Do Falling Iceberg Costs Explain Recent U.S. Export Growth?*

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March 2010

Abstract

We study the rise in U.S. manufacturing exports from 1987 to 2002 through the lens of a monopolistically competitive model with heterogenous producers and sunk costs of exporting. Using the model, we infer that iceberg costs fell nearly 27 percent in this period. Given this change in iceberg costs, we use the model to calculate the predicted increase in trade. Contrary to the findings in Yi (2003), we find that the exports should have grown an additional 70 percent (78.7 vs. 46.4). The model overpredicts export growth partly because it misses the shift in manufacturing to relatively small establishments that did not invest in becoming exporters. Contrary to the theory, employment was largely reallocated from very large establishments, those with more than 2,500 employees, toward very small manufacturing establishments, those with fewer than 100 employees. We also find that very little of the contraction in U.S. manufacturing employment can be attributed to trade.

*The authors thank Alex Monge, Satayjit Chatterjee, Richard Rogerson, Kim Ruhl, and Kei-Mu Yi for helpful discussions and seminar participants at the SED Meetings in Prague and Istanbul, NYU, Toronto, Wisconsin, and the Federal Reserve Banks of Minneapolis, Philadelphia, and San Francisco for their useful comments. The views expressed here are those of the authors and do not necessarily reflect the views of the Federal Reserve Bank of Philadelphia or the Federal Reserve System. This paper is available free of charge at www.philadelphiafed.org/research-and-data/publications/workingpapers/.

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1. Introduction

The world has become much more integrated. For instance, the share of U.S. manufacturing GDP exported more than quadrupled[1] from 1962 to 2002. While this process has been ongoing, it clearly has accelerated since the mid-1980s. Yi (2003) shows that explaining this acceleration in trade growth poses a major challenge for standard trade models since the period of high trade growth corresponds to a period of relatively small tariff cuts, while the period of slower trade growth corresponds to a period of relatively large tariff cuts. Thus, the elasticity of trade relative to trade costs has increased. In this paper, we reconsider the high export growth period,[2] 1987 to 2002, through the lens of a model of establishment heterogeneity and exporting. Through the lens of this model, we find the opposite puzzle from Yi. Given the observed change in trade costs, the puzzle is actually that trade grew so little from 1987 to 2002.

Our interpretation of the trade data differs from Yi for two reasons. First, our benchmark model of trade differs from Yi. Yi studies trade in the representative agent model of Armington (1969) in which all producers export.[3] In this model the amount each producer exports is determined solely by iceberg trade costs,[4] basically tariffs and transportation costs, and the elasticity of substitution between domestic and foreign goods. Thus, a decrease in iceberg costs increases the intensity with which producers export. In contrast, in our benchmark model producers are

[1]The ratio of nominal exports (excluding agricultural goods) to nominal manufacturing value added rose from approximately 9.9 percent in 1962 to 42.8 percent in 2002.

[2]Data also limit us to this period since the 1987 Census of Manufacturers is the first census that included questions on exporting activity, and we need this information to accurately take the model to the data.

[3]Given the failure of the Armington model to explain the growth in trade, Yi proposes an explanation based on a model of trade in intermediates and different stages of production. In his model, when tariffs fall below a certain level intermediate production becomes concentrated in a single location and start to cross the border multiple times as intermediates and in final goods.

[4]Yi takes a measure of the observed change in tariffs and computes the elasticity of substitution necessary to explain aggregate trade growth. An alternate interpretation of this puzzle is that falling tariffs have also been associated with falling trade costs; therefore, the change in trade flows reflects a change in both observed and unobserved trade barriers.

heterogenous in productivity and must incur some fixed costs to export (both to start and to continue exporting) along with iceberg costs. In this framework, not all establishments export and those that do are relatively large. Consequently, in this model the fraction of output exported may also increase either because more producers export (the extensive margin of trade) or if exporters become relatively larger than nonexporters and account for more output (what we call the size premium). Thus, this model contains two additional margins of trade growth.

The second difference from Yi comes from our measure of iceberg trade costs. In an Armington model, there is a one-to-one relationship between the share of output exported and iceberg trade costs that makes it impossible to use the model to identify the change in trade costs. Consequently, Yi takes a measure of trade costs based on changes in tariffs among industrialized countries and uses it to calculate the elasticity of trade with respect to tariffs, finding this has increased over time. However, iceberg costs also depend on transportation, insurance, finance and other charges making these changes in tariffs a potentially poor measure of changes in iceberg costs. In our model of producer heterogeneity and fixed export costs, there is no longer a one-to-one relationship between aggregate trade flows and iceberg costs. However, among exporters, the amount exported relative to total sales is determined solely by iceberg costs. Using establishment-level data on exporting from the U.S. Census of Manufacturers, we thus can infer the change in iceberg costs over this period. We find a much larger change in iceberg costs than Yi's measure of the fall in tariffs.

Given the change in iceberg costs that we infer from the data, we then use the model to ask: How much should U.S. exports have grown if the only change were a fall in iceberg cost? Surprisingly, we find that the fall in trade costs should have led to about 70 percent more export growth that it did (78.7 vs. 46.4). The model generates too much export growth primarily because the model predicts a much larger increase in the share of establishments that are exporting. The model predicts a 57 percent rise in export participation; however, in the data, export participation rose only 24 percent.

The model overpredicts the growth in export participation in the U.S. primarily because in this period, employment became more concentrated in small establishments. Despite the lower iceberg costs, these small establishments did not find it worthwhile to incur the fixed costs of exporting thereby reducing the growth in export participation. The concentration of employment in small establishments stands in stark contrast to one of the key predictions of the Melitz (2003) model that lowering trade barriers should shift employment away from relatively unproductive and small establishments toward relatively productive and large establishments.

The general equilibrium model we develop also allows us to study the reallocation of production across sectors, tradable and nontradable, resulting from the fall in trade costs. In our benchmark model, trade integration generates a very small reallocation of labor from tradable goods, which we associate with manufacturing. This reallocation of 0.2 percent is much less than the 17 percent decline from 1987 to 2002 leading us to conclude then that trade integration is primarily responsible for reshaping the distribution of economic activity across tradable producers but has only a small role on the scale of the sector.

The primary contribution of this paper is to provide the first empirical and quantitative examination of the dynamics of aggregate and establishment-level trade flows in the U.S. Previous work relating aggregate trade flows to establishment-level heterogeneity primarily focuses on explaining the cross-section of export participation and trade flows. For instance, Bernard, Eaton, Jensen, and Kortum (2003), study export participation among U.S. manufacturers in 1992 in a version of the Eaton and Kortum (2002) model that is extended to allow for Bertrand competition,[5] while Alessandria and Choi (2007b) study export participation among U.S. manufacturers in 1992 in a version of the Melitz model. These papers examine the counterfactual impact of changes in trade policy on aggregate and establishment trade flows, but they do not examine whether these predictions are consistent with the data. In terms of examining changes in trade flows, the work by Bernard, Jensen, and Schott (2006) is closest in spirit to our paper. They use an empirical model to show that across industries in the US from 1987 to 1997, declines in measured trade costs are associated with an increased likelihood of exporting and an increase in sales by exporters. Unlike their analysis, which focuses on the qualitative predictions of heterogeneous plant models for trade growth, we focus on whether the magnitude of aggregate changes are quantitatively consistent with theory. Thus, our paper provides an important test of the role of producer heterogeneity for aggregate trade flows. Given the use of various heterogeneous plant models to evaluate trade policy,[6] our analysis provides a key evaluation of these models.

Our paper is also related to a number of papers in three general areas. The first line of research studies the growth in world trade and attributes it to changes in income, tariffs, and trade costs (see Baier and Bergstrand (2001), Yi (2003), Bridgman (2008)). Hummels (2007) identifies some of the challenges in measuring the change in trade costs, showing that that the decline in aggregate measures of trade costs are understated because they do not take into account how the decline in relatively expensive air freight has lead to a massive expansion of air freight. A second line of research uses models with fixed costs of trade to understand

[5] Alvarez and Lucas (2006) also study the role of producer heterogeneity for trade but in a model in which there is no notion of an establishment. Hence, all heterogeneity can be thought of as being at the industry level.

[6] Some additional papers studying trade policy in heterogeneous plant models include Roberts and Tybout (1997), Melitz (2003), Das, Roberts and Tybout (2005), Baldwin and Robert-Nicoud (2005), Baldwin and Forslid (2006), and Atkeson and Burstein (2007).

international business cycle fluctuations (see Ruhl (2003), Alessandria and Choi (2007a), and Ghironi and Melitz (2005)). Finally, there is a partial equilibrium literature that studies the export decisions of establishments. Baldwin and Krugman (1989) and Dixit (1989) develop models of export decisions with an exogenous exchange rate process. Roberts and Tybout (1997) and Das, Roberts and Tybout (2007) develop these models further and use them to identify the presence of sunk costs of exporting.

The paper is organized as follows. The next section describes the change in the share of U.S. manufacturing output exported. We show how this change in aggregate exports is related to changes in export participation, the characteristics of exporters, and iceberg trade costs. In section 3 we develop a two-country dynamic general equilibrium model with endogenous export penetration and sunk costs of exporting. Section 4 discusses the calibration of the model. In section 5, we examine the change in exports, export participation, and exporter characteristics predicted by the model following the observed change in iceberg costs. In section 6, we investigate the sensitivity of our results. Section 7 concludes.

2. Evidence

In this section, we summarize some of the changes in exports and exporting in the U.S. manufacturing sector from 1987 to 2002. We concentrate on this period since it is the high growth period emphasized in Yi and because it is the only period for which we have data on plant characteristics of exporters in the U.S. from the Economic Census (The census only started collecting exporting information in 1987.)[7] We also relate these changes in exports to changes in fundamentals, particularly changes in iceberg trade costs and the characteristics of exporters.

[7] The data on plant export is based on a special tabulation requested from the U.S. Census Bureau.

Table 1 summarizes the key changes in the manufacturing exports over this period.

To clarify the relationship between exports and trade costs, for the sake of exposition, suppose there are N identical, monopolistically competitive establishments selling their goods at home and abroad subject to demand curves,

$$\begin{aligned} d(p, Y) &= p^{-\theta} Y, \\ ex(p^*, Y^*) &= p^{*-\theta} Y^*, \end{aligned}$$

where θ denotes the elasticity of demand, Y_t and Y_t^* denote home and foreign income, and p_t and p_t^* denote prices of the goods at home and abroad. Suppose further that the foreign consumers must incur an iceberg cost, ι, which includes both shipping costs and tariffs, to purchase these products.[8] If the establishment sells its products at home and abroad for the same price, then the ratio of exports to domestic sales equals

$$\frac{ex}{d} = \frac{(1+\iota)^{-\theta} Y^*}{Y}.$$

Taking logs, the change in the export-to-domestic sales ratio can be directly related to changes in trade costs and the relative size of the markets,

$$\Delta ex - \Delta d = -\theta \Delta \iota + \Delta y^* - \Delta y.$$

The second column of Table 1 reports a 50.3 percent increase in the ratio of exports to domestic

[8] This is identical to allowing the establishment to sell its products directly overseas subject to the iceberg costs but setting up an import/export subsidiary to transfer the goods and incur the costs.

sales from 1987 to 2002. Given this change in the export-to-domestic sales ratio and the change in relative output $(\Delta y^* - \Delta y)$ along with a measure of the elasticity of substitution, we can infer the change in iceberg trade costs[9] as

$$\Delta \iota = -\frac{(\Delta ex - \Delta d) - (\Delta y^* - \Delta y)}{\theta}.$$

This is essentially the time-series analogue of the Anderson and van Wincoop (2004) approach of determining the level of trade costs. For U.S. imports, Broda and Weinstein (2006) find an average elasticity of substitution of about 5. Based on Penn World table 6.2 data, over this period world real GDP, at PPP terms,[10] grew approximately 8.6 percent relative to U.S. GDP. Consequently, we find that iceberg costs have fallen approximately 8.3 percentage points and account for about 83 percent of the increase in export growth.

While the model can be used to infer the change in trade costs, Yi (2003) uses the same relationship and the observed change in tariff rates to infer the elasticity of demand. Given the 2.5 percentage-points fall in tariffs Yi finds in the data, the model requires an elasticity of approximately 17 to explain the data, much higher than what we observe at the micro-level or for earlier periods. Without direct measures of changes in international trade costs, at this level of aggregation we cannot distinguish between an explanation of trade growth based on falling trade costs or a high elasticity.

[9] Direct measures of the change in iceberg costs exist, but vary substantially. For instance, according to Hummels (2007) since 1990 air freight and ocean liner rates have fallen by about one-third. This decrease in transportation costs has also been associated with a shift toward more air freight, suggesting smaller declines in measured shipping costs. On the other hand, Yi (2003), focusing on just tariffs, finds a relatively small drop in the tariffs imposed on U.S. exports by its developed country partners of only about 2 percentage points. Moreover, Anderson and van Wincoop (2004) find that direct measures of trade costs are small compared with indirect measures implied by trade flows and theory.

[10] In nominal terms, U.S. GDP grew 19.5 percent faster than world GDP.

The representative agent world described above generates a one-to-one relationship between the export-to-domestic sales ratio and the share of total sales exported. However, as we see from the third and fourth columns of Table 1, the total share of sales exported rose by more than the share of sales exported by exporting establishments, what we call the *exporter intensity*. Clearly, the representative agent world misses out on some of the changes occurring in the manufacturing sector. To understand the impact of changes in the structure of exporters for aggregate exports, suppose that only n of the N manufacturing establishments export. For these establishments the ratio of exports to total sales will still be determined by trade costs and the relative market sizes. However, the ratio of exports to total sales across all establishments will depend on the relative size and number of exporters. Let establishment i have total sales $sales_i = d_i + ex_i$ then the ratio of exports to total sales can be decomposed as,

$$\frac{\text{Exports}}{\text{Total sales}} = \frac{\sum_{i=1}^{n} ex_i}{\sum_{i=1}^{N} sales_i} = \left(\frac{\sum_{i=1}^{n} ex_i/n}{\sum_{i=1}^{n} sales_i/n}\right)\left(\frac{\sum_{i=1}^{n} sales_i/n}{\sum_{i=1}^{N} sales_i/N}\right)\left(\frac{n}{N}\right).$$

Over time, the change in the ratio of exports to total sales can be decomposed into three components,

$$\overbrace{\Delta exy}^{\text{Export share}} = \overbrace{\Delta\left(\overline{ex}/\overline{sales}^{X}\right)}^{\text{Export intensity}} + \overbrace{\Delta\left(\overline{sales}^{X}/\overline{sales}\right)}^{\text{Exporter premium}} + \overbrace{\Delta\left(n/N\right)}^{\text{Export participation}}.$$

46.4	42.3	−19.5	23.7

All four components can be measured using data from the Census of Manufacturers. The data show that the 46.4 percent increase in the share of manufactured goods exported has been associated with a 42.3 percent rise in the intensity with which exporters sell their products overseas, a 19.5 percent fall in the size of exporters relative to all establishments in the U.S. and a 23.7 percent increase in export participation.

As we have already shown, the change in export intensity is primarily driven by the change in trade costs. However, from an establishment's standpoint, it doesn't matter whether the change in export intensity is from a drop in trade costs or an increase in the relative size of the foreign market. For this reason, in the next sections we will attribute all of the changes in export intensity to changes in trade costs. We then will try to answer the question: Given the characteristics of the U.S. manufacturing sector in 1987 and the observed changes in trade costs from 1987 to 2002, can the benchmark model of export participation and dynamics explain the change in exports and export participation in the U.S.?

3. The Model

In this section, we develop a model that contains the two key features of the Melitz (2003) model[11] of exporting: producer heterogeneity and fixed costs of exporting. Producers face uncertainty over both productivity and the fixed costs. Each period there is a mass of existing establishments distributed over productivity, fixed costs, countries, and export status. Idiosyncratic shocks to productivity and fixed export costs generate movements of establishments into and out of exporting. Unproductive establishments also shutdown,[12] and new establishments are created by incurring a sunk cost.

There are two symmetric countries, *home* and *foreign*. Each country is populated by a

[11] The Melitz model is a general equilibrium model of plant heterogeneity and exporting. It embeds the decision to export, studied in partial equilibrium models of Baldwin and Krugman (1989), Dixit (1989) and Roberts and Tybout (1997), in the general equilibrium model of plant heterogeneity, exit, and entry of Hopenhayn and Rogerson (1993).

[12] Unlike the Melitz model, we do not have fixed costs of continuing to produce each period. Instead, we capture the higher exit rates of small establishments in the shock process.

continuum of identical, infinitely lived consumers with mass of one. Each period, consumers are endowed with L units of labor and supply them inelastically in the labor market.

In each country there are two intermediate good sectors, tradable and nontradable, denoted T or N. In each sector, there is a large number of monopolistically competitive establishments, each producing a differentiated good. The mass of varieties in the tradable and nontradable goods sectors are $N_{T,t}$ and $N_{N,t}$, respectively. Foreign variables are denoted with an asterisk. A nontradable good producer uses capital and labor inputs to produce its variety, whereas a tradable good establishment produces using capital, labor, and material inputs.[13] In each sector, establishments differ in terms of total factor productivity and the markets they serve.

All establishments sell their product in their own country, but only some establishments in the tradable good sector export their goods abroad. When an establishment in the tradable good sector exports, the establishment incurs some international trading cost, an ad valorem transportation cost[14] with the rate of ι_t.[15] Additionally, an establishment has to pay a fixed cost to export its goods abroad. Unlike the standard Melitz formulation, we follow Dixit (1989) and Roberts and Tybout (1997) and allow the fixed costs of starting to export to differ from the costs to stay in the export market. In particular, we allow the size of the fixed cost to depend on the producer's export status in the previous period and an idiosyncratic shock κ. To start exporting, an establishment must incur a relatively high up-front sunk cost $f_0 + \kappa > 0$

[13] We introduce materials into the tradable sector to be consistent with the observation that trade as a share of gross output is considerably smaller than trade as a share of value-added.

[14] We attribute all iceberg costs to physical transportation costs rather than some combination of transport costs and tariffs. This distinction matters for the aggregate level of activity but has almost no impact on how activity is divided across countries.

[15] The transportation costs are 'iceberg.' For one unit of good to be arrived at destination, $1 + \iota$ units should be shipped.

and then can sell any amount in the export market in the next period. For an establishment that is currently exporting, to continue exporting into the following period it must incur its idiosyncratic fixed cost shock κ plus a lower but nonzero period-by-period fixed continuation cost $f_1 < f_0$. If an establishment does not pay this continuation cost, then it ceases to export. In future periods, the establishment can begin exporting only by incurring the entry cost f_0 plus its new draw of κ. These costs are valued in units of labor in the domestic country. The cost of exporting implies that the set of goods available to consumers and establishments differs across countries and is changing over time. We assume that the fixed costs must be incurred in the period prior to exporting. This implies that the set of foreign varieties is fixed at the start of each period. All the establishments are owned by domestic consumers.

Any potential establishment can enter the tradable sector by hiring f_E domestic workers. New entrants can actively produce goods and sell their products from the following period on.

Establishments differ by their technology, export status, sector, fixed costs, and nationality. The measure of home country tradable establishments with technology z, export status, $m = 1$ for exporters and $m = 0$ for non-exporters, and fixed cost shock, κ, equals $\psi_{T,t}(z, \kappa, m)$.

In each country, competitive final goods producers purchase intermediate inputs from those establishments actively selling in that country.[16] The cost of exporting implies that the set of goods available to competitive final goods producers differs across countries. The entry and exit of exporting establishments implies that the set of intermediate goods available in a country is changing over time. The final goods are used for both domestic consumption and investment.

[16] The final good production technology does not require capital or labor inputs. It is used to regulate a country's preferences over local and imported varieties.

In this economy, there exists a one-period single nominal bond denominated in the home currency.[17] Let B_t denote the home consumer's holding of the bonds purchased in period t. Let B_t^* denote the foreign consumer's holding of this bond. The bond pays 1 unit of home currency in period $t+1$. Let Q_t denote the nominal price of the bond B_t.

A. Consumers

Home consumers choose consumption and investment to maximize their utility:

$$V_{C,0} = \max \sum_{t=0}^{\infty} \beta^t U\left(C_t\right),$$

subject to the sequence of budget constraints,

$$P_t C_t + P_t K_t + Q_t B_t \leq P_t W_t L_t + P_t R_t K_{t-1} + \left(1-\delta\right) P_t K_{t-1} + B_{t-1} + P_t \Pi_t + P_t T_t,$$

where β is the subjective time discount factor with $0 < \beta < 1$; P_t is the price of the final good; C_t is the consumption of final goods; K_{t-1} is the capital available in period t; Q_t and B_t are the price of bonds and the bond holdings; W_t and R_t denote the real wage rate and the rental rate of capital; δ is the depreciation rate of capital; Π_t is the sum of real dividends from the home country's producers; and T_t is the real lump-sum transfer from the home government.

The problem of foreign consumers is analogous to this problem. Prices and allocations in the foreign country are represented with an asterisk. Money has no role in this economy and

[17] Our focus will be on a symmetric model and so there is no reason for intertemporal trade. Nonetheless, we introduce the possibility of intertemporal trade for completeness of exposition.

is only a unit of account. The foreign budget constraint is expressed as

$$P_t^* C_t^* + P_t^* K_t^* + \frac{Q_t}{e_t} B_t^* \leq P_t^* W_t^* L_t^* + P_t^* R_t^* K_{t-1}^* + (1-\delta) P_t^* K_{t-1}^* + \frac{B_{t-1}^*}{e_t} + P_t^* \Pi_t^* + P_t^* T_t^*,$$

where * denotes the foreign variables and e_t is the nominal exchange rate with home currency as numeraire.[18]

The first order conditions for home consumers' utility maximization problems are

$$\begin{aligned} Q_t &= \beta \frac{U_{C,t+1}}{U_{C,t}} \frac{P_t}{P_{t+1}}, \\ 1 &= \beta \frac{U_{C,t+1}}{U_{C,t}} (R_{t+1} + 1 - \delta) \end{aligned}$$

where $U_{C,t}$ denotes the derivative of the utility function with respect to its argument. The price of the bond is standard. From the Euler equations of two countries, we have the growth rate of the real exchange rate, $q_t = e_t P_t^* / P_t$,

$$\frac{q_{t+1}}{q_t} = \frac{U_{C,t+1}^* / U_{C,t}^*}{U_{C,t+1} / U_{C,t+1}}.$$

With symmetry, the real exchange rate is $q_t = \frac{e_t P_t^*}{P_t} = 1$.

B. Final Good Producers

In the home country, final goods are produced using only home and foreign intermediate goods. A final good producer can purchase from any of the home intermediate good producers but can purchase only from those foreign tradable good producers that are actively selling in

[18] An increase in e_t means a depreciation of domestic currency.

the home market. The final good can be produced by combining a composite good produced of tradables, D_T, and a composite good produced of non-tradables, D_N.

$$(1) \quad D_t = D_{T,t}^{\gamma} D_{N,t}^{1-\gamma}.$$

The production technology of the composite tradable and non tradable goods is given by the CES function,

$$
\begin{aligned}
(2) \qquad D_{T,t} &= \left(\sum_{m=0}^{1} \int_{z \times \kappa} y_{H,t}^{d}(z,\kappa,m)^{\frac{\theta-1}{\theta}} \psi_{T,t}(z,\kappa,m)\, dz d\kappa \right. \\
&\qquad \left. + \int_{z \times \kappa} y_{F,t}^{d}(z,\kappa,1)^{\frac{\theta-1}{\theta}} \psi_{T,t}^{*}(z,\kappa,1)\, dz d\kappa \right)^{\frac{\theta}{\theta-1}}, \\
(3) \qquad D_{N,t} &= \left(\int_{z} y_{N,t}^{d}(z)^{\frac{\theta-1}{\theta}} \psi_{N}(z)\, dz \right)^{\frac{\theta}{\theta-1}},
\end{aligned}
$$

where $y_{H,t}^{d}(z,\kappa,m)$ and $y_{F,t}^{d}(z,\kappa,1)$ are inputs of intermediate goods purchased from a home tradable good producer with technology z, fixed cost shock κ, and export status m and foreign tradable exporter with $(z,\kappa,1)$, respectively; and $y_{N,t}^{d}(z)$ is the input of intermediate good purchased from a home nontradable good producer with technology z. The elasticity of substitution between intermediate goods within a sector is θ.

The final goods market is competitive. Given the final good price at home P_t, the prices charged by each type of tradable good, the final good producer solves the following problem

$$
\begin{aligned}
(4) \qquad \max \Pi_{F,t} &= D_t - \sum_{m=0}^{1} \int_{z \times \kappa} \left[\frac{P_{H,t}(z,\kappa,m)}{P_t} \right] y_{H,t}^d(z,\kappa,m)\, \psi_{T,t}(z,\kappa,m)\, dz d\kappa \\
&\quad - \int_{z \times \kappa} \left[\frac{P_{F,t}(z,\kappa,1)}{P_t} \right] y_{F,t}^d(z,\kappa,1) \psi_{T,t}^*(z,\kappa,1)\, dz d\kappa \\
&\quad - \int_{z} \left[\frac{P_{N,t}(z)}{P_t} \right] y_{N,t}^d(z) \psi_{N,t}(z)\, dz,
\end{aligned}
$$

subject to the production technology (1), (2), and (3).[19] Here $P_{H,t}(z,\kappa,m)$ and $P_{F,t}(z,\kappa,1)$ are the prices of tradable intermediate goods produced by a home producer with (z,κ,m) and a foreign producer with $(z,\kappa,1)$, respectively, and $P_{N,t}(z)$ is the price of nontradable intermediate good produced by a home producer with z. Solving the problem in (4) gives the input demand functions,

$$
\begin{aligned}
(5) \qquad y_{H,t}^d(z,\kappa,m) &= \gamma \left[\frac{P_{H,t}(z,\kappa,m)}{P_t} \right]^{-\theta} \left(\frac{P_{T,t}}{P_t} \right)^{\theta-1} D_t, \\
(6) \qquad y_{F,t}^d(z,\kappa,1) &= \gamma \left[\frac{P_{F,t}(z,\kappa,1)}{P_t} \right]^{-\theta} \left(\frac{P_{T,t}}{P_t} \right)^{\theta-1} D_t, \\
(7) \qquad y_{N,t}^d(z) &= (1-\gamma) \left[\frac{P_{N,t}(z)}{P_t} \right]^{-\theta} \left(\frac{P_{N,t}}{P_t} \right)^{\theta-1} D_t,
\end{aligned}
$$

[19] Notice that the production function is defined only over the available products. It is equivalent to define the production function over all possible varieties but constrain purchases of some varieties to be zero.

where the price indices are defined as

$$
\begin{aligned}
(8) \qquad P_{T,t} &= \left(\sum_{m=0}^{1} \int_{z\times\kappa} P_{H,t}\left(z,\kappa,m\right)^{1-\theta} \psi_{T,t}\left(z,\kappa,m\right) dz d\kappa \right. \\
&\quad \left. + \int_{z\times\kappa} P_{F,t}(z,\kappa,1)^{\theta-1} \psi^{*}_{T,t}\left(z,\kappa,1\right) dz d\kappa \right)^{\frac{1}{1-\theta}}, \\
(9) \qquad P_{N,t} &= \left(\int_{z} P_{N,t}(z)^{\theta-1} \psi_{N,t}\left(z\right) dz \right)^{\frac{1}{1-\theta}}, \\
(10) \qquad P_{t} &= \left(\frac{P_{T,t}}{\gamma} \right)^{\gamma} \left(\frac{P_{N,t}}{1-\gamma} \right)^{1-\gamma}.
\end{aligned}
$$

The final goods are used for both consumption and investment.

C. Intermediate Good Producers

All the intermediate good producers produce their differentiated good using capital and labor. Tradable good producers also use material inputs of other tradable good producers. We assume that an incumbent's idiosyncratic productivity, z, and fixed cost shock, κ, follows a first order Markov process with a transition probability $\phi\left(z',\kappa'|z,\kappa\right)$, the probability that the productivity of the establishment will be (z',κ') in the next period, conditional on its current productivity (z,κ), provided that the establishment survived. An entrant draws productivity next period based on $\phi_{E}\left(z',\kappa'\right)$. We also assume that establishments receive an exogenous death shock that depends on an establishment's productivity, z, at the end of the period, $0 \leq n_{d}\left(z\right) \leq 1$.

Non-Tradable Good Producers

Consider the problem of a nontradable good producer from the home country in period t with technology z. The producer chooses the current price $P_{N,t}\left(z\right)$, inputs of labor $l_{N,t}\left(z\right)$, and capital $k_{N,t}(z)$, given a Cobb-Douglas production technology,

$$(11)\quad y_{N,t}(z) = e^{z} k_{N,t}(z)^{\alpha} l_{N,t}(z)^{1-\alpha}$$

to solve

$$(12)\quad V_{N,t}(z) = \max \Pi_{N,t}(z) + n_s(z) Q_t \left(\frac{P_{t+1}}{P_t}\right) \int_{z'} V_{N,t+1}(z') \phi(z'|z) dz',$$

$$(13)\quad \Pi_{N,t}(z) = \left[\frac{P_{N,t}(z)}{P_t}\right] y_{N,t}(z) - W_t l_{N,t}(z) - R_t k_{N,t}(z)$$

subject to the production technology (11), and the constraints that supplies to the nontradable goods market, $y_{N,t}(z)$ are equal to demands by final good producers $y^d_{N,t}(z)$ in (7). Here, $n_s(z)$ denotes the survival probability, $n_s(z) = 1 - n_d(z)$.

Tradable Good Producers

A producer in the tradable good sector is described by its technology, fixed cost shock, and export status, (z, κ, m). Each period, it chooses current prices $P_{H,t}(z, \kappa, m)$ and $P^*_{H,t}(z, \kappa, m)$, and inputs of labor $l_{T,t}(z, \kappa, m)$, capital $k_{T,t}(z, \kappa, m)$, materials $x_t(z, \kappa, m)$, and the next period's export status, $m_{t+1}(z, \kappa, m)$. Total materials purchases, $x_t(z, \kappa, m)$, is composed of tradable intermediate goods with a constant elasticity of substitution function

$$(14)\quad x_t(z, \kappa, m) = \left[\sum_{\mu=0}^{1} \int_{\zeta} x^d_{H,t}(\zeta, \mu; z, \kappa, m)^{\frac{\theta-1}{\theta}} \psi_{T,t}(\zeta, \mu) d\zeta + \int_{\zeta} x^d_{F,t}(\zeta, 1; z, \kappa, m)^{\frac{\theta-1}{\theta}} \psi^*_{T,t}(\zeta, 1) d\zeta\right]^{\frac{\theta}{\theta-1}},$$

where $x^d_{H,t}(\zeta,\mu;z,\kappa,m)$ and $x^d_{F,t}(\zeta,1;z,\kappa,m)$ are inputs of intermediate goods purchased from a home tradable good producer with technology $\zeta=(z,\kappa)$ and export status μ, and foreign tradable exporter with technology ζ, respectively, by the tradable good producer with technology z, export status m, and fixed cost κ. The constant elasticity of substitution (CES) aggregation function gives the input demand functions,

$$
\begin{aligned}
(15)\quad x^d_{H,t}(\zeta,\mu;z,\kappa,m) &= \left[\frac{P_{H,t}(\zeta,\mu)}{P_t}\right]^{-\theta}\left(\frac{P_{T,t}}{P_t}\right)^{\theta} x_t(z,\kappa,m),\\
(16)\quad x^d_{F,t}(\zeta,1;z,\kappa,m) &= \left[\frac{P_{F,t}(\zeta,1)}{P_t}\right]^{-\theta}\left(\frac{P_{T,t}}{P_t}\right)^{\theta} x_t(z,\kappa,m),
\end{aligned}
$$

given the prices and the choice of the aggregate material input, $x_t(z,\kappa,m)$.

The producer has a Cobb-Douglas production technology,

$$
(17)\quad y_{T,t}(z,\kappa,m) = e^{z}\left[k_{T,t}(z,\kappa,m)^{\alpha}\, l_{T,t}(z,\kappa,m)^{1-\alpha}\right]^{1-\alpha_x} x(z,\kappa,m)^{\alpha_x}
$$

and solve

$$
\begin{aligned}
(18)\quad V_{T,t}(z,\kappa,m) &= \max \Pi_{T,t}(z,\kappa,m) - m' W_t(f_m+\kappa)\\
&\quad + n_s(z)\, Q_t\left(\frac{P_{t+1}}{P_t}\right)\int_{z'\times\kappa'} V_{T,t}(z',\kappa',m')\,\phi(z',\kappa'|z,\kappa)\,dz'd\kappa'
\end{aligned}
$$

$$
\begin{aligned}
(19) \quad \Pi_{T,t}(z,\kappa,m) &= \left[\frac{P_{H,t}(z,\kappa,m)}{P_t}\right] y_{H,t}(z,\kappa,m) + \left[\frac{e_t P_{H,t}^{*}(z,\kappa,m)}{P_t}\right] y_{H,t}^{*}(z,\kappa,m) \\
&\quad - W_t l_{T,t}(z,\kappa,m) - R_t k_{T,t}(z,\kappa,m) \\
&\quad - \sum_{\mu=0}^{1} \int_{\zeta} \left[\frac{P_{H,t}(\zeta,\mu)}{P_t}\right] x_{H,t}^{d}(\zeta,\mu;z,\kappa,m)\, \psi_{T,t}(\zeta,\mu)\, d\zeta \\
&\quad - \int_{\zeta} \left[\frac{P_{F,t}(\zeta,1)}{P_t}\right] x_{F,t}^{d}(\zeta,1;z,\kappa,m) \psi_{T,t}^{*}(\zeta,1)\, d\zeta,
\end{aligned}
$$

subject to the production technology (17) and the constraints that supply to home and foreign tradable goods markets, $y_{H,t}(z,\kappa,m)$ and $y_{H,t}^{*}(z,\kappa,m)$ with $y_{T,t}(z,\kappa,m) = y_{H,t}(z,\kappa,m) + (1+\iota)\, y_{H,t}^{*}(z,m)$, are equal to demand by final good producers from (5), the foreign analogue of (6),

$$
(20) \quad y_{H,t}^{d*}(z,\kappa,m) = m\gamma \left[\frac{P_{H,t}^{*}(z,\kappa,m)}{P_t^{*}}\right]^{-\theta} \left(\frac{P_{T,t}^{*}}{P_t^{*}}\right)^{\theta-1} D_t^{*},
$$

and demand by intermediate good producers

$$
(21) \quad \sum_{\mu=0}^{1} \int_{\zeta} x_{H,t}^{d}(z,\kappa,m;\zeta,\mu)\, \psi_{T,t}(\zeta,\mu)\, d\zeta,
$$

$$
(22) \quad \sum_{\mu^{*}=0}^{1} \int_{\zeta^{*}} x_{H,t}^{d*}(z,\kappa,m;\zeta^{*},\mu^{*})\, \psi_{T,t}^{*}(\zeta^{*},\mu^{*})\, d\zeta^{*}.
$$

Let the value of the producer with state (z,κ,m) that decides to export in period $t+1$ be

$$
\begin{aligned}
(23) \quad V_{T,t}^{1}(z,\kappa,m) &= \max \Pi_{T,t}(z,\kappa,m) - W_t(f_m+\kappa) \\
&\quad + n_s(z)\, Q_t \left(\frac{P_{t+1}}{P_t}\right) \int_{z'\times\kappa'} V_{T,t+1}(z',\kappa',1)\, \phi(z',\kappa'|z,\kappa)\, dz' d\kappa',
\end{aligned}
$$

and let the value if it decides not to export in period $t+1$ be

$$(24) \quad V^0_{T,t}(z,\kappa,m) = \max \Pi_{T,t}(z,\kappa,m) + n_s(z)\, Q_t \left(\frac{P_{t+1}}{P_t}\right) \int_{z'\times\kappa'} V_{T,t+1}(z',\kappa',0)\,\phi(z',\kappa'|z,\kappa)\,dz'd\kappa'.$$

Then, the actual value of the producer can be defined as

$$(25) \quad V_t(z,\kappa,m) = \max\left\{V^1_{T,t}(z,\kappa,m), V^0_{T,t}(z,\kappa,m)\right\}.$$

Clearly, the value of a producer depends on its export status and is monotonically increasing and continuous in z given m and κ, and the states of the world. Moreover V^1_T intersects V^0_T from below as long as there are some establishments that do not export. Hence, it is possible to solve for the establishment productivity at which an establishment is indifferent between exporting or not exporting; that is, the increase in establishment value from exporting equals the cost of exporting. This level of establishment productivity differs by the establishment's current export status. For a given export cost κ, the critical level of technology for exporters and non-exporters, $z_{1,t}(\kappa)$ and $z_{0,t}(\kappa)$, satisfy

$$(26) \quad V^1_{T,t}(z_{1,t}(\kappa),1) = V^0_{T,t}(z_{1,t}(\kappa),1),$$

$$(27) \quad V^1_{T,t}(z_{0,t}(\kappa),0) = V^0_{T,t}(z_{0,t}(\kappa),0).$$

D. Entry

Each period, a new establishment can be created by hiring f_E workers. Establishments incur these entry costs in the period prior to production and must choose one sector to enter.

Once the entry cost is incurred, establishments receive an idiosyncratic productivity shock from the initial distribution $\phi_E(z', \kappa')$. All the entrants are free from death shocks. New entrants can not export in their first productive period. Thus the entry conditions are

$$
\begin{aligned}
(28)\quad V^E_{T,t} &= -W_t f_E + Q_t\left(\frac{P_{t+1}}{P_t}\right)\int_{z'\times\kappa'} V_{T,t+1}(z', \kappa', 0)\,\phi_E(z', \kappa')\,dz'd\kappa' \leq 0, \\
(29)\quad V^E_{N,t} &= -W_t f_E + Q_t\left(\frac{P_{t+1}}{P_t}\right)\int_{z'} V_{N,t+1}(z')\,\phi_E(z')\,dz' \leq 0.
\end{aligned}
$$

In the nontradable good sector, let $N_{NE,t}$ denote the mass of entrants who pay the entry cost in period t and let the mass of incumbents be $N_{N,t}$. In the tradable sector , let $N_{TE.t}$ denote the mass of entrants who pay the entry cost in period t, while the mass of incumbents is $N_{T,t}$. The mass of exporters and non-exporters is then

$$
\begin{aligned}
(30)\quad N_{1,t} &= \int_{z\times\kappa} \psi_{T,t}(z, \kappa, 1)\,dzd\kappa, \\
(31)\quad N_{0,t} &= \int_{z\times\kappa} \psi_{T,t}(z, \kappa, 0)\,dzd\kappa,
\end{aligned}
$$

and the mass of establishments in the tradable good sectors equals

$$(32)\quad N_{T,t} = N_{1,t} + N_{0,t}.$$

The fixed costs of exporting imply that only a fraction $n_{X,t} = N_{1,t}/N_{T,t}$ of home tradable goods are available in the foreign country in period t.

Given the critical level of technology for exporters and non-exporters, $z_{1,t}(\kappa)$ and $z_{0,t}(k)$, we can measure the starter ratio, the fraction of establishments that start exporting among non-exporters, as

$$(33) \quad n_{0,t+1} = \frac{\int_\kappa \int_{z_{0,t}(\kappa)}^\infty n_s(z)\,\psi_{T,t}(z,\kappa,0)\,dzd\kappa}{\int_\kappa \int_{-\infty}^\infty n_s(z)\,\psi_{T,t}(z,\kappa,0)\,dzd\kappa}.$$

Similarly, we can measure the stopper ratio, the fraction of exporters who stop exporting among surviving establishments, as

$$(34) \quad n_{1,t+1} = \frac{\int_\kappa \int_{-\infty}^{z_{1,t}(\kappa)} n_s(z)\,\psi_{T,t}(z,\kappa,1)\,dzd\kappa}{\int_\kappa \int_{-\infty}^\infty n_s(z)\,\psi_{T,t}(z,\kappa,1)\,dzd\kappa}.$$

The evolutions of mass of establishments are given by

$$\begin{aligned}(35) \quad \psi_{T,t+1}(z',\kappa',1) &= \int_\kappa \int_{z_{0,t}(\kappa)}^\infty n_s(z)\,\psi_{T,t}(z,\kappa,0)\,\phi(z',\kappa'|z,\kappa)\,dzd\kappa \\ &\quad + \int_\kappa \int_{z_{1,t}(\kappa)}^\infty n_s(z)\,\psi_{T,t}(z,\kappa,1)\,\phi(z',\kappa'|z,\kappa)\,dzd\kappa,\end{aligned}$$

$$\begin{aligned}(36) \quad \psi_{T,t+1}(z',\kappa',0) &= \int_\kappa \int_{-\infty}^{z_{0,t}(\kappa)} n_s(z)\,\psi_{T,t}(z,\kappa,0)\,\phi(z',\kappa'|z,\kappa)\,dzd\kappa \\ &\quad + \int_\kappa \int_{-\infty}^{z_{1,t}(\kappa)} n_s(z)\,\psi_{T,t}(z,\kappa,1)\,\phi(z',\kappa'|z,\kappa)\,dzd\kappa \\ &\quad + N_{TE,t}\phi_E(z',\kappa'),\\ (37) \quad \psi_{N,t+1}(z') &= \int_z n_s(z)\,\psi_{N,t}(z)\,\phi(z'|z)\,dz + N_{NE,t}\phi_E(z').\end{aligned}$$

E. Aggregate Variables

Aggregate investment, I_t, is given by the law of motion for capital

$$(38) \quad I_t = K_t - (1-\delta)\,K_{t-1}.$$

Nominal exports and imports are given as

$$
\begin{aligned}
(39) \quad EX_t^N &= \int_{z\times\kappa} e_t P_{H,t}^*(z,\kappa,1)\, y_{H,t}^*(z,\kappa,1)\, \psi_{T,t}(z,\kappa,1)\, dz d\kappa, \\
(40) \quad IM_t^N &= \int_{z\times\kappa} P_{F,t}(z,\kappa,1)\, y_{F,t}(z,\kappa,1)\, \psi_t^*(z,\kappa,1)\, dz d\kappa,
\end{aligned}
$$

respectively. Nominal GDP of the home country is defined as the sum of value added from nontradable, tradable, and final goods producers,

$$
(41) \quad Y_t^N = P_t D_t + EX_t^N - IM_t^N.
$$

The ratio of trade to GDP is given as

$$
(42) \quad TR_t = \frac{EX_t^N + IM_t^N}{2Y_t^N}.
$$

The total labor used for production, $L_{P,t}$, is given by

$$
(43) \quad L_{P,t} = \sum_{m=0}^{1} \int_{z\times\kappa} l_{T,t}(z,\kappa,m)\, \psi_{T,t}(z,\kappa,m)\, dz d\kappa + \int_z l_{N,t}(z)\, \psi_{N,t}(z)\, dz.
$$

The domestic labor[20] hired by exporters, $L_{X,t}$, is given by

$$
(44) \quad L_{X,t} = \int_\kappa \int_{z_{0,t}(\kappa)}^{\infty} (f_0+\kappa)\, \psi_{T,t}(z,\kappa,0)\, dz d\kappa + \int_\kappa \int_{z_{1,t}(\kappa)}^{\infty} (f_1+\kappa)\, \psi_{T,t}(z,\kappa,1)\, dz d\kappa.
$$

[20]Entry costs are measured in units of labor to ensure a balanced growth path.

From (44), we see that the trade cost, measured in units of domestic labor, depends on the exporter status from the previous period.

Aggregate profits are measured as the difference between profits and fixed costs and equal

$$(45) \quad \Pi_t = \Pi_{F,t} + \sum_{m=0}^{1} \int_{z\times\kappa} \Pi_{T,t}(z,\kappa,m)\psi_{T,t}(z,\kappa,m)\,dzd\kappa + \int_{z} \Pi_{N,t}(z)\,\psi_{N,t}(z)\,dz$$
$$-W_t L_{X,t} - f_E W_t \left(N_{TE,t} + N_{NE,t}\right).$$

For each type of good, there is a distribution of establishments in each country. For the sake of exposition, we have written these distributions separately by country and type of establishment. It is also possible to rewrite the world distribution of establishments over types as $\psi : R \times R \times \{0,1\} \times \{H,F\} \times \{T,N\}$, where now we have indexed establishments by their origin. The exogenous evolution of each establishment's productivity as well as the endogenous export participation and entry decisions determines the evolution of this distribution. The law of motion for this distribution is summarized by the operator T, which maps the world distribution of establishments and entrants into the next period's distribution of establishments, $\psi' = T(\psi, N_{TE}, N_{TE}^{*}, N_{NE}, N_{NE}^{*})$.

F. Equilibrium Definition

In an equilibrium, variables satisfy several resource constraints. The final goods market clearing conditions are given by $D_t = C_t + I_t$ and $D_t^* = C_t^* + I_t^*$. Each individual goods market clears; the labor market clearing conditions are $L = L_{P,t} + L_{X,t} + f_E\left(N_{TE,t} + N_{NE,t}\right)$ and the foreign analogue; and the capital market clearing conditions are $K_{t-1} = \sum_{m=0}^{1} \int_{z\times\kappa} k_{T,t}(z,\kappa,m)\,\psi_{T,t}(z,\kappa,m)\,d$ $\int_z k_{N,t}(z)\,\psi_{N,t}(z)\,dz$ and the foreign analogue. The profits of establishments are distributed to the shareholders, Π_t, and the foreign analogue. The international bond market clearing condition is given by $B_t + B_t^* = 0$. Finally, our decision to write the budget constraints in each country in units of the local currency permits us to normalize the price of consumption in each country as $P_t = P_t^* = 1$.

An equilibrium of the economy is a collection of allocations for home consumers C_t, B_t, K_t; allocations for foreign consumers C_t^*, B_t^*, K_t^*; allocations for home final good producers; allocations for foreign final good producers; allocations, prices, and export policies for home tradable good producers; allocations, prices and export decisions for foreign tradable good producers; labor used for exporting costs in both home and foreign; labor used for entry costs; real wages W_t, W_t^*, real rental rates of capital R_t, R_t^*, and real and nominal exchange rates q_t and e_t; and bond prices Q_t that satisfy the following conditions: (i) the consumer allocations solve the consumer's problem; (ii) the final good producers' allocations solve their profit maximization problems; (iii) the tradable good producers' allocations, prices, and export decisions solve their profit maximization problems; (iv) the non tradable good producers' allocations and prices solve their profit maximization problems; (v) the entry conditions for each sector holds; and (vi) the market clearing conditions hold.

4. Calibration

We now describe the functional forms and parameter values of our benchmark economy. The parameter values used in the simulation exercises are reported in Table 1. The instantaneous utility function is given as $U(C) = C^{1-\sigma}/\left(1-\sigma\right)$,where $1/\sigma$ is the intertemporal elasticity of substitution.

The choice of the discount factor, β, the rate of depreciation, δ, and risk-aversion, σ, is standard in the literature, $\beta = 0.96$, $\delta = 0.10$, and $\sigma = 2$. The labor supply is normalized to

$L = 1$.

The characteristics of establishments in the steady state of our model economy are targeted to match characteristics among U.S. manufacturing establishments in the U.S. in 1987. We also target a set of moments about how establishments evolve over time and transit across export status.

The establishment size distribution is largely determined by the underlying structure of shocks. We assume that the shocks to productivity and fixed costs are independent. Productivity of establishments in the tradable and nontradable sectors are assumed to follow the same process. An incumbent's productivity evolves as $z' = \rho_\varepsilon z + \varepsilon$, with $\varepsilon \overset{iid}{\sim} N(0, \sigma_\varepsilon^2)$.The assumption that an establishment productivity follows an AR(1) with shocks drawn from an iid normal distribution implies that this conditional distribution follows a normal distribution $\phi(z'|z) = N(\rho_\varepsilon z, \sigma_\varepsilon^2)$. We assume that entrants draw productivity based on the unconditional distribution $z' = \mu_E + \varepsilon_E$, with $\varepsilon_E \overset{iid}{\sim} N(0, \sigma_\varepsilon^2 / (1 - \rho_\varepsilon^2))$ .However, to match the observation that entrants start out small relative to incumbents, we assume this distribution to be shifted to the left, $\mu_E < 0$.

The shocks to the fixed costs are assumed to be drawn from a two-state Markov chain, $\{\kappa_L, \kappa_H\}$ with persistence of the low shock, ρ_κ^L, and the persistence of the high shock, ρ_κ^H. Since all exporters incur some fixed cost, we can normalize the low cost shock to $\kappa_L = 0$, and the high fixed cost is set to ensure an establishment does not export so $\kappa_H = \infty$. Finally, we assume that high and low fixed cost establishments have the same probability of drawing the low cost shock, i.e., $\rho_\kappa^L = 1 - \rho_\kappa^H = \rho_\kappa$.[21]

We also assume that establishments receive an exogenous death shock that depends on

[21] In the calibration exercises, we initially allowed persistence in the fixed cost shock, $\rho_\kappa^L + \rho_\kappa^H \neq 1$. However, the calibration results suggest that $\rho_\kappa^L + \rho_\kappa^H = 1$ provides us with the best fit to the data.

an establishment's last period productivity, z, so that the probability of death is given as

$$n_d(z) = 1 - n_s(z) = \max\left\{0, \min\left\{\lambda e^{-\lambda e^z} + n_{d0}, 1\right\}\right\}.$$

Our formulation of the exit probability allows for small plants to have a higher exit rate than big plants and some big plants to fail. It is a departure from Melitz and Hopenhayn models and so one might suspect that our results may depend on the way we model exit. However, previous quantitative analyses of heterogeneous plant models that focus on labor market frictions (see Veracierto 2001, for example) find similar results with endogenous or exogenous exits. For this reason, we are not concerned about the effect of this modelling assumption.

The parameter θ determines both the producer's markup as well as the elasticity of substitution across varieties. We set $\theta = 5$, which gives the producer's markup of 25 percent. This value of θ is consistent with the U.S. trade-weighted import elasticity of 5.36 estimated by Broda and Weinstein (2006) for the period 1990 to 2001.[22]

The tradable share parameter of the final good producer, γ, is set to 0.21 to match the ratio of manufacturers' nominal value-added relative to private industry GDP, excluding agriculture and mining for the U.S. from 1987 to 1992. The labor share parameter in the production, α, is set to match the labor income to GDP ratio of 66 percent. The share of materials in production, α_x, determines the ratio of gross output to value-added in manufacturing. For the period 1987 to 1992 in the U.S., this ratio averages 2.75 and implies that $\alpha_x = 0.795$.

The total mass of establishments, $N_{T,t} + N_{N,t}$, is normalized to 2 with the entry cost

[22] Anderson and van Wincoop survey elasticity estimates from bilateral trade data and conclude $\theta \in [5, 10]$. Even though the sizes of iceberg costs calibrated are critically dependent on the elasticity, the results are insensitive to the value of θ, since we calibrate the iceberg costs in 1987 and 2002, productivity process, and the fixed costs to match the key moments in the data and the elasticity adjusted moments in the model.

parameter f_E. In all the analysis, we assume that the mean establishment size of the tradable sector is as in the U.S. in 1987.

We target features of the establishment and exporter size distributions as well as some dynamic moment of exporters, non-exporters, and establishments. In particular, we target:

1. An exporter intensity of 10.0 percent in 1987.
2. An exporter intensity of 15.0 percent in 2002.
3. An exporter rate of 37.0 percent for establishments with 100+ employees (1987 Census of Manufactures).
4. A stopper rate of 17 percent as in Bernard and Jensen (1999), based on the Longitudinal Research Database (LRD) of the Bureau of the Census 1984-1992.
5. Five-year exit rate of entrants of 37 percent based on establishments that first began producing (Dunne et al. 1989).
6. Shutdown establishments' labor share of 2.3 percent (Davis et al. 1996).
7. Entrants' labor share of 1.5 percent reported in Davis et al. (1996), based on the Annual Survey of Manufactures (ASM).
8. Establishment employment size distributions (fractions of establishments given the employment sizes) as in the 1987 Census of Manufactures.
9. Distribution of export participation of establishments with 100+ employees (1987 Census of Manufactures).

The first two targets, along with θ, pin down the level of trade costs in 1987 and 2002. Given $\theta = 5$, trade costs increase export prices by 73.4 percent in 1987 and 53.7 percent in 2002. Anderson and van Wincoop (2004) also find large costs of 65 percent (excluding distribution/retail costs), but their measure also includes the trade distortions from fixed costs. The next two targets relate exporters to the population of establishments. As is well known, not all establishments export. Those that do are much bigger than the average establishment. There is also substantial churning in the export market, with the typical exporter exiting after six years of exporting (measured as the inverse of the exporter exit rate).

The next three targets help to pin down the establishment creation, destruction, and growth process. New establishments and dying establishments tend to be small, respectively accounting for only 1.5 percent and 2.3 percent of employment. Moreover, new establishments have high failure rates, with a 37 percent chance of exiting in the first five years.

The model is calibrated to match the first 7 observations, and to minimize distance between the distributions in the model and the data (measured by the sum of squared residuals).[23] The parameter values are reported in Table 2 and the fit of the benchmark model is summarized in Table 3. Figure 1 plots the distribution of plants over productivity levels and export status. We also plot the probability of the death shock.

Establishment Distribution

Overall, our model of plant dynamics and exporting does a very good job of matching the cross-sectional and dynamics of plants and exporters. This is evident from the three panels of Figure 2 that plot the key characteristics of establishment and exporter heterogeneity in the data in 1987 and our calibrated model. The top panel displays the share of establishments (on a log scale) by establishment size. The model captures the feature that most establishments

[23] Specifically, we use the following 6 bins for employment sizes: 1-99, 100-249, 250-499, 500-999, 1000-2499, and 2500 and more employees. The model is solved by discretizing the idiosyncratic shock process and then using value function iteration to solve for the marginal starters and stoppers. More details are available upon request.

are relatively small and that there are relatively few large establishments. Overall, the model slightly underpredicts the share of small establishments and overpredicts the share of large establishments. The middle panel displays the share of employment accounted for by establishments in each size class. The largest gap between the data and the model is in the employment share of establishments with 1,000 to 2,499 employees. In the data, these establishments account for 10.7 percent of employment while in the model they account for 11.3 percent of employment. Finally, the third panel displays the share of establishments exporting by establishment size. As in the data, the share of establishments exporting increases with establishment size. The model is a close fit to the data on this dimension, with the mean absolute difference of less than 0.15 percent for export participation of establishments with 100+ employees. Both the assumption about the lag in starting to export and the stochastic fixed costs are crucial to match the rise in export participation with establishment size. Without these assumptions export participation would rise much faster with establishment size.

5. Results

We begin by using the model to explore the impact of the cut in iceberg trade costs necessary to raise export intensity as in the data. This requires cutting transport costs from 73.4 percent to 53.7 percent. Our analysis is based on a comparison of the steady state of our model economy that only differs in terms of the iceberg trade costs. We consider the transition to the new steady state in the next section. The change in the model economy and the data is reported in Table 4. As before, we concentrate on the growth in trade predicted for establishments with 100+ employees.

In the first column of Table 4, we see that the model predicts a much larger increase in exports than in the data (78.7 vs. 46.4). The larger increase in the share of output exported results from a much larger increase in export participation in the model than in the data (57.3 vs. 23.7) while the decrease in the exporter premium is quite similar to the data (-20.9 vs. -19.5). As emphasized in the literature, the model also predicts that employment should shift away from relatively less productive establishments toward relatively more productive establishments because sales of exporters will rise and more of these relatively productive establishments will export. In total, the model predicts that the employment share of establishments with less than 100 employees will fall by 0.1 percentage points while the share of employment in the largest establishments will rise by 0.1 percentage points. There is a bigger increase in employment in intermediate-sized plants because these plants are the marginal plants for exporting.

Figure 3 depicts the changes in the establishment and exporter distributions in the model and the data. Panel (a) depicts the change in the share of establishments in each employment bin. In the data, the share of small establishments, those with 99 or less employees, rises by 0.8 percentage points while the model predicts an increase of 0.2 percentage points in the share of the smallest establishments. In the model, the share of establishments with 100 to 249 employees falls the most. The fall in the mid-sized establishments reflects the increased export participation by moderately productive establishments and the reduced sales of moderately unproductive establishments following the cut in transportation costs.

Panel (b) plots the distribution of employment by establishment size in the model and data for 1987 and 2002. The shift in employment toward large establishments predicted by the model is at odds with the shift toward smaller establishments that occurred in the U.S. manufacturing sector over this period. This shift is clearly evident among the largest and smallest establishment sizes. The share of employment accounted for by establishments with

2500+ employees fell 5.4 percentage points while the share of employment accounted for by the smallest establishments rose 2.9 percentage points. In contrast, the model generates a shift in employment from the small establishments (with fewer than 250 employees) to those with more than 1,000+ employees.

Panel (c) shows that export participation rose across all establishment sizes in the model and the data. In both the model and the data, the magnitude of the rise in export participation is hump-shaped in establishment size, with the greatest increase in participation by establishments with 100 to 249 employees. However, across all establishment sizes the model overstates the rise in export participation.

The model misses out on the changes in the distribution of employment over establishments in part because it misses out on the change in the mean establishment size. In the data, establishment size falls approximately 15.3 percent over this period while in the model it increases by 3.1 percent. To compensate, we rescale average establishment size in our 2002 model to match the data. This mechanical re-scaling does not alter the relative size of establishments or the export decision, but alters how we allocate establishments across employment categories. The result of this rescaling are reported in Figure 3. By shifting establishments into smaller categories the model can capture some of the changes occurring at large and small establishments but at the expense of missing out on more of the changes in mid-sized establishments. That this rescaling only partly improves the fit of the model suggests that the model is missing out on a source of the fundamental change in the establishment size distribution.

6. Sensitivity

In this section, we consider two possible explanations for the gaps between the model and the data. First, we explore whether the gap between the model and data in export participation and trade arises because transition dynamics are slow in the model so that looking at steady states overstates the growth in trade. Next, we consider whether the gap may arise from a reallocation of labor between manufacturing and nonmanufacturing industries as a result of the fall in trade costs. Both extensions close a very small amount of the gap between the model and the data.

Dynamics

To solve for the transition dynamics, it is necessary to take a stand on both the dynamics of trade costs and agents' expectations of the evolution of trade costs. In terms of iceberg costs, we assume that they are equal to the measured iceberg cost in census years (1987, 1992, 1997 and 2002) and we then generate trade costs in intermediate years by interpolation (for example, $\iota_{88} = i_{87} - \frac{\iota_{92}-\iota_{87}}{5}$). In terms of expectations of the path of trade costs, we assume that in each year the decline in trade costs is entirely unanticipated and expected to be permanent ($E_t\iota_{t+k} = i_t$). That is, agents do not anticipate future decreases in trade costs.[24]

Figure 4 plots the dynamics of export participation (in the model) and trade costs over time. We also plot the long-run changes in export participation in the model (the dashed line with crosses) and the data (the dashed line represents 2002 export participation.) Given these changes in iceberg costs, export participation by 2002 in the model is now about 3 percentage points below the model's steady state (63.4 percent vs. 65.6 percent) but still substantially

[24] This gives the model the best chance of capturing the slow growth of exporters.

above export participation in the data (46.4 percent). Indeed, the model predicts that by 1992, export participation should have equalled the level ultimately observed in 2002. Thus, it appears that transition in response to the fall in trade costs can only explain about 10 percent of the gap in export participation between the data and the model.

Nontradables

We now examine the role of the change in the sectoral composition of output for our results. In our benchmark calibration, the model generates a much smaller decline in manufacturing employment of 0.2 percent than the approximate 17.2 percent[25] decline in the data.[26] Thus it appears that falling trade costs, as well as the increased integration they generate, have contributed very little to the decline in manufacturing employment. However, the impact of falling trade costs on manufacturing will depend on the substitution it creates across sectors, which is governed by the elasticity of substitution between tradables and non-tradables. To explore this channel, we allow for a more general CES production function of final goods,

$$D = \left[aD_T^{\frac{\gamma-1}{\gamma}} + (1-a)\, D_N^{\frac{\gamma-1}{\gamma}} \right]^{\frac{\gamma}{\gamma-1}}.$$

Figure 5 plots the relationship between average establishment size, tradable employment, and the mass of tradable establishments for a range of elasticities from $\gamma = 0.2$ to $\gamma = 1.8$ following the fall in iceberg costs. For each value of γ we choose a to match the expenditure

[25] Some of the decline in employment in manufacturing is a result of a switch in the industry classification system in 1997 from SIC to NAICS. In the appendix, we show that this accounts for a 3.8 percent decline in manufacturing or slightly less than 25 percent of the decline in manufacturing over the sample.

[26] This understates the decline in manufacturing since over this period, according to the small business administration, total private employment grew almost 25 percent (from 84.9 million to 108.8 million) and the number of private establishments grew about 18 percent (6 million in 1987 to 7.2 million in 2002).

on tradables from our benchmark case. Lowering the elasticity of substitution leads to more resources being allocated to the nontradable sector. However, the changes to manufacturing employment are minor. Even with $\gamma = 0.2$, which is lower than the elasticity estimated in the literature,[27] employment in tradables falls 1.4 percent while the number of establishments falls 4.4 percent. Thus, it appears that the changes across sectors from falling iceberg costs cannot account for very much of the contraction in manufacturing employment.

Varying the elasticity of substitution has no impact on average establishment size since production in each sector is constant returns to scale. Thus, given a certain mass of establishments, the distribution of employment across those establishments is not affected by sectoral relative price. Therefore, the elasticity of substitution only affects the mass of establishments that produce in the sector and, hence, employment.

7. Conclusions

We study U.S. export growth from 1987 to 2002 using a model with heterogenous producers and fixed costs of exporting. To the best of our knowledge, ours is the first empirical and quantitative analysis of the change in trade in a dynamic heterogenous plant model. Given the common use of variants of this model in policy analysis,[28] our analysis provides an important evaluation of this model.

Understanding the changes in trade requires measuring the change in trade costs. Here we show that, in contrast to the representative agent framework commonly employed, the het-

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[27] For instance, estimates of the elasticity of substitution between tradables and nontradables range from 1.24 by Ostry and Reinhart (1991) for a group of developing countries to Mendoza's (1995) estimate of 0.74 for a group of industrialized countries.

[28] Some examples include Roberts and Tybout (1997), Melitz (2003), Bernard, Eaton Jensen and Kortum (2003), Das, Roberts and Tybout (2005), Baldwin and Robert-Nicoud (2005), Baldwin and Forslid (2006), Alessandria and Choi (2007b), Atkeson and Burstein (2007).

erogeneous plant model does not contain a one-to-one link between changes in iceberg costs and the growth in aggregate trade. We show that by using data on characteristics of exporters, in particular the intensity with which they export, we can identify the change in iceberg trade costs over this period. Given this observed decline in iceberg trade costs, the model predicts that the share of manufacturing output exported should have grown nearly 70 percent more than it did. Thus, in contrast to the commonly held view in Yi (2003), we find that the puzzle is not that trade grew so much in this period, but that it grew so little.

The model overpredicts U.S. export growth because it substantially overpredicts the increase in export participation by U.S. manufacturing establishments. Export participation did not grow as expected in large part because there was a substantial shift toward smaller establishments. Given the fixed costs of exporting, these smaller establishments did not find investing in exporting capacity worthwhile. This shift toward smaller establishments stands in contrast to the key prediction of the Melitz model that a lowering of trade costs should lead employment to become more concentrated in relatively large manufacturing establishments since they are more likely to be exporting and thus can take advantage of the lower trade costs. That we found that employment became concentrated in the smallest establishments, suggests that either there are forces beyond trade altering the establishment employment distribution or that the products produced by small and large establishments are inherently very different. Perhaps U.S. manufacturers have a comparative advantage in producing goods in establishments with smaller scale of production (see Holmes and Stevens 2007). However, such an explanation would have to operate within industries since we find that very little of the shift toward smaller plants is accounted for by changes in the industry composition of production (see appendix). Understanding the relation between changes in scale of production and trade is an important topic for future research.

Our general equilibrium model of trade also allows us to quantify the role of trade, and falling iceberg costs in particular, for the shift from tradable to nontradable production in the U.S., what we associate with manufacturing and manuracturing. We find that increasing trade integration accounts very little for the decline in employment in the tradable sector, accounting for at most 10 percent of the decline in manufacturing employment. We conclude from this that the fall in iceberg costs may matter more for the distribution of employment across manufacturing establishments rather than the allocation of employment across sectors.

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Table 1: Export Characteristics and Trade

(Establishments with 100+ Employees)

	EXD	EXY	Intensity	Premium	Participation	Y_{US}	Y_{ROW}
1987	6.5	6.1	10.0	164.6	37.0	0	0
2002	10.7	9.7	15.2	135.4	46.9	79.6	88.2
Log change	50.3	46.4	42.3	-19.5	23.7	8.6	

Notes: EXD: exports sales to domestic sales ratio; EXY: exports sales to total sales ratio; Intensity denotes the ratio of exports to sales of exporters. Premium denotes the ratio of mean sales of exporters to mean sales of all establishments. Participation denotes the ratio of the number of exporters to the number of establishments. Data are from Census of Manufacturers (1987 and 2002).

Table 2: Parameter Values

Parameters

$\beta = 0.96,\ \sigma = 2,\ \theta = 5,\ \delta = 0.10,\ \gamma = 0.21$

$\alpha = 0.285,\ \lambda = 7.563,\ n_{d0} = 0.022,\ \alpha_m = 0.795,\ \iota_{87} = 0.734,\ \iota_{02} = 0.537,$

$\rho = 0.688,\ \mu_E = -0.355,\ \sigma_\varepsilon = 0.332,$

$f_E = 1.655,\ f_0 = 0.153,\ f_1 = 0.019,\ \kappa_L = 0,\ \kappa_H = \infty,\ \rho_\kappa = 0.94$

Table 3: Target Moments

	Target Value	Sunk Cost
5-year exit rate	0.37	0.37
Startups' labor share	0.015	0.015
Shutdowns' labor share	0.023	0.023
Stopper rate	0.17	0.17
Exporter ratio (100+)	0.37	0.37
Exporter intensity (100+)	0.10	0.10
Squared sum of residuals (%)		
Establishments	0	0.06
Export participation	0	0.03

Table 4: Changes in Export Characteristics and Trade

	Export share	Intensity	Premium	Participation	L_T	N_T	L_T/N_T	s^{2500+}	$s^{<100}$
Data	46.4	42.3	-19.5	23.7	-17.2	-2.3	-15.3	-5.4	2.9
Model	78.7	42.3	-20.9	57.3	-0.2	-3.2	3.1	0.1	-0.1

Figure 1: Establishment Distribution

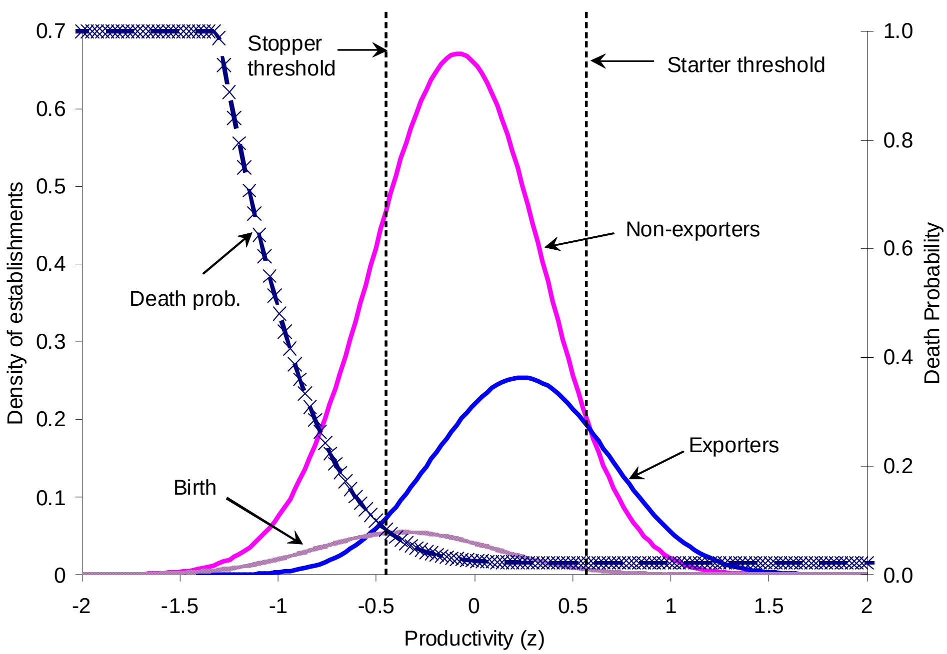
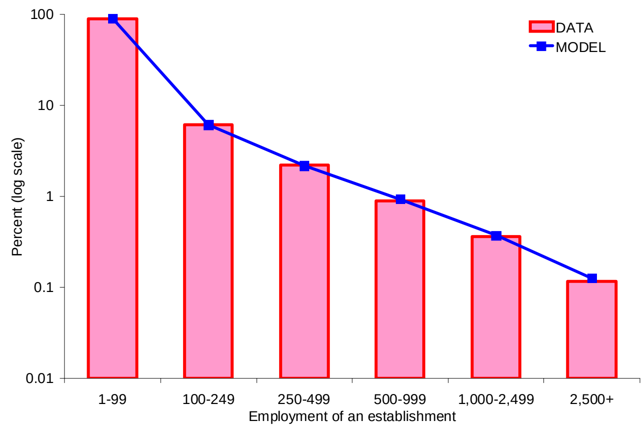
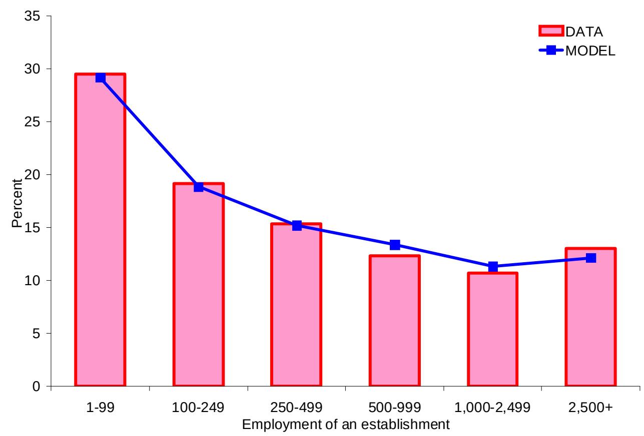


Figure 2: Establishment Characteristics by Employment Size

(a) Establishment Share



(b) Employment Share



(c) Export Participation

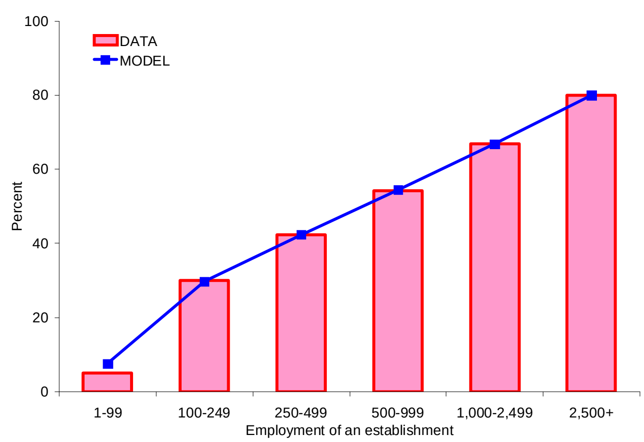
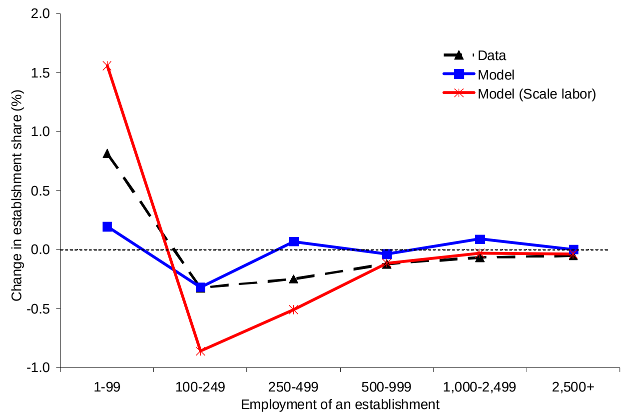
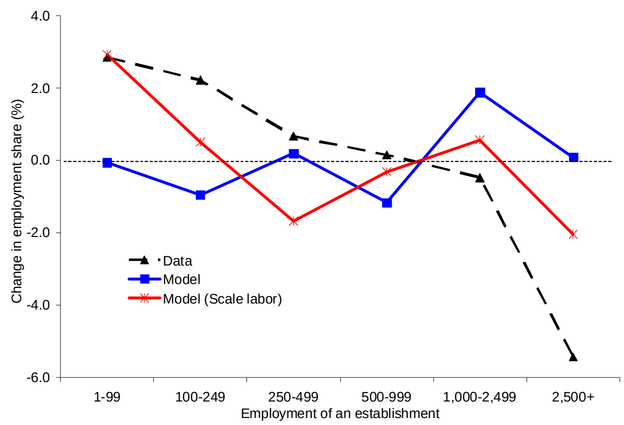


Figure 3: Change in Establishment Characteristics by Employment Size

(a) Establishment Share



(b) Employment Share



(c) Export Participation

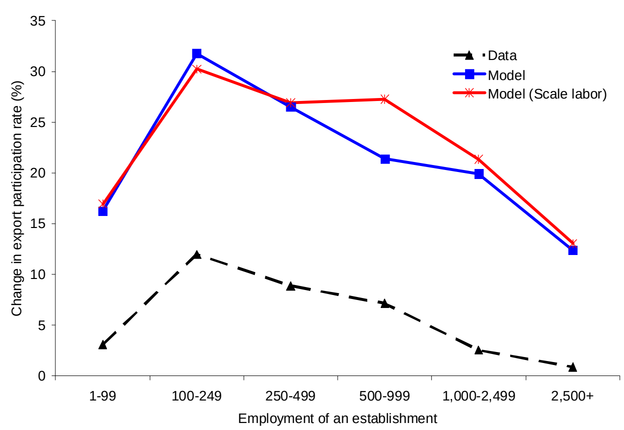


Figure 4: Dynamics of Export Participation

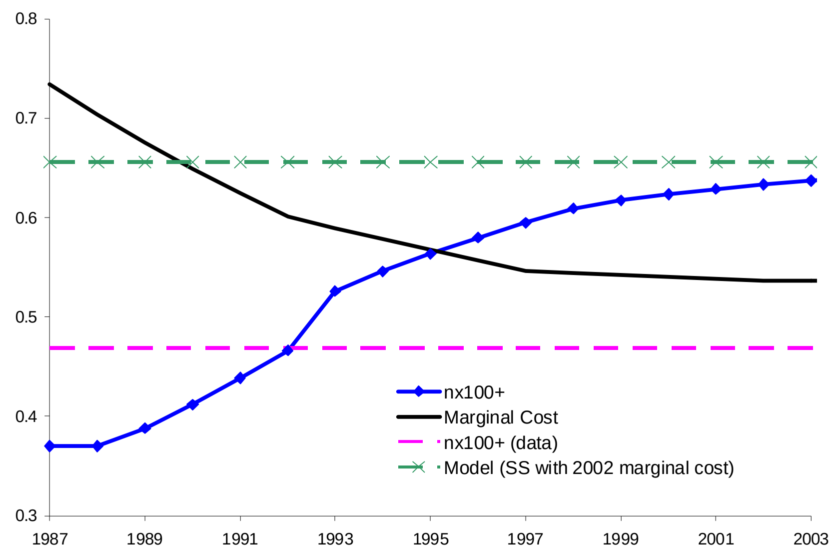
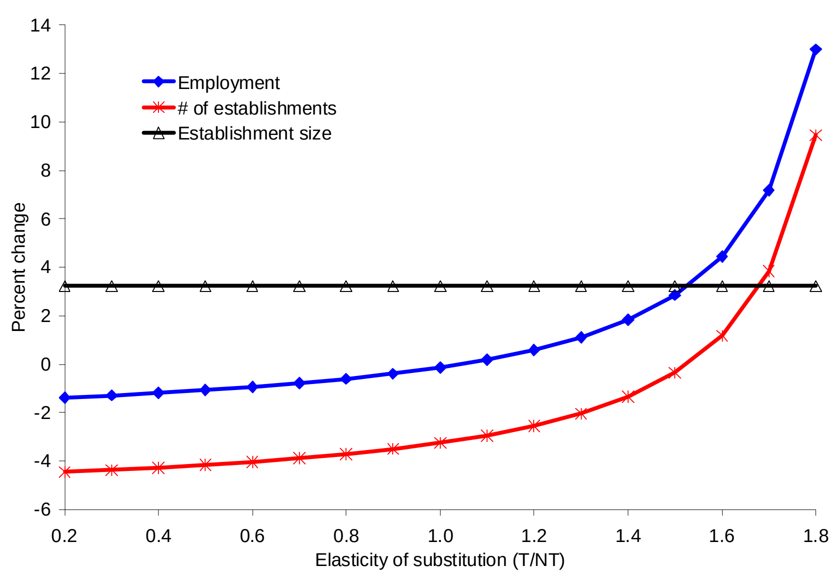


Figure 5: Tradable Sector and Elasticity of Substitution



Appendix not for publication

Here we describe some details related to solving our model (Technical Appendix) and some aspects of the data on plant heterogeneity (Data Appendix).

Technical Appendix

The simulation of the model is straightforward, once we keep track of the distributions of establishments and the value functions of producers. Here, we first describe the approximation method for the evolution of the productivity distribution of establishments and the value functions in the tradable good sector.[29] Then, we briefly describe the simulation steps for the steady state and transition dynamics computations.

Approximating Distribution of Establishments

Once we keep track of the distributions of establishments simulating the model is straightforward. Here, we describe the approximation method for the evolution of productivity densities in the tradable good sector (the non-tradable sector is similar).

In the model, the shocks to the fixed cost in exporting are drawn from a two state Markov chain, $\{\kappa_H,\ \kappa_L\} = \{\infty, 0\}$ with persistence of the low and shocks, ρ_κ^L and ρ_κ^H, respectively. From the independence of shocks between the fixed cost in exporting, κ, and the productivity, z, we have $\phi(z', \kappa'|z, \kappa) = \phi_\kappa(\kappa'|\kappa)\,\phi(z'|z)$, where $\phi_\kappa(\kappa'|\kappa)$ and $\phi(z'|z)$ are the transitional probabilities of the shock to the fixed cost in exporting and the productivity, respectively. For the entrants' distribution, we have $\phi_E(z', \kappa') = \zeta_{\kappa'}\phi_E(z')$, where $\zeta_{\kappa'}$ is the unconditional probability of $\kappa' \in \{\kappa_L, \kappa_H\}$, and $\phi_E(z')$ is the distribution of the initial idiosyncratic productivity shock.

[29] The evolution of productivity density and the value function for non-tradable good producers can be obtained using the same methods.

The measure of producers in the tradable good sector depends on the evolution of the idiosyncratic shocks and the export decisions, which are a function of the idiosyncratic and aggregate state, and evolves as

$$\begin{aligned} (46) \quad \psi_{T,t+1}\left(z',\kappa_L,1\right) &= \rho_\kappa^L \int_{z_{1,t}}^{\infty} n_s\left(z\right)\psi_{T,t}\left(z,\kappa_{L,}1\right)\phi\left(z'|z\right)dz \\ &\quad +\rho_\kappa^L \int_{z_{0,t}}^{\infty} n_s\left(z\right)\psi_{T,t}\left(z,\kappa_L,0\right)\phi\left(z'|z\right)dz, \end{aligned}$$

$$\begin{aligned} (47) \quad \psi_{T,t+1}\left(z',\kappa_L,0\right) &= \rho_\kappa^L \int_{-\infty}^{z_{1,t}} n_s\left(z\right)\psi_{T,t}\left(z,\kappa_{L,}1\right)\phi\left(z'|z\right)dz \\ &\quad +\rho_\kappa^L \int_{-\infty}^{z0} n_s\left(z\right)\psi_{T,t}\left(z,\kappa_L,0\right)\phi\left(z'|z\right)dz \\ &\quad +\left(1-\rho_\kappa^H\right)\int_{-\infty}^{\infty} n_s\left(z\right)\left[\psi_{T,t}\left(z,\kappa_{H,}1\right)+\psi_{T,t}\left(z,\kappa_{H,}0\right)\right]\phi\left(z'|z\right)dz \\ &\quad +\zeta_{\kappa_L}N_{TE,t}\phi_E\left(z'\right), \end{aligned}$$

$$\begin{aligned} (48) \quad \psi_{T,t+1}\left(z',\kappa_H,1\right) &= \left(1-\rho_\kappa^L\right)\int_{z_{1,t}}^{\infty} n_s\left(z\right)\psi_{T,t}\left(z,\kappa_{L,}1\right)\phi\left(z'|z\right)dz \\ &\quad +\left(1-\rho_\kappa^L\right)\int_{z_{0,t}}^{\infty} n_s\left(z\right)\psi_{T,t}\left(z,\kappa_L,0\right)\phi\left(z'|z\right)dz, \end{aligned}$$

$$\begin{aligned} (49) \quad \psi_{T,t+1}\left(z',\kappa_H,0\right) &= \left(1-\rho_\kappa^L\right)\int_{-\infty}^{z_{1,t}} n_s\left(z\right)\psi_{T,t}\left(z,\kappa_{L,}1\right)\phi\left(z'|z\right)dz \\ &\quad +\left(1-\rho_\kappa^L\right)\int_{-\infty}^{z_{0,t}} n_s\left(z\right)\psi_{T,t}\left(z,\kappa_L,0\right)\phi\left(z'|z\right)dz \\ &\quad +\rho_\kappa^H \int_{-\infty}^{\infty} n_s\left(z\right)\left[\psi_{T,t}\left(z,\kappa_{H,}1\right)+\psi_{T,t}\left(z,\kappa_{H,}0\right)\right]\phi\left(z'|z\right)dz \\ &\quad +\zeta_{\kappa_H}N_{TE,t}\phi_E\left(z'\right), \end{aligned}$$

where $N_{TE,t}$ is the mass of entrants in the tradable good sector in period t. We discretize the state space and interpolate to approximate the density functions as follows:

First, we choose uniformly spaced nodes for the productivity $z \in \left\{z^1, z^2, \cdots, z^J\right\}$ with an interval ω.[30] We choose z^1 and z^J so that the absolute values of them are sufficiently large enough not to affect the results. We approximate the transition probability and the entrants' initial distribution, $\widehat{\phi}\left(z^{j'}|z^j\right)$ and $\widehat{\phi}_E\left(z^{j'}\right)$, based on Tauchen (1986). The approximated densities of establishments evolve as

$$\begin{aligned}(50)\quad \widehat{\psi}_{T,t+1}\left(z^{j'}, \kappa_L, 1\right) &= \rho_\kappa^L \sum_{j=1}^{J} n_s\left(z^j\right) \widehat{\psi}_{T,t}\left(z^j, \kappa_L, 1\right) \widehat{\phi}\left(z^{j'}|z^j\right) I_{1,t}(j) \\ &+ \rho_\kappa^L \sum_{j=1}^{J} n_s\left(z^j\right) \widehat{\psi}_{T,t}\left(z^j, \kappa_L, 0\right) \widehat{\phi}\left(z^{j'}|z^j\right) I_{0,t}(j),\end{aligned}$$

$$\begin{aligned}(51)\quad \widehat{\psi}_{T,t+1}\left(z^{j'}, \kappa_L, 0\right) &= \rho_\kappa^L \sum_{j=1}^{J} n_s\left(z^j\right) \widehat{\psi}_{T,t}\left(z^j, \kappa_L, 1\right) \widehat{\phi}\left(z^{j'}|z^j\right) \left[1 - I_{1,t}(j)\right] \\ &+ \rho_\kappa^L \sum_{j=1}^{J} n_s\left(z^j\right) \widehat{\psi}_{T,t}\left(z^j, \kappa_L, 0\right) \widehat{\phi}\left(z^{j'}|z^j\right) \left[1 - I_{0,t}(j)\right] \\ &+ \left(1 - \rho_\kappa^H\right) \sum_{j=1}^{J} n_s\left(z^j\right) \left[\widehat{\psi}_{T,t}\left(z^j, \kappa_H, 1\right) + \widehat{\psi}_{T,t}\left(z^j, \kappa_H, 0\right)\right] \widehat{\phi}\left(z^{j'}|z^j\right) \\ &+ \zeta_{\kappa_L} N_{TE,t} \widehat{\phi}_E\left(z^{j'}\right),\end{aligned}$$

$$\begin{aligned}(52)\quad \widehat{\psi}_{T,t+1}\left(z^{j'}, \kappa_H, 1\right) &= \left(1 - \rho_\kappa^L\right) \sum_{j=1}^{J} n_s\left(z^j\right) \widehat{\psi}_{T,t}\left(z^j, \kappa_L, 1\right) \widehat{\phi}\left(z^{j'}|z^j\right) I_{1,t}(j) \\ &+ \left(1 - \rho_\kappa^L\right) \sum_{j=1}^{J} n_s\left(z^j\right) \widehat{\psi}_{T,t}\left(z^j, \kappa_L, 0\right) \widehat{\phi}\left(z^{j'}|z^j\right) I_{0,t}(j),\end{aligned}$$

[30] We set $n = 200$. Increasing the number of nodes more than 200 has negligible impacts on the results.

$$
\begin{aligned}
(53)\quad \widehat{\psi}_{T,t+1}\left(z^{j'},\kappa_H,0\right) \;=\;& \left(1-\rho_\kappa^L\right)\sum_{j=1}^{J} n_s\left(z^j\right)\widehat{\psi}_{T,t}\left(z^j,\kappa_{L,}1\right)\widehat{\phi}\left(z^{j'}|z^j\right)\left[1-I_{1,t}\left(j\right)\right]\\
&+\left(1-\rho_\kappa^L\right)\sum_{j=1}^{J} n_s\left(z^j\right)\widehat{\psi}_{T,t}\left(z^j,\kappa_L,0\right)\widehat{\phi}\left(z^{j'}|z^j\right)\left[1-I_{0,t}\left(j\right)\right]\\
&+\rho_\kappa^H\sum_{j=1}^{J} n_s\left(z^j\right)\left[\widehat{\psi}_{T,t}\left(z^j,\kappa_{H,}1\right)+\widehat{\psi}_{T,t}\left(z^j,\kappa_{H,}0\right)\right]\widehat{\phi}\left(z^{j'}|z^j\right)\\
&+\zeta_{\kappa_H}N_{TE,t}\widehat{\phi}_E\left(z^{j'}\right),
\end{aligned}
$$

where $I_{m,t}\left(j\right)$ is the weight function with

$$
(54)\quad I_{m,t}\left(j\right)=\begin{cases} 0 & \text{if } z^j+\omega/2\leq z_{m,t}, \\ \frac{z_{m,t}-z^j+\omega/2}{\omega} & \text{if } z^j-\omega/2<z_{m,t}<z^j+\omega/2, \\ 1 & \text{if } z^j-\omega/2\geq z_{m,t}, \end{cases}
$$

and $m\in\{0,\ 1\}$. This interpolation allows the approximated model to have continuity in the thresholds for the exporting decisions, $z_{0,t}$ and $z_{1,t}$, and smooth transition dynamics.

Value Function Approximation

We solve the model by value function iteration. The key issue in the solving the model is to solve for the evolution of the marginal exporters $\{z_{0t}, z_{1t}\}$ .Given the value functions for exporters and non-exporters in period $t+2$, $\widehat{V}_{T,t+2}\left(z^j,\kappa_i,1\right)$ and $\widehat{V}_{T,t+2}\left(z^j,\kappa_i,0\right)$, and the values of aggregate variables in period $t+1$ and $t+2$, we first obtain the value functions in period $t+1$

as

$$\begin{aligned}V_{T,t+1}\left(z^{j},\kappa_{H},m\right) &= \Pi_{T,t+1}\left(z^{j},\kappa_{H},m\right)\\&+\beta\left(\frac{C_{t+2}}{C_{t+1}}\right)^{-\sigma}n_{s}\left(z^{j}\right)\left[\left(1-\rho_{\kappa}^{H}\right)\sum_{j'=1}^{J}V_{T,t+2}\left(z^{j'},\kappa_{L},0\right)\widehat{\phi}\left(z^{j'}|z^{j}\right)\right.\\&\left.+\rho_{\kappa}^{H}\sum_{j'=1}^{J}V_{T,t+2}\left(z^{j'},\kappa_{H},0\right)\widehat{\phi}\left(z^{j'}|z^{j}\right)\right].\end{aligned}$$

$$\begin{aligned}V_{T,t+1}\left(z^{j},\kappa_{L},m\right) &= \Pi_{T,t+1}\left(z^{j},\kappa_{L},m\right)\\&+\max\left\{\beta\left(\frac{C_{t+2}}{C_{t+1}}\right)^{-\sigma}n_{s}\left(z^{j}\right)\left[\rho_{\kappa}^{L}\sum_{j'=1}^{J}V_{T,t+2}\left(z^{j'},\kappa_{L},0\right)\widehat{\phi}\left(z^{j'}|z^{j}\right)\right.\right.\\&\left.+\left(1-\rho_{\kappa}^{L}\right)\sum_{j'=1}^{J}V_{T,t+2}\left(z^{j'},\kappa_{H},0\right)\widehat{\phi}\left(z^{j'}|z^{j}\right)\right],\\&-W_{t+1}f_{m}+\beta\left(\frac{C_{t+2}}{C_{t+1}}\right)^{-\sigma}n_{s}\left(z^{j}\right)\left[\rho_{\kappa}^{L}\sum_{j'=1}^{J}V_{T,t+2}\left(z^{j'},\kappa_{L},1\right)\widehat{\phi}\left(z^{j'}|z^{j}\right)\right.\\&\left.\left.+\left(1-\rho_{\kappa}^{L}\right)\sum_{j'=1}^{J}V_{T,t+2}\left(z^{j'},\kappa_{H},1\right)\widehat{\phi}\left(z^{j'}|z^{j}\right)\right]\right\},\end{aligned}$$

With these value functions in $t+1$, we obtain the difference of values for a producer with z^{j},κ_{L}, and current exporting status m between exporting and not exporting next period as

$$\begin{aligned}dV_{T,t}\left(z^{j},\kappa_{L},m\right) &= -W_{t}f_{m}+\beta\left(\frac{C_{t+1}}{C_{t}}\right)^{-\sigma}n_{s}\left(z^{j}\right)*\\&\left\{\rho_{\kappa}^{L}\sum_{j'=1}^{J}\left[V_{T,t+1}\left(z^{j'},\kappa_{L},1\right)-V_{T,t+1}\left(z^{j'},\kappa_{L},0\right)\right]\widehat{\phi}\left(z^{j'}|z^{j}\right)\right.\\&\left.+\left(1-\rho_{\kappa}^{L}\right)\sum_{j'=1}^{J}\left[V_{T,t+1}\left(z^{j'},\kappa_{H},1\right)-V_{T,t+1}\left(z^{j'},\kappa_{H},0\right)\right]\widehat{\phi}\left(z^{j'}|z^{j}\right)\right\}.\end{aligned}$$

The difference $dV_{T,t}\left(z^{j},\kappa_{L},m\right)$ is monotonically increasing in z and passes 0 value where the producer is indifferent between exporting and not exporting. The thresholds for exporting decisions, $z_{0,t}$ and $z_{1,t}$ are obtained from

$$z_{m,t} = z_t^{j_m} - \frac{\omega dV_{T,t}\left(z_t^{j_m}, \kappa_L, m\right)}{dV_{T,t}\left(z_t^{j_m+1}, \kappa_L, m\right) - dV_{T,t}\left(z_t^{j_m}, \kappa_L, m\right)},$$

where $z_t^{j_m} = \max\left\{z^j | dV_{T,t}\left(z^j, \kappa_L, m\right) < 0\right\}$.

Parameterization and Initial Steady State Computation

Given the value for the elasticity of subsitution, θ, the iceberg trade costs in 1987 and 2002, ι_{87} and ι_{02}, are obtained based on the export intensities in 1987 and 2002. In the model, the export intensity is given as

$$\text{intensity} = \frac{(1+\iota)^{1-\theta}}{1+(1+\iota)^{1-\theta}}.$$

Thus, we set the iceberg costs in 1987 and 2002 based on the export intensity in the data as

$$\iota = \left(\frac{1-\text{intensity}}{\text{intensity}}\right)^{\frac{1}{\theta-1}} - 1$$

The other parameter values are obtained based on the key moments in the data with several steps of iterations within iterations. First, we set the parameter values for the productivity innovations and the fixed cost shock process. In this step we search for the critical levels of technology for exporters and non-exporters, z_0 and z_1, instead of the fixed costs in exporting, f_0 and f_1. Then, we find f_0 and f_1 to match the values of z_0 and z_1 in the steady state computaiton. This replacement makes computations less complicated.

1. We approximate the density function of establishment level productivity described above.

Given the values of parameters for the innovation of establishment distribution, ρ_ε, σ_ε, and μ_E, values of parameters for the shut down probability, λ, and n_{d0}, persistence of fixed cost shocks, ρ_κ^L and ρ_κ^H, and critical levels of technology for exporters and non-exporters, z_1 and z_0, together with the nomalization of entrants, we obtain the distributions of exporters, non-exporters, and non-tradable good producers.

2. With the distributions, we obtain the 5-year exit rate of entrants. We search for the parameter value of λ, given other parameter values and with the iteration in step 1, which matches the 5-year exit rate of entrants in the data.

3. We search for the critical levels of technology for exporters and non-exporters, z_1 and z_0, with the iteration in Step 2, to match the overall export participation rate and the stopper ratio of exporters.

4. In the model, the employment of an establishment is proportional to the productivity,

$$l_T(z, \kappa, m) = \eta \left[1 + m\,(1+\iota)^{1-\theta}\right] e^{(\theta-1)z},$$

where η is constant. We set η so that the model implied average employment level in the tradable good sector matches the data. Then, we obtain the distributions for establishments and export participation rate, entrants' labor share, shut-down establishments' labor share. We search for the parameter values of the innovation of establishment distribution, ρ_ε, σ_ε, and μ_E, and the shut down probability, n_{d0}, with the iteration in Step 3, to match entrants' labor share, and shut-down establishments' labor share, and minimize the distances between data and model implied distributions for the establishment share and the export participation rate.

5. Then, with the iteration in Step 4, we set the parameter values for the process of κ, ρ_κ^L. and ρ_κ^H, to minimize the distance between the model implied and data distributions.

After setting the parameter values for the innovation of productivity, the fixed cost shocks, and the thresholds for exporting decisions, z_0 and z_1, we find the steady state values, the fixed costs in exporting, f_0 and f_1, and the sunk costs in entry, f_E, with the normalization of overall number of establishments. In the steady state computation, we use a two-step procedure.

1. First, given the initial values of the aggregate variables and the fixed costs in exporting, we obtain the value functions of producers in the steady state with the thresholds for exporting decisions through the iteration of the value functions.
2. Then, we update the values of the aggregate variables, and the fixed cost parameters.
3. Repeat Steps 1 and 2 until all the steady state conditions are satisfied.

New Steady State

With the new iceberg costs, we obtain the new steady state using the following procedure:

1. Given distributions of producers and the values for the aggregate variables, we obtain the value functions in the new steady state.
2. Then, with the update of the value functions, and given distributions of producers, we update the values for the aggregate variables including z_0 and z_1.
3. With updated z_0 and z_1, we obtain the new steady state distributions of producers.
4. Repeat Steps 1 through 3 until all the steady state conditions are satisfied.

Transition Dynamics

In the transition dynamics, we assume that the steady state with ι_{1987} is achieved initially. Then, the iceberg cost falls to ι_{2002} unexpected. In the simulation exercises, we further assume that the new steady state is achieved in T periods. We set T sufficiently large so that the resulting transitions are extremely insensitive to an increase in T.[31] We set the initial guesses of the sequences of variables, value functions, and densities of establishments based on initial and new steady state values.[32] Then, we use two period overlapping blocks to update the guessed values, densities, and value functions. The two period overlapping block computation gives more flexibility in updating the values and reduces the initial value problems. We use the following procedure for the transition dynamics computation:

1. First, given the current period, t, densities of establishments, $\psi_{T,t}^{(i)}(z,\kappa,m)$ and $\psi_{N,t}^{(i)}(z)$, and the future values of the value functions, $V_{T,t+2}^{(i)}(z,\kappa,m)$ and $V_{N,t+2}^{(i)}(z)$, we obtain the current and next period, t and $t+1$, variables' values with which the current and next period equilibrium conditions are satisfied. Here, the superscript (i) denotes the i_{th} iteration. In this step, we revise the densities of establishments in period $t+1$ and $t+2$, and the value functions in period t and $t+1$ for each set of guessed variables' values.
2. Once the equilibrium conditions for period t and $t+1$ are satisfied, we update the values of period t variables, next period densities, $\psi_{T,t+1}^{(i+1)}(z,\kappa,m)$ and $\psi_{N,t+1}^{(i+1)}(z)$, and the next period value functions, $V_{T,t+1}^{(i+1)}(z,\kappa,m)$ and $V_{N,t+1}^{(i+1)}(z)$. Note that the densities of establishments in period $t+1$ is determined in period t in the model. Also note that the entrants and

[31] In the simulations, we set $T = 300$. The results show that all the variables become very close to the new steady state in $t = 100$.

[32] For example, we can set the initial guesses of sequences as the weighted averages of the two steady state values.

incumbents care about the expected value of producers next period not the current period for their entry and exporting decisions in the model.

3. Do Steps 1 and 2 for $t = 1$ through $t = T - 1$.

4. Repeat Steps 1 through 3 until all the sequences of variables, densities, and value functions converge.

5. Check if the convergence of variables to the new steady state are achieved many periods before T. Otherwise, increase the terminal period T and redo all steps again.

Data Appendix

Here we summarize some aspects of the changing scale of U.S. manufacturing establishments over time. In particular, we consider two things. First, we examine how changes in industry composition have affected the scale of establishments in manufacturing. Second, we consider how the change in industrial classification in 1997 from SIC to NAICS affects both the scale of establishments and size of the manufacturing sector. With respect to industry composition, we find that changes in the industry composition actually have hidden some of the shift to smaller scale establishments within manufacturing. With respect to the change in classification scheme, we find a very small effect on the size distribution of establishments. We do find that some of the contraction in manufacturing (about 3.8 percent out of 17.2 percent) can be attributed to industries being moved out of the manufacturing classification in NAICS.

Industry composition: One possible explanation for the shift toward smaller scale establishments is that it reflects a change in the industry composition of manufacturing. Indeed, if the US has a comparative advantage in industries with smaller establishments, then increased global integration would go hand-in-hand with smaller establishments. To see if this is the case, we control for changes in the scale of production from changes in the industry composition in production by calculating average employment per establishment as a weighted average of each industry's share of employment in a base year (data is from each Census of Manufacturers). For simplicity, we choose our base year as 1972. Thus average employment per establishment in period t is calculated as

$$
\begin{aligned}
l_t^* &= \sum_{j=1}^{J} \alpha_j L_{j,t}/N_{j,t}, \\
\alpha_j &= L_{j,1972}/\sum_{j=1}^{J} L_{j,1972},
\end{aligned}
$$

where j is a 4 digit SIC industry.[33] Figure A1 plots the change in average size (denoted unweighted), our weighted measure of size (denoted Laspeyres), and a measure that weights each industry the same (denoted even weights). Controlling for changes in industry composition, from 1972 to 1997 we actually find even larger declines in scale than with our raw measure (39 percent vs. 22 percent). Thus, it appears changes in the industry composition actually hid an even larger change in the scale of production.

SIC to NAICS in 1997: One problem in a time series study of US manufacturing is the change in the classification system in 1997 from the Standard Industrial Classification (SIC) to the North American Industrial Classification System (NAICS). At the level of manufacturing, some establishments were added to manufacturing while others were dropped.[34] This switchover

[33] In 1987 a new SIC system was put in place to replace the 1972 SIC classification and so industries were concorded.

[34] The prominent industries included in manufacturing from NAICs (but not in manufacturing in SIC) were bakeries, candy stores where candy is made on the premises, custom tailers, makers of custom draperies, and tire retreading. While the industries subtracted were primarily logging and publishing. Another change from NAICs is that auxiliaries with manufacturing are no longer included in the manufacturing date. These auxiliaries function primarily to manage, service, or support the activities of their company's operating establishments, such as a central administrative office or warehouse

potentially affects the size of manufacturing in the economy as well as the scale of production within manufacturing. Fortunately, in the switchover year, plants were classified both ways and so it is possible to get a sense of the influence of the switchover on both margins. We find that not accounting for the switchover tends to overstate the decline in manufacturing but has a much smaller effect on the scale of establishments in manufacturing.

For the size of the manufacturing sector, we find that the shift from SIC to NAICs lowers the number of manufacturing establishments by 3.8 percent and the number of employees by 3.7 percent. Given the similar drop in workers and establishments the average establishment size falls by less than 0.1 percent (from 46.47 to 46.43 employees). Thus, while the NAICS switchover contributes partly to the contraction of manufacturing, it appears to have very little impact on the average scale of production within manufacturing.

While the switchover may have a small effect on average scale, it may still have affected the size distribution since it affected many firms. From a gross standpoint, as a share of the SIC-based Census, industries dropped from manufacturing accounted for 9.8 percent of establishments and 4.7 percent of employees, while those added accounted for 6.3 percent of establishments and 0.9 percent of employees (as a share of the NAICS-based Census). Given that switchover affected 5 to 10 percent of the establishments (and 0.9 percent to 4.7 percent of employment) the NAICS switchover may contribute to some of the shift toward small scale manufacturing. Indeed, the average plant leaving manufacturing had 22.3 employees while the average new plant had only 6.7 employees. Thus, some of the shift to smaller plants may be a measurement issue.

To control for the role of this switch over our sample period, we constructed the size distribution of plants in 1997 using both the SIC and NAICS classification.[35] We then calculated the total change in the size distribution as the change in the share of employment from 1987 to 1997 using the SIC code and the change from 1997 to 2002 using the NAICS classification. Figure A2 plots our measure taking account the NAICS revision along with the raw measure in the text. Clearly, both measures tell the same story - there has been an important shift from large plants to small plants.

[35] To construct the SIC employment-size distribution, it was necessary to estimate the size distribution in a small number of industries that were affected by the switchover. For each of the affected industries we know the average size and number of plants plus some moments of the distribution (i.e. plants and employees within certain sizes) but lacked information on certain employment classes because of disclosure reasons.

Figure A1: Change in Average Employment Size in Manufacturing (1972 to 1997)

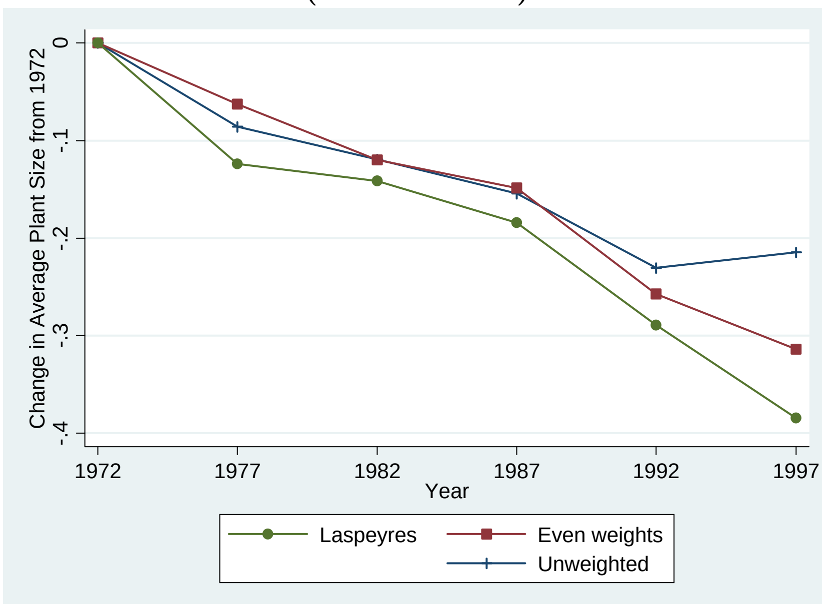


Figure A2: Change in Employment size distribution adjusted for NAICS switchover