Do Falling Iceberg Costs Account for Recent US Export Growth?*

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Abstract

We study the rise in the share of US manufactured output exported from 1987 to 2002 through the lens of the Melitz (2003) model, a monopolistically competitive model with heterogenous producers and fixed costs of exporting. Using the model, we infer that iceberg costs fell from approximately 54 percent in 1987 to nearly 41 percent in 2002. We then take a version of the model calibrated to match the employment size distribution and characteristic of exporters in 1987 and use it to measure the export growth due to the decline in iceberg costs. Contrary to common convention, we find that exports should have actually grown 75 percent more than they did. The model overpredicts export growth in large part because it misses the shift in manufacturing to relatively small establishments that did not invest in becoming exporters. In contrast to the theory, in this period, employment was largely reallocated away from very large establishments, those with more than 2500 employees, towards very small manufacturing establishments, those with less than 100 employees. We also find that trade integration from falling trade costs played a very small role in the contraction of manufacturing employment over this period.

JEL classifications: E31, F12.

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1. Introduction

The world has become much more integrated. For instance, the share of US manufacturing GDP exported more than quadrupled[1] from 1962 to 2002. While this process has been ongoing, it clearly has accelerated since the mid 1980s. Yi (2003) demonstrates that explaining this acceleration in trade growth poses a 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. In this paper we reconsider the high export growth period,[2] 1987 to 2002, through the lens of the Melitz (2003) model, the benchmark model of plant heterogeneity and exporting. Through the lens of this model, we find the opposite puzzle from Yi - the puzzle is actually that trade grew so little from 1987 to 2002 given the observed change in trade costs.

Our interpretation of the trade data differs from Yi primarily because our benchmark model of trade differs. While Yi focuses on a representative agent model in which all producers export, we use a model in which producers are heterogenous in productivity and must incur some fixed costs to export. Unlike a representative agent trade model, in which there a one-to-one relationship between the share of output exported and iceberg trade costs,[3] basically tariffs and transportation costs, in our model with producer heterogeneity, iceberg costs, fixed costs of exporting, and the productivity distribution of plants determine aggregate trade flows. In this framework not all plants export and those that do are relatively large. However, conditional on exporting, the amount exported is solely determined by iceberg costs. This breaks the one-to-one relationship between iceberg trade costs and aggregate trade flows and allows us to use the model to infer the change in iceberg costs over this period.

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

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

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

Given the change in iceberg costs we infer from the data, we then use the model to ask: How much would US exports have grown if the only change were a fall in iceberg cost? Surprisingly, we find that the fall in trade costs should have lead to about 75 percent more export growth that it did. The model generates too much export growth primarily because the model predicts a much larger increase in the share of plants exporting. The model predicts a 59 percent rise in export participation, while in the data export participation rose 24 percent.

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

The general equilibrium model we develop also allows us to study the reallocation of production across sectors, tradable and non-tradable, resulting from the fall in trade costs. In our benchmark model, trade integration generates a small reallocation of labor from tradable goods, which we associate with manufacturing, of 0.5 percent, much less than the 17 percent decline from 1987 to 2002. We conclude then that trade integration is primarily responsible for reshaping the distribution of economic activity across tradable producers, but has only a small role on the scale of the sector.

This paper is related to four lines of research. First, our focus on the relation between trade costs and plant-level trade flows is related to work by Eaton and Kortum (2002), Bernard, Eaton, Jensen and Kortum (2003), Alvarez and Lucas (2006), and Alessandria and Choi (2007b). In contrast to these papers, which study the cross-sectional relation between export participation and trade flows, we evaluate whether the change in export participation and exporter characteristic predicted by the Melitz model are consistent with the data. The second line of research studies the growth in world trade and attributes it to changes in income, tariffs, and trade costs (see Baier and Bergstrand (2001), Yi (2003), Bridgman (2004)). Hummels (2007) documents changes in air and ocean shipping costs as well as the shift toward more air shipping. He notes that the rapid fall in air freight costs, which are still quite high relative to ocean freight, and the shift towards using more air freight accounts for more modest declines in measured trade costs in aggregate measures. Bernard, Jensen and Schott (2006) show that across industries, declines in trade costs are associated with an increased likelihood of exporting. A third line of research uses models with fixed costs of trade to understand international business cycle fluctuations (see Ruhl (2003), Alessandria and Choi (2007a), and Ghironi and Melitz (2005)). Finally, there is a partial equilibrium literature that studies the export decisions of establishments. Baldwin and Krugman (1989) and Dixit (1989) develop models of export decisions with an exogenous exchange rate process. Roberts and Tybout (1997) and Das, Roberts and Tybout (2007) develop these models further and use them to identify the presence of sunk costs of exporting.

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

2. Evidence

In this section we summarize some of the changes in exports and exporting in the US manufacturing sector from 1987 to 2002. 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.

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

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

where θ denotes the elasticity of demand and Y, Y^* denote home and foreign income. Suppose further that the foreign consumers must incur an iceberg costs, ι, which includes both shipping costs and tariffs, to purchase these products.[4] If the plant sells its products at home and abroad for the same price, then the ratio of exports to domestic sales equals

$$\text{(1)} \quad \frac{ex_t}{d_t} = \frac{(1+\iota_t)^{-\theta} Y_t^*}{Y_t}.$$

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

$$\Delta ex - \Delta d = -\theta \Delta \iota + \Delta y^* - \Delta y_{US}.$$

The second column of Table 1 reports a 50.3 percent increase in the ratio of exports to domestic sales from 1987 to 2002. Given this change in the export-domestic sales ratio and both the change in relative output along and a measure of the elasticity of substitution, we can infer the change in iceberg trade costs[5] as

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

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

[5]Direct measures of the $\Delta\iota$ 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 fall in transportation costs has also been associated with a shift towards more air freight, suggesting even larger declines in shipping costs. On the other hand, Yi (2003), focusing on just tariffs, finds a relatively small drop in the tariffs imposed on US exports by its developed country partners of only about 2 percentage points. Moreover, Anderson and van Wincoop (2004) find that direct measures of trade costs are small compared to indirect measures implied by trade flows and theory.

This is essentially the time-series analogue of the Anderson and Van Wincoop (2004) approach of determining the level of trade costs. For US imports, Broda and Weinstein (2006) find an average elasticity of substitution of about 5. Based on Penn World table 6.2 data, over this period world real GDP, at PPP terms,[6] grew approximately 8.8 percent relative to US GDP. Consequently, we find that iceberg costs have fallen approximately 8.5 percentage points and account for about 82 percent of the increase in export growth.

While the model can be used to infer the change in trade costs, Yi (2003) uses the same relationship and the observed change in tariff rates to infer the elasticity of demand. Given a 2.5 percentage points fall in tariffs, the model requires an elasticity of approximately 17 to explain the data, much higher than what we observe at the micro level or for earlier periods. Without direct measures of changes in international trade costs, at this level of aggregation we can not 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-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 at exporting plants, what we call the *exporter intensity*. Clearly, the representative agent world misses out on some of the changes occurring in the manufacturing sector. To understand the impact of changes in the structure of exporters for aggregate exports, suppose that only n of the N manufacturing plants export. For these plants the export-sales ratio will still be determined by trade costs and the relative market sizes. However the ratio of exports to total sales will depend on the relative size and number of exporters. Let plant i have total sales $sales_i = d_i + ex_i$ then the ratio of exports to total sales will equal

$$(2) \qquad \frac{\text{Exports}_t}{\text{Total sales}_t} = \frac{\sum_{i=1}^{n} ex_{it}}{\sum_{i=1}^{N} sales_{it}} = \frac{\iota_t^{-\theta} Y_t^*}{Y_t + \iota_t^{-\theta} Y_t^*} \frac{\sum_{i=1}^{n_t} s_{it}}{n_t} \frac{N_t}{\sum_{i=1}^{N_t} sales_{it}} \frac{n_t}{N_t}.$$

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

[6] In nominal terms, US GDP grew 19.5 percent faster than world GDP.

ponents,

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

$$\begin{array}{cccc} 0.464 & 0.423 & -0.195 & 0.236 \end{array}$$

All four components can be measured using data from the census of manufacturers. The data show that the 46.4 percent increase in the share of manufactured goods exported has been associated with a 42.3 percent rise in the intensity with which exporters sell their products overseas, a 19.5 percent fall in the size of exporters relative to all plants in the US and 23.6 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 a plant's standpoint, it doesn't matter whether the change in export intensity is from a drop in trade costs or increase in the relative size of the foreign market. For this reason, we will attribute all of the changes in export intensity to changes in trade costs in the next sections. We then will try to answer the question: Given the characteristics of the US manufacturing sector in 1987 and the observed changes in trade costs from 1987 to 2002, can the benchmark model of export participation and dynamics explain the change in exports and export participation in the US?

3. The Model

In this section, we develop a model that contains the two key features of the Melitz (2003) model of exporting: producer heterogeneity and fixed costs of exporting.[7] Producers face uncertainty over both productivity and the fixed costs. Each period there is a mass of existing establishments distributed over productivity, fixed costs, countries, and export status. Idiosyncratic shocks to productivity and fixed export costs generate movements of establishments

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

into and out of exporting. Unproductive establishments also shutdown, and new establishments are created by incurring a sunk cost.

There are two symmetric countries, *home* and *foreign*. Each country is populated by a continuum of identical, infinitely lived consumers with mass of one. Each period, consumers are endowed with L units of labor and supply them inelastically in the labor market.

In each country there are two intermediate good sectors, tradable and non-tradable, $\{T, N\}$. 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. A non-tradable good producer uses capital and labor inputs to produce its variety, whereas a tradable good plant produces using capital, labor, and material inputs. Introducing materials into the tradable sector allows us to be consistent with the observation that trade as a share of gross output is considerably smaller than trade as a share of value-added. In each sector, establishments differ in terms of total factor productivity and the markets they serve.

All establishments sell their product in their own country, but only some establishments in the tradable good sector export their goods abroad. When an establishment in the tradable good sector exports, the establishment incurs some international trading cost, an ad valorem transportation cost[8] with the rate of ι.[9] Additionally, an establishment has to pay a fixed cost to export its goods abroad. The size of the cost depends on the producer's export status in the previous period and an idiosyncratic shock κ. To start exporting, a plant must incur a relatively high up-front sunk cost $f_0 + \kappa > 0$ and can then sell any amount in the export market in the next period. For a plant that is currently exporting, to continue exporting into the following period it must incur its idiosyncratic fixed cost κ plus a lower but nonzero period-by-period fixed continuation cost $f_1 < f_0$. If an establishment does not pay this continuation cost, then it ceases

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

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

to export. In future periods, the establishment can begin exporting only by incurring the entry cost f_0 plus its new draw of κ. These costs are valued in units of labor in the domestic country. The cost of exporting implies that the set of goods available to consumers and establishments differs across countries and is changing over time. We assume that the fixed costs must be incurred in the period prior to exporting. This implies that the set of foreign varieties is fixed at the start of each period. All the establishments are owned by domestic consumers.

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

Establishments differ by their technology, export status, sector, fixed costs, and nationality. The measure of home country tradable establishments with technology z, export status, $m = 1$ for exporters and $m = 0$ for non-exporters, and fixed cost, 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.[10] The cost of exporting implies that the set of goods available to competitive final goods producers differs across countries. The entry and exit of exporting establishments implies that the set of intermediate goods available in a country is changing over time. The final goods are used for both domestic consumption and investment.

In this economy, there exists a one-period single nominal bond denominated in the home currency. Let B_t denote the home consumer's holding of the bonds purchased in period t. Let B_t^* denotes 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.

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

A. Consumers

Home consumers choose consumption, investment, and bond holdings to maximize their utility:

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

subject to the sequence of budget constraints,

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

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

The problem of foreign consumers is analogous to this problem. Prices and allocations in the foreign country are represented with an asterisk. Money has no role in this economy and is only a unit of account. The foreign budget constraint is expressed as

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

where * denotes the foreign variables and e_t is the nominal exchange rate with home currency as numeraire.[11]

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

$$Q_t = \beta \frac{U_{C,t+1}}{U_{C,t}} \frac{P_t}{P_{t+1}},$$

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

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, $q_t = e_t P_t^* / P_t$,

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

B. Final Good Producers

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

The final good can be produced by combining a composite good produced of tradables, D_T, and a composite good produced of nontradables, D_N.

$$(3) \quad D_t = D_{T,t}^{\gamma} D_{N,t}^{1-\gamma}$$

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

$$\begin{aligned} D_{T,t} &= \left(\sum_{m=0}^{1} \int_{z \times \kappa} y^d_{H,t}(z,\kappa,m)^{\frac{\theta-1}{\theta}} \psi_{T,t}(z,\kappa,m) + \int_{z \times \kappa} y^d_{F,t}(z,1,\kappa)^{\frac{\theta-1}{\theta}} \psi^*_{T,t}(z,1,\kappa) \right)^{\frac{\theta}{\theta-1}}, \\ D_{N,t} &= \left(\int_z y^d_{H,t}(z)^{\frac{\theta-1}{\theta}} \psi_{N,t}(z)\, dz \right)^{\frac{\theta}{\theta-1}}, \end{aligned}$$

where $y^d_{H,t}(z,\kappa,m)$ and $y^d_{F,t}(z,1,\kappa)$ are inputs of intermediate goods purchased from a home tradable good producer with technology z, export status m, and fixed cost κ and foreign tradable exporter with technology (z,κ). 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

$$\text{(4)} \qquad \max \Pi_{F,t} = D_t - \sum_{m=0}^{1} \int_{z \times \kappa} \left[\frac{P_{H,t}(z,\kappa,m)}{P_t} \right] y^d_{H,t}(z,\kappa,m)\, \psi_{T,t}(z,\kappa,m) - \int_{z \times \kappa} \left[\frac{(1+\iota) P_{F,t}(z,\kappa,1)}{P_t} \right] y^d_{F,t}(z,1) \psi^*_{T,t}(z,1,\kappa) - \int_z \left[\frac{P_{N,t}(z)}{P_t} \right] y^d_{N,t}(z) \psi^*_{N,t}(z)\, dz,$$

subject to the production technology (3).[12] Solving the problem in (4) gives the input demand functions,

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

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

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

where the price indices are defined as

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

$$\text{(9)} \qquad P_{N,t} = \left[\int_z P_{N,t}(z)^{1-\theta} \psi_{N,t}(z) \right]^{\frac{1}{1-\theta}},$$

$$\text{(10)} \qquad P_t = \left(\frac{P_{T,t}}{\gamma} \right)^{\gamma} \left(\frac{P_{N,t}}{1-\gamma} \right)^{1-\gamma}.$$

The final goods are used for both consumption and investment.

C. Intermediate Good Producers

All the intermediate good producers produce their differentiated good using capital and labor. Tradable good producers also use material inputs of other tradable good producers. We

[12] 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.

assume that an incumbent's idiosyncratic productivity, z, and fixed cost, 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 $\phi_E(z', \kappa')$. We also assume that establishments receive an exogenous death shock that depends on an establishment's productivity, z, at the end of the period, $0 \leq n_d(z) \leq 1$.

Non-Tradable Good Producers

Consider the problem of a non-tradable good producer from the home country in period t with technology z. The producer chooses the 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

$$(12) \qquad V_{N,t}(z) = \max \Pi_{N,t}(z) + n_s(z) Q_t \int_{z'} V_{N,t+1}(z') \phi(z'|z) dz',$$

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

subject to the production technology (11), and the constraints that supplies to the non-tradable goods market $y_{N,t}(z)$ are equal to demands by final good producers $y_{N,t}^d(z)$ in (7).

Tradable Good Producers

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

(14)

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

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

$$\text{(15)}\quad x_{H,t}^{d}(\zeta,\mu,z,\kappa,m) = \left[\frac{P_{H,t}(\zeta,\mu)}{P_t}\right]^{-\theta} x_t(z,\kappa,m),$$

$$\text{(16)}\quad x_{F,t}^{d}(\zeta,1,z,\kappa,m) = \left[\frac{(1+\tau)\,P_{F,t}(\zeta,1)}{P_t}\right]^{-\theta} x_t(z,\kappa,m),$$

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

The producer has a Cobb-Douglas production technology,

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

and solves

$$
\begin{aligned}
(18)\quad V_{T,t}(z,\kappa,m) &= \max \Pi_{T,t}(z,\kappa,m) - W_t(f_m+\kappa) \\
&\quad + n_s(z)\,Q_t \int_{z\times\kappa} V_{T,t}(z',\kappa,m')\,\phi(z',\kappa'|z,\kappa) \\
(19)\quad \Pi_{T,t}(z,\kappa,m) &= \left[\frac{P_{H,t}(z,\kappa,m)}{P_t}\right] y_{H,t}(z,\kappa,m) + \left[\frac{e_t P^*_{H,t}(z,\kappa,m)}{P_t}\right] y^*_{H,t}(z,\kappa,m) \\
&\quad - W_t l_{T,t}(z,\kappa,m) - R_t k_{T,t}(z,\kappa,m) \\
&\quad - \sum_{\mu=0}^{1}\int_{\zeta}\left[\frac{P_{H,t}(\zeta,\mu)}{P_t}\right] x^d_{H,t}(\zeta,\mu,z,\kappa,m)\,\psi_{T,t}(\zeta,\mu)\,d\zeta \\
&\quad - \int_{\zeta}\left[\frac{(1+\iota_t)\,P_{F,t}(\zeta,1)}{P_t}\right] x^d_{F,t}(\zeta,1,z,\kappa,m)\psi^*_{T,t}(\zeta,1)\,d\zeta,
\end{aligned}
$$

subject to the production technology (11) and the constraints that supplies to home and foreign tradable goods markets, $y_{H,t}(z,\kappa,m)$ and $y^*_{H,t}(z,\kappa,m)$ with $y_{T,t}(z,\kappa,m) = y_{H,t}(z,\kappa,m) + (1+\iota_t)\,y^*_{H,t}(z,\kappa,m)$, are equal to demands by final good producers from (5), the foreign analogue of (6),

$$
(20)\quad y^{d*}_{H,t}(z,\kappa,m) = m\gamma\left[\frac{(1+\iota)\,P^*_{H,t}(z,\kappa,m)}{P^*_t}\right]^{-\theta} D^*_{T,t},
$$

and demands by intermediate good producers

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

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

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

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

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

$$(24) \quad V_{T,t}^{0}\left(z,\kappa,m\right)=\max \Pi_{T,t}\left(z,\kappa,m\right)+n_{s}\left(z\right)Q_{t}\int_{z'\times\kappa'}V_{T,t+1}\left(z',\kappa',0\right)\phi\left(z',\kappa'|z,\kappa\right)dz'.$$

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

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

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 and the cost of continuing f_1 is not too small compared to the cost of entering, f_0. Hence, it is possible to solve for the establishment productivity at which an establishment is indifferent between exporting or not exporting; that is, the increase in establishment value from exporting equals the cost of exporting. This level of establishment productivity differs by the establishment's current export status. For a given export cost κ, the critical level of technology for exporters and non-exporters, $z_{1,t}\left(\kappa\right)$ and $z_{0,t}\left(\kappa\right)$, satisfy

$$\begin{aligned}(25) \quad V_{T,t}^{1}\left(z_{1,t}\left(\kappa\right),\kappa,1\right) &= V_{T,t}^{0}\left(z_{1,t}\left(\kappa\right),\kappa,1\right), \\ (26) \quad V_{T,t}^{1}\left(z_{0,t}\left(\kappa\right),\kappa,0\right) &= V_{T,t}^{0}\left(z_{0,t}\left(\kappa\right),\kappa,0\right).\end{aligned}$$

D. Entry

Each period, a new establishment can be created by hiring f_E workers. Establishments incur these entry costs in the period prior to production and must chose one sector to enter. Once the entry cost is incurred, establishments receive their idiosyncratic shocks from the distribution $\phi_E\left(z',\kappa'\right)$. All the entrants are free from death shocks. New entrants can not export in their first productive period. Thus the entry conditions is

$$V_{T,t}^{E} = -W_t f_E + Q_t \int_{z' \times \kappa'} V_{T,t+1}^{0}(z', \kappa', 0)\, \phi_E(z', \kappa')\, dz' d\kappa' \geq 0, \tag{27}$$

$$V_{N,t}^{E} = -W_t f_E + Q_t \int_{z'} V_{N,t+1}(z')\, \phi_E(z')\, dz' \geq 0, \tag{28}$$

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

$$N_{1,t} = \int_{\kappa \times z} \psi_{T,t}(z, \kappa, 1)\, dz d\kappa, \tag{29}$$

$$N_{0,t} = \int_{\kappa \times z} \psi_{T,t}(z, \kappa, 0)\, dz d\kappa, \tag{30}$$

and the mass of establishments in the tradable good sectors equals

$$N_{T,t} = N_{1,t} + N_{0,t}. \tag{31}$$

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, $z_{1,t}$ and $z_{0,t}$, we can measure the starter ratio, the fraction of establishments that start exporting among non-exporters, as

$$n_{0,t+1} = \frac{\int_{\kappa} \int_{z_{0,t}(\kappa)}^{\infty} n_s(z)\, \psi_{T,t}(z, \kappa, 0)\, dz d\kappa}{\int_{\kappa \times z} n_s(z)\, \psi_{T,t}(z, \kappa, 0)\, dz d\kappa}. \tag{32}$$

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

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

The evolutions of mass of establishments are given by

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

E. Aggregate Variables

Investment, I_t, is given by the law of motion for capital

$$(34)\quad I_t = K_t - (1-\delta)\,K_{t-1}.$$

Nominal exports and imports are given as

$$\begin{aligned}
(35)\quad EX_t^N &= \int_z e_t P_{H,t}^*(z,\kappa,1)\,y_{H,t}^*(z,\kappa,1)\,\psi_{T,t}(z,\kappa,1)\,dz, \\
(36)\quad IM_t^N &= \int_z P_{F,t}(z,\kappa,1)\,y_{F,t}(z,\kappa,1)\,\psi_{T,t}^*(\zeta,1)\,dz,
\end{aligned}$$

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

$$Y_t^N = P_t D_t + EX_t^N - IM_t^N.$$

The trade to GDP ratio is given as

$$(37)\quad TR_t = \frac{EX_t^N + IM_t^N}{2Y_t^N}.$$

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

$$(38)\quad L_{P,t} = \sum_{m=0}^{1} \int_{z\times\kappa} l_{T,t}\left(z,\kappa,m\right)\psi_{T,t}\left(z,\kappa,m\right)dzd\kappa.$$

The domestic labor[13] hired by exporters, $L_{X,t}$, is given by

$$(39)\quad L_{X,t} = \int_{\kappa}\int_{z_{0,t}(\kappa)}^{\infty}\left(f_0+\kappa\right)\psi_{T,t}\left(z,\kappa,0\right)dzd\kappa + \int_{\kappa}\int_{z_{1,t}(\kappa)}^{\infty}\left(f_1+\kappa\right)\psi_{T,t}\left(z,\kappa,1\right)dzd\kappa.$$

From (39), we see that the trade cost, measured in units of domestic labor, depends on the exporter status from the previous period.

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

$$\begin{aligned}\Pi_t &= \Pi_{F,t} + \sum_{m=0}^{1}\int_z \Pi_{T,t}(z,m)\psi_{T,t}\left(z,\kappa,m\right)dz + \int_z \Pi_{N,t}(z)\psi_{NT,t}\left(z\right)dz \\ &\quad - W_tL_{X,t} - f_EW_t\left(N_{TE,t}+N_{NE,t}\right).\end{aligned}$$

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 establishment technology 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

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

of establishments and entrants into the next period's distribution of establishments,

$$\psi' = T\left(\psi, N_{TE}, N_{TE}^{*}, N_{NE}, N_{NE}^{*}\right).$$

F. Equilibrium Definition

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

An equilibrium of the economy is a collection of allocations for home consumers C_t, B_t, K_t; allocations for foreign consumers C_t^*, B_t^*, K_t^*; allocations for home final good producers; allocations for foreign final good producers; allocations, prices, and export policies for home tradable good producers; allocations, prices and export decisions for foreign tradable good producers; labor used for exporting costs at home and foreign; labor used for entry costs;real wages W_t, W_t^*, real rental rates of capital R_t, R_t^*, 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; (vi) the market clearing conditions hold; and (vii) the transfers satisfy the government budget constraint.

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

$$U(C) = \frac{C^{1-\sigma}}{1-\sigma},$$

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 US manufacturing plants in the US in 1987. We also target a set of moments about how plants evolve over time and transit across export status.

The establishment size distribution is largely determined by the underlying structure of shocks. We assume that the shocks to productivity and fixed costs are independent. Productivity of plants in the tradable and non-tradable sectors are assumed to follow the same process. The incumbent's productivity follows

$$z' = \rho_\varepsilon \ln z + \varepsilon, \qquad \varepsilon \overset{iid}{\sim} N(0, \sigma_\varepsilon^2).$$

The assumption that establishment technology follows an AR(1) with shocks drawn from an iid normal distribution implies that this conditional distribution follows a normal distribution $\phi\left(z'|z\right) = N\left(\rho_\varepsilon z, \sigma_\varepsilon^2\right)$. We assume that entrants draw productivity based on the unconditional distribution

$$z' = \mu_E + \varepsilon_E, \qquad \varepsilon_E \overset{iid}{\sim} N\left(0, \frac{\sigma_\varepsilon^2}{1-\rho_\varepsilon^2}\right).$$

However, to match the observation that entrants start out small relative to incumbents we assume that $\mu_E < 0$.

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

We also assume that establishments receive an exogenous death shock that depends on an establishment's last period productivity, z, so that the probability of death is given as

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

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 US trade-weighted import elasticity of 5.36 estimated by Broda and Weinstein (2006) for the period 1990-2001.[14]

The tradable share parameter of the final good producer, γ, is set to 0.21 to match the ratio of manufacturers' nominal value-added relative to private industry GDP excluding agriculture and mining for the US from 1987 to 1992. The labor share parameter in production, α, is set to match the labor income to GDP ratio of 66 percent. The share of materials in production, α_x, determines the ratio of gross output to value-added in manufacturing. For the period 1987 to 1992, in the US this ratio averages 2.75 and implies that $\alpha_x = 0.804$.

The total mass of establishments, $N_{T,t} + N_{N,t}$, is normalized to 2 with the entry cost parameter f_E. In all the analysis, we assume that the mean establishment size of the tradable sector is as in the US in 1987.

We target features of the establishment and exporter size distributions as well as some

[14] Anderson and van Wincoop survey elasticity estimates from bilateral trade data and conclude $\theta \in [5, 10]$.

dynamic moment of exporters, non-exporters, plant employment. In particular, we target:

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

The first two targets, along with θ, pin down the level of trade costs in 1987 and 2002. Given $\theta = 5$, we find trade costs increase export prices by 55 percent in 1987 and 41 percent in 2002. Anderson and van Wincoop (2004) find larger 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.

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 in a two step process. First, we use the following seven parameters μ_E, λ, n_{d0}, f_0, f_1, ι_{87}, and ι_{02} to match the first 7 observations.[15] We then choose $\rho_\varepsilon, \sigma_\varepsilon$, and ρ_κ to minimize distance between the distributions in the model and the data (measured by the sum of squared residuals). The parameter values are reported in Table 2 and the fit of the benchmark model is summarized in Table 3. Figure 1 plots the distribution of plants over productivity levels and export status. We also plot the probability of the death shock.

Establishment Distribution

The three panels of Figure 2 plot key characteristics of plant 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. Overall, the model slightly underpredicts the share of small establishments and overpredicts the share of large establishments. The middle panel displays the share of employment accounted for by establishments in each size class. The largest gap between the data and the model is in the employment share of plants with 1000 to 2499 employees. In the data, these plants account for 10.7 percent of employment while in the model they account for 13.1 percent of employment. Finally, the third panel displays the share of establishments exporting by establishment size. As in the data, the share of establishments exporting increases with establishment size. The model is a close fit to the data on this dimension, with the mean absolute difference of less than 0.4 percent for export participation of plants with 100+ employees. Both the assumption about the lag in starting to export and the stochastic fixed costs are crucial to match the rise in export participation with plant size. Without these assumptions export participation would rise much faster with establishment size.

[15] The model is solved by discretizing the idiosyncratic shock process and then using value function iteration to solve for the marginal starters and stoppers.

5. Results

We begin by using the model to explore the impact of the cut in iceberg trade costs necessary to raise export intensity as in the data. This requires cutting transport costs from 54 percent to 41 percent. Our analysis is based on a comparison of the steady state of two model economies that only differ in terms of their iceberg trade costs. The change in these model economies and the data are reported in Table 4. As before, we concentrate on the trade growth predicted for plants with 100+ employees.

From the first column of Table 4, we see that the model predicts a much larger increase in exports than in the data (0.80 vs. 0.46). The larger increase in the share of output exported results from a much larger increase in export participation than in the data (0.59 vs. 0.24) while the decrease in the exporter premium is quite similar to the data (-0.22 vs. -0.20). The model also predicts that employment should shift away from relatively less productive plants towards relatively more productive plants as sales of exporters will rise and more of these relatively productive plants will export. In total, the model predicts that the employment share of plants with less than 99 employees will fall by 1 percentage point while the share of employment in the largest plants will rise by 0.1 percentage points.

Figure 3 depicts the changes in the establishment and exporter distributions in the model and the data. Panel a depicts the change in the share of establishments in each employment bin. In the data, the share of small establishments, those with 99 or less employees, rises by 1 percentage point while the model predicts a decrease of 0.25 percentage points in the share of the smallest establishments. In the model, share of establishments with 250 to 499 employees grows the most. The increase in the mid-sized plants reflects the increased export participation by moderately productive plants.

Panel b plots the distribution of employment by establishment size in the model and data for 1987 and 2002. The shift in employment towards relatively large plants predicted by the model is at odds with the shift towards smaller plants that occurred in the US manufacturing sector over this period. This shift is clearly evident among the largest and smallest plant sizes. The share of employment accounted for by plants with 2500+ employees fell 5.4 percent while the share of employment accounted for by the smallest plants rose 2.9 percent. In contrast, the model generates a shift in employment from the smallest plants to those with more than 500 employees.

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

The model misses out on the changes in the distribution of employment over plants in part because it misses out on the change in the mean plant size. In the data, plant size falls approximately 15 percent while in the model it increases by 2.9 percent. To compensate, we re-scale average plant size in our 2002 model to match the data. This re-scaling does not alter the relative size of plants or the export decision, but alters how we allocate plants across employment categories. The result of this rescaling are reported in Figure 3. By shifting establishments into smaller categories the model can capture some of the changes occurring at large and small plants but at the expense of missing out on more of the changes in medium sized plants. That this rescaling only partly improves the fit of the model suggests that the model is missing out on a fundamental source of the change in the plant size distribution.

6. Sensitivity

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

Dynamics

To solve for the transition dynamics, it is necessary to take a stand on the evolution of trade costs along with agent's expectations. We assume that there is a once and for all, unanticipated fall in trade cost from ι_{87} to ι_{02} in 1988. Given that export intensity rose from 10.0 percent in 1987 to 13.1 percent in 1992 and 14.8 percent in 1997, our assumption accelerates the fall in trade costs relative to the data. However, from figure 4, which plots the dynamics of export participation, we see that it takes about 3 years for the model to surpass the increase in the data and that about 90 percent of the transition is complete in 7 years. The final 10 percent of the transition takes considerably longer. Given that the bulk of the transitions is fairly fast and that most of the decline in trade costs had occurred in the first 10 years of the data, we conclude that the transition dynamics may explain only a small part of the under investment in export capacity in the data.

Nontradables

We now examine the role of the change in the sectoral composition of output for our results. In our benchmark calibration, the model generates a much smaller decline in manufacturing employment of 0.5 percent than the approximate 17 percent decline in the data.[16] Thus it appears that falling trade costs, and the increased integration it generates, has contributed very little to the decline in manufacturing employment. However, the impact of falling trade costs on manufacturing will depend on the substitution it creates across sectors, which is governed by the elasticity of substitution between tradables and non tradables. To explore this channel, we allow for a more general CES production function of final goods,

$$(40) \quad D = \left[a D_T^{\frac{\gamma-1}{\gamma}} + (1-a) D_N^{\frac{\gamma-1}{\gamma}} \right]^{\frac{\gamma}{\gamma-1}}$$

Figure 5 plots the relationship between plant size, tradable employment, and the mass

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

of tradable plants for a range of elasticities from $\gamma = 0.25$ to $\gamma = 1.5$ following the fall in iceberg costs. For each value of γ we choose a to match the expenditure on tradables from our benchmark case. Lowering the elasticity of substitution leads to more resources being allocated to the non-tradable sector. However, the changes to manufacturing employment are minor. Even with $\gamma = 0.25$, lower than the elasticity estimated in the literature,[17] employment in tradables falls 1.4 percent while the number of plants falls 4.3 percent. Thus it appears that the changes across sectors from falling inceberg costs can not account for very much of the contraction in manufacturing employment.

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

7. Conclusions

We study US export growth from 1987 to 2002 using the Melitz model, by now the benchmark model of plant heterogeneity and exporting. In contrast to the representative agent framework commonly employed, the model does not contain a one-to-one link between changes in iceberg costs and the growth in trade. Instead, by using data on characteristics of exporters, in particular the intensity with which they export, we are able to identify the change in iceberg trade costs over this period. Given this observed decline in iceberg trade costs, the model predicts that the share of manufacturing output exported should have grown nearly 75 percent more than it did. Thus, in contrast to the common convention summarized in Yi (2003), we find that the puzzle is not that trade grew so much in this period, but that it grew so little.

The model overpredicts US export growth because it substantially overpredicts the increase in export participation by US manufacturing plants. Export participation did not grow as expected in large part because there was a substantial shift towards smaller plants. Given the

[17] For instance, estimates of the elasticity of substition between tradables and non-tradables is range from 1.24 by Ostry and Reinhart (1991) for a group of developing countries and Mendoza's (1995) estimate of 0.74 for a group of industrialized countries.

fixed costs of exporting, these smaller plants did not find investing in exporting capacity worthwhile. This shift towards smaller plants stands in contrast to the key prediction of the Melitz model that a lowering of trade costs should lead employment to become more concentrated in relatively large manufacturing plants since they are more likely to be exporting and thus can take advantage of the lower trade costs. That we found that employment became concentrated in the smallest establishments, suggests that either there are forces beyond trade altering the establishment employment distribution or that the products produced by small and large establishments are inherently very different. Perhaps US manufacturers have a comparative advantage in producing goods in plants with smaller scale of production.

Our general equilibrium model of trade allows us to quantify the role of falling iceberg costs for the shift from tradable to non-tradable production in the US. We find that increasing trade integration has a very small role for the decline in employment in the tradable sector, accounting for at most 10 percent of the decline in manufacturing employment. We conclude from this that the fall in iceberg costs matters more for the distribution of employment across manufacturing establishments rather than the allocation of employment across sectors.

The current model has a number of shortcomings. On the micro side, the model underpredicts export participation by small plants and overpredicts export participation by large plants. Second, we assumed all producers face the same iceberg costs so that all exporters export the same share of output. In the data there is substantial dispersion in export shares. This may reflect heterogeneity in iceberg costs across sectors or in the number of markets served. Similarly, this may reflect different investments in exporting technologies. Perhaps in a richer model of exporter dynamics the increase in export participation and change in the employment distribution will be less of a puzzle. On the macro side, we have focused on a symmetric model. The period studied involves a substantial US trade deficit as well as a large depreciation and appreciation of the real exchange rate. Perhaps, the forces giving rise to these net export and real exchange rate dynamics also tended to discourage entry by US exporters into foreign markets. We are currently exploring this topic.

Table 1: Export Characteristics and Trade

Plants with 100+ employees							
	EX/D	EXY	Intensity	Premium	Participation	Y_{US}	Y_{ROW}
1987	0.065	0.061	0.100	1.646	0.370	0	0
2002	0.107	0.097	0.152	1.354	0.469	0.796	0.882
Log Change	0.503	0.464	0.423	-0.195	0.236		0.086

EX/D denotes exports/domestic sales ratio in the manufacturing sector, EXY=Total Exports/Total Sal

Intensity is the ratio of exports to sales of exporters, Premium is the ratio of mean sales of exporters to

mean sales of all plants, Participation equals the ratio of the number of exporters to the number of plan

Calculated from Census of Manufacturers (1987 and 2002).

Table 2: Parameter Values

Parameters

$\beta = 0.96$, $\sigma = 2$, $\theta = 5$, $\delta = 0.10$, $\tau = 0$

$\alpha = 0.289$, $\lambda = 7.836$, $n_{d0} = 0.0225$, $\alpha_m = 0.804$, $\iota_{87} = 1.541, \iota_{02} = 1.413$,

$\rho_\varepsilon = 0.79$, $\mu_E = 0.335$, $\sigma_\varepsilon = 0.300$,

$f_E = 2.31, f_0 = 0.392, f_1 = 0.064, \kappa_L = 0, \kappa_H = \infty, \rho_\kappa = 0.94$

$\gamma = 1, \alpha_{NT} = 0.21$

Table 3: Target Moments and Implications

	1987		2002
	Target value	Sunk-Cost	Sunk-Cost
5-year exit rate	0.37	0.37	0.37
Startups' labor share	0.015	0.015	0.014
Shutdowns' labor share	0.023	0.023	0.022
Stopper rate	0.17	0.17	0.14
Exporter ratio (100+)	0.37	0.37	0.64
Exporter Intensity (100+)	0.10	0.10	0.152
Trade Share (%)	5.1	5.3	11.7
Squared sum of residuals (%)			
Establishments	0	5.2	
Employment share	0	4.2	
Export participation	0	0.4	

Table 4: Change in Export Characteristics and Trade

	Export Share	Intensity	Premium	Participation	N_T	L_T	s^{2500+}	$s^{<99}$
Data	0.46	0.42	-0.20	0.24	-2.0	-17.0	-5.4	2.9
Model	0.80	0.42	-0.22	0.59	-3.3	-0.5	0.1	-1.0

N_T is the number of tradable plants. L_T is employment for production in tradables. s^j measures the share of employment in plants with j employees

Figure 1: Establishment Distribution

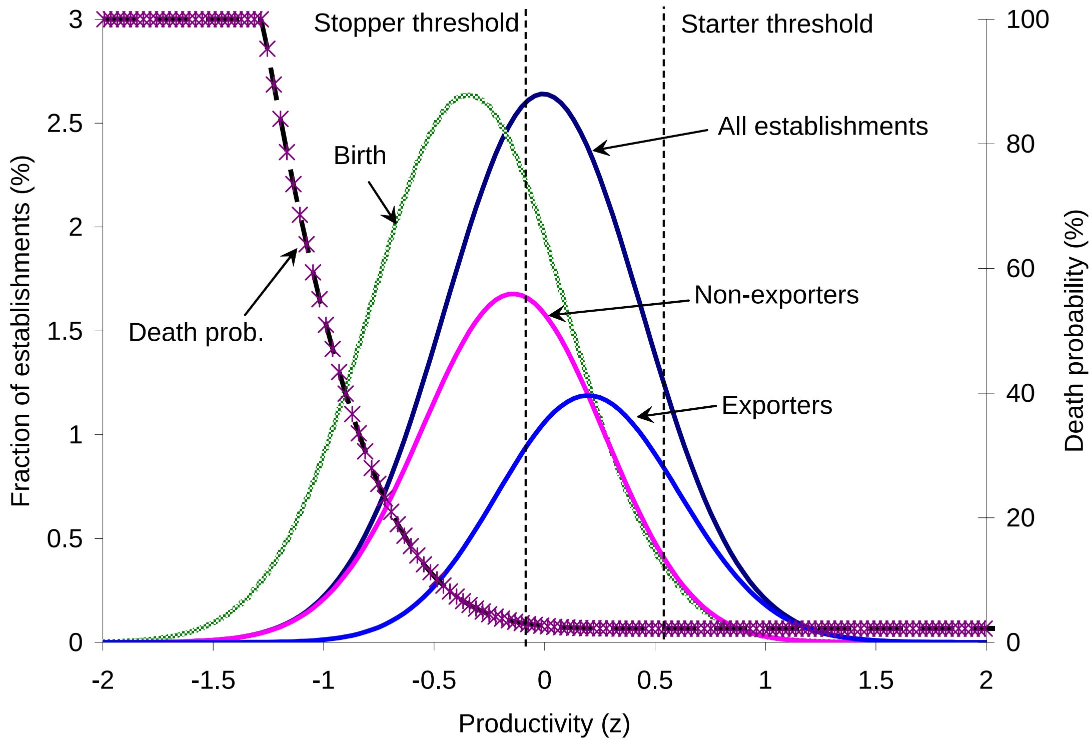
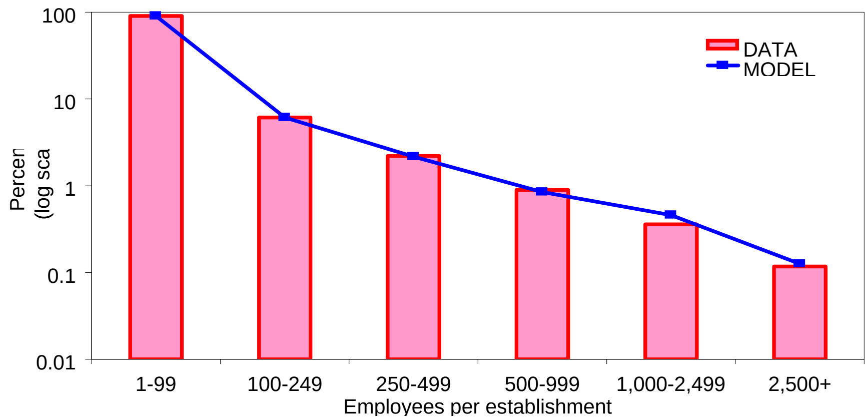
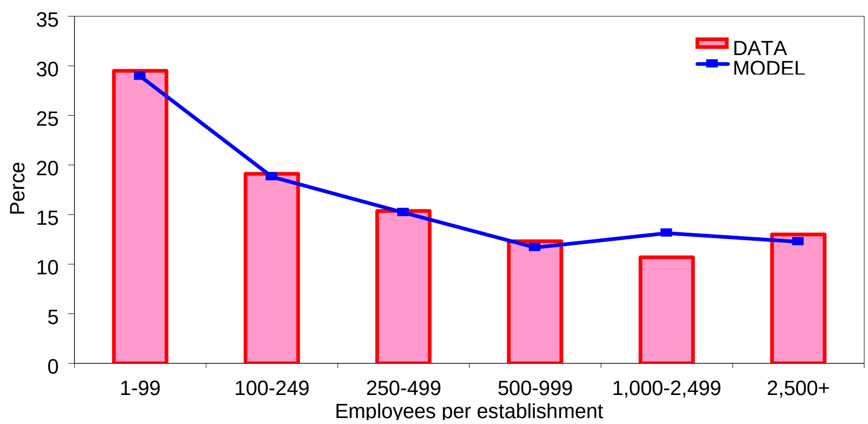


Figure 2: Plant Characteristics by Employment Size

(a) Establishment Share



(b) Employment Share



(c) Export Participation

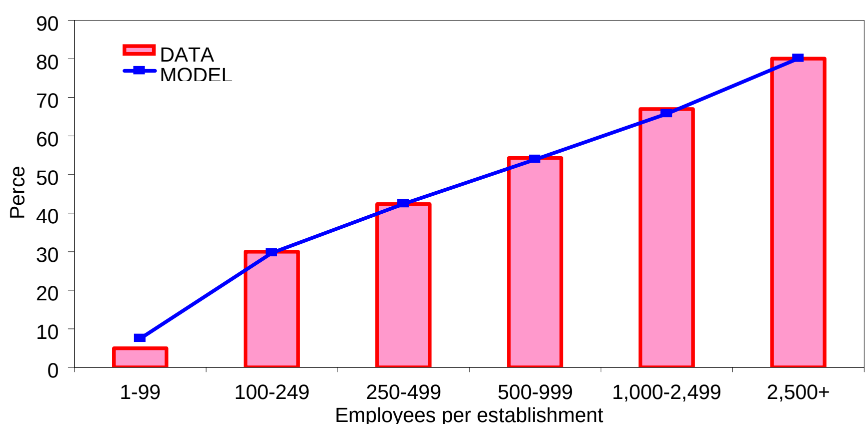
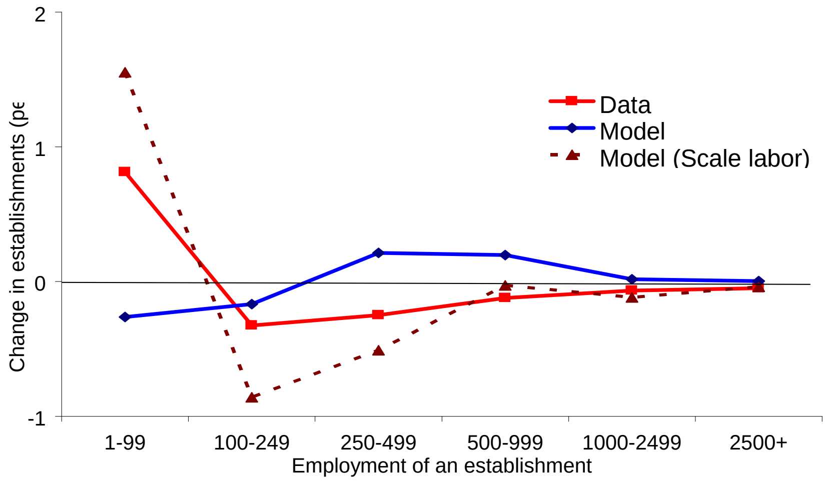
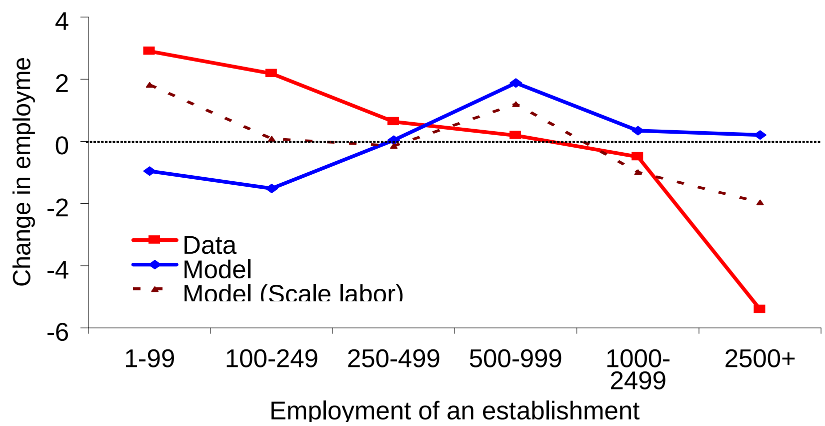


Figure 3: Change in Plant Characteristics by Employment Size

(a) Establishment Share



(b) Employment Share



(c) Export Participation

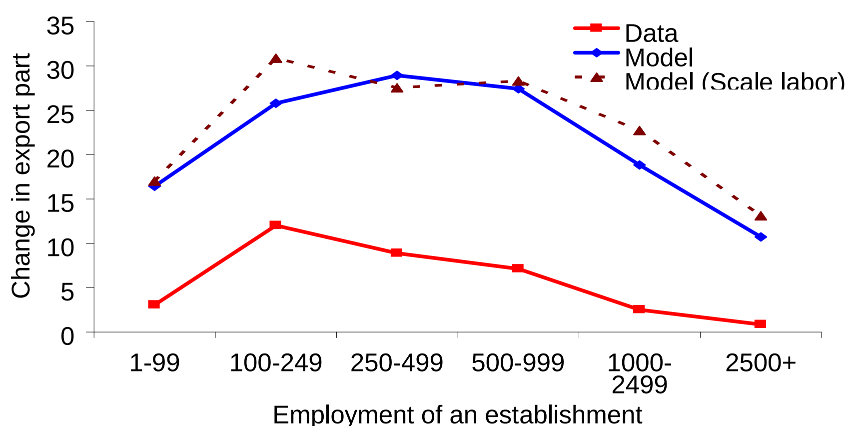


Figure 4: Dynamics of Export Participation

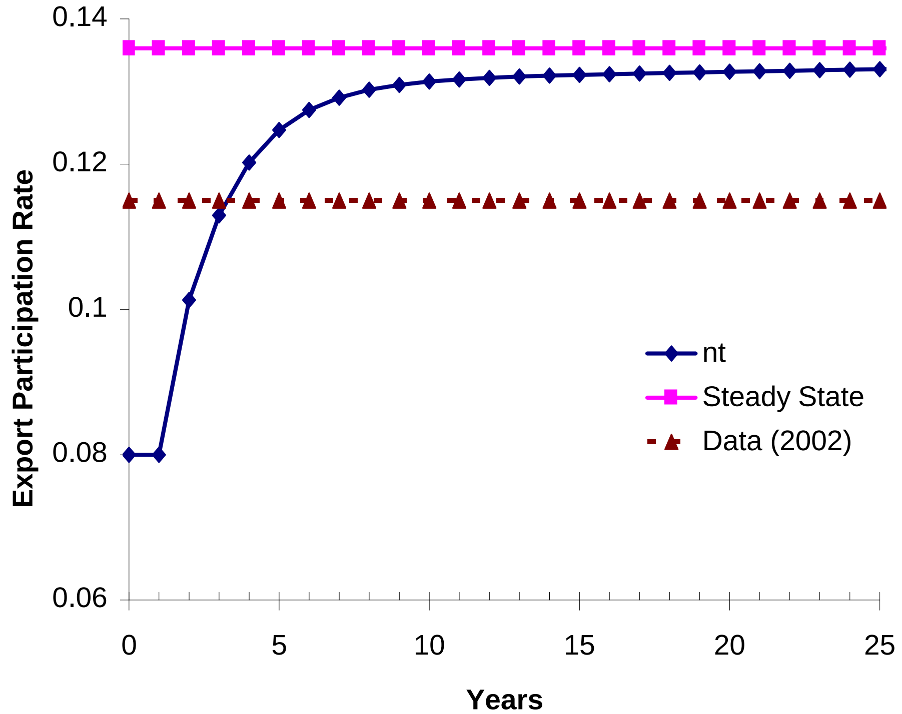
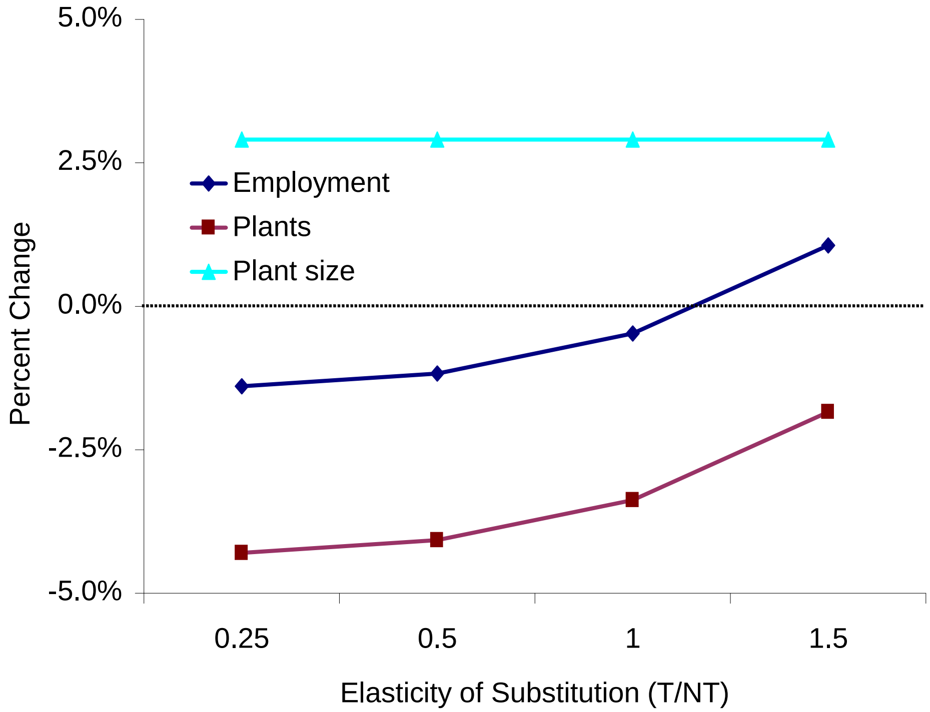


Figure 5: Tradable Sector and Elasticity of Substitution



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