minor role in explaining the large changes in the range of goods imported into the U.S. This was due to both the small estimated effects of variable trade costs on the extensive margin of trade as well as the small changes in U.S. protection over the period. [16]

Motivated by this empirical evidence as well as our estimations above, we consider matching the extensive margin trends that we see in the data assuming that $\tau_{ij}^{03} = \tau_{ij}^{87}$ and $\left(w_i^{87}/P_j^{87}\right) \div \left(w_i^{03}/P_j^{03}\right)$ stayed constant. Our work above further allows us to reasonably assume that $f_x^{03} = f_x^{87}$. After all these assumptions, (3.14) simplifies to

[16] Others, however, have argued for a larger effect of changes in variable trade costs on exports. See Yi (2003), Bernard, Jensen, and Schott (2006), and Cuñat and Maffezzoli (2007). For evidence of changes in wages in U.S. manufacturing, see the figures in the Annual Survey of Manufacturers-based U.S. Census publication *Statistics for Industry Groups and Industries: 2005.*

$$\frac{frac^{03}}{frac^{87}} = \left(\frac{Y_j^{03}}{Y_j^{87}}\right)^{\frac{\theta}{\sigma-1}} \tag{3.15}$$

The exponent $\theta/(\sigma-1)$ has been carefully estimated to be near unity and we will use the value of 1.06 from Axtell (2001) but any choice greater than one will give the same result. Using trade shares from 1987 as weights, we calculate a rise in real foreign income amongst 40 top U.S. export destinations of 67%.[17] Using this increase and $\theta/(\sigma-1) = 1.06$ in equation (3.15) yields

$$\frac{frac^{03}}{frac^{87}} = 1.67^{1.06} = 1.72$$

The model predicts the fraction of plants that export would increase by 72% solely due to the observed growth of foreign incomes. We highlight the fact that growth is sufficient to explain the entire 67% increase in foreign market participation as measured in the micro data. This significant role for foreign income is consistent with the pervasive nature of these trends for all industries and U.S. regions. Furthermore, it is compatible with empirical evidence from Baier and Bergstrand (2001), Jacks, Meissner, and Novy (2011), and Whalley and Xin (2011) who study the factors that drove aggregate worldwide exports since the 1950s.[18] Alternative assumptions that increases in w_i/P_j were cancelled by the modest declines in τ_{ij} would give us similar results. Finally, participation could be expected to increase even more if the minimum productivity to produce increased $\phi_p^{03} > \phi_p^{87}$, iceberg costs decreased, U.S. competitiveness deteriorated, or and this is our main point, if entry costs fell.

[17] We include the top 42 U.S. export destinations in 1987 with the exception of Taiwan and Kuwait due to missing data. We consider changes in real foreign income and the real level of entry costs f_x due to units cancelling in the expression in parentheses in equation (3.15).

[18] For example Whalley and Xin (2011) use a calibrated trade model and find a 76% role for income growth in the factors that drove world trade 1975-2004. Baier and Bergstrand (2001) and Jacks Meissner, and Novy (2011) instead consider estimations based on the gravity equation and find similar results. They study the periods 1958-1988 and 1950-2000, respectively. As each of these papers study bilateral trade flows, however, these results do not distinguish between the roles of domestic productivity growth and foreign income growth in driving exports from a given country.

3.6 Conclusion

In this study we have documented a significant shift towards exporting for U.S. plants over 1987-2006. A greater fraction of plants located in all regions and in all sectors export in 2003 than did in 1987. We also emphasize that the extensive margin matters for trade volumes over longer horizons. In looking at why participation increased we considered a natural explanation that has been suggested as a primary cause for similar trends in other countries: declines in the up-front costs of entering foreign markets. Simple descriptive statistics show there has been no change in the persistence of export status providing first order evidence that entry costs have not changed. The same story holds using two different estimation approaches. Our reduced form results show reductions in these barriers were unlikely to have played a significant role among all manufacturing plants. And careful estimation of a micro founded dynamic structural model that accounts for unobserved plant level heterogeneity gives the same result for four representative industries. Applying the new evidence that entry costs were stable, we find that other factors that determine export market participation, specifically foreign income growth, are sufficient to explain the pervasive increase in the extensive margin. Lastly, adding to much study of changes in variable trade barriers, our work represents an initial attempt to understand how foreign market entry barriers have evolved over time.

We close with a discussion of a few areas of research that are likely to be fruitful for future work. Firstly, qualitative evidence on the determinants of export market entry costs would be tremendously valuable. Despite the evidence presented here and their ubiquity in trade models, there is surprisingly little direct survey evidence about these costs. Retrospective research in this area could help us better understand the results presented above. Secondly, much of the work on understanding the effects of free trade agreements focuses on how declines in tariffs affect aggregate trade volumes. Total trade tends to increase through extensive margin adjustments following these agreements, however, and the details of these accords often include provisions likely to reduce barriers to entry. Disentangling these effects would significantly improve our understanding of how different impediments affect trade and would likely yield more accurate analyses of potential policy changes. Finally, an improved understanding of the experiences of other countries would also provide further insight into the evolution of foreign market entry barriers and add greatly to our understanding of trends in international trade.

3.7 Appendix

In this appendix we provide further details about our structural estimation approach. We begin by describing how we develop the extensive margin likelihood in sections 8.1 and 8.2. We then describe our approach to calculating the option value associated with exporting $\Delta E_t V_{it+1}(e_t, z_i, x_{it} \mid \theta)$. A description of our Bayesian MCMC estimation approach closes. The discussion of the model here and in the main text follows Das, Roberts, Tybout (2007); see this paper for further details about the model and estimation approach.

3.7.1 Extensive Margin Likelihood

For the purposes of estimation, we can connect the binary choice decision problem laid out in the body of the text to a likelihood function that uses our data from U.S. plants. We begin by writing observed export profit shocks as

$$v_i^+ = \left\{ \ln\left(R_{it}^f\right) - \ln(\eta_i) - \psi_0 \cdot z_i - \psi_1 \cdot e_t \mid R_{it}^f > 0 \right\}$$

We can then write the export profit shock for plant i in each year t as a function of these observed shocks and a set of m *iid* standard normal random variates μ_i such that $x_{it} = x_{it}\left(v_i^+, \mu_i\right)$. For each plant, we can write

$$\begin{aligned} P\left(y_{i0}^T, R_{i0}^{fT} \mid e_0^T, z_i\right) &= P\left(y_{i0}^T, v_i^+ \mid e_0^T, z_i\right) \\ &= P\left(y_{i0}^T \mid e_0^T, z_i, v_i^+\right) \cdot h\left(v_i^+\right) \\ &= \left[\int_{\mu_i} P\left(y_{i0}^T \mid e_0^T, z_i, x_0^T\left(v_i^+, \mu_i\right)\right) \cdot g(\mu_i)\, d\mu_i\right] \cdot h\left(v_i^+\right) \end{aligned}$$

where the density functions for μ_i and v_i^+ are given by $g(\mu_i)$ and $h\left(v_i^+\right)$. We discuss how to construct $g(\mu_i)$, $h\left(v_i^+\right)$ and the term $\Delta E_t V_{it+1}(e_t, x_{it}, z_i \mid \theta)$ in the next sections of the appendix. The value of $P\left(y_{i0}^T \mid e_0^T, z_i, v_i^+\right)$ will be calculated using the distribution of $g(\mu_i)$ and Monte Carlo integration, drawing several μ_i from $g(\mu_i)$, plugging into $P\left(y_{i0}^T \mid e_0^T, z_i, x_0^T\left(v_i^+, \mu_i\right)\right)$, and averaging. The term $P\left(y_{i0}^T, R_{i0}^{fT} \mid e_0^T, z_i, \theta\right)$ can then be linked to our data by factoring out the initial conditions such that

$$P\left(y_{i0}^T, R_{i0}^{fT} \mid e_0^T, z_i\right) = P\left(y_{i1}^T \mid e_1^T, z_i, x_1^T\left(v_i^+, \mu_i\right), y_{i0}\right) \cdot P\left(y_{i0} \mid e_0, z_i, x_0\left(v_i^+, \mu_i\right)\right)$$

Given computational constraints, we use Heckman's (1981) solution to the initial conditions problem, and estimate $P\left(y_{i0} \mid e_0, z_i, x_0\left(v_i^+, \mu_i\right)\right)$ using

$$\begin{aligned} P\left(y_{i0} \mid e_0, z_i, x_0\left(v_i^+, \mu_i\right)\right) &= \left(\Phi\left(\alpha_0 + \alpha_1' z_i + \alpha_2' x_0\left(v_i^+, \mu_i\right)\right)\right)^{y_{i0}} \cdot \\ & \quad \left(1 - \Phi\left(\alpha_0 + \alpha_1' z_i + \alpha_2' x_0\left(v_i^+, \mu_i\right)\right)\right)^{1-y_{i0}} \end{aligned}$$

Using backward induction along with Rust's (1997) random grid algorithm, we can calculate $\Delta E_t V_{it+1}\left(e_t, x_{it}, z_i \mid \theta\right)$ in each period. We then further use the export market participation rule in (8) to develop the likelihood function

$$\begin{aligned} P\left(y_{i1}^T \mid e_1^T, z_i, x_1^T\left(v_i^+, \mu_i\right), y_{i0}\right) &= \prod_{i=1}^{T} \left[E_{\varepsilon_{it}}\left(I\left(y_{it}^* > 0 \mid e_t, z_i, x_t\left(v_i^+, \mu_i\right), \varepsilon_{it}, y_{it-1}\right)\right)\right]^{y_{it}} \cdot \\ & \quad \left[E_{\varepsilon_{it}}\left(I\left(y_{it}^* \leq 0 \mid e_t, z_i, x_t\left(v_i^+, \mu_i\right), \varepsilon_{it}, y_{it-1}\right)\right)\right]^{1-y_{it}} \end{aligned}$$

Differences across plants and time in terms of export market participation, costs, and foreign and domestic sales will then help pin down our parameters of interest. In particular, variation in export market participation by firms that would earn similar levels of profits in export markets but that are different in terms of their prior foreign market presence will be important in identifying sunk entry costs.

3.7.2 Density Functions for Foreign Market Profit Shocks

In this section we describe how we construct $h\left(v_i^+\right)$ and $x_0^T\left(v_i^+,\mu_i\right)$ mentioned in Section 3.7.1. These are elements that form part of $P\left(y_{i0}^T, R_{i0}^{fT} \mid e_0^T, z_i\right)$. We begin by deriving the density function for

$$\begin{aligned} v_i^+ &= \left\{\ln\left(R_{it}^f\right) - \ln\left(\eta_i\right) - \psi_0 \cdot z_i - \psi_1 \cdot e_t \mid R_{it}^f > 0\right\} \\ &= \left\{v_{it} \equiv \iota' x_{it} \mid R_{it}^f > 0\right\} \end{aligned}$$

For each plant we observe $q_i = \sum_{t=0}^{T} y_{it}$ values of v_i^+. We first assume that each x_{it} process is in long-run equilibrium such that $x_{it} \sim N\left(0, \Sigma_\omega\left(I-\Lambda_x^2\right)^{-1}\right)$. Thus, we have $h\left(v_i^+\right) = N\left(0,\Sigma_{vv}\right)$ where $E\left[v_{it}^2\right] = \iota'\left(x_{it}x_{it}'\right)\iota = \iota'\Sigma_\omega\left(I-\Lambda_x^2\right)^{-1}\iota$ and $E\left[v_{it}v_{it-k}\right] = \iota'\Lambda_x^{|k|}\Sigma_\omega\left(I-\Lambda_x^2\right)^{-1}\iota$ where $k \neq 0$.

The next key element in constructing $P\left(y_{i0}^T, R_{i0}^{fT} \mid e_0^T, z_i\right)$ is to develop the function $x_0^T\left(v_i^+,\mu_i\right)$. We first write x_{i0}^T as an $mT \times 1$ vector $x_{i0}^T = \left(x_{i0}', \ldots, x_{iT}'\right)'$. Given the $q_i \times 1$ vector v_i^+ we can write

$$x_{i0}^T \mid v_i^+ \sim N\left(\Sigma_{xv}\Sigma_{vv}^{-1}v_i^+, \Sigma_{xx} - \Sigma_{xv}\Sigma_{vv}^{-1}\Sigma_{xv}'\right)$$

Here $\Sigma_{xx} \equiv E\left(x_{i0}^T \cdot x_{i0}^{T\,\prime}\right)$ and $\Sigma_{xv} \equiv E\left(x_{i0}^T \cdot v_i^{+\,\prime}\right)$; the elements of these matrices are given by $E\left(x_{it}\cdot x_{it+s}'\right) = \Lambda_x^{|s|}\cdot\Sigma_\omega\cdot\left(I-\Lambda_x^2\right)^{-1}$ and $E\left(x_{it}\cdot v_{it+s}\right) = \Lambda_x^{|s|}\cdot\Sigma_\omega\cdot\left(I-\Lambda_x^2\right)^{-1}\iota$. See Chow (1983) for further discussion.

We can then use these expressions to write

$$x_{i0}^T = x_{i0}^T\left(v_i^+,\mu_i\right) = \begin{cases} Av_i^+ + B\mu_i & \text{if } q_i > 0 \\ B\mu_i & \text{if } q_i = 0 \end{cases}$$

Here $A = \Sigma_{xv}\Sigma_{vv}^{-1}$, $BB = \Sigma_{xx} - \Sigma_{xv}\Sigma_{vv}^{-1}\Sigma_{xv}'$, and μ_i is an $mT \times 1$ vector of *iid* standard normal random variables with density function $g(\mu_i) = \prod_{j=1}^{mT} \phi(\mu_{ij})$. We can use this expression to form $x_{it} = x_t\left(v_i^+, \mu_i\right)$ and $x_{is}^T = x_s^T\left(v_i^+, \mu_i\right)$ that are then a part of

$$P\left(y_{i0}^T \mid e_0^T, z_i, v_i^+\right) = \int_{\mu_i} P\left(y_{i0}^T \mid e_0^T, z_i, x_{i0}^T\left(v_i^+, \mu_i\right)\right) \cdot g(\mu_i) \cdot d\mu_i$$

Specifically, we can then use this functional form to simulate $P\left(y_{i0}^T \mid e_0^T, z_i, v_i^+\right)$. This is done by (i) drawing a set of S vectors μ_i from $g(\mu_i)$ (ii) using the values to calculate $x_{i0}^T\left(v_i^+, \mu_i\right)$ and (iii) averaging over the resulting values to calculate $P\left(y_{i0}^T \mid e_0^T, z_i, v_i^+\right)$.

3.7.3 Calculating the Option Value $\Delta E_t V_{it+1}(e_t, z_i, x_{it} \mid \theta)$

In obtaining an estimate of the latent value of exporting

$$y_{it}^* = \left[u(e_t, z_i, x_{it}, \varepsilon_{it}, y_{it} = 1, y_{it-1} \mid \theta) - 0\right] + \delta \Delta E_t V_{it+1}(e_t, z_i, x_{it} \mid \theta)$$

the term $u(e_t, z_i, x_{it}, \varepsilon_{it}, y_{it} = 1, y_{it-1} \mid \theta)$ can be calculated using the functional forms presented in the text. To obtain an estimate for $\Delta E_t V_{it+1}(e_t, z_i, x_{it} \mid \theta)$ we begin by using backward induction over a 30 year time horizon to first calculate

$$V_{it}^O = \delta E_t V_{it+1}(e_{t+1}, x_{it+1}, z_i \mid y_{it} = 0, \theta)$$

$$V_{it}^E = \pi(e_{t+1}, x_{it+1}, z_i, \theta) - \kappa - \gamma_s \cdot z_i + \delta E_t V_{it+1}(e_{t+1}, x_{it+1}, z_i \mid y_{it} = 1, \theta)$$

$$V_{it}^S = \pi(e_{t+1}, x_{it+1}, z_i, \theta) - \kappa + \delta E_t V_{it+1}(e_{t+1}, x_{it+1}, z_i \mid y_{it} = 1, \theta)$$

Here V_{it}^O is the expected value of only selling domestically in period t, V_{it}^E is the expected value from entering the foreign market, and V_{it}^S is the expected value of continuing to sell abroad. The algorithm begins in the last year in which $E_t V_{it+1} = 0$ and then calculates V_{it}^O, V_{it}^E, and V_{it}^S backwards successively until the current period is reached. We use Rust's (1997) random grid algorithm to integrate numerically over the state variables x and e. We calculate

$$
\begin{aligned}
E_t\left[V_{it+1} \mid y_{it}=1\right] &= E_t \max\left(V_{it+1}^{O}, V_{it+1}^{S}+\varepsilon_{1it+1}\right) \\
&= \int_{x_{t+1}}\int_{e_{t+1}} \left[\begin{array}{c} \Phi\left(\frac{V_{it+1}^{S}-V_{it+1}^{O}}{\sigma_{\varepsilon 1}}\right) \times \left[V_{it+1}^{S}+\sigma_{\varepsilon 1}\cdot\left[\frac{\phi\left(\frac{V_{it+1}^{S}-V_{it+1}^{O}}{\sigma_{\varepsilon 1}}\right)}{\Phi\left(\frac{V_{it+1}^{S}-V_{it+1}^{O}}{\sigma_{\varepsilon 1}}\right)}\right]\right] \\ +\Phi\left(\frac{V_{it+1}^{O}-V_{it+1}^{S}}{\sigma_{\varepsilon 1}}\right)\cdot V_{it+1}^{O} \end{array}\right] \\
&\quad \cdot f\left(x_{t+1} \mid x_t\right)\cdot f\left(e_{t+1} \mid e_t\right)\cdot dx_{t+1}\cdot de_{t+1}
\end{aligned}
$$

and

$$
\begin{aligned}
E_t\left[V_{it+1} \mid y_{it}=0\right] &= E_t\left[\max\left(V_{it+1}^{O}, V_{it}^{E}+\varepsilon_{2it+1}\right)\right] \\
&= \int_{x_{t+1}}\int_{e_{t+1}} \left[\begin{array}{c} \Phi\left(\frac{V_{it}^{E}-V_{it+1}^{O}}{\sigma_{\varepsilon 2}}\right) \cdot \left[V_{it}^{E}+\sigma_{\varepsilon 2}\cdot\left[\frac{\phi\left(\frac{V_{it}^{E}-V_{it+1}^{O}}{\sigma_{\varepsilon 2}}\right)}{\Phi\left(\frac{V_{it}^{E}-V_{it+1}^{O}}{\sigma_{\varepsilon 2}}\right)}\right]\right] \\ +\Phi\left(\frac{V_{it+1}^{O}-V_{it}^{E}}{\sigma_{\varepsilon 2}}\right)\cdot V_{0it+1} \end{array}\right] \\
&\quad \cdot f\left(x_{t+1} \mid x_t\right)\cdot f\left(e_{t+1} \mid e_t\right)\cdot dx_{t+1}\cdot de_{t+1}
\end{aligned}
$$

3.7.4 Monte Carlo Markov Chain Methods

We take $S = 50k$ draws of the posterior distribution $P(\theta \mid D)$ to construct our estimates using the random-walk Metropolis-Hastings algorithm. These draws are taken after an initial burn-in period that allows the chain to converge to the posterior distribution. The means and standard deviations are estimated with $\bar{\theta} = \frac{1}{S}\sum_{s=1}^{S}\theta^s$ and the diagonal elements of the matrix

$$
\Sigma_\theta = \sqrt{\frac{1}{S}\sum_{s=1}^{S}\left(\theta^s-\bar{\theta}\right)\cdot\left(\theta^s-\bar{\theta}\right)'}
$$

where θ^s is a given draw of the entire parameter vector from the posterior distribution. We use a Metropolis-Hastings algorithm in which we update the different components of the parameter vector separately in each iteration of the chain. We choose to partition θ with $\theta^s = (\theta_1^s, \theta_2^s, \ldots, \theta_8^s)$ where $\theta_1 = \Psi$, $\theta_2 = \Lambda_x$, $\theta_3 = \Sigma_\omega$, $\theta_4 = \Gamma$, $\theta_5 = \Sigma_\varepsilon$, $\theta_6 = \eta$, $\theta_7 = (\upsilon, \rho, \sigma_\xi)$, $\theta_8 = \varsigma$. Once starting values for the chain are chosen, for each iteration we perform the following steps. These steps are then repeated for each iteration.

1. Draw a potential new value for one of the subvectors θ_i based on the value from the previous iteration of the chain. This can be written as $\tilde{\theta}_i^* = \tilde{\theta}_i^s + \upsilon_i^s$ where $\tilde{\theta}_i^s$ is the value of the subvector from the previous iteration and υ_i^s is a mean-zero vector of shocks. The covariance matrix for υ_i^s, Σ_{υ_i}, is chosen before the estimations begin and is held fixed throughout.

2. Define $\tilde{\theta}_{-i}^s$ as the set of parameters in θ excluding those in $\tilde{\theta}_i^s$. Calculate the ratio

$$\alpha_i^s = min\left(\frac{P\left(\theta_i^* \mid \theta_{-i}^s, D\right)}{P\left(\theta_i^s \mid \theta_{-i}^s, D\right)}, 1\right)$$

and update the set of parameters θ_i with

$$(\theta_i^{s+1}, \theta_{-i}^s) = \begin{cases} \left(\theta_i^*, \theta_{-i}^s\right) & \text{with probability } \alpha_i^s \\ \left(\theta_i^s, \theta_{-i}^s\right) & \text{with probability } 1 - \alpha_i^s \end{cases}$$

3. Conduct the same process for each block of parameters θ_i. Once this is done $\forall\ i$, we take the resulting value of θ as our draw from the chain. This process is repeated for each draw of the chain.

Table 3.1: Export Participation by Industry

	Plants that Export (%)			
Industry	1987	1992	1997	2003
Food	15	23	25	27
Tobacco	45	51	47	
(Beverage & Tobacco)				28
Textile Mill Products	16	25	28	
(Textile Mills)				40
(Textile Product Mills)				30
Apparel	5	9	13	13
Wood products	12	18	16	16
Furniture	10	25	24	18
Paper	19	31	32	35
Printing & Publishing	5	10	11	14
Chemicals	40	49	49	55
Petroleum & Coal	22	30	30	31
Plastics & Rubber	26	36	39	40
Leather	19	28	35	38
Nonmetallic Minerals	14	21	20	17
Primary Metals	27	39	39	43
Fabricated Metals	21	31	32	30
Machinery	33	43	41	56
Electronic & Other Electric Equipment	37	46	47	
(Electrical Equipment, etc.)				54
Instruments	48	55	56	
(Computer & Electronic Products)				58
Transportation Equipment	29	40	41	49
Miscellaneous Manufacturing	20	34	36	37
Total	21	30	32	35

Notes: The table lists the percentage of plants that export in each industry using the Census of Manufacturers in 1987, 1992, and 1997 and the Annual Survey of Manufacturers in 2003. Due to concerns about disclosure, the results reported for 1987 and 1992 are from Bernard & Jensen (2004b). The classification system used is 1987 U.S. SIC for 1987-1997 and 2002 NAICS for 2003. Similar to other reported figures, estimates are for plants with 20 or more employees. While somewhat heterogeneous in size and timepaths, these results overall suggest that the trends pictured in Figure 3.1 were pervasive across industries. See also Figure 3.2.

Table 3.2: Export Participation by Region

	Plants that Export (%)			
Region	1987	1992	1997	2003
New England	25	37	37	42
Middle Atlantic	19	29	30	34
East North Central	25	34	35	39
West North Central	23	32	33	37
South Atlantic	18	27	29	32
East South Central	18	27	27	30
West South Central	19	28	28	31
Mountain	18	26	27	32
Pacific	21	31	31	33
Total	21	30	32	35

Notes: The table lists the percentage of plants that export in each U.S. Census geographical division using the Census of Manufacturers in 1987, 1992, and 1997 and the Annual Survey of Manufacturers in 2003. We report the states corresponding to these divisions in Table 3.3. Similar to other reported figures, estimates are for plants with 20 or more employees. These results suggest the time path of participation rates of each region match the overall trend across these years. Furthermore, these trends also hold across the 50 states. See also Figure 3.3 and Table 3.3.

Table 3.3: Census Division of the States

Census Division	State	Census Division	State
New England	Connecticut	East South Central	Alabama
	Maine		Kentucky
	Massachusetts		Mississippi
	New Hampshire		Tennessee
	Rhode Island		
	Vermont	West South Central	Arkansas
			Louisiana
Middle Atlantic	New Jersey		Oklahoma
	New York		Texas
	Pennsylvania		
		Mountain	Arizona
East North Central	Indiana		Colorado
	Illinois		Idaho
	Michigan		New Mexico
	Ohio		Montana
	Wisconsin		Utah
			Nevada
West North Central	Iowa		Wyoming
	Nebraska		
	Kansas	Pacific	Alaska
	North Dakota		California
	Minnesota		Hawaii
	South Dakota		Oregon
	Missouri		Washington
South Atlantic	Delaware		
	District of Columbia		
	Florida		
	Georgia		
	Maryland		
	North Carolina		
	South Carolina		
	Virginia		
	West Virginia		

Notes: The table lists the states corresponding to the Census Divisions used for our calculations in Figure 3.3 and table 3.2.

Table 3.4: Destinations of U.S. Manufacturing Exports

	Share of U.S. Exports (%)	
Country	1987	2003
Canada	25.3	19.6
Japan	11.1	7.2
Great Britain	5.8	5.4
Germany	5.4	5.8
France	4.7	3.3
Mexico	3.2	13.9
Korea	3.1	3.2
Australia	2.5	1.9
Taiwan	2.5	2.2
Italy	2.5	1.6
Singapore	2.1	2.5
Netherlands	2.1	2.4
China	1.9	4.1
Hong Kong	1.7	1.7
Venezuela	1.6	.3
Spain	1.4	.9
Saudi Arabia	1.3	.8
Brazil	1.2	1.3
Sweden	1.2	.5
Switzerland	1.1	.8

Notes: The table lists the destination composition of U.S. manufacturing exports by value in 1987 and 2003. Thus, Germany accounted for 5.4% of total U.S. exports in 1987 and 5.8% in 2003. Calculations are done using the UN Commodity Trade and Statistics Database. We present the share for the top 20 destinations in 1987 across the two different years. These countries account for 81.7% of U.S. exports in 1987 and 79.4% in 2003. These figures demonstrate that the composition has remained stable over time. Shares come even closer when excluding Mexico from the analysis. Indeed, the rank correlation amongst the top 40 destinations in 1987 with their respective ordering in 2003 is 88%.

Table 3.5: Intensive Margin

	Starting			
Continuing	1987	1992	1997	2002
1987	1			
1992	0.75	1		
1997	0.58	0.79	1	
2002	0.46	0.58	0.71	1

Notes: The table lists the percentage of exports in each Census of Manufacturers (CMF) year that came from plants that exported in each of the previous Census years, starting in 1987. Thus only 46% of exports in 2002 came from plants that exported in 1987, 1992, and 1997. Removing any continuous exporting restriction, we find that 57% of trade in 2002 is from plants that export in both 1987 and 2002. Similar to our other figures, estimations are limited to plants with 20 or more employees.

Table 3.6: Determinants of Export Status

Variable	Specification (1)	(2)	(3)	(4)
Exported last year	.444**	.445**	.456**	.385**
	(.008)	(.008)	(.009)	(.028)
Exported last year * $Post_{95}$	-.044**	-.044**	-.034**	-.032
	(.006)	(.006)	(.007)	(.022)
Last exported two years ago	.153**	.154**	.161**	.123**
	(.013)	(.013)	(.013)	(.041)
Last exported two years ago * $Post_{95}$	-.094**	-.094**	-.092**	-.076
	(.016)	(.016)	(.017)	(.051)
Total Employment	-.002		-.007	.039
	(.012)		.013	(.040)
Wages	.025**		.031**	.030
	(.012)		.013	(.039)
Non-production/Total Employment	-.059**		-.052**	-.142**
	(.022)		.024	(.066)
Changed Product	.001		.001	-.028
	(.009)		.011	(.028)
Productivity	.006**	.007**	.009**	.014
	(.002)	(.002)	(.002)	(.009)
Industry Exchange Rate	.028	.034	.041	-.023
	(.039)	(.040)	(.043)	(.151)
Year Fixed Effects	Yes	Yes	Yes	Yes
Overall R^2	.508	.507	.514	.434
Observations	65388	65388	54947	6089

Notes: The table presents the results from estimating equation (2) in the text. The dependent variable is a 0/1 indicator for a given plant's export status in the current year. Standard errors are clustered at the plant level and non-exporting related plant-specific characteristics are lagged by one period in all specifications. The coefficient "Exported last year" is an increasing function of the costs of entering foreign markets anew F_0. The coefficient on "Last exported two years ago" is similarly an increasing function of the difference $F_0 - F_R$, where F_R is the cost of re-entering foreign markets after leaving the foreign market one year ago. $Post_{95}$ is an indicator function for the post-1995 part of the sample. The results suggest a modest decline in F_0 and an increase in F_R. Column (1) presents the results from our baseline specification and column (2) considers a similar approach that drops a number of covariates. Column (3) reports results from using a balanced panel. Column (4) restricts the sample to plants in the industries we considered for our structural analysis. ** denotes significance at the 5% level.

Table 3.7: Prior Distributions

Parameters	Priors $N(\mu,\sigma)$
	Profits
ψ_{01} (intercept)	$\psi_{01} \sim N(0,10)$
ψ_{02} (dom. size dummy)	$\psi_{02} \sim N(0,10)$
ψ_1 (exchange rate)	$\psi_1 \sim N(0,10)$
λ_x^1 (root, first AR)	$\lambda_x^1 \sim U(-1,1)$
λ_x^2 (root, second AR)	$\lambda_x^2 \sim U(-1,1)$
$\sigma_{\omega 1}^2$ (variance, first AR)	$\ln(\sigma_{\omega 1}^2) \sim N(0,20)$
$\sigma_{\omega 2}^2$ (variance, second AR)	$\ln(\sigma_{\omega 2}^2) \sim N(0,20)$
υ (foreign elas. premium)	$\upsilon \sim U[-5,5]$
λ_ξ (root, measurement error)	$\lambda_\xi \sim U(-1,1)$
σ_ξ (std. dev., measurement error)	$\ln(\sigma_\xi) \sim N(0,2)$
	Elasticities of Demand
η_μ (demand elas., μ across plants)	$\ln(\eta_i - 1) \sim N(2,1)$
η_σ (demand elas., σ across plants)	
	Exporting Decision
γ_{s1} (sunk cost, small plants)	$\gamma_{s1} \sim N(0,20)$
γ_{s2} (sunk cost, large plants)	$\gamma_{s2} \sim N(0,20)$
κ (mean, ε_1 & ε_2)	$\kappa \sim N(0,20)$
$\sigma_{\varepsilon 1}$ (st. dev., ε_1)	$\ln(\sigma_{\varepsilon 1}) \sim N(0,20)$
$\sigma_{\varepsilon 2}$ (st. dev., ε_2)	$\ln(\sigma_{\varepsilon 2}) \sim N(0,20)$
	Initial Conditions
α_0 (intercept)	$\alpha_0 \sim N(0,50)$
α_1 (dom. size dummy)	$\alpha_1 \sim N(0,50)$
α_2 (x_1)	$\alpha_2 \sim N(0,50)$
α_3 (x_2)	$\alpha_3 \sim N(0,50)$

Notes: The table presents the priors used for our structural estimations for each industry. The results are presented in Tables 3.8-3.12. We generally choose diffuse priors to allow the data to speak for itself. Variance parameters have log normal distributions to impose nonnegativity. The root of each $AR(1)$ process is bounded on $(-1,1)$ in order to ensure stationarity.

Table 3.8: Sunk Cost Parameter Estimates

	Panel	
	1987-1997	1992-2003
Preserved Fruits & Vegetables (203)		
γ_{s1} (sunk cost, small plants)	3.43 (0.35)	2.30 (0.21)
γ_{s2} (sunk cost, large plants)	3.27 (0.33)	2.05 (0.22)
Metal Forgings & Stampings (346)	4.65 (0.34)	5.35 (0.92)
γ_{s1} (sunk cost, small plants)	4.53 (0.44)	5.67 (1.05)
γ_{s2} (sunk cost, large plants)		
Aircraft & Parts (372)		
γ_{s1} (sunk cost, small plants)	2.10 (0.43)	2.22 (0.49)
γ_{s2} (sunk cost, large plants)	2.16 (0.45)	1.99 (0.45)
Measuring & Controlling Devices (382)		
γ_{s1} (sunk cost, small plants)	2.84 (0.38)	2.50 (0.54)
γ_{s2} (sunk cost, large plants)	2.54 (0.41)	2.63 (0.64)

Notes: The table presents the sunk cost estimates γ_s for each industry over the time periods 1987-1997 and 1992-2003. Means are presented along with standard deviations in parentheses. Median estimates give similar results. We interpret these results as evidence against the argument that declines in the costs to entering foreign markets have played a significant role in export trends across manufacturing as a whole. Full results for each industry are found in Tables 3.9-3.12.

Table 3.9: SIC 203 Posterior Parameter Distributions (Means & Std Deviations)

	Preserved Fruits & Vegs. (203)	
	1987-1997	1992-2003
	Profits	
ψ_{01} (intercept)	-2.06 (0.23)	-2.06 (0.27)
ψ_{02} (dom. size dummy)	1.05 (0.30)	1.12 (0.35)
ψ_1 (exchange rate)	0.37 (1.50)	-0.31 (0.75)
λ_x^1 (root, first AR)	0.13 (0.03)	0.43 (0.05)
λ_x^2 (root, second AR)	0.71 (0.02)	0.90 (0.03)
$\sigma_{\omega 1}^2$ (variance, first AR)	0.04 (0.01)	0.53 (0.09)
$\sigma_{\omega 2}^2$ (variance, second AR)	1.36 (0.07)	0.43 (0.09)
υ (foreign elas. premium)	0.03 (0.04)	0.00 (0.04)
λ_ξ (root, measurement error)	0.88 (0.01)	0.84 (0.02)
σ_ξ (std. error, measurement error)	0.22 (0.03)	0.21 (0.02)
	Elasticities of Demand	
η_μ (demand elas., μ across plants)	13.39 (7.31)	12.68 (6.14)
η_σ (demand elas., σ across plants)	11.74 (6.89)	11.78 (6.29)
	Exporting Decision	
γ_{s1} (sunk cost, small plants)	3.43 (0.35)	2.30 (0.21)
γ_{s2} (sunk cost, large plants)	3.27 (0.33)	2.05 (0.22)
κ (mean, ε_1 & ε_2)	0.16 (0.03)	0.09 (0.02)
$\sigma_{\varepsilon 1}$ (std. error, ε_1)	1.72 (0.68)	1.42 (0.22)
$\sigma_{\varepsilon 2}$ (std. error, ε_2)	1.31 (0.54)	0.66 (0.09)
	Initial Conditions	
α_0 (intercept)	11.16 (10.21)	7.27 (6.87)
α_1 (dom. size dummy)	28.87 (18.26)	24.06 (16.18)
α_2 (x_1)	46.34 (26.12)	19.36 (66.10)
α_3 (x_2)	-71.33 (31.19)	32.73 (57.31)
Observations	$N = 112, T = 11$	$N = 101, T = 12$

Notes: The table presents the results from estimating the structural model presented in Section 3.4 for the Preserved Fruits and Vegetables industry (SIC 203) over the time periods 1987-1997 and 1992-2003. We find that the average level of sunk costs associated with entering foreign markets facing this industry γ_s declined somewhat over the period from $\sim$ \$3.3 million to $\sim$ \$2.2 million. Mean estimates of foreign demand elasticities are consistent with the findings in the literature.

Table 3.10: SIC 346 Posterior Parameter Distributions (Means & Std Deviations)

	Metal Forgings & Stampings (346)	
	1987-1997	1992-2003
	Profits	
ψ_{01} (intercept)	-1.96 (0.29)	-1.27 (0.26)
ψ_{02} (dom. size dummy)	2.77 (0.38)	2.49 (0.32)
ψ_1 (exchange rate)	0.03 (0.59)	1.07 (0.49)
λ_x^1 (root, first AR)	0.04 (0.28)	0.60 (0.15)
λ_x^2 (root, second AR)	0.92 (0.02)	0.86 (0.05)
$\sigma_{\omega 1}^2$ (variance, first AR)	0.13 (0.07)	0.18 (0.09)
$\sigma_{\omega 2}^2$ (variance, second AR)	0.43 (0.08)	0.31 (0.10)
υ (foreign elas. premium)	0.12 (0.04)	0.41 (0.06)
λ_ξ (root, measurement error)	0.82 (0.02)	0.80 (0.03)
σ_ξ (std. error, measurement error)	0.11 (0.01)	0.13 (0.02)
	Elasticities of Demand	
η_μ (demand elas., μ across plants)	13.26 (6.20)	11.74 (6.84)
η_σ (demand elas., σ across plants)	11.97 (6.45)	8.34 (5.30)
	Exporting Decision	
γ_{s1} (sunk cost, small plants)	4.65 (0.34)	5.35 (0.92)
γ_{s2} (sunk cost, large plants)	4.53 (0.44)	5.67 (1.05)
κ (mean, ε_1 & ε_2)	0.55 (0.10)	0.92 (0.40)
$\sigma_{\varepsilon 1}$ (std. error, ε_1)	2.35 (0.28)	1.48 (0.54)
$\sigma_{\varepsilon 2}$ (std. error, ε_2)	1.59 (0.47)	4.72 (1.47)
	Initial Conditions	
α_0 (intercept)	34.90 (9.48)	38.60 (19.22)
α_1 (dom. size dummy)	47.67 (4.05)	45.64 (26.12)
α_2 (x_1)	-63.31 (5.19)	47.79 (45.07)
α_3 (x_2)	-30.17 (7.26)	-0.47 (33.91)
Observations	$N = 704, T = 11$	$N = 648, T = 12$

Notes: The table presents the results from estimating the structural model presented in Section 3.4 for the Metal Forgings and Stampings industry (SIC 346) over the time periods 1987-1997 and 1992-2003. We find that the average level of sunk costs associated with entering foreign markets facing this industry γ_s increased somewhat over the period from $\sim$ \$4.6 million to $\sim$ \$5.5 million. Mean estimates of foreign demand elasticities are consistent with the findings in the literature.

Table 3.11: SIC 372 Posterior Parameter Distributions (Means & Std Deviations)

	Aircraft & Parts (372)	
	1987-1997	1992-2003
	Profits	
ψ_{01} (intercept)	-0.45 (0.30)	-0.33 (0.35)
ψ_{02} (dom. size dummy)	2.52 (0.43)	2.54 (0.43)
ψ_1 (exchange rate)	-0.06 (1.00)	0.31 (0.49)
λ_x^1 (root, first AR)	0.22 (0.09)	0.40 (0.08)
λ_x^2 (root, second AR)	0.97 (0.01)	0.97 (0.01)
$\sigma_{\omega 1}^2$ (variance, first AR)	0.57 (0.08)	0.41 (0.05)
$\sigma_{\omega 2}^2$ (variance, second AR)	0.16 (0.06)	0.19 (0.04)
υ (foreign elas. premium)	1.82 (0.13)	2.40 (0.39)
λ_ξ (root, measurement error)	0.98 (0.00)	0.98 (0.00)
σ_ξ (std. error, measurement error)	1.14 (0.12)	1.38 (0.26)
	Elasticities of Demand	
η_μ (demand elas., μ across plants)	12.40 (5.44)	12.13 (4.42)
η_σ (demand elas., σ across plants)	12.39 (6.10)	12.25 (5.09)
	Exporting Decision	
γ_{s1} (sunk cost, small plants)	2.10 (0.43)	2.22 (0.49)
γ_{s2} (sunk cost, large plants)	2.16 (0.45)	1.99 (0.45)
κ (mean, ε_1 & ε_2)	0.23 (0.05)	0.18 (0.05)
$\sigma_{\varepsilon 1}$ (std. error, ε_1)	0.83 (0.36)	0.90 (0.25)
$\sigma_{\varepsilon 2}$ (std. error, ε_2)	1.05 (0.29)	0.86 (0.16)
	Initial Conditions	
α_0 (intercept)	50.36 (22.80)	27.68 (16.76)
α_1 (dom. size dummy)	8.85 (18.06)	23.72 (19.60)
α_2 (x_1)	-9.95 (19.15)	-64.19 (26.86)
α_3 (x_2)	-47.56 (57.80)	53.59 (25.83)
Observations	$N = 924, T = 11$	$N = 948, T = 12$

Notes: The table presents the results from estimating the structural model presented in Section 3.4 for the Aircraft and Parts industry (SIC 372) over the time periods 1987-1997 and 1992-2003. We find that the average level of sunk costs associated with entering foreign markets facing this industry γ_s were relatively stable over time. Mean estimates of foreign demand elasticities are consistent with the findings in the literature.

Table 3.12: SIC 382 Posterior Parameter Distributions (Means & Std Deviations)

	Measuring & Controlling Devices (382)	
	1987-1997	1992-2003
	Profits	
ψ_{01} (intercept)	-0.16 (0.17)	-0.06 (0.17)
ψ_{02} (dom. size dummy)	0.83 (0.24)	1.47 (0.25)
ψ_1 (exchange rate)	-0.83 (0.62)	0.55 (0.45)
λ_x^1 (root, first AR)	0.16 (0.17)	0.61 (0.07)
λ_x^2 (root, second AR)	0.91 (0.03)	0.82 (0.08)
$\sigma_{\omega 1}^2$ (variance, first AR)	0.19 (0.06)	0.31 (0.06)
$\sigma_{\omega 2}^2$ (variance, second AR)	0.16 (0.05)	0.10 (0.06)
υ (foreign elas. premium)	1.36 (0.07)	2.10 (0.13)
λ_ξ (root, measurement error)	0.98 (0.00)	0.98 (0.00)
σ_ξ (std. error, measurement error)	0.84 (0.09)	1.11 (0.18)
	Elasticities of Demand	
η_μ (demand elas., μ across plants)	11.46 (6.68)	10.90 (6.68)
η_σ (demand elas., σ across plants)	8.01 (5.03)	5.88 (3.84)
	Exporting Decision	
γ_{s1} (sunk cost, small plants)	2.84 (0.38)	2.50 (0.54)
γ_{s2} (sunk cost, large plants)	2.54 (0.41)	2.63 (0.64)
κ (mean, ε_1 & ε_2)	0.85 (0.33)	1.43 (0.62)
$\sigma_{\varepsilon 1}$ (std. error, ε_1)	1.48 (0.29)	1.14 (0.51)
$\sigma_{\varepsilon 2}$ (std. error, ε_2)	2.09 (0.81)	4.44 (1.49)
	Initial Conditions	
α_0 (intercept)	40.80 (17.89)	51.39 (21.09)
α_1 (dom. size dummy)	28.84 (25.01)	-5.80 (18.55)
α_2 (x_1)	46.72 (24.20)	0.42 (29.67)
α_3 (x_2)	49.97 (40.25)	64.65 (32.81)
Observations	$N = 1056, T = 11$	$N = 828, T = 12$

Notes: The table presents the results from estimating the structural model presented in Section 3.4 for the Measuring and Controlling Devices industry (SIC 382) over the time periods 1987-1997 and 1992-2003. We find that the average level of sunk costs associated with entering foreign markets facing this industry γ_s were relatively stable over time. Mean estimates of foreign demand elasticities are consistent with the findings in the literature.

Table 3.13: Four Digit Subindustries For Structural Estimations

3 Digit SIC Industry	4 Digit SIC Subindustry
Preserved Fruits and Vegetables (203)	Canned specialties (2032)
	Canned fruits and vegetables (2033)
	Dehydrated fruits, vegetables, and soups (2034)
	Pickles, sauces, and salad dressings (2035)
	Frozen fruits and vegetables (2037)
	Frozen specialties, n.e.c. (2038)
Metal Forgings and Stampings (346)	Iron and steel forgings (3462)
	Nonferrous forgings (3463)
	Automotive stampings (3465)
	Crowns and closures (3466)
	Metal stampings, n.e.c. (3469)
Aircraft and Parts (372)	Aircraft (3721)
	Aircraft Engines and Engine Parts (3724)
	Aircraft Parts and Equipment, N.E.C. (3728)
Measuring and Controlling Devices (382)	Laboratory Apparatus and Furniture (3821)
	Environmental Controls (3822)
	Process Control Instruments (3823)
	Fluid Meters and Counting Devices (3824)
	Instruments to Measure Electricity (3825)
	Analytical Instruments (3826)
	Optical Instruments and Lenses (3827)
	Measuring and Controlling Devices, N.E.C. (3829)

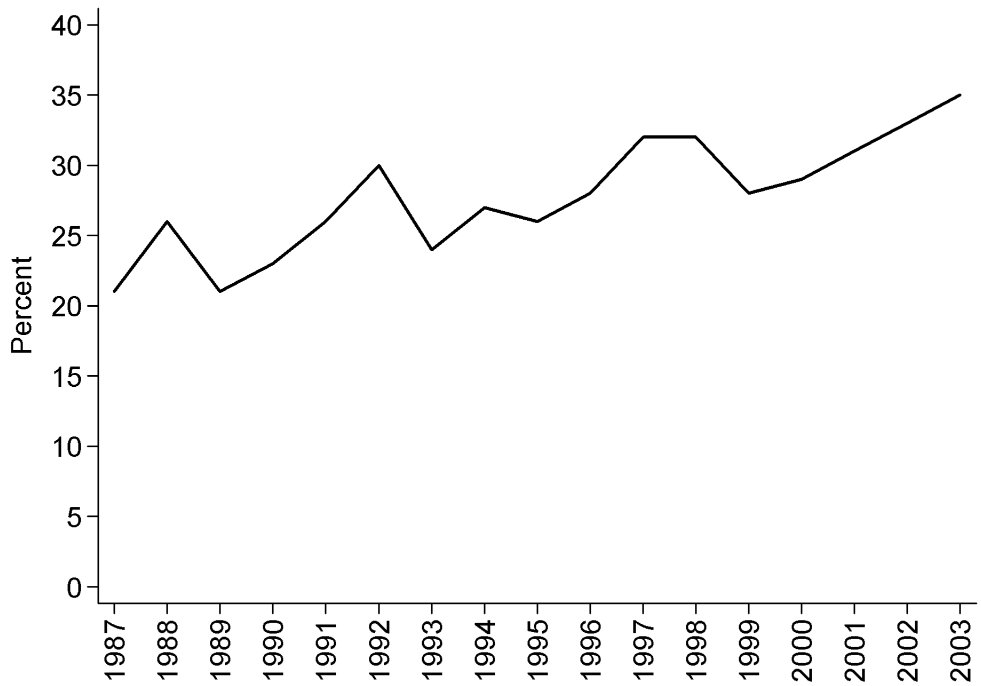
Notes: The table lists the 4 digit 1987 SIC industries that compose the 3 digit 1987 SIC industries that we consider for our structural analyses.

Table 3.14: Evolution of Nontariff Barriers

	Tariff Lines Affected (%)	
Category	1994	2004
Price Control Measures (antidumping, min import prices)	7	2
Finance Measures (foreign exchange regs)	2	2
Automatic Licensing Measures (prior surveillance)	3	2
Quantity Control Measures (quotas, seasonal prohibition)	49	35
Monopolistic Measures (sole importing agency)	1	2
Technical Measures (requirements for testing, disclosing information, packaging, certain product characteristics)	32	59
Number of Countries	52	97
Number of Tariff Lines	97706	545078

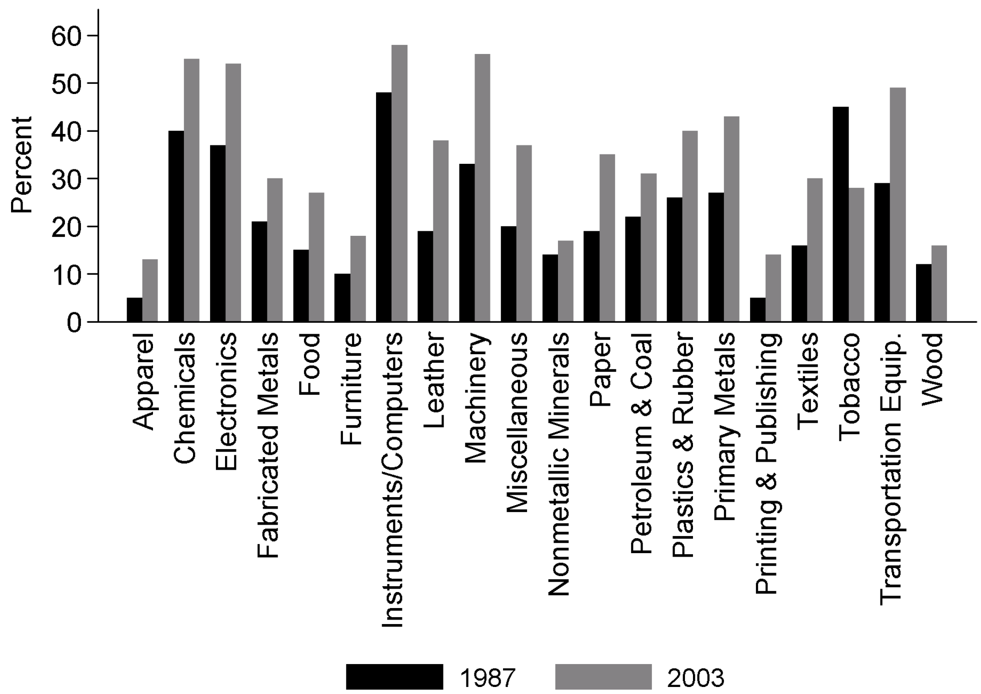
Notes: The figures in the table report the percentage of types of goods (tariff lines) that are affected by each nontariff barrier to trade. They are cited from United Nations Conference on Trade and Development (2005) and support the report's contention that the technical barriers to trade have increased substantially over time.

Figure 3.1: Percentage of U.S. Manufacturing Plants That Export



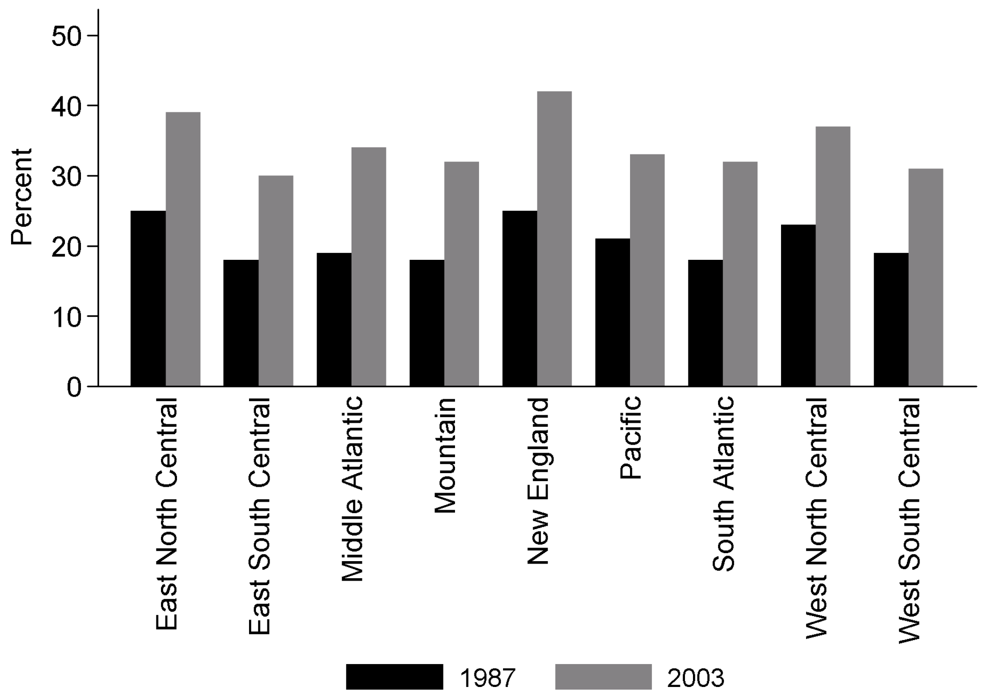
The figure graphs the percent of U.S. manufacturing plants that export in each year 1987-2003. Calculations are based on plants with 20 or more employees. Due to concerns about disclosure, estimates for 1987 and 1992 are from Bernard and Jensen (2004b).

Figure 3.2: Industry Decomposition



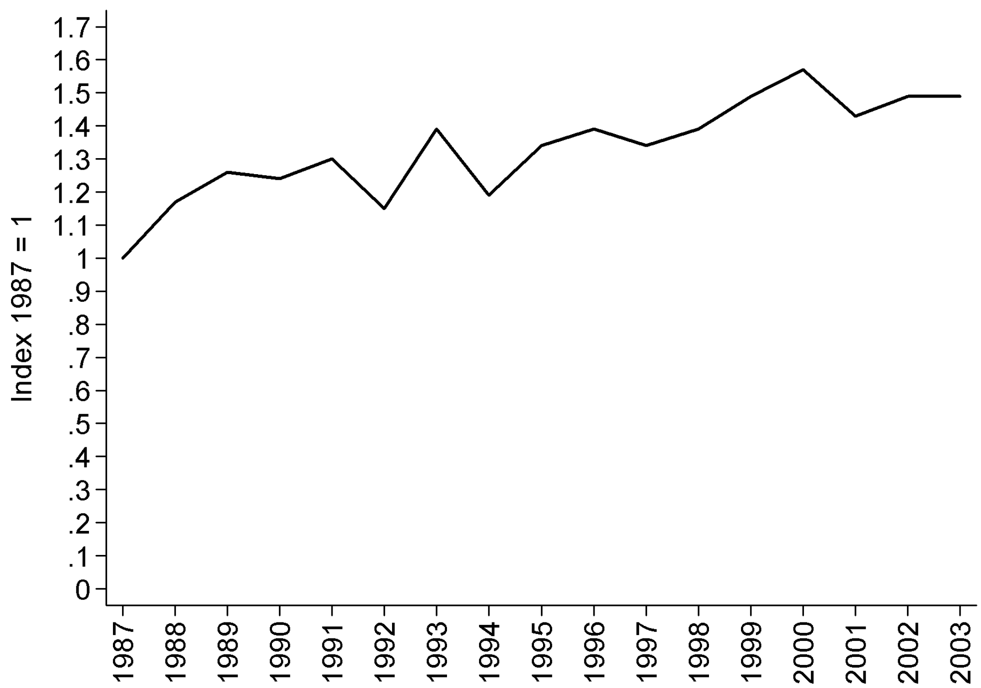
The figure depicts the percentage of plants with 20 or more employees that export for each industry in 1987 and 2003.

Figure 3.3: Geographical Decomposition



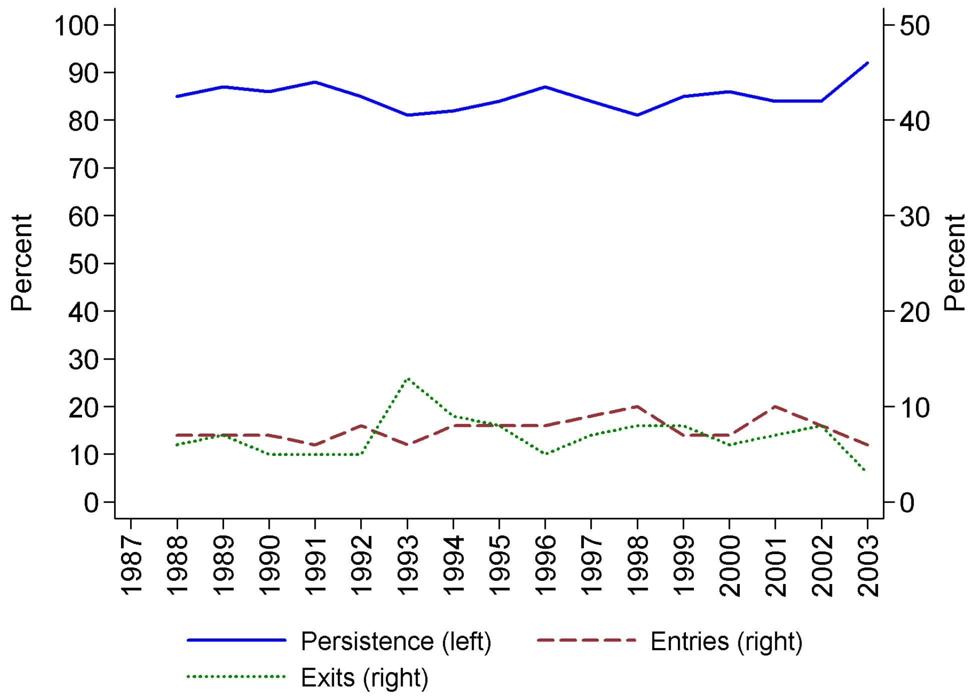
The figure depicts percentage of plants with 20 or more employees that export for each region of the US in 1987 and 2003. See Tables 3.1 and 3.2 for more details.

Figure 3.4: Average Foreign Sales Per Exporter



The figure graphs the average level of real foreign sales per exporter by year 1987-2003. To look at percentage changes, estimates are normalized such that the value in 1987 equals one. Calculations are based on plants with 20 or more employees. We exclude plants in the Computer and Semiconductor industries due to the strong decline in prices over time. Increases in this measure are even stronger when including these industries.

Figure 3.5: Export Persistence, Entries, and Exits



The figure depicts the annual percent of plants that enter foreign markets, exit, or keep the same export status (domestic or exporter). In each year, the sample is confined to plants that existed in the prior year, such that % Entries + % Exits + % Persist = 100%. Due to changes across ASM sampling frames these figures are limited to plants with 250 or more employees. The exit and entry values for 1988-1992 are from Bernard and Jensen (1999) Table 7 due to disclosure concerns.

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CHAPTER IV

Searching For Imports

4.1 Introduction

Models of international trade featuring differentiated products rarely explicitly include the process by which producers and consumers find one another. In this study, we model the nature of the importing relationship using a search and matching framework in the style of Mortensen and Pissarides (1994) embedded in a general equilibrium Melitz (2003) type heterogeneous firm model of international trade. The search and matching friction at the heart of our model arises because it takes time and expense for U.S. importers to find suitable foreign varieties. Search introduces a wedge between the final domestic price and the price of the imported good but otherwise leaves many of the standard trade results intact. In particular, the quantity traded, the productivity threshold necessary to export, and the importing country's price index all remain unchanged, largely due to profit maximizing conditions that survive the addition of search. We derive a gravity equation and show that the total value of imports falls as search frictions rise.

A few papers have considered modeling search in trade. Specifically, Rauch (1996) uses a partial equilibrium model of search to explain the existence of large Japanese intermediate general trading companies. These general trading companies pay a search cost and then match producers and consumers without producing any goods themselves. Rauch (1999) uses a gravity model and variables that proxy for the strength of links between countries to argue that search costs in trade are higher for differentiated than for homogenous products. Rauch and Trindale (2002) also use a gravity equation to argue that populations of ethnic Chinese within a country facilitate the flow of information, provide matching and referral services and otherwise reduce informal barriers to trade. For differentiated products traded between Southeast Asian countries Rauch and Trindale estimate that ethnic Chinese networks increase bilateral trade flows by nearly 60%. Finally, Portes and Rey (1999) find that bilateral telephone traffic and the number of bank subsidiaries improve information flow between countries, significantly increasing trade flows in a standard gravity equation regression. One could also argue that these measures proxy for lower search costs.

Taking a more structural modeling approach Eaton, Eslava, Krizan, Kugler and Tybout (2012) and Monarch (2013) study the relationships between U.S. importers and their exporting partners in Columbia and China respectively. Eaton et al. (2012) have a search and learning framework where firms learn about their ability slowly through export experience. Monarch (2013) focuses on the tradeoff between remaining in a current supplier relationship or paying a sunk cost to form a relationship with a lower cost supplier.

While this paper focuses on a simple model of search and the steady-state aggregate implications, viewing trading relationships through the lens of search theory allows for a micro level analysis together with business cycle implications. In particular, U.S. firms exhibit increasingly complex linkages with foreign affiliates in the globalized economy. It has been suggested that these linkages are important in propagating business cycles internationally. Given the ability of search models to match labor market dynamics, combining search and trade may be a way to understand the transmission of economy-wide and idiosyncratic firm level shocks across international borders. Recent contributions on the ability of idiosyncratic firm level shocks to generate aggregate fluctuations are provided by Gabaix (2011), Carvalho and Gabaix (2010), Acemoglu et. al, (2012) and Davis, Haltiwanger, Jarmin, and Miranda (2009). Among the first authors to consider both international transmission and idiosyncratic sources of aggregate fluctuations were di Giovanni and Levchenko (2012) and di Giovanni, Levchenko, and Mejean, (2012). Engel and Wang (2011) document that, like investment, import flows are pro-cyclical and about three times as volatile as GDP. This suggests that import fluctuations could generate fluctuations in aggregate output. One could also extend a search model to deal with the fact that imports are large and lumpy, occurring infrequently. This would involve including another state variable (the level of the imported product stored by the importing firm) and additional value functions for being in a matched relationship but not necessarily making a transaction in a given period. This would add search to the recent work of Alessandria, Kaboski and Midrigan (2012) who argue that firms treat imports as inventory. Given that inventories are a well known highly volatile component of output, this might be an additional channel through which shocks are transmitted internationally.

The current framework can be extended to incorporate ideas from Elsby and Michaels (2012), allowing the importer to contact more than one foreign producer simultaneously. This extension would allow for a quantitative assessment of the sub-extensive margin of trade as defined by Gopinath and Neiman (2012) at business cycle frequencies. They show that firm participation does not account for much trade adjustment at quarterly frequencies because entering and exiting firms are small. However, firms' country-product import status matters because while large firms hardly ever change their import status they often add and drop products. The number of products imported is highly skewed according to Bernard, Jensen and Schott (2010) who document that at least 90% of total U.S. imports are imported by firms that import 10 or more HS10 products. These same firms account for 21% of total U.S. employment. The size and importance of these firms in the economy suggest that shocks that change the sub-extensive margin could be important at the aggregate level.

The next section introduces the search and matching portion of the model. Section 3 embeds search into the Chaney (2008) trade model. Section 4 derives the gravity equation implied by the combined search and trade model and the last section presents a discussion of further research.

4.2 Modeling the search for imports

4.2.1 Value functions

The model can be summarized by the value functions in continuous time. While we begin by framing these as dynamic choices, all analysis and solutions will be in steady state. The value, $X(\varphi)$, to the foreign firm with exogenous productivity, φ, of exporting a product satisfies

$$rX(\varphi) = pq - \phi(q) - \lambda(X(\varphi) - U(\varphi)) \tag{4.1}$$

where r is the discount rate, p is the price of one unit of the exported good, q is the quantity imported, λ is the rate at which trading relationships exogenously dissolve, and $\phi(\cdot)$ is an arbitrary production cost function that depends on the level of output q as well as input prices in the foreign country.[1] This equation states that the net return from exporting must equal the flow payoff plus the capital gain from exogenously separating and transitioning to the state of being an unmatched exporter with value $U(\varphi)$. We explicitly write the value as a function of the exporter's productivity, φ, to remind the reader that each term in the flow profit is a function of this productivity; however we conserve on notation by omitting this argument in the import price and

[1] In the labor-macro literature the flow payoff here can be $wh\phi(1-h)$ where h is the hours of work sold by the worker and $\phi'(\cdot) > 0$. That is, instantaneous utility depends on current income and current hours of work and is nonlinear in the hours of work.

quantity. As is standard in the trade literature, we assume that the exporter knows their productivity, even prior to exporting, when unmatched. The value to a foreign producer looking to export to the domestic market but not presently in a relationship, $U(\varphi)$, is

$$rU(\varphi) = \kappa\chi(\kappa)(X(\varphi) - U(\varphi)) \tag{4.2}$$

where $\kappa\chi(\kappa)$ is the rate at which foreign firms find domestic partners. Here we assume the flow value of search is zero, though relaxing this assumption is straightforward. This simplification implies that the value of being in a match, $X(\varphi)$, should be interpreted as the value in addition to the foreign firm's operations in the foreign market.

The value of a domestic firm being in an importing relationship, $M(\varphi)$, is defined by its asset equation

$$rM(\varphi) = p_d(q)\,q - qp - \lambda(M(\varphi) - V) \tag{4.3}$$

where $p_d(q)$ is domestic demand. Equation (4.3) states that the asset value of importing must yield a net return that is equal to the flow payoff from being an importer plus the expected capital gain from exogenously separating and being left with the value, V, of being an unmatched importer. The domestic firm does not add any value to the product and could be viewed as a final consumer who searches for a good to consume. Alternatively, the domestic firm is a simple wholesaler, purchasing foreign products and passing them on to domestic consumers. We start with a general demand curve, $p_d(q)$, which is known to the firm, and later we choose a specific functional form. We also assume that the matched importing firm knows the productivity of the foreign exporter with which they are matched. In this sense, matches are inspection goods or search goods, as opposed to experience goods.

The value of being an unmatched importer, V, satisfies

$$rV = -c + \chi(\kappa) \int [\max\{V, M(\varphi)\} - V]\, dG(\varphi) \tag{4.4}$$

where c is the flow cost of looking for a foreign affiliate, and $\chi(\kappa)$ stands for the finding rate for the importer. Notice that V is not a function of the exporting firm's productivity, φ, but rather a function of the expected productivity with which the importer might match. When the importer meets an exporter with productivity φ, it chooses between matching with this exporter and continuing its search. Prior to being in a match, the importing firm does not know which exporter it will meet, and hence uses the expectation over all productivities it might meet in its continuation value. In equilibrium, the importer always finds it beneficial to consummate matches since the only exporters that find it worthwhile to export have productivities that result in $M(\varphi) \geq 0$. We assume that $\chi'(\kappa) \leq 0$ where κ can be viewed as a measure of the difficulty of finding an import partner. A higher κ implies it is more difficult to find a match and so the finding rate for importers will be lower. We will make the assumption of free entry into being an unmatched importer so that in equilibrium the value of being an unmatched importer, V, is driven to zero.

The domestic importer and foreign exporter Nash bargain over import price and quantity which is equivalent to maximizing the following Nash product

$$\max_{q,p} [X(\varphi) - U(\varphi)]^{\beta} [M(\varphi) - V]^{1-\beta}, 0 \leq \beta < 1 \tag{4.5}$$

where β is the foreign exporter's bargaining power.[2]

[2]Notice that equations (4.3), (4.4) and (4.15) together with $\beta = 1$ imply that for productivity levels φ above the reservation productivity level, $\bar{\varphi}$ (see discussion below equation 4.11), the domestic firm has no incentive to be a matched importer. We avoid this extreme case by assuming β strictly less than one.

4.2.2 Solution to the search model

For this section, it will be helpful to note that equations (4.1) and (4.3) imply that

$$X(\varphi) \quad = \quad \frac{pq - \phi(q) + \lambda U(\varphi)}{r + \lambda} \tag{4.6}$$

and

$$M(\varphi) = \frac{p_d(q)\, q - pq}{r + \lambda} \tag{4.7}$$

4.2.2.1 FOC w.r.t. p

Take equation (4.5), log and differentiate with respect to the price p and re-arrange to get

$$\beta \frac{1}{X(\varphi) - U(\varphi)} - (1 - \beta) \frac{1}{M(\varphi) - V} = 0 \tag{4.8}$$

which implies the simple surplus sharing rule: the foreign firm receives β of the total surplus from the trading relationship, $M(\varphi) - V + X(\varphi) - U(\varphi)$. The domestic firm receives the rest of the surplus. We do not need to calculate the partial with respect to $U(\varphi)$ or $V(\varphi)$ because the individual firms are too small to influence the market. Hence, when they meet, the firms bargain over the import price taking behavior in the rest of the market as given. In particular, the outside option of the firms does not vary with the individual's bargaining problem.

4.2.2.2 FOC w.r.t. q

Take equation (4.5), log and differentiate with respect to the quantity q to get

$$\beta \frac{1}{X(\varphi) - U(\varphi)} (p - \phi'(q)) + (1 - \beta) \frac{1}{M(\varphi) - V} (p_d(q) + p_d'(q)\, q - p) = 0 \tag{4.9}$$

where we compute the partials of $X(\varphi)$ and $M(\varphi)$ using equations (4.6) and (4.7). Now, notice that equation (4.8) implies that $X(\varphi) - U(\varphi) = \frac{\beta}{1-\beta}(M(\varphi) - V)$, and plugging this into equation (4.9) and re-arranging slightly gives

$$p_d(q) + p_d'(q)\,q = \phi'(q) \tag{4.10}$$

This expression says that the quantity produced and imported is pinned down by equating marginal revenue in the domestic market with marginal production cost in the foreign country. This is the same restriction we get from a model without search and therefore implies that adding search does not change the quantity traded. The profit maximization implied by this equation is crucial: despite being separate entities, the domestic firm and foreign affiliate decide to set marginal revenue equal to marginal cost. The result follows because of the simple sharing rule, the maximization of joint surplus, and the trivial role of the domestic firm. In order to maximize surplus the parties choose to equate marginal revenue and marginal cost. Later, the result implies that the productivity threshold needed to export is the same as in a heterogeneous firm model without search frictions.

4.2.2.3 Import relationship creation

Here we specify the conditions under which unmatched importers are open to forming new relationship with foreign exporters. Using equation (4.4) together with our assumption of free entry into the market of unmatched importers implies that

$$\frac{c}{\chi(\kappa)} = \int_{\bar{\varphi}} M(\varphi)\,dG(\varphi) \tag{4.11}$$

This states that the expected cost of being an unmatched importer equals the expected benefit from importing. Notice that we have removed the maximum over V and $M(\varphi)$ and simply integrated from the threshold productivity level that satisfies $M(\bar{\varphi}) = V$.

We can do this since $M(\varphi)$ turns out to be strictly increasing in φ, which we prove in the appendix. It is worthwhile noting that due to the surplus sharing rule, an identical productivity threshold could be attained by starting with $X(\bar{\varphi}) = U(\bar{\varphi})$. This implies that the productivity cutoffs for exporting and importing are identical. For a given cost of searching for an export partner, and a distribution of productivities, this equation pins down the market tightness.[3] Notice that as the expected benefit from importing rises, this equation implies that $\chi(\kappa)$ falls, implying that κ rises, suggesting more entry into the unmatched importer market. Potential importers create relationships until the value of being in the unmatched importer market is driven to zero.

4.2.2.4 Import relationship destruction

Start in equilibrium so that $V = 0$ and rewrite the surplus sharing rule (4.8) as

$$\beta M(\varphi) = (1-\beta)(X(\varphi) - U(\varphi)) \tag{4.12}$$

Subtracting equation (4.2) from equation (4.1) gives

$$\begin{aligned} r(X(\varphi) - U(\varphi)) &= pq - \phi(q) - \lambda(X(\varphi) - U(\varphi)) - \kappa\chi(\kappa)(X(\varphi) - U(\varphi)) \\ \Rightarrow X(\varphi) - U(\varphi) &= \frac{pq - \phi(q)}{r + \lambda + \kappa\chi(\kappa)} \end{aligned} \tag{4.13}$$

Finally, employing (4.7) from above allows us to write the surplus sharing rule as

$$\beta \frac{p_d(q)\,q - qp}{r+\lambda} = (1-\beta)\frac{pq - \phi(q)}{r + \lambda + \kappa\chi(\kappa)} \tag{4.14}$$

Solving (4.14) for p provides the equilibrium import price

[3] Notice that market tightness, κ, is intrinsically meaningless in this model as discussed in Shimer (2005). This means that one can either calibrate the cost parameter c and work with the implied κ, or one can normalize κ and get an implied c.

$$p = [1-\gamma]\, p_d(q) + \gamma \frac{\phi(q)}{q} \tag{4.15}$$

where we define the search friction as $\gamma \equiv \dfrac{(r+\lambda)(1-\beta)}{r+\lambda+\beta\kappa\chi(\kappa)}$. In the appendix we show that $\gamma \in [0,1]$. Intuitively, $p_d(q)$ has to be the highest price the importer will get if there are no search frictions, and the average production cost is the lowest price exporters can get. A price outside of this range would be unsustainable. Furthermore, we can analyze how the search friction depends on other parameters. As the foreign exporting firm gets more bargaining power ($\beta \to 1$), we approach the standard trade model and $\gamma \to 0$. In this case, the foreign exporter accrues all the profits from domestic sales and hence $p \to p_d(q)$. Also notice that if $\kappa\chi(\kappa) \to \infty$ so that exporting firms find new domestic partners immediately, which is the case in the standard trade model, then $\gamma \to 0$ and $p = p_d(q)$.

4.3 Embedding search in a Melitz framework

4.3.1 Consumer preferences

The heterogeneous firm trade model we emulate was first provided by Melitz (2003) and then extended to allow for asymmetric countries and multiple sectors by Chaney (2008). There are D possibly asymmetric destination countries indexed by d. The representative consumer in country d has Cobb-Douglas utility over the goods produced by each of $S+1$ sectors according to

$$U \equiv q_0^{\alpha_0} \prod_{s=1}^{S} q_s^{\alpha_s} \tag{4.16}$$

where we suppress the country subscript for clarity. The homogeneous good q_0 is freely traded, will serve as numeraire, and has price normalized to one. We assume it is produced using constant returns to scale where one unit of labor produces w_d units of the good. In the importing country, the output of each differentiated good sector q_s is an aggregate of Ω_s varieties. The aggregator is CES with country and sector specific elasticity of substitution σ_s across varieties

$$q_s = \left[\int_{\Omega_s} q_s(\omega)^{\frac{\sigma_s - 1}{\sigma_s}} d\omega \right]^{\frac{\sigma_s}{\sigma_s - 1}} \tag{4.17}$$

We assume utility has constant returns to scale across sectors so that $\alpha_0 + \sum_{s=1}^{S} \alpha_s = 1$ and require the elasticity across varieties to satisfy $\sigma_s > 1$. For the rest of the paper we focus on each sector individually; as such, we can suppress the sector subscript notation.

4.3.2 Production cost function

We will use a general form for the production cost function

$$\phi(q) = \frac{w_o \tau_{do}}{\varphi} q + f_{do}$$

where w_o is the wage in the exporting (origin) country, $\tau_{do} \geq 1$ is a parameter capturing one plus the iceberg transport cost between the domestic destination d and origin o, and f_{do} is the corresponding fixed cost of production for the export market in units of the numeraire. The firm that produces variety q has efficiency φ and marginal cost equal to $\frac{w_o \tau_{do}}{\varphi}$.

4.3.3 Domestic optimal price

Total income to workers in country d is $Y_d = w_d L_d + w_d L_d \pi$ where w_d is the wage, L_d is labor endowment and π is the dividend per share paid by the global mutual fund.[4] Given these consumer preferences, income and the ideal price index P_d, the

[4] See Chaney (2008) for details regarding the global mutual fund.

inverse demand for each variety within each sector is

$$p_d(q) = \left(\alpha Y_d P_d^{\sigma-1}\right)^{\frac{1}{\sigma}} q^{-\frac{1}{\sigma}} \tag{4.18}$$

The price charged in the domestic market is defined by the marginal cost equals marginal revenue expression (4.10) from above. Given the functional form assumptions we have made for the inverse demand curve and cost functions this becomes

$$p_d = \mu \frac{w_o \tau_{do}}{\varphi} \tag{4.19}$$

where $\mu = \dfrac{\sigma}{\sigma - 1}$. Notice the price charged for the imported good in the domestic market takes the standard markup over marginal cost form. Using the demand curve and domestic optimal price implies the imported quantity

$$q = \left(\mu \frac{w_o \tau_{do}}{\varphi}\right)^{-\sigma} \alpha Y_d P_d^{\sigma-1}$$

4.3.4 Productivity threshold

Next we find the productivity threshold that separates foreign exporting from non-exporting firms. We will find the productivity, $\bar{\varphi}$, for which $X(\bar{\varphi}) - U(\bar{\varphi}) = 0$. As mentioned before, an identical productivity threshold could be attained by starting with $M(\bar{\varphi}) - V = 0$. The fact that all matches are mutually beneficial implies that the minimum productivity with which a domestic importer will be willing to match is the same as the minimum productivity necessary for a foreign firm to export. Starting with equation (4.13), setting equal to zero, plugging in for the equilibrium import price, and the functional forms for demand and domestic optimal price, we derive the zero profit productivity threshold

$$\bar{\varphi}_{do} = \mu \left(\frac{\sigma}{\alpha}\right)^{\frac{1}{\sigma-1}} \frac{w_o \tau_{do}}{P_d} \left(\frac{f_{do}}{Y_d}\right)^{\frac{1}{\sigma-1}} \tag{4.20}$$

Notice that this productivity threshold pins down the $\dfrac{c}{\chi(\kappa)}$ ratio in equation (4.11).

4.3.5 Productivity distribution

The productivity cumulative density function for each sector is a Pareto distribution over $[1, +\infty)$

$$G\left[\tilde{\varphi} < \varphi\right] = 1 - \varphi^{-\theta}$$

so the probability density function is

$$g\left(\varphi\right) = \theta \varphi^{-\theta-1}$$

and we assume that $\theta > \sigma - 1$ so that the integral $\int_{\bar{\varphi}}^{\infty} z^{\sigma-1} dG\left(z\right)$ is bounded.

4.3.6 The ideal price index

The ideal price index in the destination/domestic market will take the usual form

$$P_d = \left(\sum_{k=1}^{D} w_d L_d \int_{\bar{\varphi}_{kd}}^{\infty} \left(\mu \frac{w_o \tau_{do}}{\varphi}\right)^{1-\sigma} dG\left(\varphi\right)\right)^{1/(1-\sigma)}$$

It is important to notice that the ideal price index relies on the price in the domestic market and not the import price negotiated between importers and exporters. Computing the integral provides the general equilibrium price level (the same as in Chaney (2008) since the index and thresholds are the same)

$$P_d = \lambda_2 \rho_d Y_d^{\frac{1}{\theta} - \frac{1}{\sigma-1}} \tag{4.21}$$

where $\lambda_2^\theta = \left(\frac{\theta-(\sigma-1)}{\theta}\right)\left(\frac{\sigma}{\alpha}\right)^{\frac{\theta}{\sigma-1}-1}\mu^\theta\frac{(1+\pi)}{Y}$ and the multilateral resistance term is $\rho_d^{-\theta} \equiv \left(\sum_{k=1}^{D}\frac{Y_k}{Y}\left(w_k\tau_{dk}\right)^{-\theta}f_{dk}^{-\left[\frac{\theta}{\sigma-1}-1\right]}\right)$. See the appendix for more details.

4.4 The gravity equation

Comparing the search and trade model to the standard trade model we can see that the productivity cutoff needed to export is unchanged, the quantity exported is unchanged, and the price index in the domestic market is unchanged. Most importantly, since the quantity traded and price indexes do not change, welfare in the model with search will remain the same. The main way search and trade differs from standard trade is that the price of imported goods is now different. This difference will change the value of total imports. Before we were counting the value of imports as $p_d(q)\,q$ but now the value of each variety at the dock is quantity times the import price from (4.15)

$$pq = [1-\gamma]\,p_d(q)\,q + \gamma\phi(q) \tag{4.22}$$

The value of total imports will be the integral of this value over all imported varieties

$$I_{do} = w_o L_o \int_{\bar{\varphi}}^{\infty} p(\varphi)\,q(\varphi)\,dG(\varphi)$$

Computing this integral is fairly complicated and we relegate the details to the appendix, supplying the final result here

$$I_{do} = \left(1-\frac{\gamma}{\mu\theta}\right)\alpha\frac{Y_d Y_o}{Y}\left(\frac{w_o\tau_{do}}{\rho_d}\right)^{-\theta} f_{do}^{-\left(\frac{\theta}{\sigma-1}-1\right)} \tag{4.23}$$

The main message is clear: search frictions reduce total imports to a fraction of their usual value. Notice that when $\gamma = 0$, so search frictions are removed, the usual gravity equation is obtained

$$I_{do} = \alpha \frac{Y_d Y_o}{Y} \left(\frac{w_o \tau_{do}}{\rho_d} \right)^{-\theta} f_{do}^{-\left(\frac{\theta}{\sigma-1}-1\right)}$$

The total value of sales in the domestic economy remains the same as the standard trade model. We compute this by integrating domestic sales of each variety across all imported varieties

$$S_{do} = w_o L_o \int_{\bar{\varphi}}^{\infty} p_d(\varphi) q(\varphi) dG(\varphi) = \alpha \frac{Y_d Y_o}{Y} \left(\frac{w_o \tau_{do}}{\rho_d} \right)^{-\theta} f_{do}^{-\left(\frac{\theta}{\sigma-1}-1\right)} \tag{4.24}$$

Total sales in the economy must be equal to the value of all imports plus the period profit of the importing firms which overcome the search friction

$$S_{do} = I_{do} + \Pi_{do} \tag{4.25}$$

Using the search adjusted gravity equation in (4.23), total domestic sales in (4.24) and the accounting identity in (4.25) we can be sure total period profits accruing to importers in matched relationships is

$$\Pi_{do} = \frac{\gamma}{\mu\theta} \alpha \frac{Y_d Y_o}{Y} \left(\frac{w_o \tau_{do}}{\rho_d} \right)^{-\theta} f_{do}^{-\left(\frac{\theta}{\sigma-1}-1\right)} \tag{4.26}$$

We could also obtain this quantity if we integrate $p_d(\varphi) q(\varphi) - q(\varphi) p(\varphi)$ over all imported varieties.

One important caveat to the gravity equation with search frictions is the extreme case when $\kappa\chi(\kappa) = 0$, i.e. the match rate is zero and no matches form. With no matches occurring in equilibrium no trade takes place. One cannot obtain this result by sending $\kappa\chi(\kappa) \to 0$ in the above expression since it is a corner solution. In other words, at $\kappa\chi(\kappa) = 0$ the final expression for total imports (4.23) does not apply.

4.5 Discussion

The fact that introducing search frictions into a model of trade results in a scalar times the typical gravity equation has a few interesting implications. First, Deardorff's (1998, p. 12) comment that, "any plausible model of trade would yield something very like the gravity equation, whose empirical success is therefore not evidence of anything, but just a fact of life," once again rings true. In particular, if the search frictions do not vary by exporter-importer pair so that $\gamma_{do} = \gamma$ then their impact on trade would be lost in the constant term of a gravity regression. In this case, search frictions could be a pervasive feature of international trade which would not be identifiable using aggregate data. Using disaggregated data would be the only way to quantify the importance of these frictions.

Second, if search frictions vary by importer-exporter pair so $\gamma_{do} \neq \gamma$ they may provide an additional rationale for why language, currency, common legal origin, historical colonial ties or other variables often included in gravity equations have an effect on aggregate trade flows. In particular, Rauch and Trindale (2002) argue populations of ethnic Chinese within a country facilitate the flow of information, provide matching and referral services and otherwise reduce informal barriers to trade. Interestingly, the authors' empirical specification matches the gravity equation with search that we have derived here if γ_{do} was a function of the size of the ethnic Chinese population.

Lastly, as long as $\gamma_{do} \neq \gamma$ any gravity regression that does not include adequate proxies for search frictions would suffer from omitted variable bias. An analogy to the labor search literature would suggest a matching function that is Cobb-Douglas and constant returns to scale in the number of unmatched foreign affiliates and the number of unmatched importing firms.[5] This would mean that the finding rates

[5] See, for example, Petrongolo and Pissarides (2001) for a survey of the matching function in the context of labor search.

for the exporters and importers would vary over time with the number of searching importers. As a result, any gravity regression would suffer from omitted variable bias unless the researcher included time-varying proxies for the number of unmatched importers, a very difficult variable to measure.

While the model presented in this paper improves our understanding of steady-state trade flows and the implications of including search frictions at the aggregate level, we take the resulting gravity equation from this simple exercise as a sign that search may be an important feature of trade that requires more research. Given the strong assumptions needed to derive an expression that would allow study of the search frictions at the aggregate level, we plan to focus our efforts on firm level data. We think there are many interesting implications for considering search and trade in a combined framework. Among these are the demonstrated predictions regarding aggregate trade, the potential to model international transmission of shocks and a suitable framework to study the intensive and extensive margins of trade at business cycle frequencies.

4.6 Appendix

4.6.1 $M(\varphi)$ increasing in φ

Here we show that the value of importing, $M(\varphi)$, is strictly increasing with the exporter's productivity level, φ. This fact allows us to replace the integral of the max over V and $M(\varphi)$ (equation 4.4), with the integral of $M(\varphi)$ from the productivity threshold, $\bar{\varphi}$ (equation 4.11).

Starting with equation (4.3) and $V = 0$ obtain

$$
\begin{aligned}
(r+\lambda) M(\varphi) &= p_d q - qp \\
&= p_d q - [1-\gamma] p_d q - \gamma \phi(q) \\
&= (\mu - 1) \gamma \frac{w_o \tau_{do}}{\varphi} q - \gamma f_{do} \\
&= \left(\frac{\gamma \mu^{-\sigma}}{\sigma - 1} \right) (w_o \tau_{do})^{1-\sigma} \alpha Y_d P_d^{\sigma-1} \varphi^{\sigma-1} - \gamma f_{do}
\end{aligned}
$$

where we have used the functional form for $\phi(q)$, as well as the equilibrium values for p, p_d and q. This expression implies that

$$
M(\varphi) = \left(\frac{1}{r+\lambda} \right) \left(\frac{\gamma \mu^{-\sigma}}{\sigma - 1} \right) (w_o \tau_{do})^{1-\sigma} \alpha Y_d P_d^{\sigma-1} \varphi^{\sigma-1} - \gamma f_{do}
$$

Therefore the derivative is

$$
\frac{\partial M(\varphi)}{\partial \varphi} = \left(\frac{1}{r+\lambda} \right) \gamma \mu^{-\sigma} (w_o \tau_{do})^{1-\sigma} \alpha Y_d P_d^{\sigma-1} \varphi^{\sigma-2}
$$

which is always positive.

4.6.2 Bounding the search friction

Here we show that $\gamma \in [0,1]$. Starting with the definition

$$\gamma \equiv \frac{(r+\lambda)(1-\beta)}{r+\lambda+\beta\kappa\chi(\kappa)}$$

Since all parameters are positive, $\gamma \geq 0$. The lower bound,$\gamma = 0$, is reached only when $\beta = 1$ and $c = 0$ simultaneously. Next prove $\gamma \leq 1$ by contradiction. Assuming $\gamma > 1$ implies that $0 > \beta\kappa\chi(\kappa)$ which is a contradiction since $\beta \geq 0$ and $\kappa\chi(\kappa) \geq 0$.

4.6.3 The ideal price index

The ideal price index in the destination/domestic market will take the same form as presented in Chaney (2008)

$$P_d = \left(\sum_{k=1}^{D} w_d L_d \int_{\bar{\varphi}_{kd}}^{\infty} \left(\mu \frac{w_o \tau_{do}}{\varphi} \right)^{1-\sigma} dG(\varphi) \right)^{1/(1-\sigma)}$$

The important thing to notice is that the ideal price index relies on the price in the domestic market and not the import price negotiated between importers and exporters. Computing the integral will provide the general equilibrium price level (the same as in Chaney (2008) since the index and threshold are the same).

First, convert the expression for labor income in a particular country to $\frac{Y}{(1+\pi)} \frac{Y_d}{Y} = w_d L_d$. Next, compute the integral remembering that $\int_{\bar{\varphi}_{dk}}^{\infty} z^{\sigma-1} dG(z) = \frac{\theta \bar{\varphi}^{\sigma-\theta-1}}{\theta-\sigma+1}$ to get

$$P_d = \left(\frac{Y}{(1+\pi)} \sum_{k=1}^{D} \frac{Y_k}{Y} (\mu w_k \tau_{dk})^{1-\sigma} \frac{\theta \bar{\varphi}_{dk}^{\sigma-\theta-1}}{\theta-\sigma+1} \right)^{1/(1-\sigma)}$$

Now using productivity threshold, $\bar{\varphi}_{dk}$, we found above we can get

$$P_d = \lambda_2 \rho_d Y_d^{\frac{1}{\theta} - \frac{1}{\sigma - 1}}$$

where

$$\rho_d \equiv \left(\sum_{k=1}^{D} \frac{Y_k}{Y} \left(w_k \tau_{dk}\right)^{-\theta} f_{dk}^{-\left[\frac{\theta}{\sigma-1} - 1\right]} \right)^{\frac{1}{-\theta}}$$

and

$$\lambda_2 \equiv \left[\frac{Y}{(1+\pi)} \frac{\mu^{1-\sigma}\theta}{\theta - \sigma + 1} \mu^{\sigma - \theta - 1} \left(\frac{\sigma}{\alpha}\right)^{\frac{\sigma-\theta-1}{\sigma-1}} \right]^{\frac{1}{-\theta}}$$

This is the same price index as presented in Chaney (2008) page 1713.

4.6.4 The gravity equation

The value of total imports will be

$$I_{do} = w_o L_o \int_{\bar{\varphi}}^{\infty} p(\varphi)\, q(\varphi)\, dG(\varphi)$$

We need to integrate over the varieties to get the total value of imports going into the domestic market. Since $q = p_d^{-\sigma} \frac{\alpha Y_d}{P_d^{1-\sigma}}$ and $p_d = \mu w_o \tau_{do} \varphi^{-1}$ we know $q = \mu^{-\sigma} \left(\frac{w_o \tau_{do}}{\varphi}\right)^{-\sigma} \frac{\alpha Y_d}{P_d^{1-\sigma}}$. For notational simplicity define $\mu^{-\sigma} \left(w_o \tau_{do}\right)^{-\sigma} \frac{\alpha Y_d}{P_d^{1-\sigma}} \equiv B$ so that $q = B\varphi^{\sigma}$ which also implies $p_d(q)\, q = \mu w_o \tau_{do} B \varphi^{\sigma-1}$ and $\phi(q) = w_o \tau_{do} B \varphi^{\sigma-1} + f_{do}$. Compute total imports by starting with

$$w_o L_o \int_{\bar{\varphi}}^{\infty} p(\varphi)\, q(\varphi)\, dG(\varphi) = w_o L_o \int_{\bar{\varphi}}^{\infty} [1-\gamma]\, p_d(q)\, q + \gamma \phi(q)\, dG(\varphi)$$

The first additive term in the integrand becomes

$$\int_{\bar{\varphi}}^{\infty} [1-\gamma]\, p_d(q)\, q dG(\varphi) = [1-\gamma]\, \mu w_o \tau_{do} B \frac{\theta \bar{\varphi}^{\sigma-\theta-1}}{\theta - \sigma + 1}$$

where we use the relevant moment of the productivity distribution $\int_{\bar{\varphi}_{dk}}^{\infty} z^{\sigma-1} dG(z) = \frac{\theta \bar{\varphi}^{\sigma-\theta-1}}{\theta-\sigma+1}$. The second term in the integrand is

$$\int_{\bar{\varphi}}^{\infty} \gamma\phi(q)\, dG(\varphi) = \gamma w_o \tau_{do} B \frac{\theta\bar{\varphi}^{\sigma-\theta-1}}{\theta-\sigma+1} + \gamma f_{do}\bar{\varphi}^{-\theta}$$

where we use $\int_{\bar{\varphi}}^{\infty} dG(z) = \bar{\varphi}^{-\theta}$. Combining these provides total exports from country o to country d as

$$\frac{I_{do}}{w_o L_o} = ([1-\gamma]\,\mu + \gamma)\, w_o \tau_{do} B \frac{\theta\bar{\varphi}^{\sigma-\theta-1}}{\theta-\sigma+1} + \gamma f_{do}\bar{\varphi}^{-\theta}$$

We can use the export productivity threshold to write

$$B\bar{\varphi}^{\sigma-1} = \sigma f_{do}\mu^{-1}\left(w_o\tau_{do}\right)^{-1}$$

Substituting this into the expression for total exports and simplifying provides

$$\frac{I_{do}}{w_o L_o} = \left(\frac{\sigma\theta - \gamma(\sigma-1)}{\theta-\sigma+1}\right) f_{do}\bar{\varphi}^{-\theta}$$

Using the export cutoff again

$$\frac{I_{do}}{w_o L_o} = \mu^{-\theta}\left(\frac{\sigma}{\alpha}\right)^{\frac{-\theta}{\sigma-1}}\left(\frac{\sigma\theta-\gamma(\sigma-1)}{\theta-\sigma+1}\right)\left(\frac{w_o\tau_{do}}{\rho_d}\right)^{-\theta} f_{do}^{-\left(\frac{\theta}{\sigma-1}-1\right)}\lambda_2^{\theta} Y_d$$

where λ_2 is defined above. Substituting λ_2 in here and simplifying provides the final expression

$$I_{do} = \left(1-\frac{\gamma}{\mu\theta}\right)\alpha\frac{Y_d Y_o}{Y}\left(\frac{w_o\tau_{do}}{\rho_d}\right)^{-\theta} f_{do}^{-\left(\frac{\theta}{\sigma-1}-1\right)}$$

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