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George Alessandria
Federal Reserve Bank of Philadelphia

Horag Choi
Monash University

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

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George Alessandria†
Federal Reserve Bank of Philadelphia
George.Alessandria@phil.frb.org

Horag Choi
Monash University
Horag.Choi@monash.edu

Abstract
We study empirically and theoretically the growth of U.S. manufacturing exports from 1987 to 2007. We identify the change in iceberg costs with plant-level data on the intensity of exporting by exporters. Given this change in iceberg costs, we find that a GE model with heterogeneous establishments and a sunk cost of starting to export is consistent with both aggregate U.S. export growth and the changes in the number and size of U.S. exporters. The model also captures the non-linear dynamics of U.S. export growth. A model without a sunk export cost generates substantially less trade growth and misses out on the timing of export growth. 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. Allowing for faster productivity growth in manufacturing, changes in capital intensity, and some changes in the underlying shock process makes the theory consistent with the changes in the employment size distribution. We also find that the contribution of trade to the contraction in U.S. manufacturing employment is small.

JEL classifications: E31, F12.
Keywords: Export Growth, Trade, Sunk Costs.

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†Corresponding author: george.alessandria@phil.frb.org, Ten Independence Mall, Philadelphia, PA 19106.

1. Introduction

The world has become much more integrated. For instance, the ratio of U.S. exports of non-agricultural goods to manufacturing shipments more than quadrupled[1] from 1967 to 2007. While this process has been ongoing, it clearly has accelerated since the mid-1980s. In an influential paper, Yi (2003) shows that this acceleration in U.S. export 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 appears to have increased, while in standard models it is constant. In this paper, we reconsider the high export growth period,[2] 1987 to 2007, through the lens of a model of establishment heterogeneity and endogenous exporting. We find no puzzle. Given the observed change in trade costs, trade grew about what could be expected. Moreover, any non-linearities in the relationship between trade costs and trade during this period are consistent with the model's predictions.

Our interpretation of the trade data differs from Yi for two reasons. First, our benchmark model of trade differs. Yi studies trade growth following a cut in per unit, or iceberg, trade costs 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, 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 heterogeneous in productivity and must incur some fixed costs to

[1] The ratio of nominal non-agriculatural exports to nominal manufacturing shipments rose from approximately 4.9 percent in 1967 to 20.1 percent in 2007.

[2] Data also limit us to this period since the 1987 Census of Manufactures 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 starts to cross the border multiple times as intermediates and in final goods.

export (both to start and to continue exporting) along with iceberg costs. In this framework, as in the data, 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 because exporters become relatively larger than non-exporters and account for more output (what we call the size premium). Thus, there are two additional margins of trade growth.

The second difference between our study and Yi's comes from our measure of the change in iceberg trade costs. In an Armington model, the one-to-one relationship between the share of output exported and iceberg trade costs 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 that this has increased over time. However, iceberg trade costs also depend on transportation, insurance, finance and other frictions, making these changes in tariffs a potentially poor measure of changes in iceberg costs. With 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.[4] Using establishment-level data on exporting from the U.S. Census of Manufactures, 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? Focusing on the period 1987 to 2007 for which we can measure the change in iceberg costs, we find the model

[4] Using export intensity has the added advantage in evaluating the performance of models for trade growth that the export intensity has a one-to-one relationship with the elasticity adjusted iceberg trade costs in the model. Thus, when the model is calibrated to match the size distribution with the elasticity adjusted productivity, the model becomes largely independent of the elasticity of substitution between varieties.

comes quite close to matching the growth in U.S. exports. The model predicts that the share of manufacturing shipments exported should have grown 65 to 72 percent, while in the data we find exports grew about 68 to 72 percent. Moreover, we find that the model comes close to matching the contribution from increased export participation and changes in the size premium of exporters. The key to generating these results is the presence of a sunk export cost so that the costs of starting to export are higher than the costs of continuing to export as in the models of Baldwin and Krugman (1989), Dixit (1989), and Das, Roberts, and Tybout (2007). With this sunk cost, becoming an exporter is a durable investment. When there is no sunk export cost, so the costs of starting to export are the same the costs of continuing to export, the decision to export is static and exports grow substantially less, as there are fewer plants that become exporters.

We also consider the timing of U.S. export growth from 1987 to 2007. Empirically, we find a non-linear relation between the fall in iceberg costs and the increase in trade. From 1987 to 1997, total exports grew about 36 percent more than the intensive margin of exports, while over the whole 20-year period, exports grew about 67 percent more than the intensive margin. We find that this type of non-linear relationship between export growth and trade costs arises when exporters face a sunk cost of exports. With a sunk export cost, following a cut in iceberg costs, there is a gradual buildup of exporters. When there is no sunk cost, as is the standard approach in the literature,[5] there is no non-linearity in export growth. Thus, we find that the nature of fixed export costs is crucial to explaining U.S. export growth.

With a good model of U.S. export growth, we then consider the contribution of international trade to the changes in manufacturing over this period. Specifically, we find that trade has had a relatively small role in the shift away from large manufacturing establishments and the shift from

[5] Original papers on exporting with fixed costs focused on the sunk cost to explain the non-linear response of exports to real exchange rate movements (Baldwin and Krugman, 1989, and Dixit, 1989, Roberts and Tybout, 1997). However, more recent work has abstracted from sunk costs.

manufacturing to non-manufacturing. Indeed, in our baseline model the changes in trade should have increased average plant size by about 0.9 percent, while in the data they have fallen by 20.3 percent. Moreover, the model predicts a reduction in the share of employment in manufacturing of 1.4 percent compared to nearly 52 percent in the data. Most of these changes can be resolved by feeding in the observed changes in productivity in manufacturing relative to the whole economy. Changes in the capital intensity in manufacturing and the idiosyncratic shock process hitting plants play a much smaller role.

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,[6] while Alessandria and Choi (2011) study export participation among U.S. manufacturers in 1992 in a version of the Melitz model extended to allow sunk export costs in the spirit of Das, Roberts, and Tybout (2007). 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 U.S. 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, our analysis focuses on whether the magnitude and timing of aggregate and distributional changes

[6] Alvarez and Lucas (2007) 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.

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,[7] 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), and Bridgman (2008)). Hummels (2007) identifies some of the challenges in measuring the change in trade costs, showing 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 led to a massive expansion of air freight. A second line of research uses models with fixed costs of trade to understand international business cycle fluctuations (see Ruhl (2003), Alessandria and Choi (2007), 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), Das, Roberts, and Tybout (2007) and Alessandria and Choi (2011) 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

[7] Some additional papers studying trade policy in heterogeneous plant models include Roberts and Tybout (1997), Melitz (2003), Das, Roberts and Tybout (2007), Baldwin and Robert-Nicoud (2005), Baldwin and Forslid (2006), and Atkeson and Burstein (2010).

following the observed change in iceberg costs. In section 6, we investigate the effect of the changes in manufacturing on our results and provide some sensitivity analysis. Section 7 concludes.

2. Aggregate and Disaggregate U.S. Export Growth

We begin by describing some of the changes in exports and exporting in the U.S. manufacturing sector from 1987 to 2007. We focus 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 data analysis is based on special tabulations by the Census using the 1987, 1992, 1997, 2002, and 2007 Census of Manufactures. We also relate these changes in exports to changes in fundamentals, particularly changes in iceberg trade costs and the characteristics of exporters. Table 1 summarizes the key changes in the manufacturing exports over this period using the Census of Manufactures as well as measures from customs data.

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,

$$\begin{aligned} d\left(p, Y\right) &= p^{1-\theta} Y, \\ ex\left(p^*, Y^*\right) &= p^{*1-\theta} Y^*, \end{aligned}$$

where d denotes revenue at home, ex denotes revenue from exports, θ denotes the elasticity of demand, Y and Y^* denote home and foreign income, and p and p^* denote prices of the goods at home and abroad.[8] Suppose further that the foreign consumers must incur an iceberg cost, $\iota > 1$, which includes both shipping costs and tariffs, to purchase these products. If the establishment sells its products at home and abroad for the same price (prior to the iceberg cost), then the ratio of

[8] This assumes that the price level in each country is the same and normalized to 1.

exports to domestic sales equals

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

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,

$$\Delta ex - \Delta d = (1 - \theta)\, \Delta\iota + \Delta y^* - \Delta y.$$

The second column of Table 1 reports a 73.5 percent increase in the ratio of exports to domestic sales from 1987 to 2007. 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

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

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 data from the Penn World Tables, 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 16.0 percentage points and account for about 85 percent of the increase in export growth.

[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. 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.

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. Yi argues that U.S. export tariffs fell from 5 to 3 percent from 1987 to 2000. Assuming they fell to zero from 2000 to 2007, then with the 5 percentage-point fall in tariffs, the model requires an elasticity of approximately 14 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.

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.* This is true when we look at all manufacturing plants or plants with 100+ employees. Clearly, the representative agent model 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, taking logs, the change in the ratio of exports to total sales can be decomposed into three components,

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

$$\begin{array}{cccc} 67.7 & 44.6 & -0.6 & 23.7 \end{array}$$

All four components can be measured using data from the Census of Manufactures. Focusing on all plants, the data show that the 67.7 percent increase in the share of manufactured goods exported has been associated with a 44.6 percent rise in the intensity with which exporters sell their products overseas, a 0.6 percent fall in the size of exporters relative to all establishments in the U.S. and a 23.7 percent increase in export participation. If we focus only on those plants with 100 or more employees the increase is about 61.1 percent and can be decomposed into 44.9 percent for the intensive margin, a 21.4 percent decline in the premium, and a 37.7 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 2007, can the benchmark model of export participation and dynamics explain the change in exports and export participation in the U.S.?

A. Plant- and customs-level measures of export growth

An alternative measure of the change in exports can be constructed with customs data. A benefit of the customs data is that they are based on shipment-level data and thus are likely to provide a more accurate measure of U.S. export growth than the census, which is based on a survey. That survey is not particularly well suited to capture exports by small plants. In terms of disadvantages, changes in the costs of getting goods from the factory gate to port will increase exports in the customs-level data but will not affect the measure of exports using the census. Second, goods that are exported by intermediaries such as wholesalers will be included in the customs data.

The seventh column in Table 1 shows that using customs data, the ratio of U.S. exports to manufacturing shipments grew 74.3 log points compared to 67.7 log points for the census data.[11] Removing the change in internal distribution margins reduces the increase in exports to 71.3 percent.[12] The remaining gap of about 4 percentage points between the census and the customs data may arise from measurement problems in the Census data or a rising importance of intermediated trade by wholesalers.

3. The Model

In this section, we present a variation of the dynamic model of exporting and trade developed in Alessandria and Choi (2011). This model contains the two key features of the Melitz (2003) model[13] of exporting: producer heterogeneity and fixed costs of exporting. Unlike in Melitz, producers face uncertainty over both productivity and fixed export costs. Each period a mass of existing establishments is 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 shut down,[14] and new establishments

[11] Our measure of exports excludes re-exports - essentially foreign products that are exported with no value added. Re-exports have become relatively more important over time and including the growth of re-exports would boost export growth to 82 log points.

[12] According to the census' Direct Exports report, in 2009 the wholesale margin added about 10.5 percent to the cost of goods. We assume that these margins increased by about 30 percent from 1987 to 2007, which is the same amount by which the ratio of wholesale to manufacturing shipments increased.

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

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

are created by incurring a sunk cost. We focus on this dynamic variation of the Melitz model, since work by Das, Roberts, and Tybout (2007) and Alessandria and Choi (2011) find that it more accurately captures plant-level exporter dynamics.

There are two symmetric countries, *home* and *foreign.* Each country is populated by a continuum of identical, infinitely lived consumers with unit mass. Consumers inelastically supply L units of labor each period.

In each country there are two intermediate good sectors, tradable and non-tradable, 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 non-tradable goods sectors are $N_{T,t}$ and $N_{N,t}$, respectively. Foreign variables are denoted with an asterisk. A non-tradable good producer uses capital and labor inputs to produce its variety, whereas a tradable good producer uses capital, labor, and material inputs to produce its variety.[15] In each sector, establishments differ in terms of total factor productivity and the markets they serve. The non-tradable sector is necessary to capture the large changes in the sectoral composition of output.

All establishments sell their product in their own country, but only some establishments in the tradable good sector export. When an establishment in the tradable good sector exports, the establishment incurs some international trading cost, an ad valorem transportation cost[16] with the rate of ι_t.[17] Additionally, an establishment has to pay a fixed cost to export its goods abroad. Unlike in 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.

[15] Materials are included in the tradable sector for two reasons even though the use of materials does not affect the trade share in the tradable sector directly. First, the model with material inputs in the tradable sector is consistent with the observation that trade as a share of gross output is considerably smaller than trade as a share of value-added. Second, with non-unitary substitution between non-tradables and tradables materials affect the allocations across sectors.

[16] All iceberg costs are attributed to physical transportation costs rather than a combination of transport costs and tariffs. This distinction matters primarily for welfare but has almost no impact on the division of activity across countries.

[17] 'Iceberg' transportation costs require $1 + \iota$ units to be shipped for 1 unit to arrive at the destination.

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 $e^{\kappa} f_0 > 0$ 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 period-by-period fixed continuation cost $e^{\kappa} f_1$, where $f_1 < f_0$. 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 $e^{\kappa} f_0$ where κ is a new draw. These costs are valued in a combination of domestic final goods, g_f, and domestic labor, l_f, with a Cobb-Douglas function, $g_f^{\zeta} l_f^{1-\zeta}$, and have a unit cost $P_E = (P/\zeta)^{\zeta} (PW/(1-\zeta))^{1-\zeta}$, where P and W are the price of the final goods and real wage rates, respectively. 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 incurring f_E units of the entry good, which is a combination of the domestic final goods and domestic labor with the Cobb-Douglas function, $g_f^{\zeta} l_f^{1-\zeta}$. The entry cost is sunk so that it is not recovered on exit. 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.[18] The cost of exporting implies that the set of

[18]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.

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.

In this economy, there exists a one-period single nominal bond denominated in the home currency.[19] 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,

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

where $\beta \in (0,1)$ is the time discount factor; 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; and Π_t is the sum of real dividends from the home country's producers.

The foreign consumer's problem is analogous. Prices and allocations in the foreign country are represented with an asterisk. Money has no role in this economy and is only a unit of account.

[19] 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 and to introduce the stochastic discount factor Q.

The foreign budget constraint is expressed as

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

where e_t is the nominal exchange rate with home currency as numeraire.[20]

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 combining 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 active in the home market. The final good can be produced by combining a composite good produced of tradables, D_T, and a composite

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

good produced of non-tradables, D_N, using a CES function.

$$(1)\quad D_t = \left[a^{\gamma} D_{T,t}^{\frac{\gamma-1}{\gamma}} + (1-a)^{\gamma} D_{N,t}^{\frac{\gamma-1}{\gamma}}\right]^{\frac{\gamma}{\gamma-1}}$$

The production technologies of the composite tradable and non tradable goods are,

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

where $y_{H,t}^{d}\left(z,\kappa,m\right)$ 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 state $(z,\kappa,1)$, respectively and $y_{N,t}^{d}\left(z\right)$ is the input of intermediate good purchased from a home non-tradable 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

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

subject to the production technology (1), (2), and (3).[21] Here $P_{H,t}\left(z,\kappa,m\right)$ and $P_{F,t}\left(z,\kappa,1\right)$ are

[21] 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.

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 non-tradable intermediate goods produced by a home producer with z. Solving the problem in (4) gives the input demand functions,

$$y^d_{H,t}(z,\kappa,m) = a\left[\frac{P_{H,t}(z,\kappa,m)}{P_{T,t}}\right]^{-\theta}\left(\frac{P_{T,t}}{P_t}\right)^{\gamma-1} D_t, \tag{5}$$

$$y^d_{F,t}(z,\kappa,1) = a\left[\frac{P_{F,t}(z,\kappa,1)}{P_{T,t}}\right]^{-\theta}\left(\frac{P_{T,t}}{P_t}\right)^{\gamma-1} D_t, \tag{6}$$

$$y^d_{N,t}(z) = (1-a)\left[\frac{P_{N,t}(z)}{P_{N,t}}\right]^{-\theta}\left(\frac{P_{N,t}}{P_t}\right)^{\gamma-1} D_t, \tag{7}$$

where the price indices are defined as

$$P_{T,t} = \left(\sum_{m=0}^{1}\int_{z\times\kappa} P_{H,t}(z,\kappa,m)^{1-\theta}\psi_{T,t}(z,\kappa,m)\,dzd\kappa + \int_{z\times\kappa} P_{F,t}(z,\kappa,1)^{1-\theta}\psi^*_{T,t}(z,\kappa,1)\,dzd\kappa\right)^{\frac{1}{1-\theta}}, \tag{8}$$

$$P_{N,t} = \left(\int_z P_{N,t}(z)^{1-\theta}\psi_{N,t}(z)\,dz\right)^{\frac{1}{1-\theta}}, \tag{9}$$

$$P_t = \left[aP_{T,t}^{1-\gamma} + (1-a)P_{N,t}^{1-\gamma}\right]^{\frac{1}{1-\gamma}}. \tag{10}$$

Final goods are used for consumption, investment, fixed export costs, and new establishments.

C. Intermediate Good Producers

Intermediate good producers differ by their sector, productivity, export costs,[22] and export status. We assume that an incumbent's idiosyncratic productivity, z, and fixed cost shock, κ, follows a first-order Markov process with a transition probability $\phi(z', \kappa'|z, \kappa)$, 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 $\phi_E(z', \kappa')$. An establishment's exogenous survival probability, $n_s(z) \in [0, 1]$, is

[22] This implicitly assumes non-tradable intermediates export costs are infinite and hence dropped from the notation.

assumed to depend on its productivity, z.

Non-Tradable Good Producers

The problem of a non-tradable good producer from the home country in period t with technology z is to choose its current price $P_{N,t}(z)$, inputs of labor $l_{N,t}(z)$ 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

$$\begin{aligned}(12) \quad V_{N,t}(z) &= \max \Pi_{N,t}(z) + n_s(z) Q_t \left(\frac{P_{t+1}}{P_t}\right) \int_{z'} V_{N,t+1}(z') \phi(z'|z) dz', \\ (13) \quad \Pi_{N,t}(z) &= \left[\frac{P_{N,t}(z)}{P_t}\right] y_{N,t}(z) - W_t l_{N,t}(z) - R_t k_{N,t}(z)\end{aligned}$$

subject to the production technology (11), and the constraint that the supply of the non-tradable goods, $y_{N,t}(z)$ equals the demand by final good producers $y^{d}_{N,t}(z)$ in (7).

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 $P^{*}_{H,t}(z, \kappa, m)$, inputs of labor $l_{T,t}(z, \kappa, m)$, capital $k_{T,t}(z, \kappa, m)$, and materials $x_t(z, \kappa, m)$, and the next period's export status, $m_{t+1}(z, \kappa, m)$. Total materials, $x_t(z, v, m)$, are composed of tradable intermediate goods with the CES function as in (2).

The producer has a Cobb-Douglas production technology,

$$(14) \quad y_{T,t}(z, \kappa, m) = e^{z} \left[k_{T,t}(z, \kappa, m)^{\alpha} l_{T,t}(z, \kappa, m)^{1-\alpha}\right]^{1-\alpha_x} x_t(z, \kappa, m)^{\alpha_x}.$$

The value of a producer is

$$(15)\quad V_{T,t}(z,\kappa,m)=\max\left\{V_{T,t}^{1}(z,\kappa,m),V_{T,t}^{0}(z,\kappa,m)\right\}$$

where the value of exporting in period $t+1$ is

$$\begin{aligned}(16)\quad V_{T,t}^{1}(z,\kappa,m) &= \max\Pi_{T,t}(z,\kappa,m)-\left(\frac{P_{E,t}}{P_t}\right)f_m e^{\kappa}\\ &+n_s(z)\,Q_t\left(\frac{P_{t+1}}{P_t}\right)\int_{z'\times\kappa'}V_{T,t+1}(z',\kappa',1)\,\phi(z',\kappa'|z,\kappa)\,dz'd\kappa',\end{aligned}$$

and the value of not exporting in period $t+1$ is

$$\begin{aligned}(17)\quad V_{T,t}^{0}(z,\kappa,m) &= \max\Pi_{T,t}(z,\kappa,m)\\ &+n_s(z)\,Q_t\left(\frac{P_{t+1}}{P_t}\right)\int_{z'\times\kappa'}V_{T,t+1}(z',\kappa',0)\,\phi(z',\kappa'|z,\kappa)\,dz'd\kappa'.\end{aligned}$$

Period profits are defined as

$$\begin{aligned}(18)\quad \Pi_{T,t}(z,\kappa,m) &= \left[\frac{P_{H,t}(z,\kappa,m)}{P_t}\right]y_{H,t}(z,\kappa,m)+\left[\frac{e_t P_{H,t}^{*}(z,\kappa,m)}{P_t}\right]y_{H,t}^{*}(z,\kappa,m)\\ &-W_t l_{T,t}(z,\kappa,m)-R_t k_{T,t}(z,\kappa,m)-P_{T,t}x_t(z,\kappa,m).\end{aligned}$$

The producer makes decisions subject to the production technology (14) and the constraints that the supply to home and foreign tradable goods markets, $y_{H,t}(z,\kappa,m)$ and $y_{H,t}^{*}(z,\kappa,m)$ with $y_{T,t}(z,\kappa,m)=y_{H,t}(z,\kappa,m)+(1+\iota)\,y_{H,t}^{*}(z,m)$, is equal to the demand by final good producers from (5) and the foreign analogue of (6), and demand by intermediate good producers for material inputs.

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_T^1 intersects V_T^0 from below as long as there are some establishments that do not export. Hence, it is possible to solve for the cutoff 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 an export cost κ, the critical level of technology for exporters and non-exporters, $z_{1,t}(\kappa)$ and $z_{0,t}(\kappa)$, satisfy

$$V_{T,t}^{1}\left(z_{1,t}\left(\kappa\right),1\right) = V_{T,t}^{0}\left(z_{1,t}\left(\kappa\right),1\right), \tag{19}$$

$$V_{T,t}^{1}\left(z_{0,t}\left(\kappa\right),0\right) = V_{T,t}^{0}\left(z_{0,t}\left(\kappa\right),0\right). \tag{20}$$

D. Entry

Each period, a new establishment can be created by incurring f_E entry costs. 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 $\phi_E(z', \kappa')$. Entrants are free from death shocks. New entrants can not export in their first productive period. Thus, the entry conditions are

$$V_{T,t}^{E} = -\left(\frac{P_{E,t}}{P_t}\right) f_E + Q_t \left(\frac{P_{t+1}}{P_t}\right) \int_{z' \times \kappa'} V_{T,t+1}\left(z', \kappa', 0\right) \phi_E\left(z', \kappa'\right) dz' d\kappa' \leq 0, \tag{21}$$

$$V_{N,t}^{E} = -\left(\frac{P_{E,t}}{P_t}\right) f_E + Q_t \left(\frac{P_{t+1}}{P_t}\right) \int_{z'} V_{N,t+1}\left(z'\right) \phi_E\left(z'\right) dz' \leq 0. \tag{22}$$

In the non-tradable good sector, let $N_{NE,t}$ denote the mass of entrants in period t and let the mass of incumbents be $N_{N,t}$. The mass of establishments in the non-tradable good sector equals

$$N_{N,t} = \int_z \psi_{N,t}\left(z\right) dz.$$

In the tradable sector, let $N_{TE.t}$ denote the mass of entrants in period t, while the mass of incumbents is $N_{T,t}$. The masses of exporters and non-exporters are then

$$(23) \quad N_{1,t} = \int_{z \times \kappa} \psi_{T,t}(z, \kappa, 1)\, dz d\kappa,$$

$$(24) \quad N_{0,t} = \int_{z \times \kappa} \psi_{T,t}(z, \kappa, 0)\, dz d\kappa,$$

and the mass of establishments in the tradable good sector equals

$$(25) \quad N_{T,t} = N_{1,t} + N_{0,t}.$$

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 $z_{0,t}(\kappa)$, the starter ratio, the fraction of establishments that start exporting among non-exporters, is

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

Similarly, the stopper ratio, the fraction of exporters who stop exporting among surviving establishments, is

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

The evolution of the mass of establishments is given by

$$(26) \quad \psi_{T,t+1}(z', \kappa', 1) = \int_{\kappa} \int_{z_{0,t}(\kappa)}^{\infty} n_s(z)\, \psi_{T,t}(z, \kappa, 0)\, \phi(z', \kappa' | z, \kappa)\, dz d\kappa + \int_{\kappa} \int_{z_{1,t}(\kappa)}^{\infty} n_s(z)\, \psi_{T,t}(z, \kappa, 1)\, \phi(z', \kappa' | z, \kappa)\, dz d\kappa,$$

$$(27)\quad \psi_{T,t+1}\left(z',\kappa',0\right) = \int_{\kappa}\int_{-\infty}^{z_{0,t}(\kappa)} n_s(z)\,\psi_{T,t}(z,\kappa,0)\,\phi\left(z',\kappa'|z,\kappa\right)dzd\kappa + \int_{\kappa}\int_{-\infty}^{z_{1,t}(\kappa)} n_s(z)\,\psi_{T,t}(z,\kappa,1)\,\phi\left(z',\kappa'|z,\kappa\right)dzd\kappa + N_{TE,t}\phi_E\left(z',\kappa'\right),$$

$$(28)\quad \psi_{N,t+1}\left(z'\right) = \int_z n_s(z)\,\psi_{N,t}(z)\,\phi\left(z'|z\right)dz + N_{NE,t}\phi_E\left(z'\right).$$

E. Aggregate Variables

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

$$(29)\quad I_t = K_t - (1-\delta)\,K_{t-1}.$$

Nominal exports and imports are given as

$$(30)\quad EX_t^N = \int_{z\times\kappa} e_t P_{H,t}^*(z,\kappa,1)\,y_{H,t}^*(z,\kappa,1)\,\psi_{T,t}(z,\kappa,1)\,dzd\kappa,$$

$$(31)\quad IM_t^N = \int_{z\times\kappa} P_{F,t}(z,\kappa,1)\,y_{F,t}(z,\kappa,1)\,\psi_t^*(z,\kappa,1)\,dzd\kappa,$$

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

$$(32)\quad Y_t^N = P_t D_t + EX_t^N - IM_t^N.$$

The ratio of trade to GDP is given as

$$(33)\quad TR_t = \frac{EX_t^N + IM_t^N}{2Y_t^N}.$$

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

$$(34)\quad L_{P,t} = \sum_{m=0}^{1} \int_{z\times\kappa} l_{T,t}(z,\kappa,m)\,\psi_{T,t}(z,\kappa,m)\,dzd\kappa + \int_{z} l_{N,t}(z)\,\psi_{N,t}(z)\,dz.$$

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

$$(35)\quad L_{X,t} = (1-\zeta)\left(\frac{P_{E,t}}{P_t W_t}\right)\left[\int_{\kappa}\int_{z_{0,t}(\kappa)}^{\infty} f_0 e^{\kappa}\psi_{T,t}(z,\kappa,0)\,dzd\kappa + \int_{\kappa}\int_{z_{1,t}(\kappa)}^{\infty} f_1 e^{\kappa}\psi_{T,t}(z,\kappa,1)\,dzd\kappa\right].$$

The domestic labor hired for creating new establishments, $L_{E,t}$, is given by

$$(36)\quad L_{E,t} = (1-\zeta)\,f_E\left(\frac{P_{E,t}}{P_t W_t}\right)(N_{TE,t} + N_{NE,t}).$$

From (35), we see that the trade cost depends on the exporter status from the previous period.

The domestic final goods used by exporters for fixed/sunk costs, $G_{X,t}$, are given by

$$(37)\quad G_{X,t} = \zeta\left(\frac{P_{E,t}}{P_t}\right)\left[\int_{\kappa}\int_{z_{0,t}(\kappa)}^{\infty} f_0 e^{\kappa}\psi_{T,t}(z,\kappa,0)\,dzd\kappa + \int_{\kappa}\int_{z_{1,t}(\kappa)}^{\infty} f_1 e^{\kappa}\psi_{T,t}(z,\kappa,1)\,dzd\kappa\right].$$

The domestic final goods for creating new establishments, $G_{E,t}$, is given by

$$(38)\quad G_{E,t} = \zeta f_E\left(\frac{P_{E,t}}{P_t}\right)(N_{TE,t} + N_{NE,t}).$$

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

$$(39)\quad \Pi_t = \Pi_{F,t} + \sum_{m=0}^{1}\int_{z\times\kappa} \Pi_{T,t}(z,\kappa,m)\psi_{T,t}(z,\kappa,m)\,dzd\kappa + \int_{z} \Pi_{N,t}(z)\,\psi_{N,t}(z)\,dz - \left(\frac{G_{E,t}+G_{X,t}}{\zeta}\right).$$

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 equilibrium variables satisfy several resource constraints. The final goods market clearing conditions are given by $D_t = C_t + I_t + G_{X,t} + G_{E,t}$ and $D_t^* = C_t^* + I_t^* + G_{X,t}^* + G_{E,t}^*$. Each individual goods market clears; the labor market clearing conditions are $L = L_{P,t} + L_{X,t} + L_{E,t}$ and the foreign analogue; and the capital market clearing conditions are

$$K_{t-1} = \sum_{m=0}^{1} \int_{z \times \kappa} k_{T,t}(z,\kappa,m)\, \psi_{T,t}(z,\kappa,m)\, dz d\kappa + \int_{z} k_{N,t}(z)\, \psi_{N,t}(z)\, dz$$

and the foreign analogue. Profits are distributed to shareholders, Π_t, and the foreign analogue. The international bond market clearing condition is given by $B_t + B_t^* = 0$. Finally, writing 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 structure of shocks. We assume that the productivity process is the same in the tradable and non-tradable sectors. An incumbent's productivity evolves as $z' = \rho_\varepsilon z + \varepsilon$, with $\varepsilon \overset{iid}{\sim} N(0, \sigma_\varepsilon^2)$. The assumption that productivity follows an AR(1) with shocks drawn from an iid normal distribution implies that this conditional distribution follows a normal distribution $\phi_z\left(z'|z\right) = N\left(\rho_\varepsilon z, \sigma_\varepsilon^2\right)$. We assume that entrants draw productivity based on the unconditional distribution $z' = \mu_E + \varepsilon_E$, with $\varepsilon_E \overset{iid}{\sim} N\left(0, \sigma_\varepsilon^2/\left(1-\rho_\varepsilon^2\right)\right)$ where and $\mu_E < 0$ is chosen to match the observation that entrants start out small relative to incumbents.

The shocks to the fixed export costs are assumed to be log normally distributed, $\kappa \tilde{} N(0, \sigma_{\kappa}^{2}(z))$. Similar to the set up in Das, Roberts, and Tybout (2007), the standard deviation of fixed cost shocks depends on a plant's productivity. Specifically, we assume that the variance is a convex combination of the variance of small plants, $\sigma_{\kappa S}^{2}$, and large plants, $\sigma_{\kappa L}^{2}$,

$$\sigma_{\kappa}(z) = \omega(z)\,\sigma_{\kappa S} + (1 - \omega(z))\,\sigma_{\kappa L}$$

where the function $\omega(z) \in [0, 1]$ decreases in z. We set $\omega(z) = 1$ for $z < z_l$ and $\omega(z) = 0$ for $z > z_h$, where z_l and z_h are the critical productivity values that mark the bottom and top 1 percent of establishments, respectively. For $z \in [z_l, z_h]$, we use linear interpolation, $\omega(z) = (z_h - z) / (z_h - z_l)$. We set $\sigma_{\kappa S}$ and $\sigma_{\kappa L}$ to match the distribution of export participation in 1987.

Establishments are assumed to receive an exogenous death shock that depends on its last period productivity, z, so that the probability of death is

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

This formulation of the exit rate allows small plants to have a higher exit rate than big plants and allows some big plants to fail. [23]

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.[24]

[23] The assumption of exogenous exit 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.

[24] 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

The tradable share parameter of the final good producer, a, is chosen 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 of 21 percent. We assume the elasticity of substitution between tradables and non-tradables, γ, is 0.5 (Mendoza, 1995, and Stockman and Tesar, 1995).[25] A low elasticity of substitution between tradables and non-tradables is necessary for reductions in trade costs to shift labor out of manufacturing. The labor share parameter in the production, α, is set to match the labor income to GDP ratio of 66 percent. In the model, the ratio of value-added to gross output in manufacturing equals $1 - \alpha_x (\theta - 1) / \theta$. In the U.S., this ratio averages 2.75 from 1987 to 1992 and implies that $\alpha_x = 0.795$. The goods share in fixed/sunk costs ζ is set to match the growth rate of the average establishment size in the tradable good sector over 1987-2007, $\zeta = 0.889$.

The entry cost parameter, f_E, is set to normalize the total mass of establishments, $N_{T,t}+N_{N,t}$, to 2. In all the analysis, the mean establishment size of the tradable sector is set to match 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 9.9 percent in 1987 (1987 Census of Manufactures).
2. An exporter intensity of 15.5 percent in 2007 (2007 Census of Manufactures).
3. Five-year exit rate of entrants of 37 percent based on establishments that first began producing (Dunne et al. 1989).
4. Shutdown establishments' labor share of 2.3 percent (Davis et al. 1996).
5. Entrants' labor share of 1.5 percent reported in Davis et al. (1996), based on the Annual

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.

[25] Our estimate is a bit below Mendoza's (1995) estimate of 0.74 for a group of industrialized countries and slightly above the estimate in Stockman and Tesar (1995) of 0.44 for a broader cross-section of countries. It is chosen to be consistent with the changes in output and productivity in the sector over this period.

Survey of Manufactures (Annual Survey of Manufactures).

6. 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.[26]
7. Establishment employment size distributions (fractions of establishments given the employment sizes) as in the 1987 Census of Manufactures.
8. Distribution of export participation of establishments (1987 Census of Manufactures).

The first two targets, along with θ, pin down the level of trade costs in 1987 and 2007. Given $\theta = 5$, trade costs increase export prices by 73.8 percent in 1987 and 52.9 percent in 2007. 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 6 observations, and to minimize distance between the distributions in the model and the data (measured by the sum of squared residuals).[27] The parameter values are reported in Table 2

[26] Bernard and Jensen find an average stopper rate of about 17 percent in this period. We adjust this by matching the 17 percent stopper rate among establishments with 100+ employees since the sample in Bernard and Jensen is severely biased toward large plants.

[27] 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. For the export paricipation rate distribution, we use 3 bins 1-99, 100-499, and 500 and more employess as the data for export participation rate distribution are limited to these bins. 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.

and the fit of the benchmark model is summarized in Table 3. Figure 1 plots the distributions of plants over productivity levels and export status, and entrants. We also plot the start and stopper hazard rates together with 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 are relatively small and that there are relatively few large establishments. The model only slightly under-predicts the share of establishments with 1,000 to 2,499 employees (0.1 percentage point) and over-predicts the share of large establishments with 2500+ employees (0.01 percentage point). 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 13.5 percent of employment. The model closely matches the employment share of establishments when considering the share of those with 1,000+ employees. In the data they account for 23.7 percent, while in the model they account for 24.6 percent. 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 0.2 percent. 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 there would be too low (high) export participation among small (large) establishments.

5. Results

We first consider the impact in the model of a cut in iceberg trade costs necessary to raise export intensity as in the data. We compare the steady states of our model economy that only differ in terms of the iceberg trade costs. We consider the transition to the new steady state in the next section. The changes in the model economy and the data are reported in Table 4.

The model generates only slightly more overall export growth than in the data (71.7 percent compared to 67.7 percent in the census and 71.3 percent from customs). Export participation rises slightly more than in the data (36.8 percent compared to 23.7 percent) and exporters become a bit smaller than in the data (the premium falls 9.9 percent compared to a drop of 0.6 in the data). Focusing just on the largest plants (100+ employees), overall export growth exceeds the data by more (68.4 percent compared to 61.1 percent), export participation rises by slightly less than the data (33.4 percent compared to 37.7 percent), and exporters do not shrink by enough (the premium drops 9.8 percent compared to 21.4 percent in the data).

The main shortcomings of the model relate to the changes in the structure of manufacturing. First, the change in the size distribution of plants differs from the data. As emphasized in the literature, the cut in trade costs shifts employment 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. Indeed, the model predicts average plant size should rise by 0.9 percent, while in the data plants became about 20.3 percent smaller on average. Moreover, the share of employment in large plants with 1000+ employees falls 7.9 percent while in the model it rises 0.3 percent. Second, manufacturing remains quite important in our model while it has become a smaller part of the private economy in this period. The share of employment in manufacturing fell 51.4 percent, while in the model it only falls 1.4 percent.

6. Sensitivity

In this section, we explore the sensitivity of our model. We first consider the two important shortcomings about the changes in the structure of manufacturing. Specifically, we explore how changes in the productivity and capital intensity of manufacturing affect the structure of manufacturing. We find that most of the shift of employment out of manufacturing and the shift towards smaller establishments within manufacturing can be accounted for by manufacturers becoming more productive relative to the whole economy. These changes have a negligible impact on export growth. We also consider how changes in the dispersion of idiosyncratic shocks, the structure of fixed costs, transition dynamics, and changes in corporate taxes alter our findings on export growth. We find that small reductions in the dispersion of shocks can explain the shift to smaller plants and that this reduces export growth. The changes in the U.S. corporate tax code also reduce export growth.

A. Manufacturing and Non-manufacturing

Figure 3 summarizes some key aspects of the changes in U.S. manufacturing relative to the private economy. The top panel shows that the share of the private economy in manufacturing has fallen over time. The share of employment (measured by workers or compensation) has fallen somewhat less than the share of physical capital. This shift away from manufacturing starts prior to the period we study. The middle panel shows that the capital-labor ratio in manufacturing relative to the capital labor ratio in the whole economy has risen over this period. The bottom panel shows that the share of output in manufacturing in the private economy fell about 15 percent from 1987 to 2007 and manufacturing labor productivity grew about 30 percent relative to the non-farm business sector. To capture these changes in productivity and output we can feed into the model a change in average productivity in the tradable sector relative to the non-tradable sector. To capture the change in capital intensity we allow the capital share parameter, α, in the tradable sector to change.

The column labeled A reports the impact of only increasing tradable productivity. The main effect of making the tradable sector more productive is to lower the average size of plants substantially (plant size falls 25.1 percent compared to a 0.9 percent increase in the benchmark) and to reduce the share of employment in manufacturing close to that in the data (-49.7 percent vs -51.4 percent in the data). Export growth at the aggregate is essentially unchanged, while export growth at large plants rises slightly. With a smaller average plant size, we can capture some of the shift out of large plants as the share of employment in plants with 1000+ employees falls 4.1 percent compared to a drop of 7.9 percent in the data.

The shift from manufacturing arises because the productivity gains in manufacturing reduce the price of manufacturing goods relative to non-manufacturing goods. With a less than unitary elasticity of substitution across sectors, this then reduces the size of manufacturing. The shift to smaller plants arises because part of the entry costs are denominated in goods and goods have become cheaper. Thus, the share of plants in manufacturing falls about 37.2 percent (compared to 33.7 percent in the data).

B. Changes in Plant Size: Capital Intensity and Dispersion

Figure 4 depicts changes in the distribution of activity across plants within manufacturing from 1987 to 2007. The solid and dashed lines show that the change in the share of employment and payroll by each employment-size bin is decreasing with size. The share of employment in plants with less than 100 employees rose by 4.7 percent (5.1 percent when measured in payroll), while the share of employment at plants with greater than 2500+ employees fell 6.1 percent (9.1 percent in payroll). Compared to the changes in payroll, there is a much more muted shift in value added by plant size (line with the triangle markers). Indeed, the value added share of employment of the smallest plants rose only 1.0 percent, while the value added of the largest plants fell only 6.9 percent. To capture the different changes in value added and employment in the most parsimonious fashion, we allow the capital intensity of plants in the manufacturing sector to depend on productivity. Specifically, we allow the capital share parameter, $\alpha(z)$, to be a function of the productivity of the firm

$$y_{T,t}(z,\kappa,m) = e^{z}\left[k_{T,t}(z,\kappa,m)^{\alpha_i(z)}\, l_{T,t}(z,\kappa,m)^{1-\alpha_i(z)}\right]^{1-\alpha_x} x_t(z,\kappa,m)^{\alpha_x}.$$

We keep $\alpha_0(z) = \alpha$ for the 1987 economy but choose $\alpha_1(z)$ to match the change in value added by plant size in 2007. Specifically, for the bottom 97.1 percent, which corresponds to <250 plants, we set α so that there is a drop in the value added to wage bill ratio by 5.5 percent, and for the top 0.3 percent of plants, which corresponds to plants with 1000+ employees, we choose α_H so that the ratio of value added to wage bill rises by 3.6 percent. In between we linearly interpolate. To capture the rise in the capital intensity of manufacturing relative to to non-manufacturing of 28.2 percent, we lower the capital share in non-manufacturing.

The column titled *KnoNT* shows the impact of changing the dispersion of capital intensity only within manufacturing. The increase in capital intensity leads to an increase in average plant size of 3.2 percent compared to our benchmark model's increase of 0.9 percent. However, the share of employment in plants with 1000+ plants falls by 2.98 percent. The impact on international trade is primarily distributional as now trade grows 68.3 percent when looking at 100+ employee plants and 71.4 percent for all plants.

The column labeled K shows the impact of also changing the capital intensity between manufacturing and non-manufacturing. In short, the across-sector changes in capital intensity imply that average plant size is now only 1.7 percent larger. With the smaller plants, the share of employment in plants with 1000+ employees falls by 2.96 percent. Again, the impact on trade is minor.

The changes in capital intensity do not fully capture the changes in the distribution of plant size. Thus, to capture the shift out of very large scale manufacturing, we next consider a change in the dispersion of idiosyncratic productivity shocks. In particular, we reduce the standard deviation of productivity shocks hitting plants by 3.8 percent. This shift compresses the unconditional size distribution of plants. We consider this case in the column labeled *K+A+sigma*. Average plant size goes up slightly while the share of employment in plants with 1000+ employees falls an additional 4.4 percentage points and is now quite close to the data (-8.5 in the model vs. -7.9 in the data). The reduction in dispersion lowers export growth from 71.7 percent to 68.4 percent. The reduction is entirely attributed to a reduction in the exporter premium as the largest exporters are no longer as large and small non-exporters are no longer as small.

C. Static Export Decision: No Sunk Cost

We next show how the structure of startup and continuation costs of exporting affect export growth. Specifically, we consider a model in which exporting is a static decision. We assume that the cost to enter and the cost to stay in the export market are the same (i.e. $f_0 = f_1$) and all entry is done in the same period. This is the typical formulation of fixed costs in the theoretical literature. We calibrate this model in a manner similar to our benchmark except we do not match the high persistence of exporting. Indeed, the model generates much too much churning of exporters as the exit rate is 46 percent vs. 17 percent in the data. Parameters are reported in Table 2, and the fit is reported in Table 3 in the column *Fixed cost*. The fit is similar to our benchmark in terms of the distribution of exporters and establishments. However, the fixed cost model requires much more volatile shocks to fixed export costs.

The column *Fixed cost* in Table 4 reports the changes in exports in this model economy. With just a fixed cost, the model generates substantially less export growth than both the data and the sunk cost model. With just the fixed cost, trade growth is 55.4 percent for all plants and 58.6 percent among plants with 100+ employees. The weaker export growth arises from a smaller increase in export participation rates. The overall export participation rate rises by 19.3 percent, whereas it actually rose by 23.7 percent in the data. If we focus on plants with 100+ employees, the model predicts a rise in export participation of 26.1 percent (37.7 percent in the data).

Two main factors lead to weaker export growth in the static fixed cost model. First, there is less growth in export participation than in the sunk cost model since the value of being an exporter increases more steeply with idiosyncratic productivity than in the sunk cost model. The steeper slope arises because with fixed costs export profits are solely determined by current productivity, while with the sunk cost model future productivity also matters. This means that with sunk costs more plants are at the margin in the long run. Second, to match the initial export participation rate distribution, the fixed cost model requires large shocks to the fixed costs even for big plants. The standard deviation of the shock for the top 1 percent plants in size needs to be 2.6 compared to 0.6 for the benchmark model. With a large shock to fixed costs in exporting, the model generates more exporting from random selection and less from endogenously determined exporters.

D. Transition and Non-linear Dynamics

We next consider the timing of U.S. export growth. The top panel of Figure 5 shows the ratio of exporter intensity growth to aggregate trade growth from 1987 to 1997 and over the whole period.[28] In the first ten years, the intensive margin accounted for 73.5 percent of the change in exports shipments, while by 2007 the intensive margin accounted for only 60 percent of the growth in export shipments. Thus, there is a non-linear relationship between trade and trade costs.

Figure 5 also shows that our benchmark model can capture these non-linear dynamics in the data with a reasonable path of iceberg costs and that the fixed cost model does not lead to any non-linearity. Indeed, in the fixed cost model the relationship between exports and export intensity is constant. That the sunk cost model can generates non-linear export dynamics should not be surprising, since this was the original motivation for the model (Baldwin and Krugman, 1989). What may be surprising is that it does so well.

[28] In this analysis we use the customs data as a measure of total exports, since we require annual data on exports.

Specifically, we assume that in 1987 agents expect a new path of iceberg cost that will fall linearly until 2007. The linear trend in iceberg costs is chosen to be consistent with the average growth of imports and exports. Additionally, we assume that there are iid temporary shocks each year that affect the iceberg cost but not the trend. These shocks are chosen to match the export intensity in census years and minimize the distance between exports in the model and data over the sample.[29] The bottom panel of Figure 5 shows the path of exporter intensity (which is linearly related to iceberg costs) as well as the trend. To match the movements in trade requires iceberg costs to fall more than trend initially and then return strongly to trend 1998 to 2007.

E. Corporate Taxes

We next explore to what extent changes in U.S. corporate taxes can account for the muted response of exports and exporters to the fall in iceberg costs. To summarize, from 1971 to 2004, the U.S. corporate tax code allowed U.S. exporters to pay a lower tax rate on export income. From 1984 to 2004, this tax benefit implied that export income was taxed at 29.75 percent, while domestic income was taxed at 35 percent. This favorable treatment of export income was disputed by the EU with the WTO beginning in 1997. From early on in the dispute process, the WTO findings pointed to the eventual removal of this benefit. Indeed, Desai and Hines (2008) find that on the day the EU announced its dispute, November 18, 1997, that there was a sizeable drop in the stock market capitalization of U.S. exporters; thus, the dispute was expected to lead to the elimination of the tax benefit.

To allow for corporate taxes in the model, we redefine after-tax profits in the model as $\pi = \left(1-\tau^D\right)\pi^D + \left(1-\tau_t^x\right)\pi^x$, where π^D is the profits on domestic sales net of fixed export costs and the cost of capital. We recalibrate our model to $\tau^D = 0.35$ and $\tau_{87}^X = 0.2975$. We then raise the

[29] There is not an exact match between our model and the data because we are choosing 16 iceberg costs but have 20 observations on trade. Our approach shows that there is a sequence of iceberg costs consistent with the non-linear dynamics of exports and export intensity.

tax rate on exports to $\tau^x = \tau^D$. Again, we consider the impact of this policy change on the steady state of the model. The results are reported in the row leabeled *Corporate Tax* of Table 4. Lowering the corporate tax benefit weakens export growth by about 3.0 percentage points compared to our benchmark. This arises through a 5.2 percentage point reduction in export participation growth and a 2.2 percentage increase in the change of the size premium as most of the reduction in export participation is among relatively small producers.

7. Conclusions

We study U.S. export growth from 1987 to 2007 in a two-country model with heterogenous producers and a sunk cost of starting to export. To the best of our knowledge, ours is the first empirical and quantitative analysis of the change in trade in a GE dynamic heterogeneous plant model. Given the common use of variants of this model in policy analysis, our analysis provides an important evaluation of this model.

Understanding the changes in trade requires measuring the change in trade costs. We show that data on the characteristics of exporters, in particular the intensity with which they export, can be used to identify the change in iceberg trade costs over this period. Given this observed decline in iceberg trade costs, we find the model comes quite close to matching the growth in the share of manufacturing output exported. Thus, in contrast to the commonly held view from Yi (2003), we find that there is nothing puzzling about the growth in U.S. exports since 1987.

We find that a model with a sunk cost of starting to export does a better job of capturing the size and timing of trade growth than a model with only a fixed cost of exporting. Indeed, while the sunk cost model captures nearly all of the changes in the extensive margin of trade, the basic fixed cost model captures only about half the changes. Moreover, the sunk cost model also better captures the non-linear dynamics of export growth and export intensity since 1987. Specifically, the model can capture the slow growth of exports relative to export intensity in the early periods and the fast growth of exports relative to export intensity in the latter period. Thus, it appears that a model with a sunk cost of exporting can more accurately capture both the micro and macro dynamics of trade.

While our benchmark model captures the main changes in exports, it misses out on both the changes in the allocation of production across establishments within manufacturing and the shift out of manufacturing in the U.S., suggesting a small role of international trade in the changing structure of manufacturing. To capture the shift out of manufacturing in the U.S. economy, we feed into the model the productivity gains in manufacturing relative to non-manufacturing over this period. When all entry costs are paid in a combination of goods and labor, this also leads to a reduction in plant size that captures the observed shift to small-scale manufacturing. We also consider the effect of changes in the capital intensity of manufacturing plants and find that they have had a minimal impact on the shift from manufacturing and the changes in the size distribution in manufacturing plants. To explain the final changes in plant size requires a reduction in the idiosyncratic shocks hitting plants. Incorporating these changes into our model economy improves its fit and points to an important role of the size distribution in understanding the determinants of trade growth.

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Table 1: Export Characteristics and Trade

	Census of Manufactures*					Customs**	
	Exports/Domestic Sales	Exports/Sales	Participation	Premium	Intensity	Customs	Adjusted for wholesales margins
All							
1987	5.9	5.5	18.3	305.1	9.9	8.1	7.5
2007	12.2	10.9	23.2	303.2	15.5	17.1	15.3
Log Change	73.5	67.7	23.7	-0.6	44.6	74.3	71.3
100+							
1987	6.7	6.3	43.2	148	9.9		
2007	13.2	11.6	63	119.5	15.5		
Log Change	66.9	61.1	37.7	-21.4	44.9		

* 1987 data based on Analytical Report on Establishments that export. 2007 data applies the methodology from the 1987 report to a special tabulation of the 2007 census to adjust for nonresponse.

** Data is based on the ratio of Exports of Manufactured Commodities (f.a.s. Value, Mil.$) excluding reexports and Mfrs' Shipments: All Manufacturing Industries (SA, Mil.$). Note the 1987 data are based on SIC and 2007 are based on NAICS. Adjusted for wholesale margins assumes that wholesale costs from plant to port increased from 8 percent to 10.5 percent.

Table 2: Parameter Values

Common Parameters

$\beta = 0.96$, $\sigma = 2$, $\theta = 5$, $\delta = 0.10$, $a = 0.091, \gamma = 0.5$, $\iota_{87} = 0.738$, $\iota_{07} = 0.529$, $\alpha_x = 0.795$

Sunk Cost

$\alpha = 0.113$, $\lambda = 7.562$, $n_{d0} = 0.022$, $\zeta = 0.889, \rho = 0.690$, $\mu_E = -0.354$, $\sigma_\varepsilon = 0.331$.
$f_E = 0.971$, $f_0 = 0.058$, $f_1 = 0.028$, $\sigma_{\kappa S} = 4.400$, $\sigma_{\kappa L} = 0.600$.

Fixed Cost

$\alpha = 0.118$, $\lambda = 7.564$, $n_{d0} = 0.022$, $\zeta = 0.862, \rho = 0.690$, $\mu_E = -0.354$, $\sigma_\varepsilon = 0.330$,
$f_E = 0.926$, $f_0 = f_1 = 0.101$, $\sigma_{\kappa S} = 5.200$, $\sigma_{\kappa L} = 2.600$.

Exporting Cost Shock Weight

$$\omega(z) = \begin{cases} 1, & z < z_L \text{ where } \Pr(z_L) = 0.01, \\ \frac{z_H - z}{z_H - z_L}, & z \in (z_L, z_H), \\ 0, & z \geq z_H \text{ where } \Pr(z_H) = 0.99. \end{cases}$$

Productivity Growth: $\ln(A_{T,07}/A_{N,07}) = 0.291$

Capital Deepening

$$\alpha_{T,new}(z) = \begin{cases} \alpha_L = 1 - e^{0.055}(1 - \alpha_{old}), & z < z_L \text{ where } \Pr(z_L) = 0.971, \\ \alpha_L + (\frac{z - z_L}{z_H - z_L})(\alpha_H - \alpha_L), & z \in (z_L, z_H), \\ \alpha_H = 1 - e^{-0.036}(1 - \alpha_{old}), & z \geq z_H \text{ where } \Pr(z_H) = 0.997. \end{cases}$$

$$\alpha_{N,new} = \left[1 + e^{0.282}\left(\frac{1 - \alpha_{T,new}}{\alpha_{T,new}}\right)\right]^{-1}.$$

Low Dispersion (Sigma):

Sunk Cost: $\sigma_{\varepsilon,new} = 0.961\sigma_\varepsilon$, Fixed Cost: $\sigma_{\varepsilon,new} = 0.958\sigma_\varepsilon$.

Table 3: Target Moments

	Target Value	Sunk Cost	Fixed Cost
5-year exit rate	0.370	0.370	0.370
Startups' labor share	0.015	0.015	0.015
Shutdowns' labor share	0.023	0.023	0.023
Stopper rate (100+)	0.170	0.170	0.461*
Exporter intensity (100+)	0.100	0.100	0.100
Squared sum of residuals (%)			
Establishments	0	0.304	0.331
Export participation	0	0.211	0.194

* denotes moment not targeted.

Table 4: Changes in Export Characteristics and Trade

	Data	Benchmark	A	$KnoNT$	K	$K+A+sigma$	*Fixed cost*	*Corporate tax*
$\frac{N_T}{N_T+N_N}$	-33.6	-2.1	-37.2	-2.3	-1.4	-32.8	-30.7	-1.5
$\frac{L_T}{L_T+L_N}$	-51.4	-1.4	-49.7	0.3	-2.4	-46.0	-46.5	-0.5
$\frac{L_T}{N_T}$	-20.3	0.9	-25.1	3.2	1.7	-20.3	-20.3	2.3
L_{250-}*	7.7	-0.9	4.9	-0.1	-0.1	7.2	7.4	-2.0
L_{1000+}*	-7.9	0.3	-4.1	-3.0	-3.0	-8.5	-8.3	0.2
L_{100-}*	4.7	-1.6	3.5	-0.4	-0.4	5.5	6.9	-1.5
L_{500+}*	-8.0	2.1	-3.3	-0.2	-0.2	-8.8	-9.0	2.0
				All plants				
Trade	67.7	71.7	71.7	71.4	71.4	68.4	55.4	68.7
Intensity	44.6	44.9	44.9	44.9	44.9	44.9	44.9	44.9
Participation	23.7	36.8	36.8	37.1	37.1	36.9	19.3	31.5
Premium	-0.6	-9.9	-9.9	-10.5	-10.5	-13.4	-8.8	-7.8
				100+ plants				
Trade	61.1	68.4	70.9	68.3	68.3	68.4	58.6	65.9
Intensity	44.9	44.9	44.9	44.9	44.9	44.9	44.9	44.9
Participation	37.7	33.4	38.6	33.4	33.4	36.1	26.1	29.5
Premium	-21.4	-9.8	-12.6	-10.0	-10.0	-12.6	-12.3	-8.5

* denotes percentage point changes, others are percentage changes. A denotes the benchmark model with tradable productivity rising 29.1 percent. $KnoNT$ denotes changing the capital intensity across tradable plants. K denotes changing the capital intensity across tradable plants and between tradables and non-tradables. K+A+$sigma$ includes the changes with K and A as well as lowering the dispersion of idiosyncratic shocks by 3.8 percent. Fixed cost includes the changes in (K+A+$sigma$) in a model with a static export decision based on just a fixed cost ($f_0 = f_1$). *Corporate tax* is the benchmark model with a change in how export income is taxed.

Figure 1: Establishment Characteristics by Employment Size

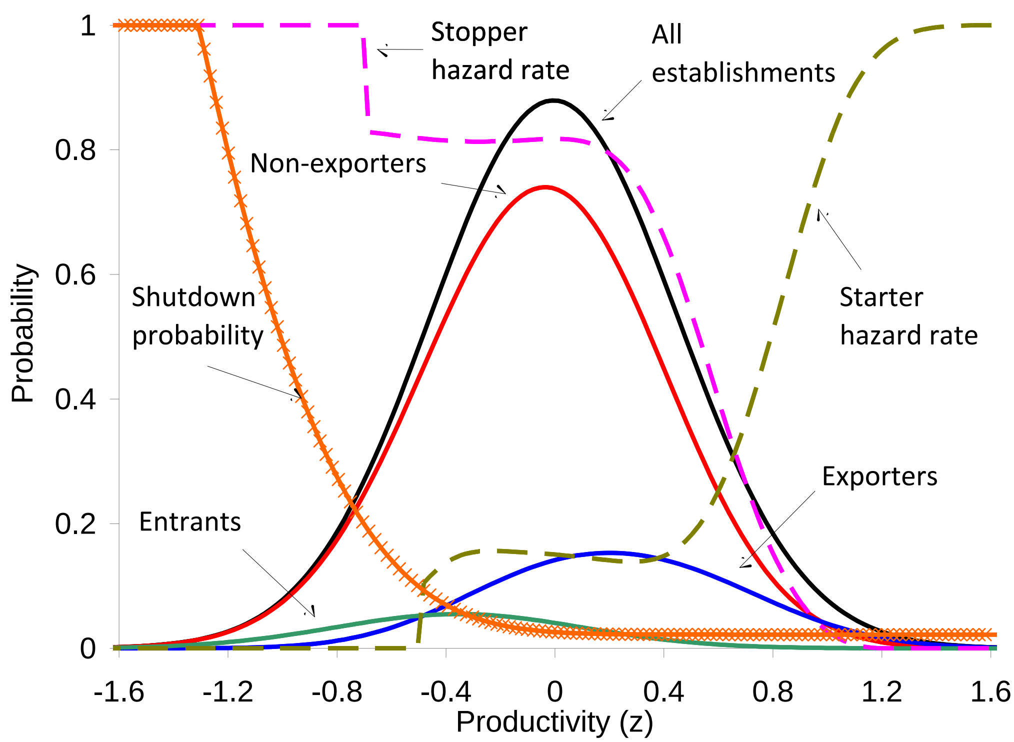
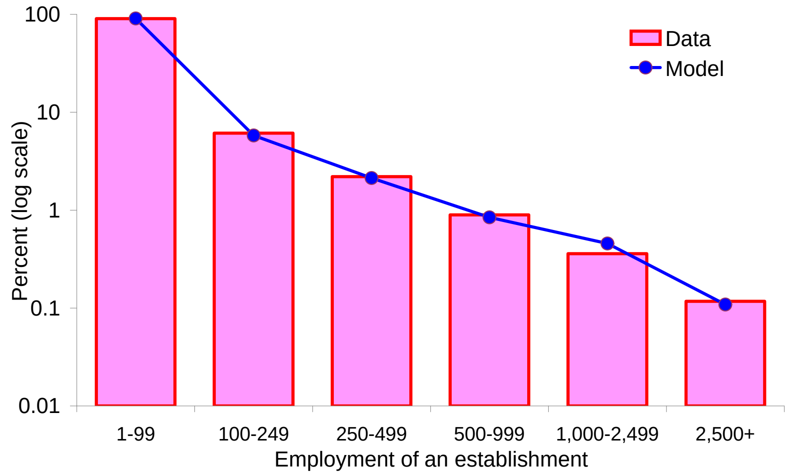
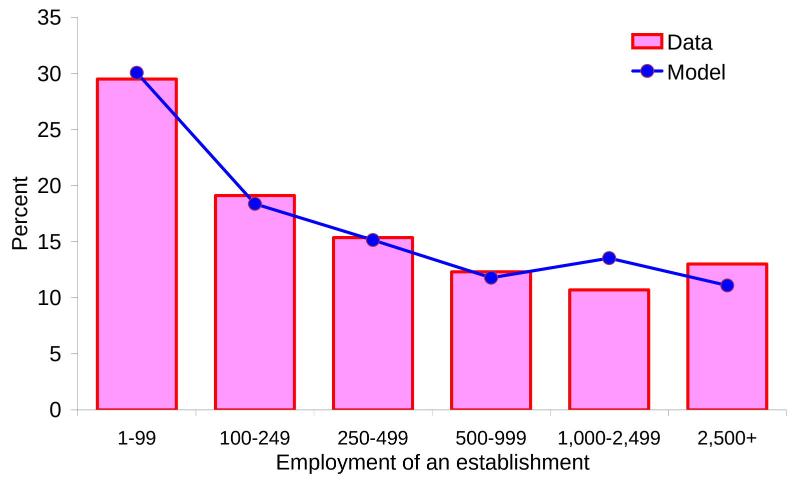


Figure 2: Establishment Characteristics by Employment Size

(a) Establishment Share



(b) Employment Share



(c) Export Participation

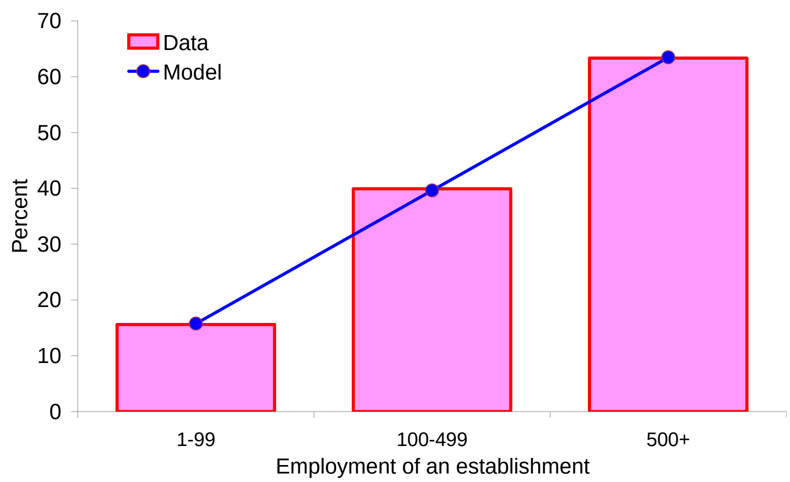


Figure 3: Relative Importance of U.S. Manufacturing over Time

Figure 4: Change in Establishment Characteristics by Employment Size

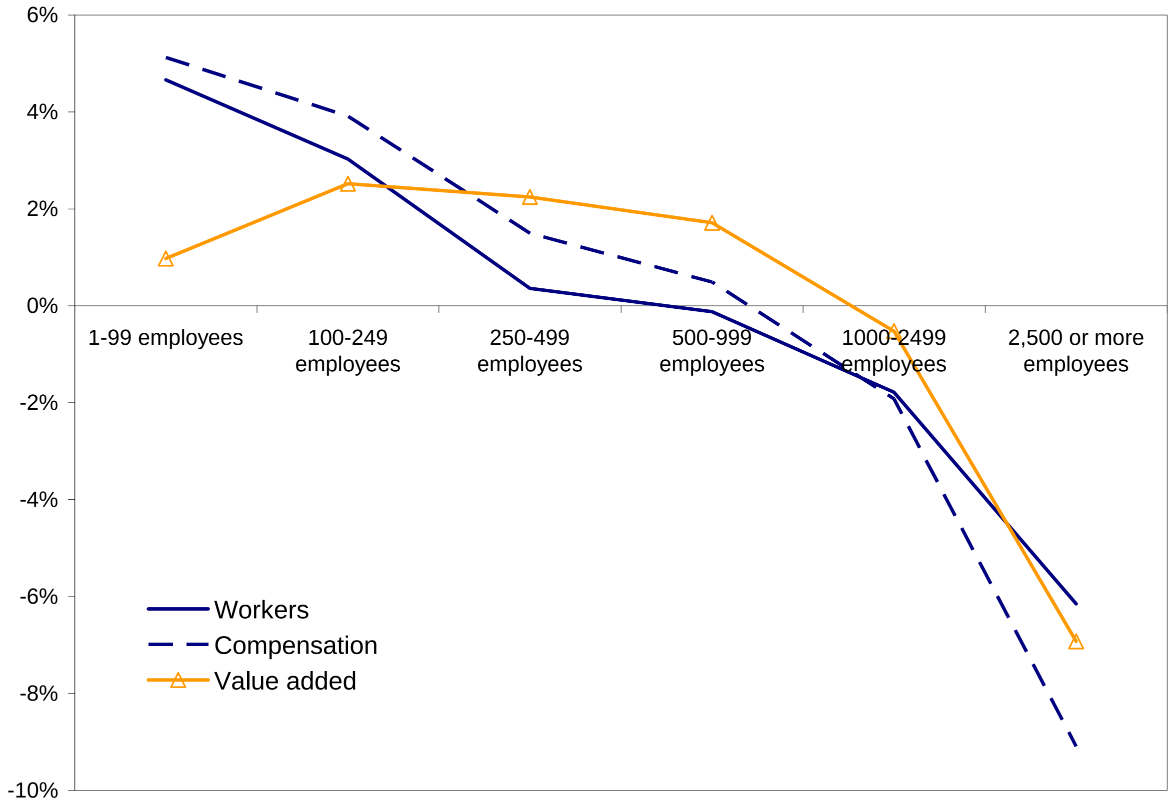
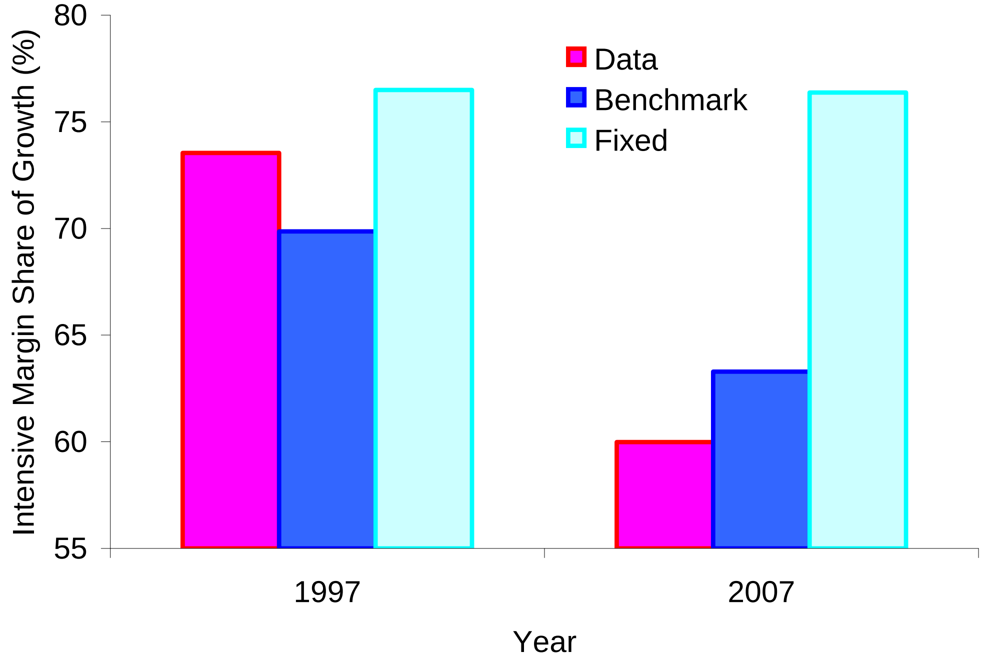
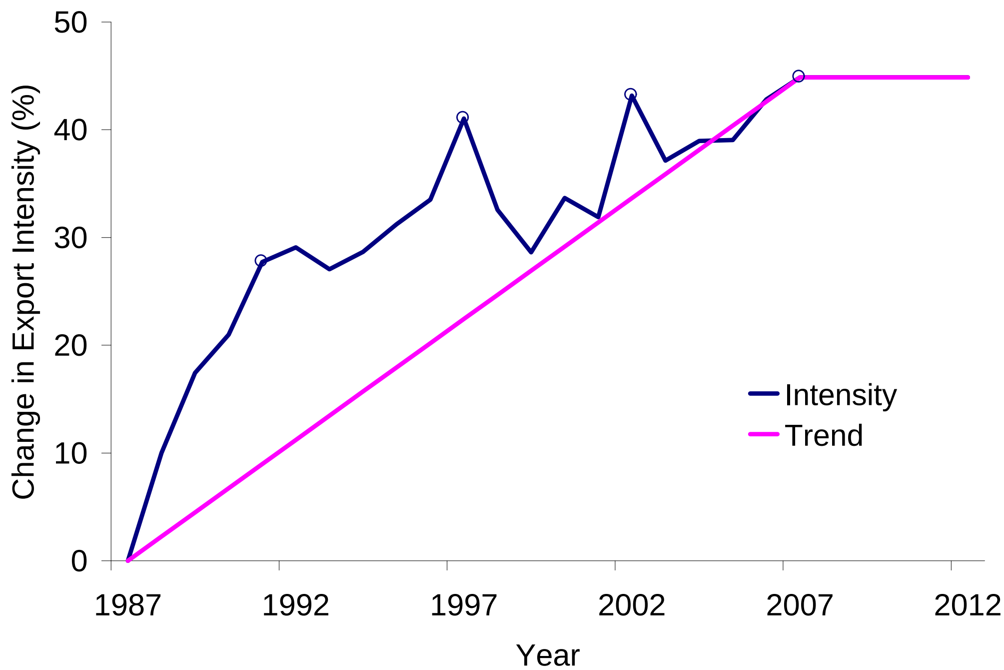


Figure 5: Export and Export Intensity Dynamics

a. Contribution of Intensive Margin to US Export Growth



b. Change in Export Intensity (Trend and Imputed)



Data Appendix

Table 1, Figure 2c, and Figure 5

1. Based on Census' 1987 Analytical Report (1987AR) on Establishments that Export and a special tabulation from 2007 Census of Manufactures (CM).
   (a) Measuring aggregate exports and export participation in the census requires imputing participation by non-surveyed and non-respondent establishments. In the 1987AR, the census imputed export participation based on the size, industry, and location of non-resondents. We follow a similar approach to measure exporting in 2007 but base it on only size, since we lack industry and location data. To make things concrete, suppose there are three types of establishments exporters, non-exporters, and non-respondents, $\{X, N, NR\}$, by each size bin. We impute the probability of exporting of plants in bin i as

   $$p_i = N_i^X / \left(N^X + N_i^N\right)$$

   We assume that all exporters in a bin have the same export intensity so that

   $$exs_i = Exports_i^X / Sales_i^X$$

   Sales of exporters are imputed assuming that non-respondent exporters are bigger than non-respondent non-exporters by the same amount that respondent exporters are bigger than respondent exporters. Specifically, we calculate exporter sales in size bin i

   $$\begin{aligned} Exporter\ Sales_i &= Sales_i^X + p_i * Sales_i^{NR} * \frac{\frac{Sales_i^X}{Sales_i^X + Sales_i^N}}{p_i} \\ &= \left[\frac{Sales_i^X}{Sales_i^X + Sales_i^N}\right]\left[Sales_i^X + Sales_i^N + Sales_i^{NR}\right] \end{aligned}$$

   and finally exports equal

   $$Exports_i = exs_i * Exporter\ Sales_i$$

   (b) Export intensity in Figure 5 for 1997 and 2007 is based on special tabulation of CM.
2. Customs data (Table 1 and Figure 5)
   (a) Shipments: All Manufacturing Industries SIC product code, Census, ends in 2000
   (b) Mfrs' Shipments: All Manufacturing Industries NAICS product code, Census.
   (c) Exports: Manufactured Commodities (f.a.s.), Census Bureau, Trade in Goods (census basis) by selected SIC-Based Product Code (1986 to 1999)
   (d) Exports: Manufacturing, Total (f.a.s.), Census, (1999 to 2011)
   (e) Reexports: Manufactured Goods (f.a.s.), Census, Trade in Goods: Principal Commodity Grouping, NSA, We estimate re-exports in 87m1 to m6 using the growth from Q3 to Q4
   (f) Exports: Manufactured Goods (f.a.s.) by Principal SITC Commodity Groupings: Census Basis [starts Jul-1987] Since data is based on a partial year in 1987, we base the change in exports from 87 to 88 on the manufactured commodities series.

Table 4

1. Employment share of manufacturing in private economy from BEA: Compensation of Employees: Private Industries (Mil.$) and Compensation of Employees: Manufacturing (Mil.$)

2. Table 4: Establishment share: Plants from CM (1987 to 2007) divided by private establishments in County Business Patterns (1987 to 2007). Adjusting the census data for the NAICS changeover (there are 4 percent fewer plants and workers measured in NAICS vs SIC in 1997) reduces the decline in plants to -30.0 percent.
3. Employment distribution based on CMs.

Figures 2-4

1. Figures 2a, 2b, and 4 based on 1987CM and 2007CM.
2. Figure 3 manufacturing-non-mfr facts based on
   (a) Capital stock (BEA): Net Stock: Private Equipment & Software (Bil.$); Net Stock: Private Nonres Equip & Software: Manufacturing (Bil.$)
   (b) Employment (BLS): All Employees: Total Private Industries (SA, Thous) and All Employees: Manufacturing (SA, Thous)
   (c) Labor compensation (BEA): Compensation of Employees: Private Industries (Mil.$) and Compensation of Employees: Manufacturing (Mil.$). The BEA has 4 series for each variable that are based on different industry classifications/time periods. These series line up in the year of the change in classifications (1947 and 1987) but not in 1998 with the change to NAICS. However, from 98 to 2000 both series are measured using SIC87 and NAICS and so we splice these series. That is, we increase the NAICS series by the average difference from 98 to 00.
   (d) K/L ratio is measured as the ratio of the capital stock of equipment & software in manufacturing to the private economy at historical cost.
   (e) Productivity and Business Sector Output (BEA): Nonfarm Business Sector: Real Output per Hour of All Persons (2005=100); Nonfarm Business Sector: Real Output (2005=100); Manufacturing Sector: Real Output Per Hour of All Persons (2005=100); Manufacturing Sector: Real Output (2005=100).

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.[30] Then, we briefly describe the simulation steps for the steady state and transition dynamics computations.

Approximating Distribution of Establishments

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 log normal distribution, $\phi_\kappa(\kappa|z) = N(0, \sigma_\kappa^2(z))$ in which the standard deviation of the shock depends on the productivity level. Since the productivity follows a normal distribution, $\phi_z(z'|z) = N\left(\rho_\varepsilon z, \sigma_\varepsilon^2\right)$, it is straightforward to construct the joint distribution of the two shocks. Let the transition probabilities of the shock to the fixed cost in exporting and the productivity be $\phi(z', \kappa'|z, \kappa)$. From the processes of productivity and fixed cost shocks, we can construct the joint density of z' and κ' conditional on z and κ' as

$$(40) \quad \begin{aligned} \phi\left(z', \kappa'|z, \kappa\right) &= \phi\left(\kappa'|z', z, \kappa\right)\phi\left(z'|z, \kappa\right) \\ &= \phi_\kappa\left(\kappa'|z'\right)\phi_z\left(z'|z\right). \end{aligned}$$

For the entrants' distribution, we have $\phi_E(z', \kappa')$. 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

$$(41) \quad \psi_{T,t+1}\left(z', \kappa', 1\right) = \sum_{m=0}^{1} \int_\kappa \int_{z_{m,t}(\kappa)}^{\infty} n_s(z)\,\psi_{T,t}(z, \kappa, m)\,\phi\left(z', \kappa'|z, \kappa\right) dz d\kappa,$$

$$(42) \quad \begin{aligned} \psi_{T,t+1}\left(z', \kappa\prime, 0\right) = & \sum_{m=0}^{1} \int_\kappa \int_{-\infty}^{z_{m,t}(\kappa)} n_s(z)\,\psi_{T,t}(z, \kappa, m)\,\phi\left(z', \kappa'|z, \kappa\right) dz d\kappa \\ & + N_{TE,t}\phi_E\left(z', \kappa'\right), \end{aligned}$$

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_z.[31] We choose z^1 and z^J so that their absolute values are sufficiently large to not affect the results. We approximate the transition probability and the entrants' initial distribution, $\widehat{\phi_z}\left(z^{j'}|z^j\right)$ and $\widehat{\phi_E}\left(z^{j'}\right)$. Next, we choose uniformly spaced nodes for the fixed cost shocks $\kappa \in \left\{\kappa^1, \kappa^2, \cdots, \kappa^G\right\}$

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

[31] We set $n = 200$. Increasing the number of nodes above 200 has a negligible impact on the results.

with an interval ω_κ. We approximate the probability of the shocks with the smallest and the largest standard deviations as $\widehat{\phi_\kappa^L}(\kappa^g)$ and $\widehat{\phi_\kappa^H}(\kappa^g)$. The probability of fixed cost shocks conditional on productivity is given as

$$\widehat{\phi_\kappa}\left(\kappa^g|z^j\right) = \omega\left(z^j\right)\widehat{\phi_\kappa^L}(\kappa^g) + \left[1-\omega\left(z^j\right)\right]\widehat{\phi_\kappa^H}(\kappa^g), \tag{43}$$

$$\omega\left(z^j\right) = \begin{cases} 1, & z^j < z_L \text{ where } \Pr(z_L) = 0.01, \\ \frac{z_H - z^j}{z_H - z_{lL}}, & z^j \in (z_L, z_H), \\ 0, & z^j \geq z_H \text{ where } \Pr(z_H) = 0.99. \end{cases} \tag{44}$$

Finally the joint probability of z and κ is constructed as

$$\widehat{\phi}\left(z^{j'}, \kappa^{g'}|z^j, \kappa^g\right) = \widehat{\phi_\kappa}\left(\kappa^{g'}|z^{j'}\right)\widehat{\phi_z}\left(z^{j'}|z^j\right), \tag{45}$$

$$\widehat{\phi_E}\left(z^{j'}, \kappa^{g'}\right) = \widehat{\phi_\kappa}\left(\kappa^{g'}|z^{j'}\right)\widehat{\phi}_E\left(z^{j'}\right). \tag{46}$$

The approximated densities of establishments evolve as

$$\widehat{\psi}_{T,t+1}\left(z^{j'}, \kappa^{g'}, 1\right) = \sum_{m=0}^{1}\sum_{g=1}^{G}\sum_{j=1}^{J} n_s\left(z^j\right)\widehat{\psi}_{T,t}\left(z^j, \kappa^g, m\right)\widehat{\phi}\left(z^{j'}, \kappa^{g'}|z^j, \kappa^g\right) I_{m,t}(j,g), \tag{47}$$

$$\begin{aligned} \widehat{\psi}_{T,t+1}\left(z^{j'}, \kappa^{g'}, 0\right) = & \sum_{m=0}^{1}\sum_{g=1}^{G}\sum_{j=1}^{J} n_s\left(z^j\right)\widehat{\psi}_{T,t}\left(z^j, \kappa^g, m\right)\widehat{\phi}\left(z^{j'}, \kappa^{g'}|z^j, \kappa^g\right)\left[1 - I_{m,t}(j,g)\right] \\ & + N_{TE,t}\widehat{\phi}_E\left(z^{j'}, \kappa^{g'}\right), \end{aligned} \tag{48}$$

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

$$I_{m,t}(j,g) = \begin{cases} 0 & \text{if } z^j + \omega_z/2 \leq z_{m,t}, \\ \frac{z_{m,t}(\kappa^g) - z^j + \omega_z/2}{\omega_z} & \text{if } z^j - \omega_z/2 < z_{m,t}(\kappa^g) < z^j + \omega/2, \\ 1 & \text{if } z^j - \omega_z/2 \geq z_{m,t}(\kappa^g), \end{cases} \tag{49}$$

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

Value Function Approximation

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

$$
\begin{aligned}
(50) \quad V_{T,t+1}\left(z^j,\kappa^g,m\right) \;&=\; \Pi_{T,t+1}\left(z^j,\kappa^g,m\right)+\max\left\{\beta\left(\frac{C_{t+2}}{C_{t+1}}\right)^{-\sigma} n_s\left(z^j\right)\cdot\right.\\
&\sum_{g'=1}^{G}\sum_{j'=1}^{J} V_{T,t+2}\left(z^{j'},\kappa^{g'},0\right)\widehat{\phi}\left(z^{j'},\kappa^{g'}|z^j,\kappa^g\right),\\
&\beta\left(\frac{C_{t+2}}{C_{t+1}}\right)^{-\sigma} n_s\left(z^j\right)\sum_{g'=1}^{G}\sum_{j'=1}^{J} V_{T,t+2}\left(z^{j'},\kappa^{g'},1\right)\widehat{\phi}\left(z^{j'},\kappa^{g'}|z^j,\kappa^g\right)\\
(51) \quad &\left.-W_{t+1}f_m e^{\kappa^g}\quad\right\},
\end{aligned}
$$

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

$$
\begin{aligned}
(52) \quad dV_{T,t}\left(z^j,\kappa^g,m\right) \;&=\; -W_t f_m e^{\kappa^g}+\beta\left(\frac{C_{t+1}}{C_t}\right)^{-\sigma} n_s\left(z^j\right)\cdot\\
&\sum_{g'=1}^{G}\sum_{j'=1}^{J}\left[V_{T,t+1}\left(z^{j'},\kappa^{g'},1\right)-V_{T,t+1}\left(z^{j'},\kappa^{g'},0\right)\right]\widehat{\phi}\left(z^{j'},\kappa^{g'}|z^j,\kappa^g\right).
\end{aligned}
$$

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

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

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

Parameterization and Initial Steady State Computation

Given the value for the elasticity of substitution, θ, the iceberg trade costs in 1987 and 2007, ι_{87} and ι_{07}, are obtained based on the export intensities in 1987 and 2007. In the model, the export intensity is given as

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

Thus, we set the iceberg costs in 1987 and 2007 based on the export intensity in the data as

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

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, $z_0(\kappa)$ and $z_1(\kappa)$, 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 $z_0(\kappa)$ and $z_1(\kappa)$ in the steady state computaiton.

This replacement makes computations less complicated.

1. Guess 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}; the smallest and the largest standard deviations of fixed cost shocks, $\sigma(z_L)$ and $\sigma(z_H)$; and critical levels of technology for exporters and non-exporters, $z_1(\kappa)$ and $z_0(\kappa)$.
2. We approximate the density function of establishment level productivity described above and obtain the distributions of exporters, non-exporters, and non-tradable good producers with the nomalization of entrants.
3. 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 2, which matches the 5-year exit rate of entrants in the data.
4. We obtain the distributions for establishments and export participation rate, entrants' labor share, shut-down establishments' labor share. Note that, 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.
5. We search for the critical levels of technology for exporters and non-exporters, $z_1(\kappa)$ and $z_0(\kappa)$, with the iteration in Step 3 and 4, to match the overall export participation rate and the stopper ratio of exporters.
6. 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 5, 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.
7. Then, with the iteration in Step 6, we set the parameter values for the process of κ, $\sigma(z_L)$ and $\sigma(z_H)$, 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, $z_0(\kappa)$ and $z_1(\kappa)$, 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 guesses of the aggregate variables, the fixed costs in exporting, and the sunk costs in entry, 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/sunk 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, we obtain the value functions in the new steady state and the values for the aggregate variables.
2. Then, with the update of the values for the aggregate variables, we update the value functions, the thresholds for exporting decisions, $z_0(\kappa)$ and $z_1(\kappa)$, and the distributions of exporters and non-exporters.
3. Repeat Steps 1 and 2 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, in 1987 the agents get a new path of iceberg costs. Each year there is a shock to iceberg costs that is assumed to be temporary. 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.[32] We set the initial guesses of the sequences of variables, value functions, and densities of establishments based on initial and new steady state values.[33] 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, $\widehat{\psi}_{T,t}^{(i)}(z,\kappa,m)$ and $\widehat{\psi}_{N,t}^{(i)}(z)$, 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, $\widehat{\psi}_{T,t+1}^{(i)}(z,\kappa,m)$ and $\widehat{\psi}_{N,t+1}^{(i)}(z)$, 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 $t+1$ are determined in period t in the model. So, we use updated densities, $\widehat{\psi}_{T,t+1}^{(i)}(z,\kappa,m)$ and $\widehat{\psi}_{N,t+1}^{(i)}(z)$, for the computation in the next period $t+1$ for the same i_{th} iteration. Also note that the entrants and incumbents care about the expected value of producers next period not the current period for their entry and exporting decisions in the model. So, the updated value functions , $V_{T,t+1}^{(i+1)}(z,\kappa,m)$ and $V_{N,t+1}^{(i+1)}(z)$, in i_{th} iteration are used in $(i+1)_{th}$ iteration on in t_{th} iteration.
3. Do Steps 1 and 2 for $t=1$ through $t=T$.
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 additional 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 the 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

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

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

contraction in manufacturing (about 3.8 percentage points out of 17.2 percentage points) 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 U.S. 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 from each CM). For simplicity, we choose our base year as 1972. Thus average employment per establishment in period t is calculated as

$$l_t^* = \sum_{j=1}^{J} \alpha_j L_{j,t}/N_{j,t},$$

$$\alpha_j = L_{j,1972}/\sum_{j=1}^{J} L_{j,1972},$$

where j is a 4 digit SIC industry.[34] 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 U.S. 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.[35] This switchover 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

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

[35] 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 tailors, 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

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 switchover during our sample period, we constructed the size distribution of plants in 1997 using both the SIC and NAICS classification.[36] 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.

[36] 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 for disclosure reasons.

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

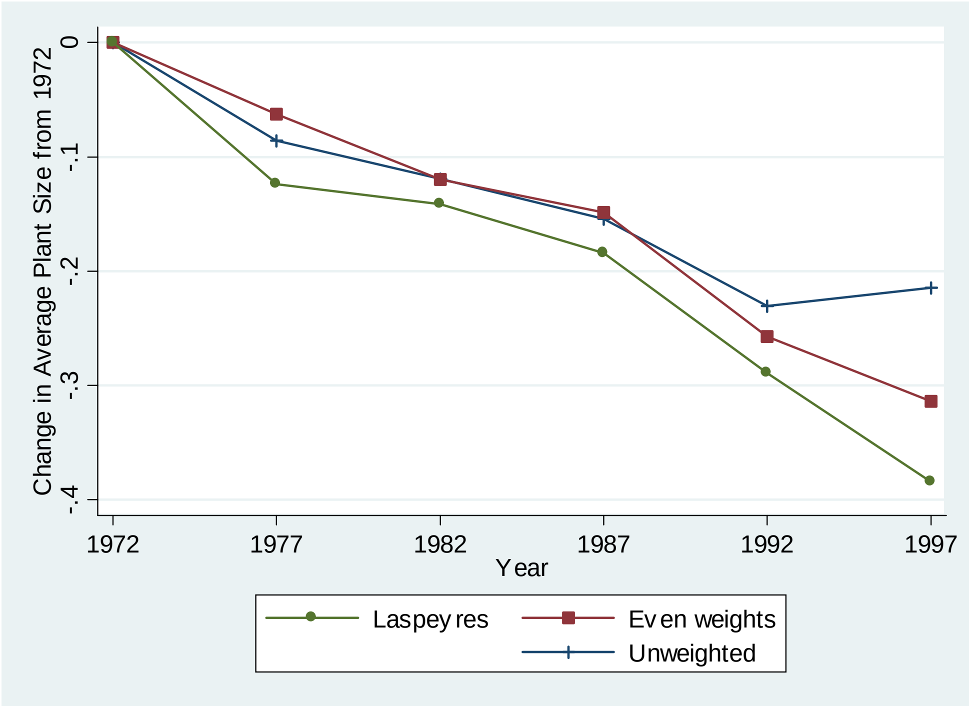


Figure A2: Change in Employment size distribution adjusted for NAICS switchover