Trade Adjustment Dynamics and the Welfare Gains from Trade*

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Abstract

We introduce time and risk into the fixed-variable cost tradeoff in heterogeneous firm trade models: Investing in exporting gradually and stochastically lowers the costs of exporting. In the model, aggregate trade dynamics arise from producer-level decisions to invest in lowering their future variable export costs, and tariff reforms generate time-varying trade elasticities. The gains from reducing tariffs arise from substituting away from firm creation and towards exporting. This substitution is larger when new exporters are smaller and take longer to grow into successful exporters. The welfare gains from reducing tariffs are much larger than the long-run changes in consumption and the welfare gains cannot be recovered from a static model or from formulas based on those models. Comparing steady-state outcomes can predict a welfare loss from reform when the actual change is positive.

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JEL: F1, F4, F6

1. Introduction

For the United States, and much of the world, the 1950s–2000s was a period of major trade reform. Standard international trade models (e.g., Baldwin, 1992; Eaton and Kortum, 2002; Melitz, 2003) predict that, as the transitional effects of these reforms wind down, the U.S. economy should be converging to higher levels of trade, consumption, and income. While international trade has grown, it is less clear that income and consumption have grown in the ways that the models predicted. The highly visible increase in trade and the recent stagnation in income have provided fodder for a growing backlash against trade integration.

Against this backdrop, we argue that understanding the welfare gains from tariff reform requires accounting for the transition between the high- and low-tariff equilibria. Simply comparing the two steady states generates misleading predictions that can substantially

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understate the welfare gains from trade reform. Most of the welfare gain occurs early in the transition when the economy is far from its new steady state.

Understanding the post-reform transition is crucial for welfare. What is crucial for understanding the post-reform transition? We show that the substitutability between firm creation and export capacity—a relationship that is central to all models with firm heterogeneity since Melitz (2003)—is the key determinant of the gains from trade. A tariff cut increases imports, which drives a decrease in firm creation, freeing resources to use in production. This generates a rapid expansion in consumption that overshoots its new steady-state value. The extent to which imports can increase and firm creation can decrease depends on the ease of expanding export capacity. Surprisingly, we find that the substitution between trade and firm creation is greater when it takes longer for firms to expand their exports.

We build a general equilibrium, heterogeneous firm model in which we introduce time and risk into the export cost structure: Investing in exporting gradually and stochastically lowers the iceberg cost of exporting. The model captures the tendency of new exporters to export on a small scale, to have low survival rates, and to take time to grow into large exporters.[1] In transition following a tariff cut, aggregate trade dynamics arise from producers' decisions to invest in lowering their future iceberg export costs, and generate a trade elasticity that increases over time.

We develop a parsimonious model of producer export entry, expansion, and exit within a two-country general equilibrium model with capital, roundabout production, and asset trade. The model nests the standard models of heterogeneous producers with fixed export costs. To capture the observed new-exporter dynamics, we allow the producer's exporting technology to require a series of repeated export-specific investments. As in the standard models, nonexporters have an infinite iceberg trade cost. By paying a fixed cost, nonexporters lower their iceberg cost to a finite level and become exporters. Existing exporters must pay another, potentially different, fixed cost to continue exporting. As long as a new exporter continues to export, its iceberg cost falls stochastically over time. As producers become more efficient exporters, their export intensity increases, consistent with the data. It takes time, resources, and a bit of luck to become an efficient exporter. Efficient exporters accumulate a better technology for the distribution of their exports than non-exporters and new exporters.

To see why an endogenous exporting technology is important, consider the standard sunk-cost model of Das et al. (2007) and Alessandria and Choi (2014). In this model, new exporters make a large upfront investment in export access in order to export on a large scale. Continuing exporters do not invest in expanding the scale of exporting—they pay only to maintain market access. In our benchmark model, in contrast, new exporters make a small upfront investment to export on a small scale, and they must make repeated investments in market access to expand their exports. Thus, tariffs discourage investments on two margins—market access for new exporters and the scale of market access by all exporters—further distorting trade. Since tariffs distort trade more in the benchmark model, liberalization leads to a larger increase in trade and a larger decrease in firm creation compared to the

[1] Our model integrates the structural, partial equilibrium literature that studies establishment-level export patterns (Das et al., 2007; Kohn et al., 2015; Rho and Rodrigue, 2016; Ruhl and Willis, 2017) and the general equilibrium literature focused on measuring the gains from trade.

sunk-cost model. This generates more overshooting in the benchmark model and larger gains from trade.

With this general export technology, the aggregate volume of trade now depends on tariffs and the joint distribution of iceberg costs and productivity. Trade expands through accumulated exporters (extensive margin) and a better exporting technology (intensive margin). Because of the dynamic nature of the extensive and intensive margins, there is no simple mapping between the structural parameters of the model, tariffs, and the volume of trade along the transition. By disciplining our model of producer-level exporting technology with producer-level data, we avoid making any assumptions about how aggregate trade behaves. In particular, we are not forced to estimate a trade elasticity that will govern the aggregate behavior of trade—a difficult undertaking given that the trade elasticity is not constant.[2] Indeed, a key advantage of our dynamic model is its ability to capture the well-known feature of the data that the trade elasticity increases with time.

The generality of our model allows us to estimate the exporting technology without imposing a priori restrictions. This yields new insights into the firm-level costs, risks, and benefits of trade. When the model generates a data-consistent exporter life cycle, the estimated entry cost is much smaller than those derived from models that ignore new-exporter dynamics and the export continuation costs are more important. This implies that exporters are making substantial risky investments to expand market access beyond those paid at entry. These dynamics imply that the return to exporting is delayed and discounted, which makes a cut in tariffs less important to the value of a new firm. Thus, a decrease in tariffs discourages firm creation, as potential entrants are mostly concerned with the extra competition they will face at home.

We use the calibrated model to quantify the aggregate effects of a unilateral and global reduction of a ten-percent tariff, taking into account the transition period. Even though new exporter dynamics cause the aggregate trade volume to grow slowly along the transition, the welfare gain exceeds the change in steady-state consumption. In the global tariff reduction experiment, consumption peaks in year seven, at which point the trade elasticity has grown to only 75 percent of its long-run value. When we take the transition into account, the welfare gain is 15 times larger than the change in steady-state consumption. The transition is even more important when we consider unilateral liberalization: Welfare in the liberalizing country increases by 0.5 percent, even though its steady-state consumption falls by 2.4 percent.

In our model, two competing forces shape the transition and long-run effects of a cut in tariffs. First, trade adjusts slowly as producers make investments in export-specific capacity that may boost future exports and profits. The aggregate export technology improves as the distribution over producer export costs endogenously improves. This force reduces the resources available for production and consumption in the short run, while improving the efficiency of the economy in the long run. These investments in exporting in the transition period act to reduce welfare. The second force is a desire to reduce investments in new varieties. Lowering tariffs increases the varieties available from foreign exporters. This extra competition and the strongly discounted future opportunities to export decrease entry. This

[2] Baier and Bergstrand (2007) and Baier et al. (2014), for example, provide empirical evidence on the delayed impacts of trade liberalization and their lagged effect on trade volumes.

frees resources for production and consumption in the transition thereby increasing welfare, but lowering the mass of producers in the long-run. These two forces summarize the trade-off between firm creation and export capacity expansion that is at the heart of the model.

The dynamic features of our model—trade in financial assets, capital accumulation, and the gradual adjustment of trade—make it ideally suited for studying the impact of a unilateral trade liberalization. We find that both countries gain from a unilateral reform, but with incomplete financial markets, the reforming country's gain is relatively small compared to its trading partner's (0.51 percent versus 5.7 percent). We show that focusing on the steady-state change or evaluating the policy in a model without an export decision would lead to the conclusion that welfare in the reforming country would decrease. The reform also leads to interesting current account dynamics that depend on the nature of export costs. The reforming country becomes a net lender to the rest of the world, accumulating net assets of almost seven percent of GDP. The initial trade surpluses are substantial, peaking at 0.7 percent of GDP two years after the liberalization. In a model without export costs, borrowing and lending are much smaller or even non-existent.

Arkolakis et al. (2012) showed that, in many static models, the welfare gains from trade will be identical across models that generate the same trade elasticity. Essentially, the producer details can be ignored—simpler environments yield the same welfare outcomes. The non-linear relationship between the trade elasticity and consumption along the transition implies that their sufficient statistic approach does not extend to our model.

Models with simpler export technologies are poor approximations to the welfare outcomes from a change in trade policy in the benchmark model. To demonstrate this, we consider two variants of the benchmark model. In the first, there are no export entry costs, so that all producers export and there are no new exporter dynamics. In the spirit of Arkolakis et al. (2012), we modify the model so that its aggregate trade dynamics are identical to our benchmark model. We find that the consumption dynamics, however, are very different in this model. Without an exporter decision, consumption grows smoothly during the transition, and the welfare gain is 71 percent of that in the baseline model, even though the steady-state increase in consumption is almost 15 times larger than the baseline model.

In the second variant, we remove the new exporter dynamics but keep the export entry decision. When we decrease the tariff, we also decrease the iceberg export cost so that the aggregate change in exports following the liberalization is the same as in the benchmark model. This modification brings the model close to matching many of the producer-level moments as well. We find that the aggregate effects in this model—in which we match the change in the macro and the micro details—is also a poor approximation to the benchmark model: Welfare in this model is more than twice as large. These experiments reveal that the source of the slow adjustment is an important determinant of aggregate outcomes.

This paper is part of the growing literature that quantifies the aggregate effects of trade on welfare. Atkeson and Burstein (2010) and Arkolakis et al. (2012) find that producer-level exporting details matter little for welfare, while Head et al. (2014) and Melitz and Redding (2015) find a role for producer-level exporting in welfare when the trade elasticity depends on the level of trade costs.[3] Melitz and Ottaviano (2008) and Edmonds et al. (2015) consider

[3] Simonovska and Waugh (2014) show that micro details are important for model parameters.

the effects of trade on competition. While these papers focus on trade and markups, tariffs in our model affect competition through entry and alter the share of income from profits.

Our model's trade elasticity is time-varying because time and resources are required to expand trade after a decrease in tariffs. This is consistent with the slow adjustment of trade to changing trade barriers or relative prices documented in the empirical literature.[4] A number of researchers have studied the transition following tariff reform. Alvarez et al. (2013) study the transition following a change in trade frictions; however, this study does not model the intensive export margin. Ravikumar et al. (2019) study trade imbalances following liberalization in a model with capital accumulation and financial assets. They also find that welfare gains accrue gradually and that the dynamic gains are larger than the static gains. In their model, gradual adjustment arises primarily from capital accumulation, whereas our gradual adjustment arises as firms adopt better exporting technology.

In Section 2, we review the data on the exporter life cycle, laying out key producer-level facts to discipline our model of the producer's exporting technology. In Section 3, we present the model, and in Section 4, we describe our calibration strategy. Section 5 reports the estimated export technology and its implications for the dynamics of firm profits. In Section 6, we report the results from the baseline model and show how the gain from trade liberalization is much larger than the steady-state comparisons would suggest. In Sections 7–9, we present alternative versions of the model, highlighting the importance of producer heterogeneity in understanding the welfare gain from trade. In Section 10, we consider a unilateral tariff reform, and we conclude in Section 12.

2. The Exporter Life Cycle

We generalize the exporting technology in our model to include risky, time-to-build investment. We are motivated by recent empirical work showing that: 1) exporting intensively takes many years of sustained foreign market participation; 2) many new exporters exit before achieving this status; 3) and many new exporters exported recently. To set ideas and discipline the importance of these margins, we summarize some features of the exporter life cycle using manufacturing sector plant-level data from Colombia and Chile and firm-level data from the United States. The results from both balanced and unbalanced panels are in Table 1, as are some statistics from the literature.[5]

Our focus is on the aggregate implications of the exporter life cycle. We begin by summarizing the importance of new exporters in overall exports at annual and eight-year horizons.[6] New exporters are common, but relatively unimportant, at one-year intervals but grow in

[4] A large empirical literature identifies different short-run and long-run trade responses to aggregate shocks (Hooper et al., 2000; Gallaway et al., 2003). Many theoretical studies of the role of trade adjustment explicitly or implicitly calibrate the trade elasticity differently, according to the horizon considered (Obstfeld and Rogoff, 2007). Some recent theoretical work has endogenized the dynamics of the trade elasticity; these include Alessandria and Choi (2007), Drozd and Nosal (2012), Engel and Wang (2011), Ramanarayanan (2017), Ruhl (2008), and Alessandria et al. (2013b).

[5] Our aim is to reorganize facts that others have emphasized, so we do not report the regression tables. These are available upon request.

[6] We focus on eight-year windows due to data limitations and for comparability with the results for the United States, which are reported in other studies.

importance over longer horizons. Panels A and B in Table 1 show that, at the end of an eight-year window, 57 percent of exporters entered the export market during the sample, and they accounted for just under 40 percent of total exports. These numbers are similar in both Colombia and Chile. New exporters are less important annually—they account for 17.6 percent of exporters but only 4.2 percent of total exports from Colombia.

2.1. Export Intensity

New exporters account for a small share of annual total exports because they are relatively small, in terms of both their total sales and their export-sales ratios, what we call their *export intensity*. Panel C in Table 1 shows that the total sales of new exporters are 40 to 50 percent of those of an average exporter, and their export intensity is about 45 percent of the average exporter's. Combining these two discounts, a new exporter exports about one-fourth as much as a continuing exporter. As first noted by Ruhl and Willis (2017), new exporters become more important in aggregate trade at longer horizons because continuing starters gradually expand their overall sales and export intensity. To measure this growth, we regress the export intensity of establishment i, exs_{it}, on lagged export intensity and dummies for incumbent and new exporters,[7]

$$exs_{it} = \alpha_0 + \rho_{exs} exs_{it-1} + \alpha_1 I_{it}^{\text{starter}} + \alpha_2 I_{it}^{\text{incumbent}} + \varepsilon_{it}. \quad (1)$$

Export intensity starts out low and is quite persistent, with an autocorrelation of about 90 percent annually (Table 1, Panel D).

Using the estimated coefficients from (1), we can compute the export intensity of the average exporter that has exported continuously for a years as

$$\widehat{exs}_a = (\alpha_0 + \alpha_1)\,\rho_{exs}^a + (\alpha_0 + \alpha_2)\,\frac{1 - \rho_{exs}^a}{1 - \rho_{exs}}. \quad (2)$$

Our estimates imply that it takes between nine and 11 years for a new exporter to export as intensively as the average exporter (Table 1, Panel D). If a new exporter grew for 20 consecutive years, it would export 20–50 percent more intensively than an average exporter (Table 1, Panel D). Ruhl and Willis (2017) take a different empirical approach and find growth in export intensity to be faster: New exporters take five years of continuous exporting to catch up. We will use their more-conservative estimate as a target in our calibration.

2.2. Exporter Survival

The slow growth of new exporters documented above is conditional on their remaining in the export market; many new exporters exit. To evaluate the persistence of export participation, we estimate a linear probability model,

$$I_{it}^{\text{exporter}} = \beta_0 + \beta_1 I_{it-1}^{\text{starter}} + \beta_2 I_{it-1}^{\text{exporter}} + \beta_3\left(1 - I_{it-1}^{\text{exporter}}\right) I_{it-2}^{\text{exporter}} + \varepsilon_{it}. \quad (3)$$

The coefficients capture the probability that a producer is exporting at t if it entered the export market at $t-1$, was an incumbent exporter at $t-1$, or did not export in $t-1$ but exported in $t-2$. This last coefficient captures the importance of *export reentry*.

[7] Our interest is in the aggregate importance of the exporter life cycle. In all of our regressions, we do not control for industry or year and we weight by establishment sales.

In Table 1, Panel E, we report the results from (3). Survival rates increase with export history. The survival rate for an incumbent exporter is between 80 and 90 percent, while the continuation rate for an exporter starter is 15 to 25 percentage points lower. Export reentrants are 26 to 30 percent more likely to export—thus, many new exporters are not truly new to the market. This is an aspect of the data that is rarely incorporated into models. We show in Section 9 that allowing for reentry improves the model's ability to account for the size of new exporters.

2.3. Other Countries

The patterns we document in the Colombian and Chilean data are also present in data from other countries and periods. New exporter dynamics are documented, for example, in Portuguese data by Bastos et al. (2018), in Irish data by Fitzgerald et al. (2017), and in French data by Piveteau (2017). Alessandria et al. (2019) provide a review.

We will calibrate our quantitative model to data from the United States. While we do not have access to the U.S. Census of Manufacturing, we find similar patterns for U.S. manufacturing firms in Compustat, which is, perhaps, surprising given its selective sample of firms. This is a balanced panel, so, for comparison, we also report the results from a balanced panel of Chilean and Colombian producers. As in the unbalanced panels, the relative importance of export entrants increases significantly from one-year to eight-year horizons. The starter size discounts are very similar to those in Colombia and Chile, but the intensity dynamics are more persistent.

In the last column of Table 1, we report some moments for U.S. manufacturing plants from other papers and find similar patterns. New exporters are smaller than incumbent exporters but grow faster (Bernard et al., 1995; Bernard and Jensen, 1999). While not directly comparable to our measures in the table, Bernard and Jensen (2004) find that exporting is persistent and that having exported in the past increases the probability of exporting. They also show that about half of starters from 1984 to 1992 reentered the export market after leaving for a year. Bernard et al. (2009) show that net export entry accounts for two to five percent of trade growth annually and about 20 percent over five-year horizons.

3. Model

We develop a dynamic general equilibrium model of the establishment and exporter life cycle that introduces investments in market access that lower foreign distribution costs gradually and stochastically over time. To highlight the effect of firm dynamics on the aggregate response to a change in tariffs, we model two symmetric countries, home and foreign, each populated by a unit mass of identical, infinitely-lived consumers.[8] We focus on the home-country decision problems. The foreign-country problems are analogous. Variables chosen in the foreign country are denoted with an asterisk. Goods produced in the home

[8]As shown by Mix (2018), introducing additional countries would allow us to explore how country size and openness would shape the gains from trade but would not affect our findings about the timing or size of the gains relative to static models.

country are subscripted with an h and goods produced in the foreign country are subscripted with an f.

In each country, final-goods producers purchase differentiated intermediate inputs from both countries. The nontraded final good is used for consumption, investment, and as a production input. There exists a one-period nominal bond, denominated in units of the home-country final good, that pays one unit of the final good in the next period. Let B_t and B_t^* denote the holdings of bonds purchased in period t and Q_t denote the nominal bond price. The home-country final good is the numeraire, so $P_t = 1$ in every period. With symmetric economies and symmetric policies, the foreign price level is $P_t^* = 1$ and bond holdings are zero. With asymmetric policies, the real exchange rate is $q_t = P_t^*$, and B_t will vary.

Intermediate-goods producers in each country are characterized by their productivity, fixed export cost, and iceberg trade cost. Productivity is stochastic. Iceberg costs are endogenous and stochastic, while the fixed cost is endogenous. The shocks to productivity and iceberg costs generate movements of establishments into and out of exporting; unproductive establishments exit and new establishments enter.

All intermediate-goods producers sell to their own country, but only some export. All exporters face the same ad valorem tariff, $\tau \geq 1$, but differ in their iceberg transportation cost, $\xi \geq 1$, and fixed export cost. The tariff is a policy variable and tariff revenue is rebated lump-sum to consumers. The transportation cost is a feature of technology. Fraction $\xi - 1$ of an export shipment is destroyed in transit. Fixed export costs are paid in units of domestic labor. We depart from the literature by assuming three possible iceberg costs $\xi \in \{\xi_L, \xi_H, \infty\}$ with $\xi_L \leq \xi_H < \infty$ and two possible export fixed costs $\kappa \in \{\kappa_L, \kappa_H\}$, $\kappa_L \leq \kappa_H$. This is the smallest departure from standard models that allows for new exporter dynamics, and yet, it yields rich predictions that differ substantially from standard models.

Fixed export costs and variable iceberg costs are related. Producers with an iceberg cost of $\xi_t = \infty$ are nonexporters. A nonexporter can deterministically lower its next-period iceberg cost to ξ_H by paying κ_H. An exporter with iceberg costs $\xi_t \in \{\xi_L, \xi_H\}$ may pay κ_L to draw its next-period iceberg cost. The transition probabilities are Markovian and iceberg costs are persistent: $\rho_\xi(\xi_L|\xi_H) \leq \rho_\xi(\xi_L|\xi_L)$. Thus, continuing exporters with $\xi_t = \xi_H$ are investing in lowering their future marginal cost of exporting. If an exporter does not pay κ_L, it exits the export market and begins the next period as a nonexporter with $\xi_{t+1} = \infty$.

This formulation of fixed and iceberg costs is general and nests the many common trade models. When $\kappa_L < \kappa_H$ and $\xi_L = \xi_H$, there is a sunk cost of exporting, as in Das et al. (2007). When $\kappa_L = \kappa_H$ and $\xi_L = \xi_H$, exporting is a static decision. When $\kappa_L = \kappa_H = 0$ and $\xi_L = \xi_H$, all firms export as in the Krugman (1980) model with monopolistic competition.

An establishment is created by hiring κ_E domestic workers and begins producing in the following period. Let $\varphi_t(z, \xi, \kappa)$ denote the measure of establishments with technology z, iceberg cost ξ, and fixed cost κ.[9] Establishment exit ("death") is exogenous and depends on the current productivity level.[10] The aggregate state variables are the measure of establishments, $\varphi_t(z, \xi, \kappa)$, and the capital stocks in each country. For notational ease, aggregate

[9] Note that the producer's state is given by (z, ξ); there is a one-to-one mapping between κ and ξ. However, we describe producers with (z, ξ, κ) to explicitly denote the producer's fixed cost.

[10] Introducing endogenous exit from a fixed production cost is straightforward and yields similar results to our benchmark model. In the appendix, we study a model with a constant exit rate.

state variables are subsumed in the time subscript.

3.1. Consumers

Consumers in each country inelastically supply labor and choose consumption, investment, and bond holdings to maximize utility subject to the sequence of budget constraints

$$\max E_0 \sum_{t=0}^{\infty} \beta^t U(C_t),$$
$$P_t [C_t + K_t + Q_t B_t] \leq P_t [W_t L_t + R_t K_{t-1} + (1-\delta) K_{t-1} + B_{t-1}] + \Pi_t + T_t, \tag{4}$$

where $\beta \in (0,1)$ is the discount factor;C_t is final consumption; K_{t-1} is the capital available in period t; 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 real dividends from home producers; and T_t is the real lump-sum transfer of tariff revenue. Investment is $I_t = K_t - (1-\delta) K_{t-1}$.[11]

The first-order conditions for the consumers' utility maximization problems are

$$Q_t = \beta E_t \frac{U_{C,t+1}}{U_{Ct}} = \beta E_t \frac{U^*_{C,t+1}}{U^*_{Ct}} \frac{P^*_t}{P^*_{t+1}}, \tag{5}$$
$$1 = \beta E_t \frac{U_{C,t+1}}{U_{Ct}} (R_{t+1} + 1 - \delta) = \beta E_t \frac{U^*_{C,t+1}}{U^*_{Ct}} \frac{P^*_t}{P^*_{t+1}} \left(P^*_{t+1} R^*_{t+1} + 1 - \delta\right), \tag{6}$$

where U_C denotes the derivative of the utility function with respect to its argument. Equation 5 is the no-arbitrage condition for bonds that equates the difference in expected consumption growth across countries to the expected change in the real exchange rate. Equation 6 is the standard Euler equation for capital accumulation in each country.

3.2. Final-goods Producers

Final goods are produced by combining intermediate goods from both countries. The aggregation technology is a CES function

$$D_t^{\frac{\theta-1}{\theta}} = \sum_{\xi \in \{\xi_L, \xi_H, \infty\}} \left[\int_z y_{h,t}(z,\xi,\kappa)^{\frac{\theta-1}{\theta}} \varphi_t(z,\xi,\kappa)\, dz + \int_z y_{f,t}(z,\xi,\kappa)^{\frac{\theta-1}{\theta}} \varphi^*_t(z,\xi,\kappa)\, dz \right], \tag{7}$$

where $y_{h,t}(z,\xi,\kappa)$ and $y_{f,t}(z,\xi,\kappa)$ are intermediate goods from home producers and foreign exporters. The elasticity of substitution between intermediate goods is $\theta > 1$.

The final-goods market is competitive. Given the price of inputs, the final-goods producer chooses domestic and imported intermediate goods, $y_{h,t}$ and m_t, to solve

$$\max \quad D_t - \sum_{\xi \in \{\xi_L, \xi_H, \infty\}} \int_z P_{h,t}(z,\xi,\kappa)\, y_{h,t}(z,\xi,\kappa)\, \varphi_t(z,\xi,\kappa)\, dz \tag{8}$$
$$- \sum_{\xi \in \{\xi_L, \xi_H\}} \int_z \tau P_{f,t}(z,\xi,\kappa)\, y_{f,t}(z,\xi,\kappa)\, \varphi^*_t(z,\xi,\kappa)\, dz,$$

[11] We study a model with endogenous labor supply in the appendix.

where $P_{h,t}(z,\xi,\kappa)$ and $P_{f,t}(z,\xi,\kappa)$ are the factory-gate prices of intermediate goods. Solving this problem yields the input demand functions,

$$y_{h,t}^{d}(z,\xi,\kappa) = [P_{h,t}(z,\xi,\kappa)]^{-\theta} D_t, \tag{9}$$

$$y_{f,t}^{d}(z,\xi,\kappa) = [\tau P_{f,t}(z,\xi,\kappa)]^{-\theta} D_t, \tag{10}$$

and the final-goods price

$$P_t^{1-\theta} = \sum_{\xi\in\{\xi_L,\xi_H,\infty\}} \int_z \left[P_{h,t}(z,\xi,\kappa)^{1-\theta}\varphi_t(z,\xi,\kappa) + [\tau P_{f,t}(z,\xi,\kappa)]^{1-\theta}\varphi_t^*(z,\xi,\kappa)\right] dz. \tag{11}$$

3.3. Intermediate-goods Producers

An intermediate-good producer is described by its technology, iceberg cost, and fixed cost, (z,ξ,κ). It produces using capital, k, labor, l, and final good materials, x, according to

$$y_{h,t}(z,\xi,\kappa) = e^z\left[k_t(z,\xi,\kappa)^{\alpha} l_t(z,\xi,\kappa)^{1-\alpha}\right]^{1-\alpha_x} x_t(z,\xi,\kappa)^{\alpha_x}. \tag{12}$$

The producer's export status is predetermined. It maximizes current-period gross profits by choosing prices for each market, $P_{h,t}(z,\xi,\kappa)$ and $P_{h,t}^*(z,\xi,\kappa)$ and inputs to solve

$$\begin{aligned}\Pi_t(z,\xi,\kappa) = \max P_t(z,\xi,\kappa)\, y_t^d(z,\xi,\kappa) + P_{mt}(z,\xi,\kappa)\, m_t^{d*}(z,\xi,\kappa) \\ - W_t l_t(z,\xi,\kappa) - R_t k_t(z,\xi,\kappa) - P_t x_t(z,\xi,\kappa),\end{aligned} \tag{13}$$

subject to the production technology (12) and a constraint that the producer supplies all that is demanded

$$y_{h,t}(z,\xi,\kappa) = y_{h,t}^d(z,\xi,\kappa) + \xi y_{h,t}^{d*}(z,\xi,\kappa). \tag{14}$$

The monopolistic producer charges a constant markup over marginal cost in each market,

$$P_{h,t}(z,\xi,\kappa) = \frac{\theta}{\theta-1} MC_t e^{-z}, \tag{15}$$

$$P_{h,t}^*(z,\xi,\kappa) = \frac{\theta}{\theta-1} \xi MC_t e^{-z}, \tag{16}$$

where

$$MC_t = \alpha_x^{-\alpha_x}(1-\alpha_x)^{-(1-\alpha_x)}\left[\left(\frac{R_t}{\alpha}\right)^{\alpha}\left(\frac{W_t}{1-\alpha}\right)^{1-\alpha}\right]^{1-\alpha_x}. \tag{17}$$

The value of a producer with (z,ξ,κ), if it decides to export in period $t+1$, is

$$V_t^1(z,\xi,\kappa) = -W_t\kappa + n_s(z)\, Q_t \sum_{\xi'\in\{\xi_L,\xi_H\}} \int_{z'} V_{t+1}(z',\xi',\kappa_L)\, \phi(z'|z)\, \rho_\xi(\xi'|\xi)\, dz', \tag{18}$$

and the value of the producer, if it does not export in period $t+1$, is

$$V_t^0(z,\xi,\kappa) = n_s(z)\, Q_t \int_{z'} V_{t+1}(z',\infty,\kappa_H)\, \phi(z'|z)\, dz', \tag{19}$$

where $n_s(z)$ is the probability that the producer will survive until the next period. This probability varies with the producer's productivity and, in the calibrated model, is increasing in productivity, z. This is a parsimonious way to capture the low exit rate of large producers and high exit rate of small and new producers. The value of the producer is

$$V_t(z, \xi, \kappa) = \Pi_t(z, \xi, \kappa) + \max\left\{V_t^1(z, \xi, \kappa), V_t^0(z, \xi, \kappa)\right\}. \tag{20}$$

The value of a producer depends on its fixed cost, iceberg cost, and productivity. With three possible iceberg costs, there are three possible cutoffs, $z_{m,t}$, with $m \in \{L, H, \infty\}$. The critical level of productivity for exporting, $z_{m,t}$, satisfies

$$V_t^1(z_{m,t}, \xi_m, \kappa) = V_t^0(z_{m,t}, \xi_m, \kappa). \tag{21}$$

It is straightforward to show that the threshold for exporting is largest for nonexporters and smallest for exporters with the low iceberg cost ($z_{\infty,t} > z_{H,t} \geq z_{L,t}$).

3.4. Entry

New establishments are created by hiring κ_E workers in the period prior to production. Entrants draw their productivity from the distribution $\phi_E(z')$. Entrants cannot export in their first productive period. The free-entry condition is

$$V_t^E = -W_t\kappa_E + Q_t \int_{z'} V_{t+1}(z', \infty, \kappa_H)\, \phi_E(z')\, dz' \leq 0. \tag{22}$$

The mass of entrants in period t is $N_{E,t}$ and the mass of incumbents, N_t, is

$$N_t = \int_z \varphi_t(z, \xi_L, \kappa_L)\, dz + \int_z \varphi_t(z, \xi_H, \kappa_L)\, dz + \int_z \varphi_t(z, \infty, \kappa_H)\, dz, \tag{23}$$

where the first term on the right-hand side is the mass of establishments with ξ_L (denoted N_L), the second term is the establishments with ξ_H (denoted N_H), and the third term is the establishments with $\xi = \infty$ (denoted N_∞). The mass of exporters is $N_{1,t} = N_{L,t} + N_{H,t}$; the mass of nonexporters is $N_{0,t} = N_{\infty,t}$; and the mass of establishments is $N_t = N_{1,t} + N_{0,t}$. The fixed costs of exporting imply that only a fraction, $n_{x,t} = N_{1,t}/N_t$, of home intermediates are available in the foreign country in period t. The critical levels of productivity for exporters and nonexporters, $z_{m,t}$, determine the starter ratio (the fraction of nonexporters that start exporting) and the stopper ratio (the fraction of exporters among surviving establishments who stop exporting),

$$n_{0,t+1} = \frac{\int_{z_{\infty,t}}^{\infty} n_s(z)\, \varphi_t(z, \infty, \kappa_H)\, dz}{\int_z n_s(z)\, \varphi_t(z, \infty, \kappa_H)\, dz}, \tag{24}$$

$$n_{1,t+1} = \frac{\sum_{m\in\{L,H\}} \int_{-\infty}^{z_{m,t}} n_s(z)\, \varphi_t(z, \xi_m, \kappa_L)\, dz}{\sum_{m\in\{L,H\}} \int_z n_s(z)\, \varphi_t(z, \xi_m, \kappa_L)\, dz}. \tag{25}$$

The law of motion, Γ_t, for the mass of establishments evolves according to

$$\varphi_{t+1}(z', \infty, \kappa_H) = \sum_{m \in \{L,H,\infty\}} \int_{-\infty}^{z_{m,t}} n_s(z)\, \varphi_t(z, \xi_m, \kappa)\, \phi(z'|z)\, dz + N_{E,t}\phi_E(z'), \tag{26}$$

$$\varphi_{t+1}(z', \xi_H, \kappa_L) = \sum_{m \in \{L,H,\infty\}} \rho_\xi(\xi_H|\xi_m) \int_{z_{m,t}}^{\infty} n_s(z)\, \varphi_t(z, \xi_m, \kappa)\, \phi(z'|z)\, dz, \tag{27}$$

$$\varphi_{t+1}(z', \xi_L, \kappa_L) = \sum_{m \in \{L,H,\infty\}} \rho_\xi(\xi_L|\xi_m) \int_{z_{m,t}}^{\infty} n_s(z)\, \varphi_t(z, \xi_m, \kappa)\, \phi(z'|z)\, dz. \tag{28}$$

The average efficiency of all operating producers is

$$\psi_{dt} = \frac{1}{N_t} \sum_{\xi \in \{\xi_L, \xi_H, \infty\}} \int z\, \varphi_t(z, \xi, \kappa)\, dz. \tag{29}$$

3.5. Government and Aggregate Variables

The government collects tariffs and redistributes the revenue lump-sum to domestic consumers. The government's budget constraint is

$$T_t = (\tau - 1) \sum_{\xi \in \{\xi_L, \xi_H\}} \int_z P^*_{mt}(z, \xi, \kappa_L)\, y_{f,t}(z, \xi, \kappa_L)\, \varphi^*_t(z, \xi, \kappa_L)\, dz. \tag{30}$$

Aggregate exports and ex-tariff imports are

$$EX_t = \sum_{\xi \in \{\xi_L, \xi_H\}} \int_z P_{mt}(z, \xi, \kappa_L)\, m^*_t(z, \xi, \kappa_L)\, \varphi_t(z, \xi, \kappa_L)\, dz, \tag{31}$$

$$IM_t = \sum_{\xi \in \{\xi_L, \xi_H\}} \int_z P^*_{mt}(z, \xi, \kappa_L)\, y_{f,t}(z, \xi, \kappa_L)\, \varphi^*_t(z, \xi, \kappa_L)\, dz. \tag{32}$$

The share of domestically-produced goods in total expenditure, λ_t, is

$$\lambda_t = \left(\frac{\tau_t \sum_{\xi \in \{\xi_L, \xi_H\}} \int_z P^*_{mt}(z, \xi, \kappa_L)\, y_{f,t}(z, \xi, \kappa_L)\, \varphi^*_t(z, \xi, \kappa_L)\, dz}{\sum_{\xi \in \{\xi_L, \xi_H, \infty\}} \int_z P_t(z, \xi, \kappa)\, y_{h,t}(z, \xi, \kappa)\, \varphi_t(z, \xi, \kappa)\, dz} + 1 \right)^{-1}. \tag{33}$$

Labor used in production, rather than to pay fixed costs is

$$L_{P,t} = \sum_{\xi \in \{\xi_L, \xi_H, \infty\}} \int_z l_t(z, \xi, \kappa)\, \varphi_t(z, \xi, \kappa)\, dz. \tag{34}$$

The domestic labor hired by exporters to cover the fixed costs of exporting is

$$L_{X,t} = \sum_{m \in \{L,H\}} \kappa_L \int_{z_{m,t}}^{\infty} \varphi_t(z, \xi_m, \kappa_L)\, dz + \kappa_H \int_{z_{\infty,t}}^{\infty} \varphi_t(z, \infty, \kappa_H)\, dz. \tag{35}$$

Labor market clearing can be expressed as $L = L_{P,t} + L_{X,t} + \kappa_E N_{E,t}$. The capital and intermediate good clearing conditions are

$$K_{t-1} = \sum_{\xi \in \{\xi_L, \xi_H, \infty\}} \int_z k_t\left(z, \xi, \kappa\right) \varphi_t\left(z, \xi, \kappa\right) dz, \tag{36}$$

$$X_t = \sum_{\xi \in \{\xi_L, \xi_H, \infty\}} \int_z x_t(z, \xi, \kappa) \varphi_t\left(z, \xi, \kappa\right) dz \tag{37}$$

and the final-good feasibility constraint is $D_t = C_t + I_t + X_t$.

Aggregate profits are the difference between profits and fixed costs,

$$\Pi_t = \sum_{\xi \in \{\xi_L, \xi_H, \infty\}} \int_z \Pi_t(z, \xi, \kappa) \varphi_t\left(z, \xi, \kappa\right) dz - W_t L_{X,t} - W_t \kappa_E N_{E,t}. \tag{38}$$

Even with free entry aggregate profits are generally positive. These profits compensate consumers for waiting for their investment in producers to mature. Only with $\beta = 1$, will steady-state profits equal zero.

3.6. Equilibrium

We follow the standard equilibrium concept for infinite-horizon, dynamic, heterogeneous-agent models. Given initial conditions $\{K_{-1}, B_{-1}, K^*_{-1}, B^*_{-1}, \varphi_0(z, \xi, \kappa), \varphi^*_0(z, \xi, \kappa)\}$, and a deterministic path of tariffs, $\{\tau_t, \tau^*_t\}_{t=0}^{\infty}$, an equilibrium is sequences from $t = 0, 1, \ldots, \infty$ of: allocations for consumers $\{C_t, B_t, K_t, C^*_t, B^*_t, K^*_t\}$ and final-goods producers, $\{D_t,\ D^*_t,$ $y_{h,t}\left(z, \xi, \kappa\right),\ y_{f,t}\left(z, \xi, \kappa\right),\ y^*_{h,t}\left(z, \xi, \kappa\right),\ y^*_{f,t}\left(z, \xi, \kappa\right)\}$;masses of entrants $\{N_{E,t}, N^*_{E,t}\}$; allocations, prices, input choices, and export decisions for home and foreign intermediate producers; government transfers $\{T_t, T^*_t\}$; real wages and rental rates $\{W_t, R_t, W^*_t, R^*_t\}$; bond price and real exchange rate, $\{Q_t, q_t\}$; and the laws of motion for the mass of establishments, $\{\Gamma_t, \Gamma^*_t\}$ that satisfy the following conditions: (i) the consumers' allocations solve the consumers' problem; (ii) the final-goods producers' allocations solve their profit-maximization problems; (iii) intermediate-goods producers' input choices, prices, and export decisions solve their dynamic programming problems; (iv) the entry conditions hold; (v) the market-clearing conditions on labor and bonds hold; (vi) the transfers satisfy the government budget constraint; and (vii) rationality/consistency so that the laws of motions are consistent with firms' decisions' rules.

When tariffs are constant, the model converges to a stationary steady state in which the aggregate quantities, the measures φ, and prices are constant. In section 6, we will begin with an economy in a stationary steady state. At $t = 0$, we lower τ unexpectedly. Once agents learn of the surprise liberalization, they have perfect foresight and the economy will converge to a new stationary steady state. This implies that agents have rational expectations at all t, except in period $t = -1$.

4. Calibration

The model's parameters are set so that the model's stationary steady state matches features of the U.S. economy in the early 1990s. The parameter values are summarized in Table 2.

The instantaneous utility function is $U(C) = \frac{C^{1-\sigma}}{1-\sigma}$. With a period equal to one year, the discount factor, β, depreciation rate, δ, and risk aversion, σ, are standard: $\beta = 0.96$, $\delta = 0.10$, and $\sigma = 2$. The parameter θ determines both the producer's markup and the elasticity of substitution across varieties. We set $\theta = 5$ to yield a producer markup of 25 percent. The tariff rate is $\tau = 0.10$.

The steady-state distribution of establishments is determined by the structure of shocks. To eliminate the role of the elasticity of substitution, θ, in establishment dispersion, we assume that producer productivity is $z = \frac{1}{\theta-1} \ln a$. An incumbent's productivity follows $\ln a' = \rho \ln a + \varepsilon$, $\varepsilon \overset{iid}{\sim} N(0, \sigma_\varepsilon^2)$ and the unconditional steady-state distribution of productivity is $N\left(0, \frac{\sigma_\varepsilon^2}{1-\rho^2}\right)$. Entrants draw their initial productivity from the incumbent's unconditional distribution, but shifted to the left, $\ln a' = \mu_E + \varepsilon_E$, $\varepsilon_E \overset{iid}{\sim} N\left(0, \frac{\sigma_\varepsilon^2}{1-\rho^2}\right)$, where $\mu_E < 0$ will be chosen to match the observation that entrants are smaller than incumbents. Establishments receive an exogenous death shock that depends on an establishment's previous-period productivity; the probability of death is $1 - n_s(a) = \max\{0, \min\{e^{-\gamma_0 a} + \gamma_1, 1\}\}$.

The labor share parameter in production, α, is set to match the ratio of labor income to GDP in the United States (66 percent). In the model, α_x determines the ratio of gross output to value added in manufacturing. In the United States, this ratio averaged 2.8 over 1987–1992 and implies that $\alpha_x = 0.81$. The entry cost, κ_E, is set to normalize the total mass of establishments, N, to one in the initial steady state. The mean establishment size is equated to the mean establishment size in the United States in 1992.

Four parameters determine the dynamics of export intensity: the two iceberg costs (ξ_H, ξ_L) and the transition probabilities, which we denote (ρ_{LL}, ρ_{HH}). For simplicity, we assume that $\rho_{LL} = \rho_{HH} = \rho_\xi$, so that three parameters determine the trade intensity dynamics.

The ten parameters, $\{\gamma_0, \gamma_1, \rho, \sigma_\varepsilon, \mu_E, \kappa_L, \kappa_H, \xi_L, \xi_H, \rho_\xi\}$, are chosen to match the following 18 observations:

1. A mean export intensity of 13.3 percent (1992 U.S. Census of Manufactures, CM).
2. An initial export intensity of half the mean export intensity (Table 1).
3. A five-year export intensity twice the initial export intensity (Ruhl and Willis, 2017).
4. A stopper rate of 17 percent as in Bernard and Jensen (1999), based on the Annual Survey of Manufactures (ASM) of the Bureau of the Census, 1984–1992.
5. An export participation rate of 22.3 percent (1992 CM).
6. Five-year exit rate for entrants of 37 percent (Dunne et al., 1989).
7. Entrants' labor share of 1.5 percent (Davis et al., 1998).
8. Shut-down establishments' labor share of 2.3 percent (Davis et al., 1998).
9. Establishment employment size distribution as in the 1992 CM (10 data points).

While the parameters are not individually identified, some moments strongly influence some parameters. The first three targets summarize export intensity dynamics and determine the shipping technology (ξ_L, ξ_H, ρ_ξ). The next two targets relate exporters to the population of establishments and largely determine the fixed costs (κ_L, κ_H). The next three targets help pin down the establishment creation, destruction, and growth process $(\rho, \sigma_\varepsilon, \gamma_0, \gamma_1, \mu_E)$:

Newborn establishments and dying establishments tend to have few employees, and newborn establishments have high failure rates. These features lead us to estimate a survival probability that is increasing in productivity. Finally, we minimize the distance between the model's producer size distribution and the size distribution of U.S. establishments.[12]

5. Export Technology and Export Dynamics

The calibration provides estimates of the establishment creation and exporting technologies. We discuss the benchmark model first and then compare it's characteristics to the sunk-cost model. The cost of starting to export is relatively small, only 3.8 percent of the cost of creating an establishment, but it is 1.4 times larger than the cost of continuing to export (0.25 versus 0.18). The high iceberg cost, ξ_H, is 63 percent larger than the low cost, ξ_L (1.72 versus 1.07), and the idiosyncratic iceberg cost is persistent, $\rho_\xi = 0.916$. Most active exporters have the high iceberg cost and are investing in improving their export ability. Based on the ergodic distribution, Figure 1a shows how the average export intensity rises with years of exporting experience. Export intensity grows gradually beyond the five-year period being targeted. This reflects a rising probability that a long-term exporter has accumulated the low iceberg cost. Figure 1b shows that the probability of continuing in the export market rises over time after the second year in the market, consistent with the evidence in Table 1. This reflects the tendency for older exporters to have the better distribution technology and stay in the market to avoid losing this capability. This model outcome was not targeted and provides independent validation of the model.

The low and rising export intensity and fixed continuation costs implies that export profits start low and rise over time. Figure 1f plots the path of export profits net of fixed costs over the export life cycle for two types of continuing exporters: a firm that started at the low threshold, z_∞, and the entire cohort of new exporters. We define net profits as:

$$\mu_t = 100 \times \frac{E\left(\pi_t - f_t | \xi_j < \infty, j = 1, .., t\right)}{\kappa_H}. \tag{39}$$

In the year prior to exporting, $\mu_0 = -100$ since the producer pays κ_H and earns $\pi_0 = 0$. A firm that starts at the minimum productivity has an expected loss in its first year equal to 25 percent of the entry cost and only starts earning a small profit equal to 5 percent of the entry cost in its second period exporting. This profit then grows monotonically for those that have shocks that keep them exporting. The expected path of profits for the average new exporter is slightly higher but the gap closes quickly owing to the relatively small differences in productivity across new exporters.[13] After five years, the average continuing exporter is earning profits equal to about 80 percent of its initial export costs. This profit measure overstates the return to exporting since many exporters have already left the market. In Figure 1d, we plot the accumulated profits from the time of entry adjusting for exit from exporting or death and discounting using the steady state interest rate. For a marginal

[12] The model is solved using value function iteration and a shooting algorithm. We largely follow the approach described in the computational appendix of Alessandria and Choi (2014).

[13] The productivity gap is only about 10 percent. Recall, that new exporters are firms with $z_{-1} < z_\infty$ that received positive shocks such that $z > z_\infty$.

exporter this measure asymptotes to zero. We find the cohort of exporters recovers its investments five years after paying the entry cost and has an overall return of about 90 percent.

The last two panels plot the importance of exporting in sales and profits since a firm was created, aggregating over each birth cohort. Figure 1e shows that the export-sales ratio starts at zero and grows gradually to more than 10 percent as more firms enter the export market and become better exporters. Figure 1f shows that the share of profits from exporting starts out negative owing to the investments in export capacity, and rises gradually before reaching five percent. Since export profits come later in a firm's life, they account for a smaller share of the present value of firm and thus are less important in the entry decision.

5.1. The Sunk-Cost Model

Equating the iceberg costs, $\xi_L = \xi_H = \xi$, yields the traditional sunk-cost model of Das et al. (2007), studied in general equilibrium in Alessandria and Choi (2014). We estimate the single iceberg cost to be 1.43 (Table 2, column "sunk-cost").

Compared to the baseline model, the sunk component of the entry cost is much larger in this model: The estimated export entry cost is 3.8 times the cost of continuing to export. In the sunk-cost model, an important reason that exporters stay in the market is to avoid paying the large upfront cost of reentering—sunk costs generate persistent exporting. This can be seen in Figure 1b, where survival rates are high, but falling with time in the market. In the benchmark model, this effect is smaller since the gap between the startup and continuation costs is smaller. In the benchmark model, exporters stay in the market to maintain access to the good exporting technology, ξ_L, and to avoid going through the growth process again.

To show how the timing of profits depends on the structure of trade costs, we plot the path of profits for the average exporter in the sunk-cost model (Figure 1c). To make profits comparable across models, net profits are measured relative to the export entry cost from the benchmark model. The higher sunk entry cost implies net profits start out lower, but they quickly rise and begin to revert to the mean. The producer starts earning a net profit from the first period in the market. This reflects, in part, a higher initial export intensity and a smaller continuation cost (about half that of our benchmark model). By year five, the exporters in the benchmark model are earning higher profits than those in the sunk cost model. In Figure 1d, we plot the path of accumulated profits for a cohort of exporters. In the sunk-cost model, an exporter recovers its initial investment in its second year. By year six, the cohort has reached 75 percent profit and this slowly grow to over 100 percent. It is worth noting that each model has the same level of trade and markups, so gross profits are identical. Finally, Figures 1e and 1f show that export sales grow faster in the sunk-cost model and account for a larger share of profits than in the benchmark model.

5.2. The Sunk-Cost-High Model

In the benchmark model, the producer-level cost of entering the export market is relatively low but the aggregate cost of maintaining international trade is relatively high. In the stationary steady state, payments of fixed export costs are 58.1 percent of export profits in the benchmark model and only 47.6 percent in the sunk-cost model. If we recalibrate the sunk-cost model so that the aggregate share of profits paid to fixed export costs is 58.1

percent, the export entry cost needs to be 11.1 times the continuation cost.[14] We refer to this model as the *sunk-cost-high* model and summarize its parameters in Table 2. In the sunk-cost-high model, exporting is a very persistent activity: The exporter exit rate in the data and the benchmark model is 17 percent; it falls to 3.95 percent in the sunk-cost-high model. Finally, Figures 1e and 1f show that, while the sunk-high model matches the path of export over the firm's life cycle from the benchmark model, the different nature of export costs implies that profits are larger and more front-loaded than in the benchmark model. We discuss the sunk-cost-high model further in Section 7.

6. Global Trade Liberalization

In this section, we consider the transition following an unanticipated once-and-for-all global elimination in tariffs.[15] While there are no examples of these types of reforms, they are a useful benchmark. It is straightforward to consider the more empirically relevant case of gradual liberalizations, which we take up in section 11. Table 3 reports the changes in welfare and trade, and Figure 2 plots the dynamics of some key variables. To aggregate over time, it is useful to calculate the discounted sum of the change of each variable as $\widehat{X}_s = (1-\beta)\sum_{t=s}^{\infty} \beta^t \log(X_t/X_s)$.

With lower tariffs, trade expands substantially, rising from 8.1 percent of manufacturing shipments to 22.6 percent. We summarize aggregate trade growth with the trade elasticity relative to the initial steady state,

$$\varepsilon_t = -\frac{\ln\left(\lambda_t^{-1}-1\right) - \ln\left(\lambda_{-1}^{-1}-1\right)}{\ln\left(\tau_t/\tau_{-1}\right)}. \tag{40}$$

Figure 2A shows that this expansion takes time, as the trade elasticity grows slowly. In the first year, only the intensive margin operates, so the trade elasticity is $\theta - 1$. With time, as more exporters enter, continue, and mature, export shipments expand. Ten years after the policy change, the endogenous part of the trade elasticity—that due to entry, expansion, and exit rather than to the static intensive margin—has increased by only 69 percent of its long-run change. The short-run trade elasticity is four; the discounted trade elasticity is 10.15; and the steady-state to steady-state trade elasticity is 11.55.

The additional growth in trade comes from an increase in export participation and greater export intensity. Firms grow their foreign sales over time by investing in better export technology. On average, these investments lower a firm's shipping cost and raise its export intensity. Following a trade liberalization, more firms invest in improving their exporting technology, leading the steady-state average export intensity to rise from 13.3 percent to 24.7 percent. This increase in export intensity is greater than that induced by the lower tariff

[14]The sunk-cost-high model is calibrated to match observations 5 to 9 on page 14. Additionally, the iceberg cost and the two fixed costs are set to generate the export participation rate (22.3 percent), the ratio of exports to GDP (9.7 percent), and the ratio of fixed export costs to export profits (58.1 percent), as in the benchmark model.

[15]The irreversible investments in the model imply that tariff increases and decreases have asymmetric outcomes. We study this in the appendix.

alone (19.8 percent). In the long-run, investment in market access drives the average trade cost down from 1.42 to 1.32.

Even though trade grows gradually, consumption booms during the transition, so the welfare gain is about 15 times larger than the change in steady-state consumption (6.30 versus 0.42). Thus, the conventional view that slow trade adjustment should lower the gain from trade liberalization does not hold in the model with endogenous export participation and exporter growth, even though the model includes physical capital. Consumption has a hump shape, peaking seven years after the policy change at 9.75 percentage points above its long-run change of 0.42 percent (Figure 2B). Figure 2C shows how different forms of investment evolve during the transition. Investment in capital initially falls and then recovers strongly as the economy uses capital to smooth out the benefits of the policy change. Capital dynamics imply that output expands a bit more strongly than consumption. Investment in establishment creation falls in the first few years and then recovers to a level below the initial steady state. The stock of establishments falls gradually to its new steady-state level.

The reduction in firm creation following the policy change is key to the overshooting behavior in the model since it implies that more resources are initially available for production along the transition (Figure 2C) and that there is a large stock of establishments that can be converted to exporting. The decline in establishments is gradual because the overshooting in aggregate economic activity increases profits enough to offset the negative effect of increased trade on entry.

The decline in firm entry occurs because the expansion in future export profits with lower tariffs is smaller than the reduction in local profits from increased competition. In models where all firms export with the same intensity, these two forces offset exactly and firm creation is unaffected by trade barriers. Since Melitz (2003), nearly all heterogeneous-firm models with an export decision predict a negative relationship between the number of firms and trade.[16] In dynamic models, the strength of this effect depends on the structure of export profits in the firm's lifecycle and their valuation through discounting. Our dynamic model finds this substitution is stronger than in other models, holding the denomination of entry costs constant, because it implies that export profits are backloaded and, thus, a relatively small share of the expected value of an entrant. Owing to the exporter life cycle, the effect here is stronger than in work by Atkeson and Burstein (2010), Burstein and Melitz (2013), Alessandria and Choi (2014), and Perla et al. (2015).

The effect of the decline in establishment creation on the aggregate dynamics of the economy is clearest in a counterfactual experiment that holds the mass of entrants constant.[17] Figure 3 plots the dynamics of the trade elasticity and consumption in this counterfactual and in the benchmark model. When establishment creation does not change, trade expands by less, as exporters are discouraged from entering in the face of greater local competition. Consumption declines slightly in the first period, owing to the investments in expanding export participation. It then grows monotonically to the new steady-state level, which is seven percentage points above that in the benchmark model (7.41 versus 0.42). It takes 20

[16] Pavcnik (2002) is one of the first studies to use micro data to document the negative relationship between trade and firm entry. Alessandria and Ruhl (2020) studies the evidence for the United States.

[17] We impose a subsidy to entry costs, financed by a lump-sum tax, so that $N_t = 1$ in every period.

years for this alternative model to reach the level of consumption of the benchmark model.

We decompose output growth as

$$\widehat{Y}_t = \left[S_t - \alpha_x \widehat{\frac{\theta - 1}{\theta}} \right] - \frac{\widehat{\lambda}_t}{(\theta - 1)(1 - \alpha_x)} + \frac{\widehat{N}_t + \widehat{\psi}_{d,t}}{(\theta - 1)(1 - \alpha_x)} + \alpha(\widehat{K}_t - \widehat{L}_{p,t}) + \widehat{L}_{p,t}, \qquad (41)$$

where the "hat" denotes the discounted log change from the initial steady state.[18] The first term represents the change in tariff revenue. It depends on the tariff distortion, $S_t = (1 + \tau_t \zeta_t^{-1})/(1 + \zeta_t^{-1})$ where $\zeta_t = \tau_t^{\theta} \xi_t^{\theta - 1} \leq 1$, and a measure of the material share and cost share of firm revenue. When $\tau = 1$, there are only iceberg trade costs (as is usually considered in the literature) and this term is a constant. The next two terms comprise the familiar trade-variety-efficiency effect: Output is increasing in the mass of producers and their efficiency and falling in the domestic expenditure share. These terms are scaled by the markup $1/(\theta - 1)$ and the inverse of the value-added share in production, $1 - \alpha_x$. The next term measures capital deepening per production worker. The final term measures the change in workers producing goods.

The bottom panel of Table 3 and Figure 5 report the results of our output decomposition. As with welfare and consumption, the discounted sum of output is higher than the new steady state (6.33 vs 0.52). The higher level of output along the transition arises because employment, capital deepening, productivity, and the stock of establishments are above their new steady-state levels even though trade is below its new steady-state level. A sizeable share of the boost in output in the first few years comes from increases in efficiency and employment in production. To evaluate the long-run effects of eliminating tariffs, it is useful to consider the direct effect and indirect effects. The direct effect is the gain from a lower domestic expenditure share offset by the change in the tariff distortion, a net gain of 19.22 percentage points. In contrast to a change in iceberg costs, there is no direct resource gain from a tariff cut. The indirect effects are the declines in the mass of producers (−17.24) and labor allocated to production (−2.11) and a small gain (0.65) from capital deepening.

7. The Role of Exporter Export Intensity Dynamics

Slow producer-level export growth is an important determinant of the response of welfare and trade volumes to a change in trade barriers. To see this, consider a variant of the benchmark model in which we eliminate the slow producer-level export growth: the sunk-cost model from Section 5.1. Table 2 summarizes the parameters, Table 3 summarizes the effect of the change in tariffs, and Figures 3 and 4 plot some aspects of the transition.

Relative to the benchmark model, the sunk-cost model has a smaller long-run expansion of trade and a faster transition. The trade elasticity is 63 percent of the benchmark model (7.2 versus 11.5) and, by year three, 90 percent of trade growth has been realized, while in the benchmark model, only 54 percent of trade growth has been realized. The smaller trade growth arises from a smaller increase in export participation (72 versus 105 percent).

[18] To convert this into the change in utility we need to account for the change in the investment rate, but since these are small we focus on decomposing output growth.

Compared to the benchmark model, the sunk-cost model has a larger change in steady-state consumption (1.99 versus 0.42) but a smaller welfare gain (4.78 versus 6.33). The benchmark model generates a larger welfare gain than the sunk-cost model because, even though trade grows more slowly, consumption overshooting is stronger. The models generate similar consumption dynamics in the first few years. The sunk-cost model, however, peaks four years earlier and at a level below the benchmark model. The gap that opens between the models closes slowly. The more-delayed and more-variable consumption dynamics in the benchmark model reflect the dynamics of new exporter growth. In the benchmark model, since exporters need time to increase export efficiency, more time and resources are initially used to increase the stock of exporters, so it takes longer to benefit from this entry. The long-run effect on consumption in the sunk-cost model is stronger because there is less substitution between trade and establishment creation than in our benchmark model. In the long run, the stock of domestic producers falls by only 4.8 percent in the sunk-cost model versus 13.1 percent in the benchmark model.

The smaller drop in entry in the sunk-cost model arises because potential entrants value future export profits more than in the benchmark model. The smaller decrease in establishment creation leads to the smaller welfare gain in the sunk-cost model.

The aggregate variables in the sunk-cost model behave more like those in the benchmark model if we increase the export entry cost: the sunk-cost-high model from 5.2. While this may seem counterintuitive—entry costs are already larger in the sunk-cost model—the slow expansion of new exporters in the benchmark model implies that the export continuation costs (κ_L) are a form of entry cost as well.

In the sunk-cost-high model, new exporters are less important in the aggregate, so the model behaves more like the benchmark model (Table 3): trade grows more and more gradually; the number of establishments shrinks more; and there is more overshooting than in the model with the sunk-cost model. Thus, our benchmark model with a small export entry cost and new exporter dynamics yields aggregate properties that are more consistent with a traditional sunk-cost model with a very large export entry cost. The sunk-cost-high model comes closer to approximating our benchmark model because it requires relatively similar investments in exporting (measured as fixed costs relative to export profits) to generate a given stream of export revenue. Even though the sunk-cost-high model does a better job of approximating the benchmark model, the welfare gain is lower (5.69 versus 6.33 percent), and the long-run change in consumption is higher (1.65 versus 0.42 percent).

8. Aggregate Trade and Welfare

Arkolakis et al. (2012) showed that, in many static models, the welfare gains from trade will be identical across models that generate the same trade elasticity. Essentially, the producer details can be ignored—simpler environments yield the same welfare outcomes. In this section, we show that this result does not extend to dynamic environments. We consider two variants of the benchmark model that abstract from producer-level decisions but generate the same aggregate trade elasticity as the benchmark model. These variants provide poor approximations of the benchmark model's welfare.

In our first extension, we remove the producer-level export intensity dynamics but keep the export entry decision. This is the sunk-cost model. To generate the same long-run trade elasticity as in the benchmark model, we cut the tariff in the sunk-cost model and simultaneously decrease the iceberg trade cost so that the long-run trade elasticity matches that in the benchmark model. The results are reported in the *sunk-cost-iceberg* column of Table 3. While we did not target these moments, the sunk-cost-iceberg model closely approximates the steady-state changes in the number of exporters, the export intensity, and the exporter premium. The exogenous change in the iceberg cost is similar to the endogenous change in the benchmark model, too (29 versus 26 percent).

The new model's discounted trade elasticity is similar (11.21 versus 10.15), but the change in welfare (13.23 versus 6.33) and steady-state consumption (9.43 versus 0.42) are substantially larger than in the benchmark model owing primarily to a much smaller drag from the contribution in the firm creation margin (−17.24 versus −9.96). Thus, models that generate identical trade elasticities at the aggregate level—and generate similar producer-level responses, too—do not generate identical—or even similar—welfare consequences. It is important to model how trade policy distorts endogenous producer-level investments in export capacity.

In our second extension, we strip away all of the producer's export decisions. All establishments can costlessly export from birth ($\kappa_H = \kappa_L = 0$) and face the same iceberg cost ($\xi_L = \xi_H$). This is the *no-cost model* and it is a variation of the model in Krugman (1980). For the no-cost model to match the benchmark model's long-run trade elasticity, we modify the final good aggregator so that the bundles of home and foreign intermediates are more substitutable than individual varieties from the same country. The elasticity of substitution between home and foreign bundles, the Armington elasticity, θ_A is set to equal 12.54. Without some further modification, the trade elasticity is constant in this model. To match the gradual increase in the trade elasticity in the benchmark model, we introduce an adjustment friction to the final-goods aggregator.[19] Specifically, we introduce a time-varying weight on imported goods, g_t, into the aggregator:

$$D_t^{\frac{\theta_A-1}{\theta_A}} = \left[\int_z y_{h,t}^d(z)^{\frac{\theta-1}{\theta}} \varphi_t(z)\, dz\right]^{\frac{\theta}{\theta-1}\frac{\theta_A-1}{\theta_A}} + g_t \left[\int_z y_{f,t}^d(z)^{\frac{\theta-1}{\theta}} \varphi_t^*(z)\, dz\right]^{\frac{\theta}{\theta-1}\frac{\theta_A-1}{\theta_A}}, \tag{42}$$

$$g_t = g_{t-1}^{\rho_g}\left[\left(\frac{\lambda_t}{\lambda_{t-1}}\right)^{\upsilon}\right]^{1-\rho_g}, \quad g_{-1} = 1, \tag{43}$$

where λ_t is the aggregate home intermediate goods' expenditure share. With $\upsilon > 0$, an increase in the import share lowers the weight on imports in the aggregator.[20] This demand shifter is external to the final-goods producer. It affects only the transition and not the steady state.

The parameters of the final goods aggregator, υ and ρ_g, are set to minimize the sum of squared differences between the paths of the trade elasticity in the benchmark model and

[19] This specification is meant to represent the challenges that producers face in adjusting their inputs in the short run and is similar to the adjustment cost in Erceg et al. (2008), Engel and Wang (2011), and Rabanal and Rubio-Ramírez (2015). Alternatively, slow trade growth would arise from allowing tariffs to fall gradually or allowing the iceberg cost to depend on the change in the import share (i.e., $\xi_t = \xi e^{-\upsilon \ln \lambda_t/\lambda_{t-1}}$). Both of these approaches yield similar findings in that they reduce consumption along the transition.

[20] The term g_t generates a wedge in a standard CES demand system. Levchenko et al. (2010) and Alessandria et al. (2013a) find substantial cyclical fluctuations in this wedge.

the no-cost model. We find $\upsilon = 1.89$ and $\rho_g = 0.25$. In Figure 3, we plot the trade elasticity in the no-cost, the benchmark, and the sunk-cost models.

The simpler no-cost model is a poor approximation of the benchmark model. The welfare gain from the cut in tariffs is almost two percentage points smaller (4.51 versus 6.33), even though the steady-state change in consumption is almost 4 percentage points larger (6.22 versus 0.42). The large difference in welfare occurs because consumption in the benchmark model overshoots the new steady state, while, in the no-cost model, consumption grows gradually. The gap in consumption between the models is as large as 6.6 percentage points five years after the policy change (Figure 3). The gradual consumption growth in the no-cost model occurs because there is only a small and temporary decline in establishments and capital and trade grow gradually due to the adjustment friction in the production of final goods.[21] The relationship between the trade elasticity and welfare is not invariant in the dynamic models considered here, making the sufficient-statistic approach to measuring the gains from trade liberalization inapplicable. It is important,to consider how the scale of the economy (the mass of operating establishments) is changing.

9. Sensitivity

In this section, we modify several features of our benchmark model and discuss how these modifications change (or do not change) our findings. Additional sensitivity analyses can be found in the appendix.

9.1. Sensitivity to New Exporter Size

The benchmark model closely matches several features of exporter dynamics but overstates the importance of new exporters in aggregate trade: New exporters export too much. In our benchmark model, the average new exporter exports 65 percent as much as the average exporter, compared with 25 percent in the data. Even so, the benchmark model does much better than the sunk-cost model (138 percent) or the sunk-cost-high model (301 percent). We consider three modifications to the export cost structure and study their implications for aggregate trade growth and welfare. In doing so, we further draw out the relationship between firm creation and trade. We find that making new exporters smaller generally leads to larger welfare gains and long-run trade elasticities.

Since our baseline calibration closely matches other aspects of producer growth and dynamics, we focus on changing the process for fixed and variable trade costs rather than on reestimating the entire model. In each model extension, we target the same aggregate export intensity, export participation, and exit rate from exporting. The first moment ensures that any comparison of aggregate effects is appropriate. The last two moments ensure that each model has the same share of new exporters in the steady state. We summarize the new parameters in Table 2 and the results in Table 3.

[21] Eliminating input adjustment cost speeds up the transition and increases the welfare gain in the no-cost model to 3.5 percent. The path of aggregate dynamics, however, would remain qualitatively different from that in our benchmark model.

Our first extension, *reentry*, allows an exporter to exit the export market and reenter at a later date by paying a smaller fixed entry cost. Specifically, an exporter can take a one-period break from the export market and return the following period by paying $\kappa_R < \kappa_H$.[22] Consistent with the data (Table 1), recent exporters in the model are now more likely to export than a firm that last exported three periods ago. We set $\kappa_R/\kappa_L = 2/3$. This increases the option value of export entry, so, to make this model match the aggregate export data, we must increase the cost of exporting for first-time exporters. We find that $100 \times \kappa_H/\kappa_E = 5.9$, compared with 3.8 in the benchmark.

In the reentry model, the average exports of new exporters, relative to incumbent exporters, is 63 percent—adding reentry does not shrink the aggregate importance of new exporters. Reentry allows for smaller reentrants, but the larger initial entry cost requires larger (more productive) initial entrants. In our parameterization, these two forces roughly cancel each other out. With reentry, establishments and exporters are more substitutable, and the model's long-run trade elasticity from a ten-percent tariff reduction rises from 11.55 to 12.23. The number of establishments falls by 14.4 percent, compared with 13.1 percent in the benchmark model, and long-run consumption increases by 0.70 percent, compared with 0.42 percent in the benchmark model. The welfare gain rises to 6.85 percent.

In our second extension, *search*, we make the variable trade cost upon export entry stochastic. In the benchmark model, a new exporter always faced $\xi = \xi_H$. We now assume that, with probability η, the variable trade cost is $\xi = \xi_H$, and with probability $1 - \eta$, the variable trade cost is $\xi = \infty$. We interpret this setup as a simple model of searching for, and sometimes failing to find, an export market. We set $\eta = 0.33$. To keep the exit decision unaffected, we assume that $\kappa_R = \kappa_H/\eta$. To maintain the same aggregate export intensity, we scale down the variable trade costs. We find that the average exports per new exporter are 53 percent of those of the average incumbent exporter, compared with 25 percent in the data and 65 percent in the benchmark model. It is possible to further reduce the probability of a match (η), which will reduce the importance of new exporters, but doing so leads to a worse fit of the size distribution. Establishments and exporters are also better substitutes in this model. The trade elasticity rises to 12.8 and the number of establishments falls by 15.8 percent. Long-run consumption, however, grows by less than it does in the benchmark, rising by only 0.21 percent, but welfare increases by more, 6.9 percent.

In our last extension, *starters*, we directly target the exports of new exporters. The gap between the high and low export cost is set so that the average exports per new exporter are 25 percent of the average incumbent exporter's, as in the data.[23] This requires increasing the high variable trade cost to $\xi_H = 2.2$ and decreasing the low variable trade cost $\xi_L = 1.0$. In this model, establishments and exporters are the most substitutable. The trade elasticity rises to 13.7 and the number of establishments falls by 17.7 percent. Long-run consumption rises by only 0.11 percent, but welfare rises the most in all the extensions, by 7.29 percent.

9.2. Sensitivity to Preference Parameters

Unlike static models, our dynamic model generates non-trivial transitions and model-dependent long-run effects from trade reforms. In this section, we consider two factors

[22] We present the modified model in the appendix.

[23] Alternatively, making the low variable trade cost an absorbing state yields similar results.

that influence post-liberalization transitions and the gains from trade: the intertemporal elasticity of substitution and the discount factor. Altering these parameters has a minor effect on welfare and the path of the trade elasticity, but the discount factor changes the consumption dynamics.

The intertemporal elasticity of substitution, $1/\sigma$, determines how agents value fluctuations in consumption over time. We set this to 0.5, but there is disagreement about its value. When we raise this elasticity to one, we make consumption more volatile (Figure 6). Changing the intertemporal elasticity has no impact on the long-run effect of a change in tariffs but leads to a faster transition. This has little impact on the trade elasticity, but leads to a faster reduction in establishments and more overshooting in consumption and capital. The faster transition arises because fluctuations in consumption are less costly than in our benchmark case.

Next, we vary the discount factor, $\beta \in \{0.95, 0.98\}$. To keep the capital-output ratio constant, we adjust the capital depreciation rate.[24] The trade elasticity is, again, largely unaffected by changing the discount factor. When we decrease β, firms discount future profits more, so the benefits of a cut in tariffs are smaller for new firms. This leads to a larger drop in establishment creation in the new steady state, which drives the long-run change in consumption negative, falling by 0.6 percent. The smaller discount factor implies that the welfare gain is less than in our benchmark (6.1 versus 6.3 percent). When we increase β, the long-run benefits increase: steady-state consumption now rises by 3.2 percent. We also find more consumption growth in the early transition, with consumption growth peaking at 12 percent in year seven compared with 10.5 percent in the benchmark model. The 6.8 percent increase in welfare, however, is not much larger than that in our benchmark model. The small difference in welfare across these alternative calibrations with vastly different long-run effects makes clear that understanding the early periods following reforms—rather than the long-run effects—is much more important for judging the benefits of reform.[25]

9.3. Further Sensitivity

Our findings are robust to introducing a per-period operating cost as in the models in Hopenhayn (1992) or Melitz (2003). With a fixed operating cost, the extra substitution between active and inactive firms increases the incentive to create a plant and, thus, the firm creation rate falls even more than in our benchmark model. Finally, our findings are also robust to introducing an endogenous labor supply decision, which we study in the appendix. With endogenous labor supply, the long-run effects of trade liberalization will depend on whether income or substitution effects dominate and how the lost tariff revenue is replaced. For standard balanced-growth preferences and lump sum taxes, there is substantial overshooting.

[24] In the neoclassical growth model $K/Y = \frac{\alpha}{(1-\beta)+\delta}$. Here, the profit share is affected by discounting, too.

[25] The high-β economy generates a welfare gain similar to that in our benchmark economy even though there is more overshooting and substantially larger long-run consumption growth because, when we change β, periods are not valued equally. With a high β, the overshooting period is a smaller share of lifetime utility.

10. Unilateral Trade Liberalization

In this section, we consider the effect of an unanticipated unilateral cut in the home tariff. As in the global liberalization, the steady-state change in consumption is a poor approximation of the welfare gain and, for the reforming country, it may not even indicate its correct sign.

We solve the model under three common financial market assumptions: a non-contingent bond, financial autarky, and complete markets. These alternative cases illustrate the role financial markets play in transferring changes in wealth that arise from trade liberalization. We also include the results for the no-cost model with a non-contingent bond to clarify how the structure of trade costs and the source of slow trade adjustment influence the welfare gain from liberalization and international borrowing and lending. Figure 7 plots the dynamics of some key variables, and Table 4 reports the changes in welfare and steady-state values.

When only a non-contingent bond is traded, home welfare rises by 0.51 percent, even as steady-state consumption falls by 2.4 percent. Foreign welfare rises by 5.7 percent and steady-state consumption rises by 2.8 percent. The foreign country gains more than the home country because the foreign country's positive tariff generates a beneficial terms-of-trade adjustment. As in the global reform, there is substantial overshooting of consumption, so the change in steady-state consumption is a poor approximation of the welfare gain. This overshooting is driven by the reduction in new-establishment creation. In the new steady state, the number of home establishments falls by 6.6 percent and foreign establishments falls by 5.9 percent. Along the transition, the home country runs a trade surplus in the first 11 years. The surplus peaks in year two at 0.72 percent of GDP. The home country accumulates net external assets equal to 6.9 percent of GDP. Its real exchange rate depreciates by 5.4 percent initially and then appreciates slightly for a total depreciation of 4.5 percent. This depreciation, and the large increase in foreign income, leads to a stronger expansion of exporting among the home producers. The home country is a net saver initially because, after liberalization, its large stock of firms makes it relatively rich. The foreign country is initially a net borrower because it will gain the most in the long-run and wants to bring some of that gain forward.

In financial autarky, the home country's welfare increases a bit more than in the bond economy (0.55 versus 0.51), and the foreign country's welfare increases a bit less (5.66 versus 5.70).[26] While there is a minor effect on welfare, the differences in steady-state consumption growth are larger, as home steady-state consumption now drops more (–2.85 versus –2.43) and foreign consumption rises more (3.22 versus 2.82). These long-run differences largely reflect the accumulation of assets by the home country in the bond economy.

When countries trade a complete set of contingent claims, the wealth effect from the liberalization eliminated.[27] In contrast to the bond economy and financial autarky, the home country is the main beneficiary of the reform, as its welfare increases by 4.3 percent, while the foreign country's welfare increases by only 1.9 percent. The trade balance is also

[26]Home gains from this asset market restriction owing to a more favorable terms of trade. See Heathcote and Perri (2016) for an analysis of the desirability of capital controls.

[27]The asset structure closely follows Lucas (1982) and leads to the familiar risk-sharing condition $U_{C,t} = U^*_{C,t}/P^*_t$, from Backus and Smith (1993).

significantly different with complete markets. The home country runs a trade deficit of 2.3 percent of GDP in year one, that expands to 2.8 percent of GDP in the steady state.

Lastly, we consider a unilateral tariff reform in the no-cost model from Section 8 with the single-bond asset structure. As with the global reform, we find that the welfare and consumption paths in the no-cost model are quite different from those in the benchmark model. Most striking is the implication for welfare: In the no-cost model, home-country welfare rises only by 0.32 percent, compared to the 0.51 percent increase in the benchmark model. In the steady state, home consumption rises by only 0.89 percent, compared to a decline of 2.43 percent in the benchmark model. Figure 7f shows that borrowing and lending are qualitatively similar to the benchmark model, in that the home country initially runs trade surpluses, but the fluctuations in the trade balance are 40 percent as large. Without slow trade adjustment in the no-cost model, there would be no borrowing. Thus, the source of gradual trade adjustment influences the dynamics of the trade balance.

11. Empirical Challenges

The transition following a cut in tariffs has three striking features absent from static models: a slow increase in trade, a decrease in the number of operating firms, and overshooting in aggregate output and consumption. Identifying these relationships is straightforward for the empirically irrelevant once-and-for-all liberalization, but is much more challenging for the more relevant case of gradual and uncertain trade reforms. We now consider alternative reforms in our model and discuss how measuring these relationships becomes more challenging since they lead to small but persistent changes in the growth rates of trade, entry, and output and, owing to the forward-looking nature of the world, may lead some variables to respond substantially in advance of trade policy and trade volumes.[28]

In Figure 8, we contrast the dynamics of consumption, trade, and entry for alternative symmetric, gradual reforms with our *once-and-for-all* case. Specifically, we consider the transition from a gradual phaseout of a 10-percent tariff that occurs in equal steps over 20 years. We do this when 1) agents learn about this policy path in year zero (*gradual-foreseen*) and 2) each new tariff change is a surprise (*gradual-surprise*). We also consider a reform that is known at time one but starts in year five and tariffs fall twice as fast (*future*).

A gradual tariff reform leads output (and consumption) to grow gradually with the peak impact 10–15 years later and 3–4 percent smaller than in our benchmark case (Figure 8c). In the once-and-for-all reform, output peaks in year six at 11 percent above its initial level, while it peaks in year 20 at 8.5 percent when the gradual reform is foreseen. When the gradual reform is unforeseen, it peaks in year 21 at 9.1 percent. The gradual, but faster, reform peaks two years after the reform ends (year 17) at 8.4 percent. These trade reforms thus lead to small persistent movements in output and consumption that may be absorbed in macroeconomic trends or hidden by aggregate fluctuations.

A second key feature of these reforms is that agents will respond in advance of trade policy (and trade volumes). This is clearest when comparing the responses from the gradual-foreseen and gradual-surprise tariff reforms. In both cases, tariffs change by only 0.5 percent

[28]We are grateful to our referees who suggested we add this section.

in the first year (and trade changes by a similar amount), but the gradual-foreseen reform leads to a more than two percent increase in consumption while the gradual-surprise leads to a very small increase of less than 0.2 percent. The future reform has no change in tariffs in year one but consumption increases by almost as much as it does in the gradual liberalizations. It is very important to have a good measure of the path of future trade policy in order to identify the aggregate effects of trade policy.

Can we identify the effect of trade reform on firm entry? A first approach might be to compare trade volumes with firm entry or entry rates. In Figures 8b and 8d, we plot this relationship in the model under our alternative trade reforms. The relationship between trade and entry is highly non-linear and depends on both how we measure entry (in levels or a rate) and how we treat expectations and trends. Better identification might be attained by considering trade and entry across industries which may alleviate some of the problems with trends. This approach is considered in Alessandria and Ruhl (2020).

Beyond the concerns related to the nature of the trade reform (unilateral, gradual, and expectations), there are several additional factors such as labor supply decisions and the capital intensity of trade. In the appendix, we show that the effect of labor supply on the transition depends on the strength of the income and substitution effects on labor supply. Building on our framework, Mix (2018) incorporates capital-intensive trade in a multi-country framework and finds more muted overshooting and larger steady-state changes in aggregate variables. Finally, there are also important measurement issues to overcome, since a source of the gains from trade is the increase in available varieties that is not captured well in official statistics.

12. Conclusions

What conclusions emerge from our analysis? First, the relationship between trade and the benefits of trade, measured by welfare, depends strongly on how exporting substitutes for firm creation. Somewhat paradoxically, this substitution and, hence, the welfare gain, is stronger when new exporters are less important. When new exporters are small, more investment in export capacity is done by incumbent exporters and the returns to these investments are discounted. These features of the exporter life cycle make future export profits less important in the firm's value at entry.

Second, the long-run effects of a change in trade policy depend on the dynamic incentives to export. They cannot be recovered from a static trade model or from the formula proposed by ACR. Even the canonical sunk cost model seems to provide a poor approximation of the welfare gains from our general model, particularly when guided by the firm-level data. Moreover, because transitions can be slow, these long-run effects are largely discounted and, thus, are not the key determinants of the welfare gains from trade.

Third, the latter stages of trade integration, as trade converges to its new steady state, can be characterized by falling incomes. Whether this has contributed to the trade backlash and slow growth in the post Great Recession (and Great Trade Liberalization) world remains an open question. It would be useful to apply our theory to understand the impact of the globalization that has expanded U.S. manufacturing openness from seven percent to 35 percent over the last 40 years. There are, of course, challenges to this approach—in particular, specifying the timing of expectations regarding changes in trade policy, a challenge that does not arise in static trade models (Alessandria and Mix, 2017).

Our theoretical analysis suggests several challenges to the existing empirical approach and directions for future research. First, the non-linear, and non-monotonic, relationship between trade and growth suggests revisiting the empirical work on the effects of trade and growth. Second, given that the benefits of trade are front-loaded, while trade is back-loaded, it would be useful to consider how different generations gain or lose from reform, as well as the incentives to initiate and maintain these trade reforms. Third, our analysis suggests that a better understanding of the substitution between firm creation and export capacity is paramount. To highlight this mechanism, we have assumed a simple process by which firms become better exporters. Continuing to integrate recent work on the growth patterns of exporters into general equilibrium models may yield further insights. Fourth, our quantitative theory can be used to formulate and evaluate alternative formulas to approximate the gains from policy reform in a world with different short-run and long-run trade elasticities. It can also be used to clarify how forward-looking variables, such as asset prices, can be useful in identifying the impact of changes in trade policy (Alessandria et al., 2018).

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Table 1: New Exporter Importance and Growth

	Unbalanced panels		Balanced panels			
	Chile (98–06)	Colombia (81–89)	Chile (98–06)	Colombia (81–89)	Compustat (84–92)	U.S. Census (84–92)
Participation rate						
8-year	56.7	57.2	25.0	33.9	27.7	42.0
1-year	11.8	17.6	10.8	14.4	4.7	14.0
Export share						
8-year	39.2	38.4	6.7	13.6	11.0	
1-year	3.5	4.2	3.2	3.2	1.4	
Starter size discount						
Sales	0.53	0.62	0.46	0.59	0.51	0.40–0.55
Intensity	0.45	0.57	0.50	0.65	0.52	0.55
Intensity dynamics						
ρ_{exs}	0.88	0.86	0.88	0.81	1.00	
T	11	10	9	7	16	
$\widehat{exs}_{20}/\overline{exs}$	1.19	1.12	1.29	1.16	1.16	
Export survival						
Incumbent	0.81	0.86	0.83	0.85	0.93	0.66
Entrant	0.65	0.62	0.66	0.64	0.83	
Reentrant probability	0.26	0.28	0.29	0.33	0.03	0.27

Notes: *Participation rate* reports the fraction of exporting producers that entered during either the eight-year sample period or in an average year. *Export share* reports the share of total exports accounted for by producers that entered during either the eight-year sample period or in an average year. *Starter size discount* reports the average sales of a new exporter relative to the average sales of incumbent exporters. ρ_{exs} is the export-intensity autocorrelation from (1). T is the number of years an average exporter needs stay in the market to reach the average export intensity in the sample. *Export survival* reports the probability that an exporter exports in the following period and *reentrant probability* is the probability that a firm exports next year if it did not export this year but did in the previous year.

Table 2: Model Parameters

Common Parameters	β	σ	δ	τ	γ_0, γ_1	ρ, σ_ϵ	μ_E
	0.96	2.0	0.10	1.10	21.0, 0.02	0.65, 1.32	–1.34
Model-specific Parameters	Bench-mark	Sunk Cost	Sunk-cost High	No Cost	Reentry	Search	Starters
θ	5.0	5.0	5.0	5.0	5.0	5.0	5.0
α	0.132	0.132	0.132	0.132	0.132	0.132	0.132
α_x	0.810	0.810	0.810	0.810	0.810	0.810	0.810
$\theta\kappa_E$	32.7	33.2	32.7	35.4	32.6	32.6	32.5
$100 \times \kappa_H/\kappa_E$	3.76	5.80	18.34	0.00	5.90	1.12	2.76
κ_H/κ_L	1.40	3.80	11.08	–	2.23	0.38	0.89
ξ_H	1.72	1.42	1.34	1.11	1.70	1.67	2.20
ξ_L	1.07	1.42	1.34	1.11	1.06	1.04	1.00
ρ_ξ	0.92	0.50	0.50	0.50	0.92	0.92	0.92
η	1.00	1.00	1.00	1.00	1.00	0.33	1.00
κ_R/κ_L	1.40	3.80	11.08	–	0.67	1.14	0.89
Overall Fit (RMSE): Size Distributions							
Estab. + Empl.	0.70	0.70	0.78	1.29	0.70	0.67	0.70
Export	14.6	15.7	3.8	49.6	11.9	4.5	15.2
Fixed Trade Costs Relative to							
Plant Creation Cost	10.8	8.7	10.8	0.0	11.3	11.2	11.5
Export Profits	58.1	47.6	58.1	0.0	60.6	60.4	63.0
Selected moments (Data)							
Exit Rate (17.0)	17.0	17.0	4.0	0.0	17.0	17.0	17.0
Starter Ratio (25.1)	65.5	137.5	309.5	–	63.2	52.1	25.1
Starter Export Share (4.9)	12.8	26.4	23.0	–	12.4	10.2	4.9
5-yr Incumbent Share	48.7	29.8	43.5	–	52.7	54.0	58.7
Dom. Expenditure Share	91.2	91.2	91.2	91.2	91.2	91.2	91.3
Export Participation	22.3	22.3	22.3	100.0	22.3	22.3	22.6
Export Intensity	13.3	13.1	16.1	8.1	13.8	15.4	13.0
Exporter Premium	273.5	277.8	226.2	100.0	267.1	239.9	275.1
Average ξ	141.8	142.5	134.2	111.3	140.3	135.9	142.9

Table 3: Effect of Eliminating a 10-percent Tariff

	Bench	Sunk-cost	Sunk-cost High	Sunk-cost Iceberg	Reentry	Search	Starters	No-Cost
Trade Elasticity								
Discounted	10.16	6.90	8.67	11.21	10.75	10.96	11.87	10.19
Steady state	11.55	7.19	9.44	11.55	12.23	12.77	13.72	11.55
Change in								
Welfare	6.30	4.75	5.67	13.44	6.83	6.87	7.28	4.59
Consumption	0.42	1.98	1.65	9.42	0.70	0.21	0.11	6.22
Estab.	−13.11	−4.82	−8.60	−7.57	−14.41	−15.82	−17.68	0.00
Exporters	104.65	72.25	89.16	101.96	111.96	112.26	116.06	0.00
Ex. Intensity	61.77	39.97	38.30	64.11	61.50	59.16	74.57	102.44
Ex. Premium	−63.98	−43.28	−40.91	−63.63	−66.04	−60.06	−72.19	−0.00
Iceberg Cost	−26.20	0.00	0.00	−28.78	−27.39	−28.81	−43.76	0.00
SS output decomposition (Discounted values in brackets)								
$\widehat{Y}$	0.52	2.08	1.74	9.52	0.79	0.30	0.20	6.31
	[6.59]	[4.98]	[5.93]	[13.78]	[7.13]	[7.18]	[7.59]	[4.70]
$\widehat{L}_p$	−2.11	−1.01	−1.34	−1.51	−2.14	−2.40	−2.61	0.00
	[−1.08]	[−0.70]	[−0.83]	[−0.99]	[−1.06]	[−1.03]	[−1.23]	[0.49]
$\alpha \widehat{\frac{K}{L}}$	0.65	0.71	0.71	1.76	0.69	0.66	0.67	1.14
	[1.31]	[1.05]	[1.20]	[2.17]	[1.37]	[1.37]	[1.44]	[0.61]
$S - \frac{\widehat{\alpha_x(\theta-1)}}{\theta}$	−2.28	−2.28	−2.28	−2.28	−2.28	−2.28	−2.23	−3.14
	[−2.28]	[−2.28]	[−2.28]	[−2.28]	[−2.28]	[−2.28]	[−2.23]	[−3.14]
$\widehat{N}^\dagger$	−17.26	−6.35	−11.32	−9.97	−18.97	−20.82	−23.26	0.00
	[−10.40]	[−3.88]	[−7.09]	[−6.33]	[−11.68]	[−12.49]	[−14.41]	[−0.16]
$\widehat{\psi}_d^\dagger$	0.00	−0.00	0.00	0.00	0.00	−0.00	−0.00	0.00
	[0.92]	[0.34]	[0.63]	[0.56]	[1.03]	[1.11]	[1.28]	[0.01]
$\widehat{\lambda}^\dagger$	21.51	11.00	15.97	21.51	23.49	25.14	27.64	7.45
	[18.12]	[10.45]	[14.29]	[20.65]	[19.74]	[20.51]	[22.76]	[6.31]

Notes: Welfare change is a value of x that satisfies $\sum_{t=0}^{\infty} \beta^t U(C_{-1}e^x) = \sum_{t=0}^{\infty} \beta^t U(C_t)$, where C_{-1} is the consumption level in the initial steady state. The discounted trade elasticity is $\bar{\varepsilon} = (1-\beta)\sum_{t=0}^{\infty} \beta^t \varepsilon_t$, where ε_t is the trade elasticity based on the difference in trade between period t and the initial steady state. †Variable is divided by $(\theta-1)(1-\alpha_x)$.

Table 4: Effect of Unilaterally Eliminating a 10-percent Tariff

	Benchmark			No-cost
Change	Bond	Fin. Autarky	Complete	Bond
Welfare				
Home	0.51	0.55	4.34	0.32
Foreign	5.70	5.66	1.91	4.32
SS Consumption				
Home	–2.43	–2.85	1.45	0.89
Foreign	2.82	3.22	–1.00	4.90
SS Establishments				
Home	–6.65	–6.71	–6.10	—
Foreign	–5.90	–5.85	–6.45	—

Notes: Welfare gain is a value of x that satisfies $\sum_{t=0}^{\infty} \beta^t U\left(C_{-1} e^x\right) = \sum_{t=0}^{\infty} \beta^t U\left(C_t\right)$, where C_{-1} is the consumption level in the initial steady state.

Figure 1: New exporter dynamics in stationary steady state

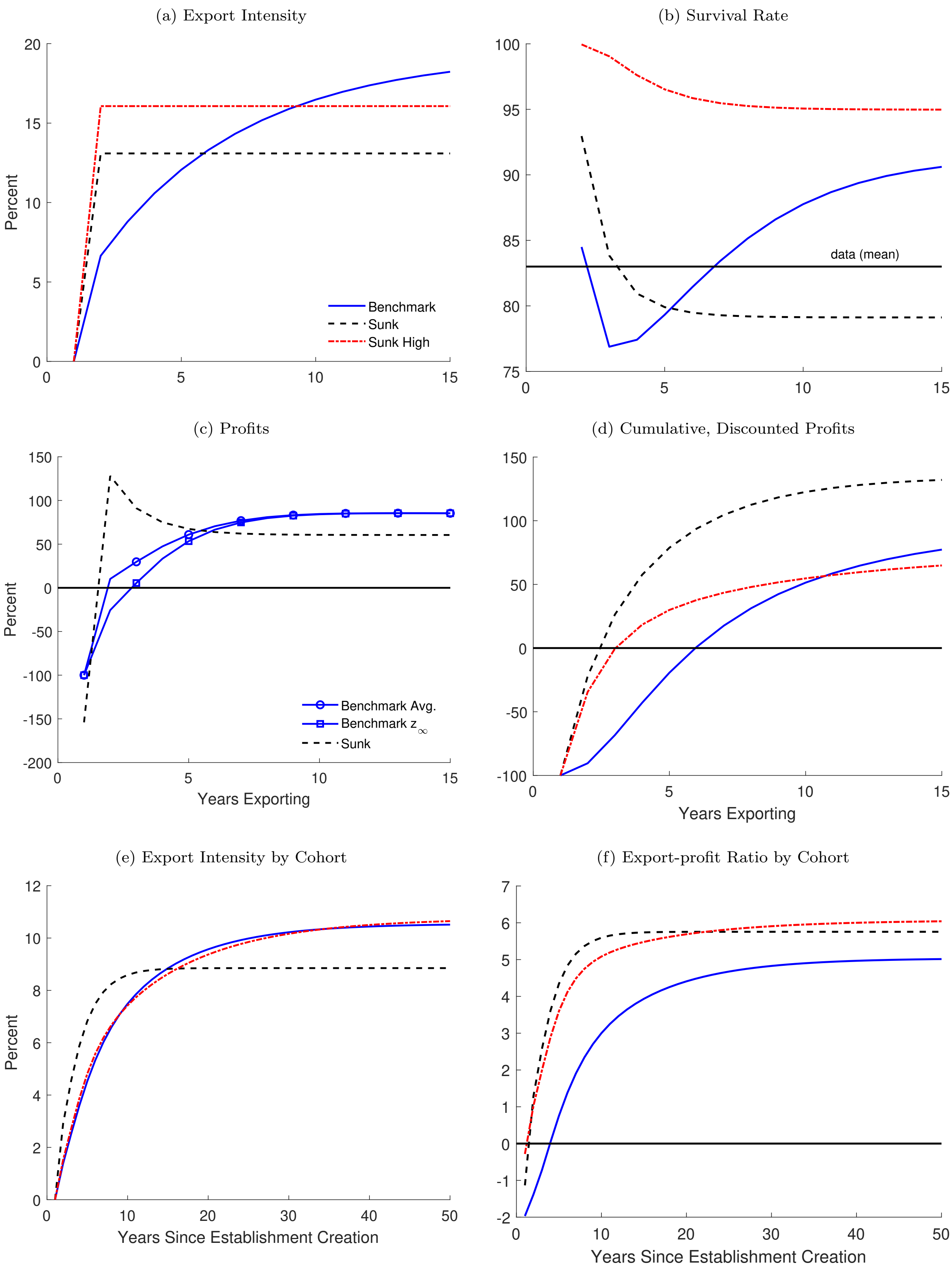
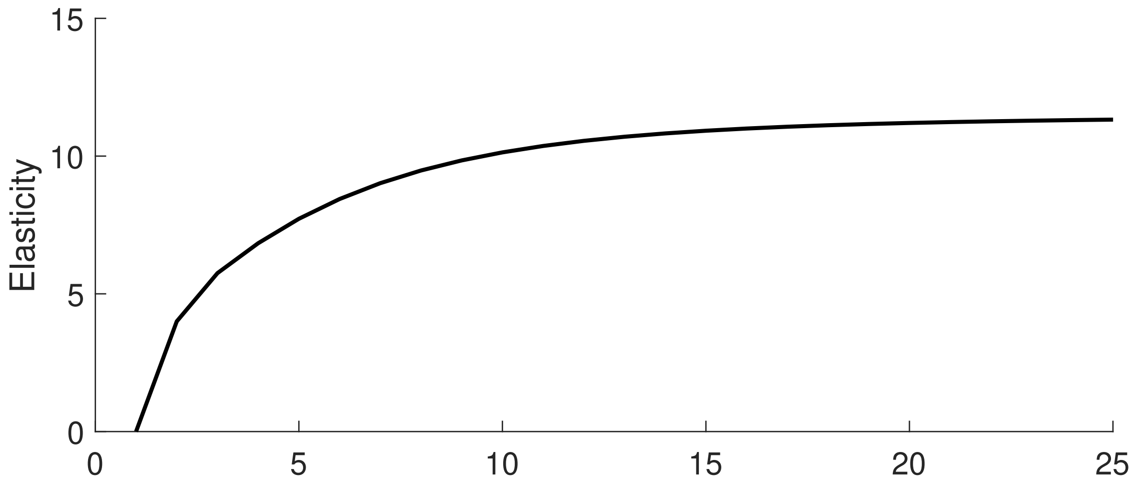
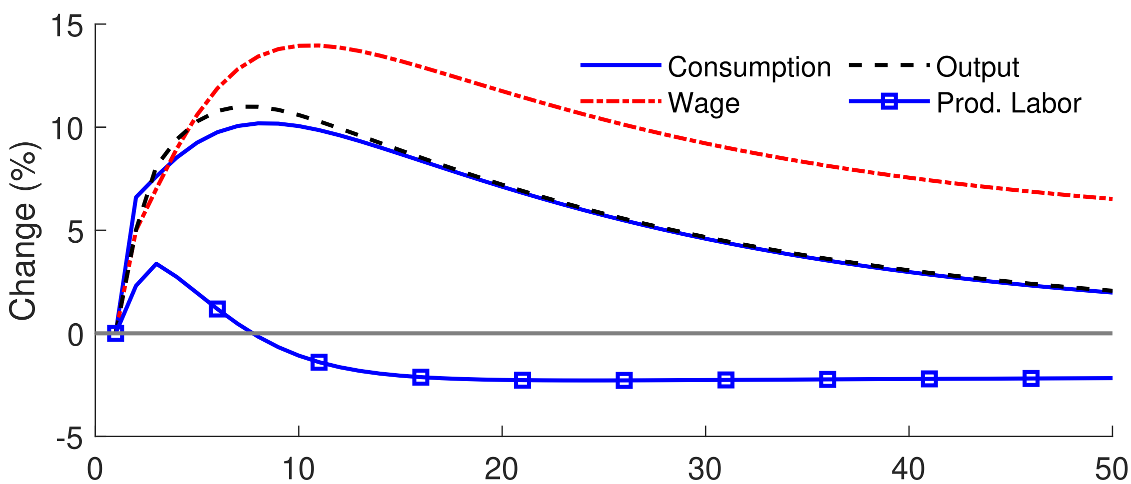


Figure 2: Elimination of 10-percent tariff in benchmark model

(a) Trade Elasticity



(b) Consumption, output, wages, and production labor



(c) Capital, entrants, and establishments

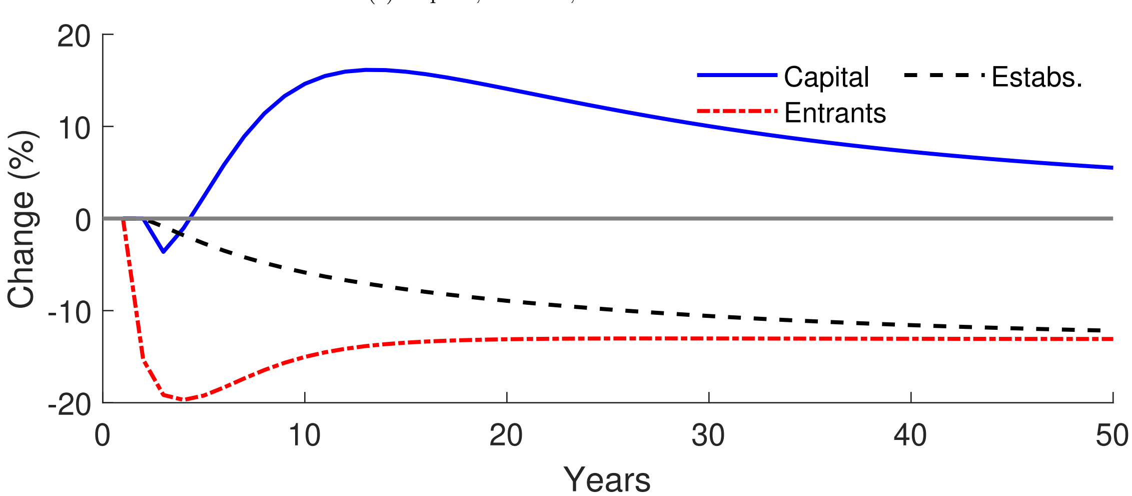
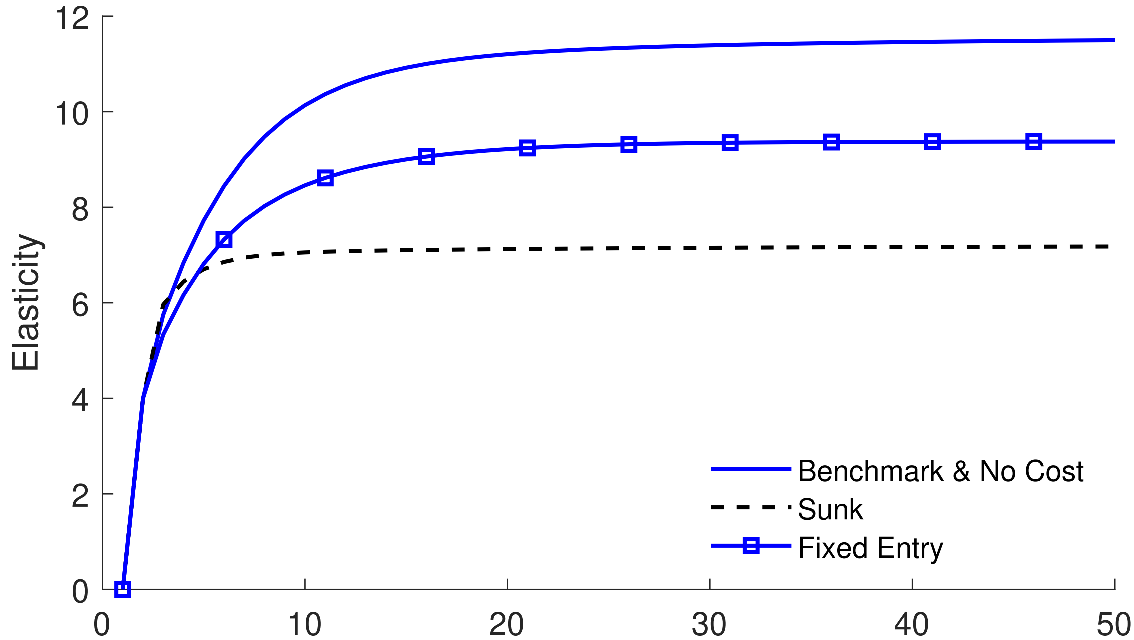


Figure 3: Effect of entry adjustment on trade and consumption

(a) Trade Elasticity



(b) Consumption

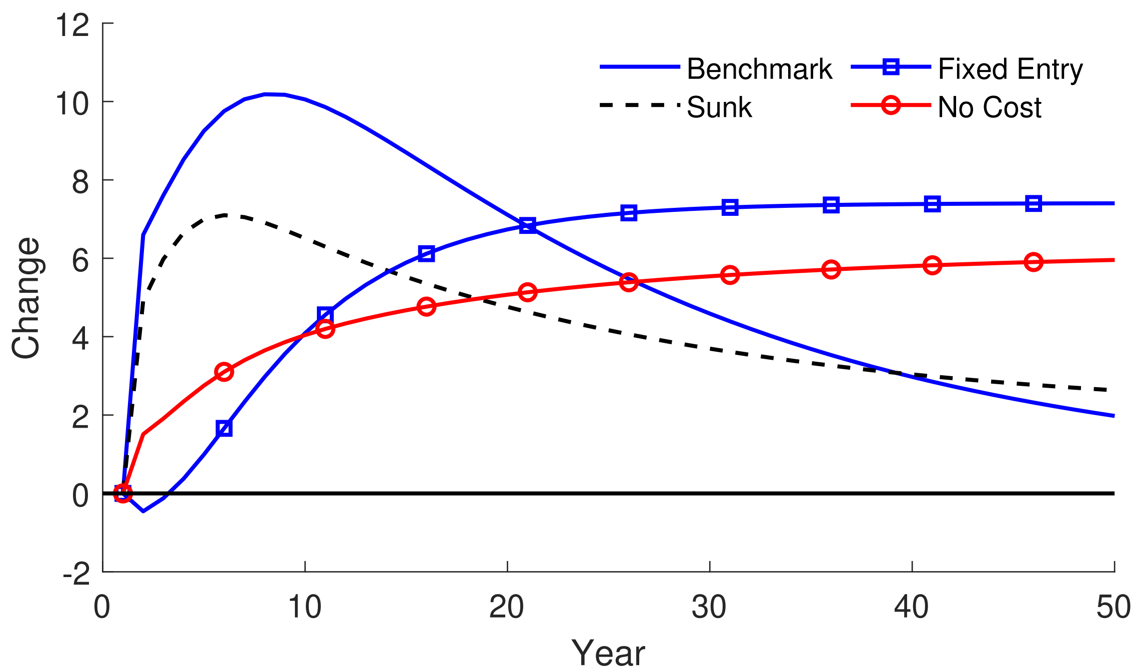


Figure 4: Comparing Dynamics across Models

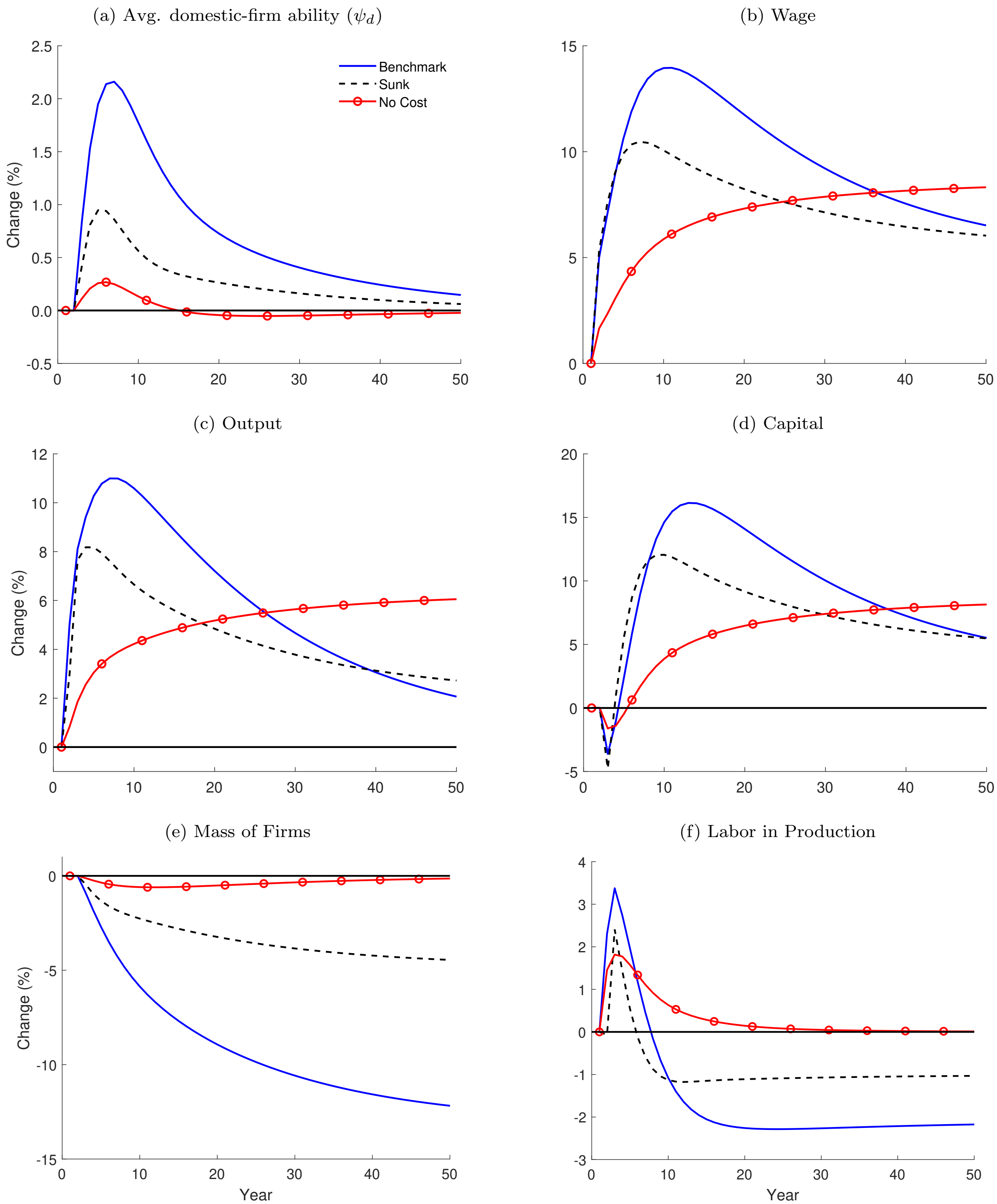


Figure 5: Decomposition in the benchmark model

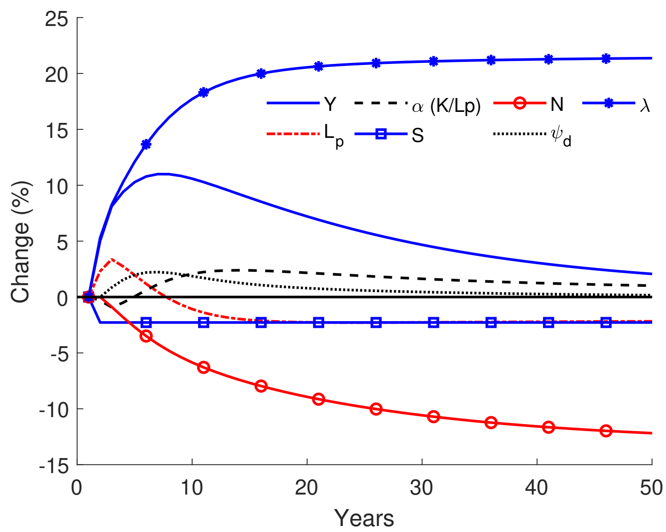


Figure 6: Sensitivity to interest rate and intertemporal elasticity

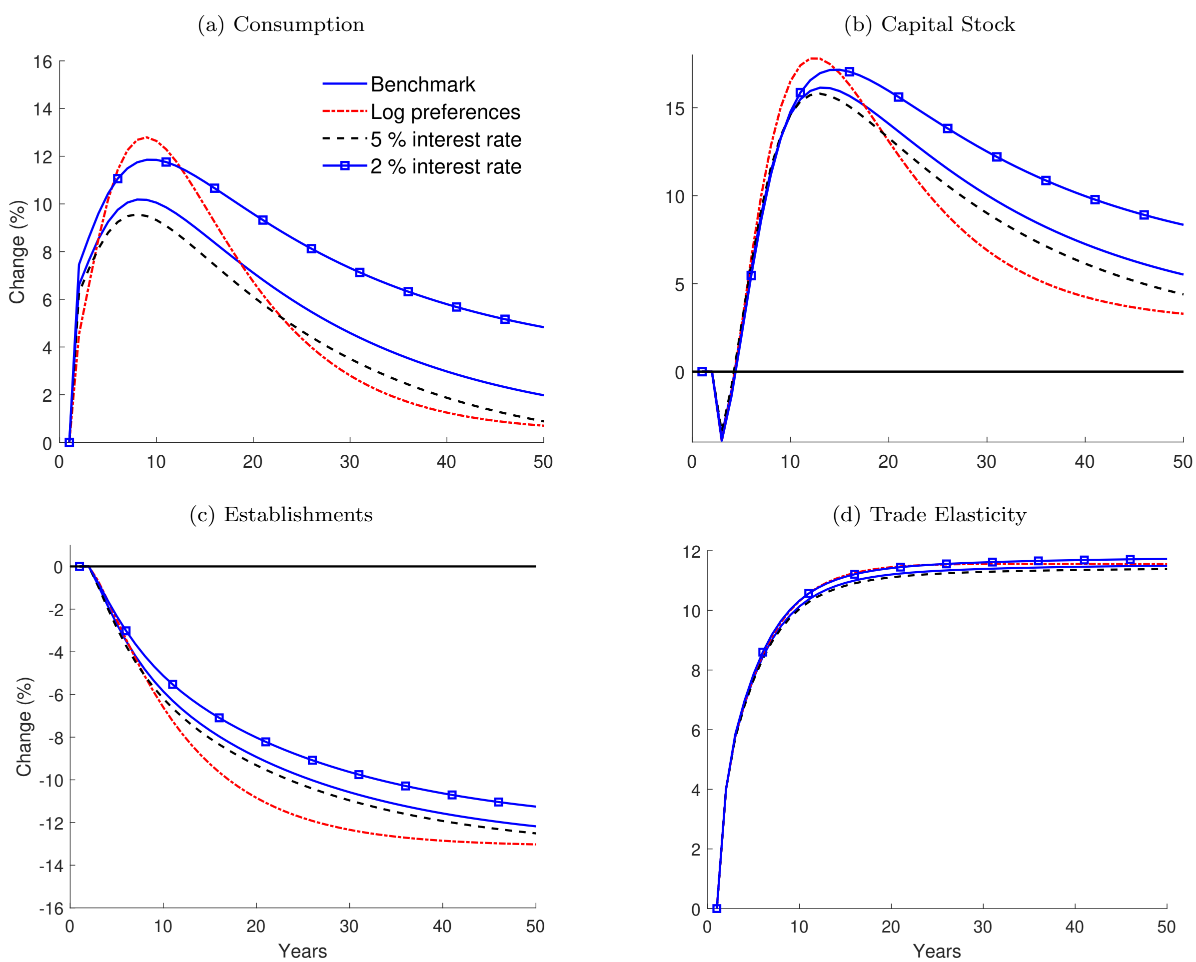


Figure 7: Transition following unilateral liberalization

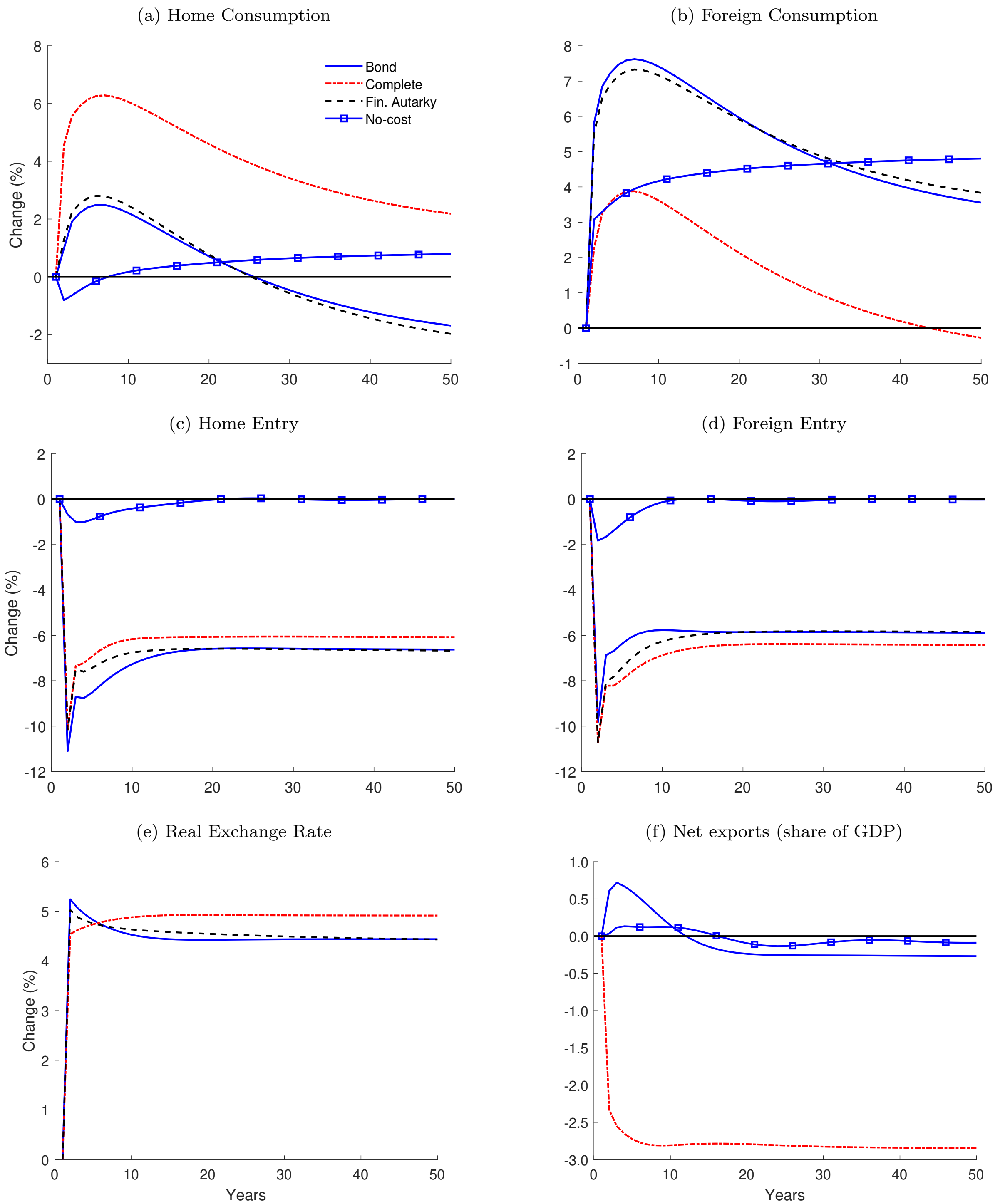


Figure 8: Trade liberalization timing