

Trade Adjustment Dynamics and the Welfare Gains from Trade*

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Abstract

We construct a two-country dynamic general equilibrium model in which trade responds more to a cut in tariffs in the long run than in the short run. The model introduces a dynamic element to the fixed-variable cost trade-off in a heterogeneous producer trade model, and nests standard models. The dynamics of aggregate trade adjustment arise from producer-level decisions to invest in lowering their future variable export costs. The model is calibrated to match salient features of new exporter growth and provides a new estimate of the exporting technology. At the producer level, we find that the marginal new exporter incurs substantial losses in its first three years in the export market; export profits are back-loaded. In the aggregate, a cut in tariffs generates a long-run trade elasticity that is three times the short-run trade elasticity. We estimate the welfare gain from global and unilateral tariffs cuts, taking into account the transition period, and allowing for international capital flows. While the intensity of trade expands slowly, consumption overshoots its new steady-state level, so the welfare gain is larger than the long-run change in consumption. Models without this dynamic export decision underestimate the gain from tariff reform and even predict a loss where we find a gain.

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1 Introduction

Becoming a successful exporter is difficult. It takes time for a new exporter to export as intensively as the typical continuing exporter, and most new exporters stop exporting before ever reaching this level of success. While interest in new exporter dynamics is growing,¹ these dynamics are largely ignored in the heterogeneous producer trade models used to measure trade costs² or to evaluate the welfare costs of trade policies. Here, we build a model of the entry, growth, and exit dynamics of these marginal exporters and show that these features have important consequences for measuring trade costs and welfare. Matching new exporter dynamics substantially reduces the estimated producer-level costs of starting to export, but increases the fixed export costs incurred in aggregate. These new exporter dynamics also determine the size and timing of the welfare gain from a tariff reduction, leading to a gradual expansion in trade, but a rapid expansion in consumption that substantially overshoots the new steady state. This overshooting leads the welfare gain from reform to substantially exceed the change in steady-state consumption. Contrary to the conventional view,³ the benefits to trade reform are front-loaded even as trade expansion itself is back-loaded. Relative to existing static or dynamic models, this leads to much larger benefits from reform. In the case of a unilateral reform, we even find a welfare gain where static models find a loss.

We develop a parsimonious model of producer export entry, expansion, and exit within a two-country general equilibrium model with capital, round-about production, and asset trade. The model nests the now-standard models of heterogeneous producers with fixed export costs (Krugman 1980, Melitz 2003, Das, Roberts, and Tybout 2007). To capture the observed new exporter dynamics, we allow the producer’s exporting technology—in particular, the fixed versus variable cost trade-off—to be dynamic. As in the standard models, non-exporters have an infinite iceberg cost. By paying a fixed cost, non-exporters lower their

¹See recent papers by Ruhl and Willis (2008), Eaton, Eslava, Kugler, and Tybout (2008), Kohn, Leibovici, and Szkup (2015), and Rho and Rodrigue (2015).

²See Roberts and Tybout (1997), Das, Roberts, and Tybout (2007), Aw, Roberts, and Xu (2011), Alessandria and Choi (2014b), and Impullitti, Irarrazabal, and Opmolla (2013)

³Baldwin (1992) shows that the “dynamic” gain from the increased capital accumulation in response to a cut in tariffs are offset by the forgone consumption necessary to support the extra capital stock, unless capital is subject to external economies of scale. Dix-Carneiro (2014) finds the transition lowers the gain from reform when there are adjustment costs to moving labor across establishments.

iceberg cost to a finite level and become exporters. Existing exporters must pay another, potentially different, fixed cost to continue exporting. In our model, unlike in standard models, a producer's iceberg cost is allowed to evolve dynamically. 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.⁴

With this general export technology, the aggregate volume of trade now depend on tariffs and the joint distribution of iceberg costs and productivity. Trade expands by accumulating 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 in the short- or long-run. 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. Indeed, a key feature of our dynamic model is its ability to capture the well-known feature that the trade elasticity increases with time.

The generality of our model allows us to estimate the exporting technology without imposing *a priori* restrictions. Following the literature, we divide the fixed export costs into a sunk entry cost and a continuation cost. Consistent with Ruhl and Willis (2008), when the model generates a reasonable exporter lifecycle, the estimated sunk cost is much smaller than those derived from models that ignore new-exporter dynamics: Lowering the initial profit from exporting and pushing the returns from exporting into the future reduces the present value of exporting, so smaller entry costs are needed to match the observed levels of export participation.⁵ In contrast to much of the literature, we find that the costs of starting to export are about as large as the costs of continuing to export. This significant difference from the literature arises because the continuation cost in our model is partially an

⁴While the focus is on generalizing the exporting technology, it is isomorphic to allow for export demand to increase with tenure in the foreign market.

⁵In our model, the marginal new exporter will, on average, earn negative profits in its first three years of exporting.

investment, as paying it could further reduce an exporter's future iceberg cost and increase its future export profits.

Our estimate of a relatively small sunk cost, however, does not imply that the costs of exporting are negligible. In the aggregate, spending on fixed export costs are larger than in a typical sunk-cost model. The larger aggregate fixed export cost is due to the many producers that either exit before being successful or are investing in lowering their iceberg cost. For a sunk-cost model to generate aggregate trade costs as large as our benchmark model, a much larger sunk export cost is needed.

We use the calibrated model to measure the aggregate effects of a unilateral and global reduction of a 10-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. 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, which generates overshooting in consumption, is a desire to reduce investments in new varieties. In our framework, varieties are long-lived assets resulting from a sunk investment. Lowering tariffs increases competition from foreign exporters, reducing entry.⁶ This frees resources for production and consumption in the transition, increasing welfare. In the long run, though, the smaller stock of establishments and the increased resources directed to exporting reduce the scale of production, explaining why the change in steady-state

⁶This feature is present in Alessandria and Choi (2006), Atkeson and Burstein (2010), Burstein and Melitz (2013), and Alessandria and Choi (2014b), but is much more prominent here.

consumption is relatively small even though the trade elasticity grows substantially.

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 unilateral reform, but the loss of tariff revenue implies that the reforming country’s gain is relatively small compared to its trading partner (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 one to conclude that welfare in the reforming country would fall. 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 is much smaller or even non-existent.

That the transition period may increase the welfare gain from lowering tariffs—even though the volume of trade grows slowly—is also true in Alessandria and Choi (2014b), who model sunk export costs, but do not model new exporter dynamics, and consider only global trade liberalization.⁷ Relative to their sunk-cost model, tariffs in our baseline model are more distortionary. The gain from liberalization is one-third larger in the model with new exporter dynamics than in the sunk-cost model, even though the long-run change in consumption in the benchmark model is only one-fifth of that in the sunk-cost model.

The larger welfare gain in the benchmark model arises because consumption overshoots by more, even as trade grows much more gradually, than in the sunk-cost model. It is, in large part, attributed to a greater decline in the stock of establishments. The aggregate implications of the sunk-cost model with a very large sunk cost are better approximations of the our benchmark new exporter model than the version calibrated to get the transitions of exporter participation.

The non-linear relationship between the trade elasticity and consumption along the transition implies that the sufficient statistic approach pioneered by Arkolakis, Costinot, and

⁷Alessandria and Choi (2014b) is a version of the well-known sunk-cost-of-exporting model developed by Dixit (1989), Baldwin and Krugman (1989), and Das, Roberts, and Tybout (2007).

Rodríguez-Clare (2012) (ACR, hereafter) does not extend to our model. We make this point quantitatively and theoretically. To make the quantitative point, we construct a model without export entry costs, so that all producers export, as in Krugman (1980). To make the aggregate trade dynamics in this model be consistent with our benchmark model, we introduce an adjustment friction. While the aggregate trade dynamics in the baseline model and this no-cost model are identical, the consumption dynamics are very different. Without an exporter decision, consumption grows smoothly during the transition and the welfare gain is only 37 percent of that in the baseline model, even though the steady-state increase in consumption is larger.

To make the theoretical point, we consider a version of our model without capital or material inputs. We derive a simple decomposition of consumption into five margins and relate it to the ACR formula. The decomposition is simple enough to distinguish between the change in steady-state consumption and welfare. We find that the welfare gain from trade liberalization is higher than the change in steady-state consumption because the available varieties, labor used in production, and average plant productivity are all relatively high along the transition.

This paper is part of the growing literature that quantifies the aggregate effects of trade on welfare. Atkeson and Burstein (2010) and ACR find producer-level exporting details matter little for welfare,⁸ while Head, Mayer, and Thoenig (2014), and Melitz and Redding (2015) find a role for producer-level exporting on welfare when the trade elasticity depends on the level of trade costs. Melitz and Ottaviano (2008) and Edmonds, Midrigan, and Xu (2015) consider 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.⁹ Alvarez,

⁸Simonovska and Waugh (2014) show that micro details are important for model parameters.

⁹A large empirical literature identifies different short-run and long-run trade responses to aggregate shocks (Hooper, Johnson, and Marquez 2000, Gallaway, McDaniel, and Rivera 2003). Many theoretical studies of the role of trade adjustment explicitly or implicitly calibrate the trade elasticity differently based on the horizon considered, (Obstfeld and Rogoff 2005). Some recent theoretical work has endogenized the dynamics

Buera, and Lucas (2013) study the transition following a change in trade frictions, however, these studies do not model the intensive export margin.

Lastly, in contrast to much of the literature, our model draws a meaningful distinction between tariffs (a policy choice) and trade costs (a technological constraint). In our model, producers increase investment in their export technologies in response to a change in trade policy. In static multi-country models, Alvarez and Lucas (2007), Caliendo and Parro (2015), and Ossa (2014) also study the aggregate implications of policy frictions.

In Section 2, we review the data on the exporter lifecycle, laying out key producer-level facts used to discipline our model of the producer’s exporting technology. In Section 3, we lay out the model, and in Section 4, we describe our strategy for calibrating the model. In Section 5, 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 Section 6, we present alternative versions of the model, highlighting the importance of producer heterogeneity in understanding the welfare gain from trade. In Section 7, we consider a unilateral tariff reform.

2 New-Exporter Dynamics

At the center of our model is a novel generalization of the producer’s exporting technology. This generalization allows us to capture key facts about exporters that the existing literature has largely ignored. Before laying out the model, we briefly review the data describing the exporter lifecycle that motivate, and, ultimately, will be used to calibrate, our specification of the exporting technology.

New exporters begin by exporting small amounts and increase their exporting activity over several years. Figure 1A, from Ruhl and Willis (2008), plots the average export-total sales ratio of new exporters in Colombia. The average continuing exporter ships 13 percent of its output abroad, while a new exporter ships about six percent of total sales abroad in its first year. It takes five years for the new exporter to reach the same export intensity as

of the trade elasticity, including Alessandria and Choi (2007), Drozd and Nosal (2012), Engel and Wang (2011), Ramanarayanan (2007), Ruhl (2008), and Alessandria, Pratap, and Yue (2013).

the existing exporters. Similar patterns of new exporter behavior are documented in Eaton, Eslava, Krizan, Kugler, and Tybout (2009), Rho and Rodrigue (2015), and Kohn, Leibovici, and Szkup (2015).

A second important aspect of export entry is evident in Figure 1B, also from Ruhl and Willis (2008). In this figure, we plot the one-period survival rate of exporters conditional on their time in the export market. An export entrant has a 65-percent chance of continuing to export, and this survival rate increases with the time spent as an exporter. The slowly expanding export flows and the high rates of exit imply that export entry is a decision that likely pays off only in the long run—if at all.

3 Model

We develop a dynamic general equilibrium model that captures the lifecycle of both establishments and exporters. There are two symmetric countries: *home* and *foreign*, $\{H, F\}$. Each country is populated by a unit mass of identical, infinitely-lived consumers that inelastically supply one unit of labor.¹⁰

In each country, competitive final goods producers purchase home and foreign differentiated intermediate inputs. The final good is not traded and is used for consumption, investment,¹¹ and as an input into production. There exists a one-period nominal bond, denominated in units of the home final good, that pays one unit of the home final good in the next period. Let B_t denote the home consumer’s holding of bonds purchased in period t , B_t^* denote the foreign consumer’s holding of this bond, and let Q_t denote the nominal bond price. The home 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 $B_t = 0$. 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 have an

¹⁰Results with an endogenous labor supply are available.

¹¹Capital accumulation is included to more accurately quantify the gain from trade. In most models, capital accumulation tends to increase the steady-state gain from a cut in trade barriers, but makes the steady-state change overstate the welfare gain. Hence, our results are even more surprising.

endogenous and stochastic element, while the fixed cost is exogenous. 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. Exporting requires paying fixed and variable costs. All exporters face the same ad valorem tariff, τ , but differ in their iceberg transportation cost, $\xi \geq 1$, and fixed export costs. The tariff is a policy variable, and the revenues collected from the tariff are 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 in allowing for three possible iceberg costs $\xi \in \{\xi_L, \xi_H, \infty\}$ with $\xi_L \leq \xi_H < \infty$ and two possible fixed export costs $f \in \{f_L, f_H\}$, $f_L \leq f_H$.¹² Fixed export costs and the variable iceberg costs are related. Producers with an iceberg cost of $\xi = \infty$ are non-exporters. A non-exporter can deterministically lower its next-period iceberg cost to ξ_H by paying a cost f_H . An exporter with iceberg costs $\xi_t = \{\xi_L, \xi_H\}$ can incur a cost f_L to draw its next-period iceberg cost. We assume that the transition probabilities are Markovian and that the probability of drawing the low iceberg costs, ξ_L , is lower for an exporter with a high iceberg cost than a producer with a low iceberg cost (i.e., $\rho_\xi(\xi_L|\xi_H) \leq \rho_\xi(\xi_L|\xi_L)$). Thus, part of exporting is making an investment that may lead to a lower marginal cost of exporting in the future. If an exporter does not pay f_L , it is choosing to exit the export market, and its next period iceberg cost rises to $\xi = \infty$.

This formulation of fixed and iceberg costs is quite general and nests the most common approaches to modeling trade. When $f_L < f_H$, there is a sunk cost of exporting, as in Das, Roberts, and Tybout (2007). When $f_L = f_H$ and $\xi_L = \xi_H$, exporting is a static decision. When $f_L = f_H = 0$ and $\xi_L = \xi_H$, there is no export decision, and this is a general version of the Krugman (1980) model of monopolistic competition.

An establishment is created by hiring f_E domestic workers and begins producing in the following period. The measure of country $j \in \{H, F\}$ establishments with technology z , iceberg costs ξ , and fixed costs f is $\varphi_{j,t}(z, \xi, f)$.¹³ Establishment exit (“death”) is exogenous

¹²This is the smallest departure from the standard models that allows for new exporter dynamics, yet yields rich predictions that differ from standard models.

¹³Here, f is the fixed cost that the producer has to pay if it decides to export, $f = f_H$ if $\xi = \infty$ and

and depends on the current productivity level.¹⁴ The state variable of the economy includes the measure of establishments across individual state variables from each country and the capital stock in each country. For notational ease, economy-wide state variables are subsumed in the time subscript.

3.1 Consumers

Home consumers choose consumption, investment, and bonds to maximize utility subject to the sequence of budget constraints,

$$V_{C,0} = \max E_0 \sum_{t=0}^{\infty} \beta^t U(C_t),$$

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

where $\beta \in (0, 1)$ is the subjective time 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 local tariff revenue. Investment is $I_t = K_t - (1 - \delta) K_{t-1}$.

The foreign consumer's problem is analogous. Foreign prices and allocations are denoted with an asterisk. The foreign budget constraint is

$$(2) \quad P_t^* C_t^* + P_t^* K_t^* + Q_t P_t^* B_t^* \leq W_t^* P_t^* L_t^* + R_t^* P_t^* K_{t-1}^* + (1 - \delta) P_t^* K_{t-1}^* + P_t^* B_{t-1}^* + \Pi_t^* + T_t^*,$$

where all prices are quoted in units of the home final good.

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

$$(3) \quad Q_t = \beta E_t \frac{U_{C,t+1}}{U_{C,t}} = \beta E_t \frac{U_{C,t+1}^*}{U_{C,t}^*} \frac{P_t^*}{P_{t+1}^*},$$

$$(4) \quad 1 = \beta E_t \frac{U_{C,t+1}}{U_{C,t}} (R_{t+1} + 1 - \delta) = \beta E_t \frac{U_{C,t+1}^*}{U_{C,t}^*} \frac{P_t^*}{P_{t+1}^*} (P_{t+1}^* R_{t+1}^* + 1 - \delta),$$

where $U_{C,t}$ denotes the derivative of the utility function with respect to its argument. Equation 3 is the no-arbitrage condition for bonds that equates the difference in expected con-

$f = f_L$ otherwise. Note that the producer-specific state is given by (z, ξ) . However, we describe producers with (z, ξ, f) to explicitly denote the fixed cost that producers face.

¹⁴Introducing endogenous exit from a fixed production cost is straightforward and yields similar results to our benchmark model.

sumption growth across countries to the expected change in the real exchange rate. Equation 4 is the standard Euler equation for capital accumulation in each country.

3.2 Final Goods Producers

Final goods are produced by combining home and foreign intermediate goods. The aggregation technology is a CES function

$$(5) \quad D_t = \left\{ \sum_{j \in \{H, F\}} \sum_{\xi \in \{\xi_L, \xi_H, \infty\}} \int_z y_{j,t}^d(z, \xi, f)^{\frac{\theta-1}{\theta}} \varphi_{j,t}(z, \xi, f) dz \right\}^{\frac{\theta}{\theta-1}},$$

where $y_{j,t}^d(z, \xi, f)$ are inputs of intermediate goods purchased from country j intermediate good producers. 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 purchases of intermediate inputs, $y_{j,t}^d$, to solve

$$(6) \quad \max \Pi_{F,t} = D_t - \sum_{\xi \in \{\xi_L, \xi_H, \infty\}} \int_z P_{H,t}(z, \xi, f) y_{H,t}^d(z, \xi, f) \varphi_{H,t}(z, \xi, f) dz \\ - (1 + \tau) \sum_{\xi \in \{\xi_L, \xi_H\}} \int_z P_{F,t}(z, \xi, f) y_{F,t}^d(z, \xi, f) \varphi_{F,t}(z, \xi, f) dz,$$

subject to the production technology in (5). Here, $P_{j,t}(z, \xi, f)$ are the home-country prices of intermediate goods produced in country j establishments. Solving the problem in (6) yields the input demand functions,

$$(7) \quad y_{H,t}^d(z, \xi, f) = [P_{H,t}(z, \xi, f)]^{-\theta} D_t,$$

$$(8) \quad y_{F,t}^d(z, \xi, f) = [(1 + \tau) P_{F,t}(z, \xi, f)]^{-\theta} D_t,$$

where the final goods price is defined as

$$(9) \quad P_t^{1-\theta} = \sum_{\xi \in \{\xi_L, \xi_H, \infty\}} \int_z \left[P_{H,t}(z, \xi, f)^{1-\theta} \varphi_{H,t}(z, \xi, f) + [(1 + \tau) P_{F,t}(z, \xi, f)]^{1-\theta} \varphi_{F,t}(z, \xi, f) \right] dz.$$

3.3 Intermediate Goods Producers

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

$$(10) \quad y_t(z, \xi, f) = e^z [k_t(z, \xi, f)^\alpha l_t(z, \xi, f)^{1-\alpha}]^{1-\alpha_x} x(z, \xi, f)^{\alpha_x}.$$

The markets that the producer serves in the current period are predetermined, so the producer maximizes current-period gross profits by choosing prices for each market, $P_{H,t}(z, \xi, f)$ and $P_{H,t}^*(z, \xi, f)$, labor $l_t(z, \xi, f)$, capital $k_t(z, \xi, f)$, and materials $x_t(z, \xi, f)$ to solve

$$(11) \quad \begin{aligned} \Pi_t(z, \xi, f) = \max & P_{H,t}(z, \xi, f) y_{H,t}(z, \xi, f) + P_{H,t}^*(z, \xi, f) y_{H,t}^*(z, \xi, f) \\ & - W_t l_t(z, \xi, f) - R_t k_t(z, \xi, f) - P_t x_t(z, \xi, f), \end{aligned}$$

subject to the production technology (10), a constraint that supplies to home and foreign goods markets, $y_{H,t}(z, \xi, f)$ and $y_{H,t}^*(z, \xi, f)$, are feasible

$$(12) \quad y_t(z, \xi, f) = y_{H,t}(z, \xi, f) + \xi y_{H,t}^*(z, \xi, f),$$

and the constraints that supplies to home and foreign goods markets are equal to the demands from final good producers from (7) and its foreign analogue,

$$(13) \quad y_{H,t}(z, \xi, f) = y_{H,t}^d(z, \xi, f),$$

$$(14) \quad y_{H,t}^*(z, \xi, f) = y_{H,t}^{d*}(z, \xi, f).$$

Given its downward-sloping demand curve, the monopolistic producer charges a constant markup over marginal cost in each market,

$$(15) \quad P_{H,t}(z, \xi, f) = \frac{\theta}{\theta - 1} MC_t e^{-z},$$

$$(16) \quad P_{H,t}^*(z, \xi, f) = \frac{\theta}{\theta - 1} \xi MC_t e^{-z},$$

where

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

Note that when $\xi = \infty$, the producer is a non-exporter.

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

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

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

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

where $n_s(z)$ is the probability that the producer survives until the next period. Note that this probability varies with the producer's productivity. The value of the producer is

$$(20) \quad V_t(z, \xi, f) = \Pi_t(z, \xi, f) + \max \{V_t^1(z, \xi, f), V_t^0(z, \xi, f)\}.$$

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

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

It is straightforward to show that the threshold for exporting is largest for non-exporters 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 f_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

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

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

the two types of exporters and the non-exporters,

$$(23) \quad N_{L,t} = \int_z \varphi_{H,t}(z, \xi_L, f_L) dz,$$

$$(24) \quad N_{H,t} = \int_z \varphi_{H,t}(z, \xi_H, f_L) dz,$$

$$(25) \quad N_{\infty,t} = \int_z \varphi_{H,t}(z, \infty, f_H) dz.$$

The mass of exporters equals $N_{1,t} = N_{L,t} + N_{H,t}$; the mass of non-exporters equals $N_{0,t} = N_{\infty,t}$; and the mass of establishments equals $N_t = N_{1,t} + N_{0,t}$. 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 .

Given the critical level of productivity for exporters and non-exporters, $z_{m,t}$, the starter ratio (the fraction of establishments among non-exporters that start exporting) and the stopper ratio (the fraction of exporters among surviving establishments who stop exporting) are, respectively,

$$(26) \quad n_{0,t+1} = \frac{\int_{z_{\infty,t}}^{\infty} n_s(z) \varphi_{H,t}(z, \infty, f_H) dz}{\int_z n_s(z) \varphi_{H,t}(z, \infty, f_H) dz},$$

$$(27) \quad n_{1,t+1} = \frac{\sum_{m \in \{L,H\}} \int_{-\infty}^{z_{m,t}} n_s(z) \varphi_{H,t}(z, \xi_m, f_L) dz}{\sum_{m \in \{L,H\}} \int_z n_s(z) \varphi_{H,t}(z, \xi_m, f_L) dz}.$$

The mass of establishments evolves according to

$$(28) \quad \varphi_{t+1}(z', \infty, f_H) = \sum_{m \in \{L,H,\infty\}} \int_{-\infty}^{z_{m,t}} n_s(z) \varphi_{H,t}(z, \xi_m, f) \phi(z'|z) dz + N_{E,t} \phi_E(z'),$$

$$(29) \quad \varphi_{t+1}(z', \xi_H, f_L) = \sum_{m \in \{L,H,\infty\}} \rho_{\xi}(\xi_H|\xi_m) \int_{z_{m,t}}^{\infty} n_s(z) \varphi_{H,t}(z, \xi_m, f) \phi(z'|z) dz,$$

$$(30) \quad \varphi_{t+1}(z', \xi_L, f_L) = \sum_{m \in \{L,H,\infty\}} \rho_{\xi}(\xi_L|\xi_m) \int_{z_{m,t}}^{\infty} n_s(z) \varphi_{H,t}(z, \xi_m, f) \phi(z'|z) dz.$$

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

$$(31) \quad T_t = \tau \sum_{\xi \in \{\xi_L, \xi_H\}} \int_z P_{F,t}(z, \xi, f_L) y_{F,t}(z, \xi, f_L) \varphi_{F,t}(z, \xi, f_L) dz.$$

Nominal exports and imports are, respectively,

$$(32) \quad EX_t^N = \sum_{\xi \in \{\xi_L, \xi_H\}} \int_z P_{H,t}^*(z, \xi, f_L) y_{H,t}^*(z, \xi, f_L) \varphi_{H,t}(z, \xi, f_L) dz,$$

$$(33) \quad IM_t^N = \sum_{\xi \in \{\xi_L, \xi_H\}} \int_z P_{F,t}(z, \xi, f_L) y_{F,t}(z, \xi, f_L) \varphi_{F,t}(z, \xi, f_L) dz.$$

Home nominal GDP is the sum of value added from intermediate and final goods producers, $Y_t^N = C_t + I_t + EX_t^N - IM_t^N$. The trade-to-GDP ratio is $TR_t = \frac{EX_t^N + IM_t^N}{2Y_t^N}$, and IMD_t is the expenditure on imported goods relative to home goods,

$$(34) \quad IMD_t = \frac{(1 + \tau_t) \sum_{\xi \in \{\xi_L, \xi_H\}} \int_z P_{F,t}(z, \xi, f_L) y_{F,t}(z, \xi, f_L) \varphi_{F,t}(z, \xi, f_L) dz}{\sum_{\xi \in \{\xi_L, \xi_H, \infty\}} \int_z P_{H,t}(z, \xi, f) y_{H,t}(z, \xi, f) \varphi_{H,t}(z, \xi, f) dz},$$

so the share of expenditures on domestic goods is

$$(35) \quad \lambda_t = \frac{1}{1 + IMD_t},$$

and the trade elasticity is

$$(36) \quad \varepsilon_t = -\frac{\ln(IMD_t/IMD_{-1})}{\ln((1 + \tau_t)/(1 + \tau_{-1}))}.$$

Labor used in production, rather than to pay fixed costs, $L_{P,t}$, is

$$(37) \quad L_{P,t} = \sum_{\xi \in \{\xi_L, \xi_H, \infty\}} \int_z l_t(z, \xi, f) \varphi_{H,t}(z, \xi, f) dz.$$

The domestic labor hired by exporters to cover the fixed costs of exporting, $L_{X,t}$, equals

$$(38) \quad L_{X,t} = \sum_{m \in \{L, H\}} f_L \int_{z_{m,t}}^{\infty} \varphi_{H,t}(z, \xi_m, f_L) dz + f_H \int_{z_{\infty,t}}^{\infty} \varphi_{H,t}(z, \infty, f_H) dz.$$

From (38), we see that the trade cost, measured in units of domestic labor, depends on the exporter status from the previous period. Aggregate profits are the difference between profits and fixed costs,

$$(39) \quad \Pi_t = \sum_{\xi \in \{\xi_L, \xi_H, \infty\}} \int_z \Pi_t(z, \xi, f) \varphi_{H,t}(z, \xi, f) dz - W_t L_{X,t} - W_t f_{EN_{E,t}}.$$

Even though there is free entry in the model, aggregate profits are generally positive. These profits compensate consumers for waiting for their investment in producers to mature.

3.6 Equilibrium Definition

In an equilibrium, variables satisfy several resource constraints. The final goods market-clearing conditions are $D_t = C_t + I_t + X_t$, and $D_t^* = C_t^* + I_t^* + X_t^*$, where X_t is total material inputs in production, given by

$$(40) \quad X_t = \sum_{\xi \in \{\xi_L, \xi_H, \infty\}} \int_z x_t(z, \xi, f) \varphi_{H,t}(z, \xi, f) dz.$$

Each individual goods market clears; the labor market-clearing conditions are $L = L_{P,t} + L_{X,t} + f_E N_{E,t}$ and the foreign analogue; the capital market-clearing conditions are

$$(41) \quad K_{t-1} = \sum_{\xi \in \{\xi_L, \xi_H, \infty\}} \int_z k_t(z, \xi, f) \varphi_{H,t}(z, \xi, f) dz,$$

and the foreign analogue. The government budget constraint is given by (31) and the foreign analogue. The profits of each country's establishments, Π_t , are distributed to its consumers. The international bond market-clearing condition is given by $B_t + B_t^* = 0$.

An equilibrium of the economy is a collection of allocations for home consumers C_t , B_t , and K_t ; allocations for foreign consumers C_t^* , B_t^* , and K_t^* ; allocations for home final goods producers; allocations for foreign final goods producers; allocations, prices, and export decisions for home intermediate producers; allocations, prices, and export decisions for foreign intermediate producers; labor used for exporting costs and for entry costs by home and foreign producers; transfers T_t , T_t^* by home and foreign governments; real wages W_t , W_t^* , real rental rates of capital R_t , R_t^* , and bond prices Q_t that satisfy the following conditions: (i) the consumer allocations solve the consumer's problem; (ii) the final good producers' allocations solve their profit-maximization problems; (iii) intermediated good producers' allocations, prices, and export decisions solve their profit-maximization problems; (iv) the entry conditions holds; (v) the market-clearing conditions hold; and (vi) the transfers satisfy the government budget constraint.

4 Calibration

We calibrate the model to match features of the U.S. economy. We first describe the functional forms and parameter values of our benchmark economy. The parameter values are summarized in Table 1.

The instantaneous utility function is $U(C) = \frac{C^{1-\sigma}}{1-\sigma}$, where $1/\sigma$ is the intertemporal elasticity of substitution. The discount factor, β , depreciation rate, δ , and risk aversion, σ , are standard: $\beta = 0.96$, $\delta = 0.10$, and $\sigma = 2$.

The 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 $z = \frac{1}{\theta-1} \ln a$. An incumbent's productivity has an autoregressive component ($\rho < 1$) of $\ln a' = \rho \ln a + \varepsilon$, $\varepsilon \stackrel{iid}{\sim} N(0, \sigma_\varepsilon^2)$. With an AR(1) shock process, the conditional distribution is normal, $\phi(\ln a' | \ln a) = N(\rho \ln a, \sigma_\varepsilon^2)$, and the unconditional distribution is $N\left(0, \frac{\sigma_\varepsilon^2}{1-\rho^2}\right)$. Entrants draw productivity based on the unconditional distribution $\ln a' = \mu_E + \varepsilon_E$, $\varepsilon_E \stackrel{iid}{\sim} N\left(0, \frac{\sigma_\varepsilon^2}{1-\rho^2}\right)$, where $\mu_E < 0$ is 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, a ; the probability of death is $n_d(a) = 1 - n_s(a) = \max\{0, \min\{e^{-\lambda a} + n_{d0}, 1\}\}$.

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. We set the tariff rate to ten percent to include the direct measure of tariff and non-tariff barriers.

Recall that four parameters determine the dynamics of export intensity: the two iceberg costs $\{\xi_H, \xi_L\}$ and the transition probabilities, which we denote $\{\rho_{LL}, \rho_{HH}\}$. For simplicity, we assume that $\rho_{LL} = \rho_{HH} = \rho_\xi$, so that three parameters determine the trade intensity dynamics.

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 value added to gross output in manufacturing. In the United States, this ratio averaged 2.8 from 1987 to 1992 and implies that $\alpha_x = 0.81$. The entry cost, f_E , is set to normalize the total mass of establishments, N , to one. The mean establishment size is normalized to the mean

establishment size in the United States in 1992.

The ten parameters, $\{\lambda, n_d, \rho_z, \sigma_z^2, \mu_E, f_L, f_H, \xi_L, \xi_H, \rho_\xi\}$, are chosen to match the following 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 (Ruhl and Willis 2008).
3. A five-year export intensity twice the initial export intensity (Ruhl and Willis 2008).
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, Roberts, and Samuelson 1989).
7. Entrants' labor share of 1.5 percent (Davis, Haltiwanger, and Schuh 1998).
8. Shut-down establishments' labor share of 2.3 percent (Davis, Haltiwanger, and Schuh 1998).
9. Establishment employment size distribution as in the 1992 CM.

The first three targets summarize the dynamics of export intensity and determine the technology for shipping (ξ_L, ξ_H, ρ_ξ). The next two targets relate exporters to the population of establishments and largely determine the fixed costs (f_L, f_H). The next three targets help pin down the establishment creation, destruction, and growth process ($\rho_z, \sigma_\varepsilon, \lambda, \mu_E, n_d$): Newborn establishments and dying establishments tend to have few employees, and newborn establishments have high failure rates. Finally, we minimize the distance between the model's producer size distribution and the size distribution of U.S. establishments.

4.1 The Benchmark Model

The calibration provides an estimate of the establishment creation and exporting technologies. The cost of starting to export is relatively small, only 3.7 percent of the cost of creating an establishment, but it is about 40-percent larger than the cost of continuing to export (0.246 versus 0.176). The high iceberg cost, ξ_H , is estimated to be 63-percent larger than the low cost, ξ_L (1.718 versus 1.084), and the idiosyncratic iceberg cost is persistent,

$\rho_\xi = 0.916$. In the aggregate, fixed export costs account for 58.1 percent of gross export profits.

Figure 2A shows, based on the ergodic distribution, how the average export intensity, measured as the ratio of export revenue to total revenue, 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 acquired the low iceberg cost. Figure 2B shows that the probability of continuing in the export market rises over time after the second year in the market, consistent with the Colombian data in Figure 1B. This primarily reflects the fact that older exporters are more likely to have become efficient exporters and are less willing to give this up by exiting. This model outcome was not targeted and provides independent validation of the model. These two figures are consistent with the evidence from Ruhl and Willis (2008).

The low export intensity and continuation probabilities suggest that export profits are quite low initially and rise over time. Figure 2C shows how the net profits of a marginal starter (i.e., a producer with productivity z_∞ in period zero) evolve over time when it is subject to shocks that lead it to continue exporting ($\prod_{j=1}^t \pi_j > 0$). In this figure, we plot

$$(42) \quad \mu_t = 100 * \frac{E(\pi_t - f_t | \pi_j > 0, j = 1, \dots, t)}{f_H}.$$

In the year prior to exporting, $\mu_0 = -100$ since the producer pays f_H and earns $\pi_0 = 0$. This measure of net profits to entry costs is rising with time in the market, primarily because older exporters tend to be more-efficient exporters. Given this profile of gross profits, a new marginal exporter expects to have negative net profits over its first three years in the market, in addition to the loss incurred in the year prior to entry. Over this period, the new exporter is willing to lose money in order to have the chance to become an efficient exporter in the future. This investment is risky, as many new exporters exit right away.

4.2 The Sunk-Cost Model

Eliminating the variance in iceberg costs, $\xi_L = \xi_H = \xi$, yields the traditional sunk-cost model of Das, Roberts, and Tybout (2007), studied in general equilibrium in Alessandria and Choi

(2014b). We report the parameter estimates from this version of the model in the column “sunk-cost” in Table 1. We estimate the single iceberg cost, ξ , to be 1.43.

Compared to the baseline model, in which the export entry cost is 1.4 times the continuation cost, 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 up-front cost of re-entering—sunk costs generate persistent exporting. In the benchmark model, this effect is much smaller since the gap between the startup and continuation costs is small. Rather, 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 take the marginal new exporter from the benchmark model (Figure 2C) and subject it to the trade cost structure estimated in the sunk-cost model. The new exporter faces the same productivity shocks and uses the same exit rule as in the benchmark model.¹⁵ In this way, we can see how the path of expected profits varies with exporting tenure for a particular path of productivity and participation decisions. To make profits comparable across models, net profits are measured relative to the export entry cost from the benchmark model. Figure 2C shows that, with the sunk-cost export technology, the up-front investment to enter is about twice as large, and the producer starts earning a net profit from the first period in the market. This partly reflects a much higher initial export intensity and a smaller continuation cost (about half that of our benchmark model). Over time, the profit rate does not change much. Comparing the models, the sunk-cost model front-loads the costs and benefits from exporting relative to the benchmark model. The rising net profits in the benchmark model make it clear that the continuation cost in that model is primarily an investment in lowering the future marginal cost of exporting. Figure 2D reports the cumulative profits in both models. It takes almost seven years for the cumulative net profits in the benchmark model to exceed the net profits in the sunk-cost specification.

In the benchmark model with new exporter dynamics, we find the producer-level cost of entering the export market to be relatively low, but the aggregate cost of maintaining

¹⁵Obviously, this producer would make different exit decisions in this sunk-cost environment.

international trade to be relatively high. In the stationary steady state, payments of fixed export costs are 58.1 percent of total 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 the same as in the benchmark model, the export entry cost needs to be 11.1 times the continuation cost.¹⁶ We refer to this model as the *sunk-cost-high* model, and summarize its parameters in Table 1. In the sunk-cost-high model, exporting becomes 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. We discuss the sunk-cost-high model in more detail in Section 6.1.

5 Global Trade Liberalization

In this section, we consider the impact of a global change in tariffs on welfare and the dynamics of trade. In particular, we assume an unanticipated worldwide elimination of the ten-percent tariff. We focus on an unanticipated change in tariffs to clarify the aggregate effect of tariffs in the baseline model and a range of simpler models. It is straightforward to consider the more empirically relevant case of anticipated changes in trade policy, such as a gradual liberalization.

Table 2 reports the changes in welfare and trade, and Figure 3 plots the dynamics of some key variables. 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 to trade liberalization does not hold in the model with endogenous export participation and exporter growth.

With lower tariffs, trade expands substantially, rising from 9.7 percent of manufacturing shipments to 29.2 percent. Figure 3A shows that this expansion takes time, as the trade elasticity grows slowly. In the first year, only the intensive margin operates, so the trade

¹⁶The sunk-cost-high model is calibrated to match observations 5 to 9 on page 17. 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 ratio of fixed export costs to export profits (58.1 percent) as in the benchmark model.

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 elasticity¹⁷ has increased only by 69 percent of its long-run change: Trade is quite sluggish.

A simple way to compare trade dynamics across models is to measure the discounted average trade elasticity,

$$(43) \quad \bar{\varepsilon}_t = (1 - \beta) \sum_{t=0}^{\infty} \beta^t \varepsilon_t.$$

This measure weights the early periods of trade adjustment more than later periods and provides a relevant measure of the speed of trade adjustment. In our model, the short-run elasticity is four; the discounted trade elasticity is 10.15; and the long-run elasticity is 11.55.

Slow trade elasticity growth, however, does not lead to slow growth in consumption or output (see Figure 3B); consumption and output jump initially. Consumption has a hump shape, peaking seven years after the policy change and 9.75 percentage points above its long-run change of 0.42 percent. Figure 3C shows how different forms of investment change during the transition to the new steady state. 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 of establishment creation that is lower than that in the initial steady state. The stock of establishments falls gradually to its new steady-state level.

The desire to reduce the number of establishments 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 (see Figure 3C) 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. This is a similar mechanism to that discussed by Alessandria and Choi (2014b) in a model with only a sunk cost. Chaney (2005) and Burstein and Melitz (2013) also argue for overshooting in consumption, but, in their framework with

¹⁷This is the part due to entry, expansion, and exit rather than to the static intensive margin.

no dynamic exporting decision or capital accumulation, the overshooting arises because of a sharp drop in entry.

The effect of the decline in establishment creation on the aggregate dynamics of the economy can be seen most clearly in a counterfactual experiment in which the mass of entrants does not change. For this experiment, we impose a subsidy on establishment creation of τ_t^E , which is financed by a lump-sum tax. We choose the subsidy so that $N_t = 1$ in every period. Figure 4 plots the dynamics of the trade elasticity and consumption in this counterfactual and in the benchmark model. With no change in establishment creation, 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 the level in the benchmark model (7.41 versus 0.42). It takes 20 years for this alternative model to reach the same level of consumption as in the benchmark model.

6 Sensitivity

To evaluate the role of producer-level export dynamics in the aggregate effect of tariffs, we consider two variations of the benchmark economy. In the first variation, we eliminate the sluggishness in producer-level export growth. This version of the sunk-cost model of Das, Roberts, and Tybout (2007) clarifies the role of export intensity growth on the aggregate economy. In the second variation, we examine a model without a producer-level export decision, but the model is calibrated to generate the same aggregate export growth in the transition and in the new steady state as in our benchmark model. This allows us to explore whether the idea from Arkolakis, Costinot, and Rodríguez-Clare (2012)—that the welfare gain from trade will be identical across models that generate the same trade elasticity—extends to a dynamic environment. Finally, we present a decomposition of the gain from trade in a simplified version of our model that clarifies which margins generate the departures from Arkolakis, Costinot, and Rodríguez-Clare (2012).

6.1 No Exporter Growth (Sunk-Cost Model)

The slow export growth of producers is important for the response of welfare and trade volumes to a change in trade barriers. To show this, we set $\xi_L = \xi_H = \xi$ so that there is no difference in export intensity between new and old exporters. This is a variation of the model studied by Alessandria and Choi (2014b). It shares the qualitative features of our benchmark model, and we recalibrate this model to match the same kinds of features of the U.S. economy that we used in calibrating the benchmark model. Table 1 summarizes the parameters, while Table 2 summarizes the effect of abstracting from export intensity dynamics on aggregate outcomes. Figures 5–7 plot the transition to the new steady state.

Compared to the benchmark model, the sunk-cost model generates a smaller long-run expansion of trade. The trade elasticity is about 63 percent of the benchmark model (7.2 versus 11.5). The transition, though, is relatively faster, as the discounted trade elasticity is about 68 percent of the benchmark model’s (6.9 versus 10.15). 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 sunk-cost model also generates a larger change in steady-state consumption than the benchmark model (1.98 versus 0.42) but a smaller welfare gain (4.75 versus 6.30).

The benchmark model generates a larger welfare gain than the sunk-cost model because, even as trade grows more slowly, overshooting is stronger. In terms of consumption, both models generate similar dynamics in the first two to three 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 dynamics of consumption 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 stronger long-run effect on consumption in the sunk-cost model arises because there is less substitution between trade and establishment creation than in our benchmark model. Indeed, in the long run, the stock of domestic producers falls by only 4.8 percent in the sunk-cost model compared to 13.1 percent in the benchmark model.

Relative to the benchmark model, the sunk-cost model generates a smaller gain from trade reform because new exporters contribute too much to aggregate trade. While both models are calibrated to have the same number of export entrants each period, new exporters in the benchmark model face much higher iceberg trade costs. Consequently, a new exporter in the sunk-cost model will export twice as much as the otherwise-identical new exporter in the benchmark model.

We can make the aggregate variables in the sunk-cost model behave more like those in the benchmark model by increasing the export entry cost. While this may seem counterintuitive—entry costs in the sunk-cost model are already larger than in the benchmark model—the slow expansion of new exporters in the benchmark model implies that the export continuation costs (f_L) are a form of entry cost as well. We report this parameterization in the column labeled “sunk-cost high” in Table 1. We calibrate the sunk-cost-high model to match the same moments as in the sunk-cost model, except we can no longer target the export exit rate. In its place, we set the share of aggregate export profits paid to export fixed costs to be 0.58, as it is in the benchmark model. This implies that the sunk-cost-high model and the benchmark model both dedicate the same share of aggregate resources to trade and generate the same aggregate trade share.

In the sunk-cost-high model, the much larger entry cost ($f_H/f_L = 11.1$) increases the selection on productivity into exporting, and decreases the export exit rate from 17 percent to 3.95 percent. Since we have calibrated both models to match the export participation rate in the data, the lower exit rate means that the entry rate falls. Cohorts of new exporters in the sunk-cost-high model are smaller than in the original sunk-cost model.

Reducing the importance of the new cohort of exporters leads the sunk-cost-high model to behave more like the benchmark model. Trade grows more and more gradually, the number of establishments shrinks more, and there is more overshooting than in the model with the small sunk cost. 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.

It is evident from Table 2 that the sunk-cost-high model is a better approximation of the benchmark model than the calibrated sunk-cost model. Even so, the welfare gain in the sunk-cost-high model is still below (5.67 percent versus 6.3 percent), and the long-run change in consumption is still above (1.65 percent versus 0.42 percent), that in our benchmark model.

6.2 No Export Decision (No-Cost Model)

To further explore how the producer-level details of exporting matter for welfare, we now consider a version of the model in which all establishments export from birth (i.e., there are no fixed export costs, $f_H = f_L = 0$) and face the same iceberg cost (i.e., $\xi_L = \xi_H$). This is a variation of the Krugman (1980) model. Without some modification, the trade elasticity is constant in this model. To generate the gradual increase in the trade elasticity that we observe in the benchmark model, it is necessary to introduce an adjustment friction to either the final goods aggregator or the trade cost. We introduce an adjustment cost into the aggregation of intermediates by final goods producers.^{18,19} Specifically, we modify the aggregator in (5) to include a time-varying weight on imported goods, g_t , such that

$$(44) \quad D_t = \left[\int_z y_{H,t}^d(z)^{\frac{\theta-1}{\theta}} \varphi_t(z) dz + g_t \int_z y_{F,t}^d(z)^{\frac{\theta-1}{\theta}} \varphi_t^*(z) dz \right]^{\frac{\theta}{\theta-1}},$$

$$(45) \quad g_t = g_{t-1}^{\rho_g} \left[\left(\frac{\lambda_t}{\lambda_{t-1}} \right)^v \right]^{1-\rho_g}, \quad g_{-1} = 1,$$

where λ_t is the home intermediate goods' expenditure share. With $v > 0$, the term g_t implies that an increase in the import share will lower the weight on imports in the aggregator.²⁰ This demand shifter is assumed to depend on aggregate imports and is external to the final goods producer. It can be interpreted as a cost of adjusting inputs. It affects only the

¹⁸One can think of this specification as representing the challenges that producers face in adjusting their inputs in the short run. This adjustment cost shares some similarities with that in Engel and Wang (2011).

¹⁹Alternatively, we could have generated slow trade growth by making the tariff fall gradually or allowing the iceberg cost to depend on the change in the import share (i.e., $\xi_t = \xi e^{-v \ln \lambda_t / \lambda_{t-1}}$). Both of these approaches yield similar findings in that they reduce consumption along the transition, but the trade elasticity would be constant in these cases.

²⁰The term g_t can be thought of as a wedge that accounts for the changes in trade that cannot be explained by relative prices. Recent work by Levchenko, Lewis, and Tesar (2010) and Alessandria, Kaboski, and Midrigan (2013) show that there are substantial cyclical fluctuations in this wedge.

transition and not the steady state.

The parameters of the final goods aggregator, v and ρ_g , are set to minimize the gap between the trade elasticity in the benchmark model and in this *no-cost* model,

$$(46) \quad \{v^*, \rho_g^*\} = \arg \min_{\{v, \rho_g\}} \left\{ \sum_{t=0}^{\infty} [\beta^t (\varepsilon_{\text{benchmark},t} - \varepsilon_{\text{nocost},t})]^2 \right\},$$

which yields $v^* = 1.89$ and $\rho_g^* = 0.25$. In Figure 5, we plot the trade elasticity in two versions of the no-cost models: one with the adjustment friction slowing down trade (the no-cost model) and one without the adjustment friction (the no-cost no-sluggish model).

For the no-cost model to match the long-run trade elasticity in the benchmark model, we increase the elasticity of substitution, θ , from 5 to 12.54. This lowers markups from 25 percent to about eight percent, which has the effect of changing the labor share of income, the ratio of gross-output to value added, and the ratio of trade to value added. To maintain the same macro targets for the ratio of trade to shipments, labor share, and materials usage, we must adjust α , α_x , and ξ . The capital share is doubled from 14 percent to 28 percent; the material usage is lowered from 80 percent to 70 percent; and the iceberg cost is lowered to 1.11. The parameters are reported in the column labeled “no-cost” in Table 1. The column labeled “no-cost” in Table 2 summarizes the aggregate effects of the cut in tariffs in this alternative model, and Figures 5 to 7 plot some aspects of the transition.

The key focus is on the change in welfare. The welfare gain is almost four percentage points larger in the benchmark model (6.3 versus 2.3), even though the steady-state change in consumption is about 3.5 percentage points lower in the benchmark model (0.42 versus 3.93). This large gap 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 7.8 percentage points five years after the policy change. The gradual consumption growth in the no-cost model occurs because the economy decumulates establishments only temporarily, with much smaller magnitudes, and capital and trade grow gradually due to the adjustment cost in the use of inputs in the production of final goods.²¹ This suggests that focusing on the relationship between the

²¹Eliminating the adjustment cost in inputs would speed up the transition and increase the welfare gain

trade elasticity and welfare is not sufficient to estimate the gain from trade liberalization. Instead, one must also consider how the scale of the economy is changing.

6.3 Inspecting the Mechanism

Why does the benchmark model generate a welfare gain that differs from the Krugman model, even though the trade elasticity in the two models is the same at every point in the transition? The short answer is that the scales of the two economies differ substantially, owing to the different incentives to invest in establishment creation. To see this, we derive a simple decomposition of the gain from trade that generalizes the formula in Arkolakis, Costinot, and Rodríguez-Clare (2012) in a variation of the model that abstracts from capital.

We begin with the labor market clearing condition, which implies

$$(47) \quad \frac{P_t C_t}{S_t} = \frac{\theta}{\theta - 1} W_t L_{p,t},$$

where $S_t = \frac{1+\tau_t \zeta_t^{-1}}{1+\zeta_t^{-1}}$ is the distortion from a tariff ($\zeta_t = \tau_t^\theta \xi_t^{\theta-1} \leq 1$). Notice that, if there were only iceberg trade costs, $S = 1$. The change in consumption from a change in tariff policy is

$$(48) \quad \hat{C}_t = \hat{W}_t - \hat{P}_t + \hat{S}_t + \hat{L}_{p,t},$$

where a “hat” variable is the change relative to the previous steady state. Normalizing the wage to one, the change in the price level is

$$(49) \quad \hat{P}_t = \frac{\hat{\lambda}_t - \hat{N}_t - \hat{\Psi}_{d,t}}{\theta - 1},$$

where $\hat{\Psi}_d = \int_{a_d}^{\infty} a \phi_t(a) da$ is the average ability of domestic producers (a is the elasticity-adjusted productivity of a producer). The price level is increasing in the domestic expenditure share (λ) and decreasing in the number of establishments (N) and average productivity of establishments (Ψ_d). These effects are stronger when the markup is larger. Combining

in the no-cost model to 3.5 percent. The path of aggregate dynamics, however, would remain quite different from that in our benchmark model.

(48) and (49) yields the change in consumption,

$$(50) \quad \hat{C}_t = \frac{\hat{N}_t + \hat{\Psi}_{d,t} - \hat{\lambda}_t}{\theta - 1} + \hat{S}_t + \hat{L}_{p,t}.$$

We begin by analyzing (50) for two of the standard trade models in the literature, deriving the main result in Arkolakis, Costinot, and Rodríguez-Clare (2012). Consider a static trade model, such as the Krugman (1980) model, without tariffs. A change in the iceberg cost, ξ , implies that $\hat{L}_p = \hat{S} = \hat{N} = \hat{\Psi}_d = 0$ so that

$$(51) \quad \hat{C}_t^K = -\frac{\hat{\lambda}_t}{\theta - 1} = -\frac{\hat{\lambda}_t}{\varepsilon^K},$$

where $(\theta - 1)^{-1}$ is the markup and the inverse of the trade elasticity, ε^K .

Next, consider the typical presentation of the Melitz (2003) model with a fixed operating cost and a Pareto distribution of productivity with slope η , but without tariffs. In this model, a change in the iceberg cost, ξ , also implies that $\hat{L}_p = \hat{S} = \hat{N} = 0$, but $\hat{\Psi}_d = \frac{\eta-1}{\eta}\hat{\lambda}$, so

$$(52) \quad \hat{C}_t^M = \frac{\left(\frac{\eta-1}{\eta}\right)\hat{\lambda}_t - \hat{\lambda}_t}{\theta - 1} = -\frac{\hat{\lambda}_t}{\eta(\theta - 1)} = -\frac{\hat{\lambda}_t}{\varepsilon^M},$$

where the trade elasticity is now $\varepsilon^M = \eta(\theta - 1)$. When the Krugman and Melitz models are disciplined to have the same trade elasticity ($\varepsilon^M = \varepsilon^K$), a change in trade costs will yield the same gain from trade, as shown in Arkolakis, Costinot, and Rodríguez-Clare (2012).

In our dynamic exporting model, however, \hat{L}_p , \hat{S} , and \hat{N} generally do change in the new steady state. Since accumulating varieties is costly, when $\hat{N} \neq 0$, the transition will matter for steady-state consumption. Along the transition, the number of establishments affects the productivity distribution of establishments through the producer-level growth process, so $\hat{\Psi}_d$ is complicated. With risk-neutral consumers we can express the welfare gain from a change in tariffs as

$$(53) \quad \hat{C} = \frac{\hat{N} + \hat{\Psi}_d - \hat{\lambda}}{\theta - 1} + \hat{L}_p + \hat{S},$$

where the bars denote the discounted average of a variable,

$$(54) \quad \widehat{X}_t = (1 - \beta) \sum_{t=0}^{\infty} \beta^t \hat{X}_t.$$

In Figure 8, we plot the dynamics of consumption and the contribution of each of the components in (53), following the elimination of a 10-percent tariff in this model without capital and material inputs. Table 3 reports the discounted and steady-state change in each variable. Consumption overshoots and declines slightly in the long run. The overshooting of consumption is a result of several competing forces. Labor used in production and average productivity both increase temporarily. The variety effect (\hat{N}) gradually reduces consumption, while the growth in trade ($-\lambda$) gradually boosts consumption. The lost tariff revenue (S) reduces welfare.

In total, the decline in steady-state consumption of 0.17 percent is attributed to a 4.09 percent increase from trade that is offset by the reduction in varieties (-2.89 percent), labor used in production (-0.56 percent), and tariff revenue (-0.81 percent). The average productivity of producers is unchanged across the steady states.

Compared to the change in steady-state consumption, the welfare gain of 0.66 percent arises because, even though trade contributes less (3.50 percent versus 4.09 percent), along the transition, it grows faster than the stock of establishments shrinks. In addition, the labor used in production declines less and there is an increase in average productivity.

In Figure 8B, we plot the dynamics of utility in the simple model and the predicted change in utility from applying the ACR formula to the data generated by the model.^{22,23} The ACR formula understates the gain over the first 11 years and then substantially overstates the gain, as utility in the model quickly declines below the previous steady-state level. Over the first 25 years, the ACR formula predicts an average utility gain of 0.83 percent, and the mean absolute deviation of the predicted utility from the model utility is 0.40 percent. Thus, the formula is, on average, off by 50 percent.

²²Note that the ACR formula is derived for a change in iceberg costs and not tariffs

²³To focus on utility, the change in consumption is scaled by the discount factor β^t .

7 Unilateral Trade Liberalization

We next consider the effect of an unanticipated unilateral cut in the home tariff. The model is well-suited to this experiment since it allows for international borrowing and lending, capital accumulation, and a different short-run and long-run trade elasticity. As in the global tariff reduction, the steady-state change in consumption does not yield a good approximation of the welfare gain. In particular, for the reforming country, the steady-state change in consumption predicts a sizeable loss even though welfare actually increases.

In Figure 9, we plot the dynamics of some key variables, and Table 4 reports the welfare gain and change in steady-state consumption. We solve the model under three alternative financial market assumptions: trade in a non-contingent bond, financial autarky, and complete markets. The latter two cases illustrate the role of financial markets and the effects of the wealth transfer from the loss of tariff revenue. 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 the pattern of international borrowing and lending.

When countries trade only a non-contingent bond, home country welfare rises by 0.51 percent and foreign country welfare rises by 5.7 percent. Home steady-state consumption falls by 2.43 percent and foreign steady-state consumption rises by 2.82 percent. As in the global reform, there is substantial overshooting of consumption, so the change in steady-state consumption does not provide a good approximation of the welfare gain. This overshooting arises, in large part, from a strong reduction in the investment in new establishments. In the new steady state, the number of home establishments falls by 6.5 percent and foreign establishments falls by 5.91 percent. The strong decline in establishments in both countries arises because, as the thresholds for exporting decline substantially in both countries, local producers face more competition from importers.

In Figure 9, we can see that, along the transition, the home country runs a trade surplus in the first 11 years following the liberalization. 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. The home country's 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.

In the model without trade in financial assets, home country welfare increases a bit more than in the bond economy (0.55 versus 0.51) and foreign country welfare increases a bit less (5.66 versus 5.70). 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 we model countries that trade a complete set of contingent claims, the wealth effect from the loss in tariff revenue is eliminated. In contrast to the bond economy and financial autarky, the home country is now the main beneficiary of the reform, as its welfare increases by 4.34 percent and foreign country welfare increases by 1.91 percent (Table 4). The trade balance is also significantly different with complete markets. The home country runs a trade deficit of 2.3 percent of GDP in year one, which gradually expands to 2.8 percent of GDP in the steady state.

Lastly, we consider unilateral tariff reform in the no-cost model with slow trade adjustment from Section 6.2. As with the global reform, we find welfare and consumption paths in the no-cost model are quite different from the benchmark model. Most striking is the implication for welfare: In the no-cost one-bond model, home country welfare decreases by 0.62 percent compared to the 0.51 percent increase in the benchmark one-bond model (Table 4). In the steady state, home consumption falls only 0.06 percent, compared to a decline of 2.43 percent in the benchmark model. The last panel of Figure 9 shows that borrowing and lending is qualitatively similar to the benchmark model, in that the home country initially runs trade surpluses, but the fluctuations in the trade balance are muted. The home country accumulates assets of 6.9 percent of GDP in the benchmark model compared to 2.6 percent in the no-cost model. Without slow trade adjustment, net foreign assets would remain equal to zero. Thus, the source of gradual trade adjustment matters in determining the pattern of international borrowing.

8 Conclusions

We solve for the transition dynamics following a reduction in tariffs (global and unilateral) in a model with round-about production, capital accumulation, and producer export entry, expansion, and survival dynamics. While the aggregate trade share grows slowly, the consumption benefits are more immediate. Including the transition leads to a much larger gain in welfare than the change in steady-state allocations. Models without this dynamic export decision substantially underestimate the gain from removing tariffs and even predict a loss where we find a gain. These results suggest caution about policy prescription in models that abstract from the behavior of these marginal exporters.

Our theory is consistent with the key producer-level facts about new exporter dynamics and nests standard static and dynamic theories of export participation. It allows a producer's expansion into the export market to require multiple investments in exporting over time and involve some risk. This is a more general version of the standard fixed-variable cost trade-off emphasized in the literature. We find that the estimated technology for exporting is risky and that time in the export market is important to becoming a successful exporter. New exporters are willing to incur substantial losses for a number of years to build up their foreign sales. This leads us to find smaller up-front costs but larger continuation costs compared to those found in other studies; it also suggests that, unlike in the aggregate, the benefits to individual producers from entering the export market accrue gradually.

Even though we find relatively low producer-level export entry costs, in the aggregate we find payments of fixed export costs as a share of export profits are much larger than in typically calibrated sunk-cost models. The relatively large fixed export costs in the aggregate, and the longer producer-level period of investment in exporting, imply dynamics are even more important in understanding aggregate trade and welfare than found previously (Alessandria and Choi 2014b). Indeed, we find that the aggregate properties of the baseline model are closer to a model with even larger sunk costs than typically found in the literature.

We focus on a particular friction related to the technology for exporting that gives rise to gradual export growth. Other sources of producer-level export growth, such as building distribution networks or brand recognition (Drozd and Nosal 2012), are likely to also matter,

but will generate similar micro and macro dynamics since they also increase the costs of entry and push the profits from exporting into the future, making exporters reluctant to exit the export market. The aggregate trade elasticity following a trade reform may also gradually increase because of the need to make investments in infrastructure for trade, such as customs, ports, pipelines, and railroads. Accumulating these forms of trade-specific physical capital, as opposed to the producer-specific exporter capital emphasized here, is likely to generate familiar neoclassical transition dynamics.²⁴

Our theoretical analysis also suggests numerous directions and challenges in empirical work. First, the model points to a key link between trade participation and establishment creation, with trade reducing establishment creation. In the United States, as trade has expanded, the rate of establishment creation in manufacturing has indeed declined substantially (see, e.g., Alessandria and Choi, 2014a). Second, expectations about the size and timing of trade reform at home and abroad and the state of the aggregate economy will influence the evolution of the economy. Third, the structure of financial asset trade shapes the dynamics of the economy when trade reform is not global. These issues are normally not considered in studies of the welfare gain from trade, but given the micro details generating trade, should be.

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²⁴There is potential for similar overshooting if the trade technology being accumulated is specific to a particular industry and a country expects its comparative advantage in that industry to be reduced in the future.

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Table 1: Model Parameters

Common parameters				
β	σ	δ	τ	
0.96	2.0	0.10	0.10	
Model-specific parameters				
	Benchmark	Sunk-Cost	Sunk-Cost	
			High	No-Cost
θ	5.00	5.00	5.0	12.54
α	0.132	0.132	0.132	0.276
α_m	0.810	0.810	0.810	0.704
λ	21.04	21.04	21.04	21.04
n_{d0}	0.0226	0.0226	0.0226	0.0226
ρ_z	0.654	0.654	0.654	0.654
σ_ε	1.32	1.32	1.32	1.32
μ_E	-1.34	-1.34	-1.34	-1.34
θf_E	32.7	33.2	32.7	34.7
f_H/f_E	0.0376	0.0579	0.183	0.000
f_H/f_L	1.40	3.81	11.1	-
ξ_H	1.718	1.430	1.342	1.112
ξ_L	1.07	1.430	1.342	1.112
ρ_ξ	0.916	1.000	1.000	1.000
Overall Fit (RMSE)				
Estab + Empl.	0.697	0.698	0.778	1.286
Export	14.61	15.69	3.83	49.6
Fixed Trade Costs				
Relative to				
Plant Creation Cost	10.8	8.7	10.8	0
Export Profits	58.1	47.6	58.1	0

Table 2: Effect of Eliminating a 10-percent Tariff

Change	Benchmark	Sunk-Cost	Sunk-Cost High	No-Cost-No Sluggish	No-Cost
Welfare gain	6.30	4.75	5.67	3.34	2.34
Consumption	0.42	1.98	1.65	3.93	3.93
Disc. trade elasticity	10.15	6.90	8.68	11.55	10.15
Trade elasticity	11.55	7.19	9.44	11.55	11.55

Note: Welfare gain 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. The long-run trade elasticity is $\lim_{t \rightarrow \infty} \varepsilon_t$.

Table 3: Decomposition of Gain from Eliminating a 10-percent Tariff

	\widehat{C}	$\widehat{\frac{N}{\theta-1}}$	$\widehat{\frac{\Psi_d}{\theta-1}}$	$\widehat{\frac{\lambda}{\theta-1}}$	\widehat{L}_p	\widehat{S}
Discounted average	0.66	-2.13	0.19	3.50	-0.09	-0.81
Steady-state	-0.17	-2.89	0	4.09	-0.56	-0.81

Note: The discounted change in a variable is the difference between $\bar{x} = (1 - \beta) \sum_{t=0}^{\infty} \beta^t x_t$ and the initial steady state.

Table 4: Effect of Eliminating a 10-percent Tariff

Change	Benchmark			No-Cost
	Bond	Fin. Autarky	Complete Markets	Bond
Welfare				
Home	0.51	0.55	4.34	-0.62
Foreign	5.70	5.66	1.91	4.92
SS Consumption				
Home	-2.43	-2.85	1.45	-0.06
Foreign	2.82	3.22	-1.00	5.49

Note: Welfare gain 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. The long-run trade elasticity is $\lim_{t \rightarrow \infty} \varepsilon_t$.

Figure 1A: Export Intensity Colombian Exporters

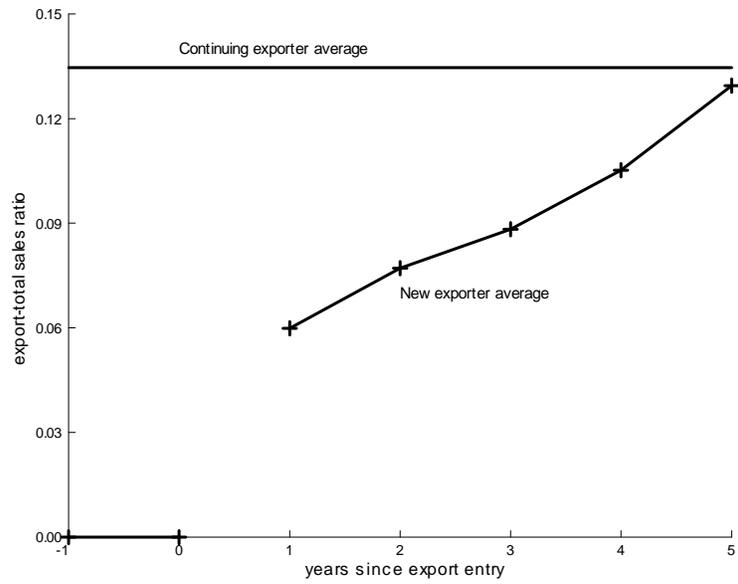


Figure 1B: Colombian Exporter Continuation Rate

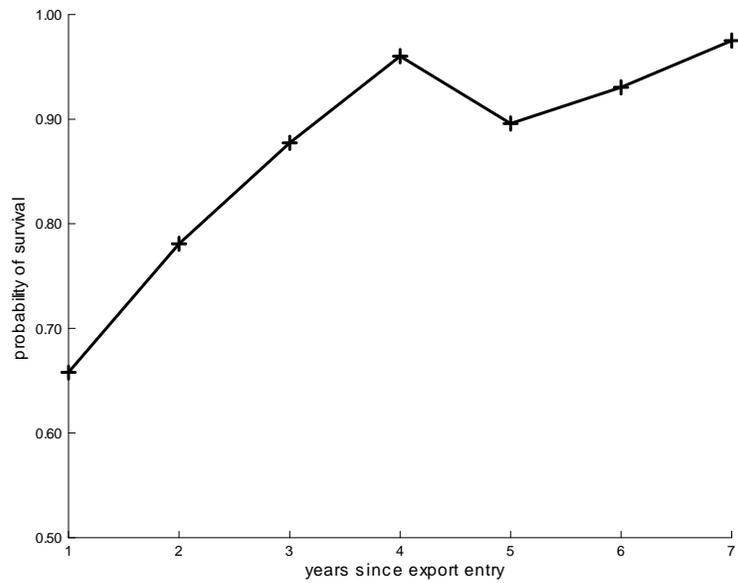
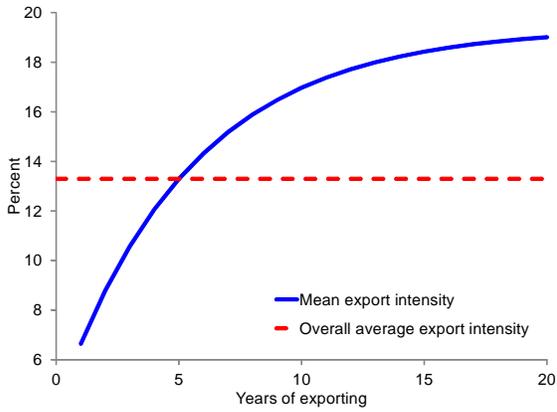
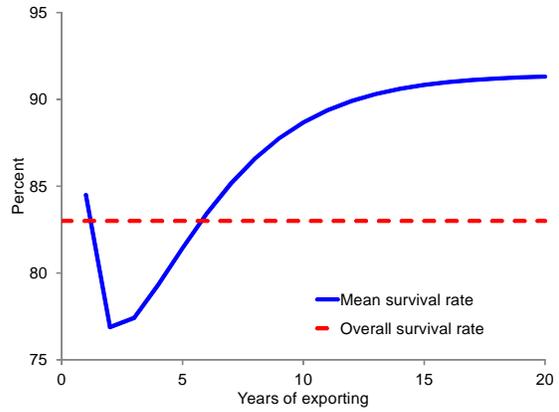


Figure 2: Exporter Dynamics in Stationary Steady State

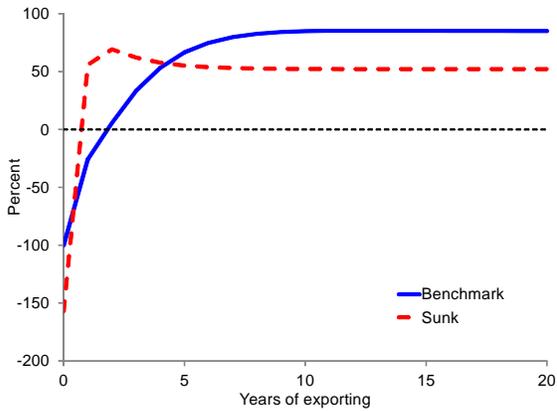
A. Exporter Intensity and Duration



B. Continuation rate (1 year) and Duration



C. Profits (net/entry costs) of Marginal Starters



D. Cumulative Profits of Marginal Starters

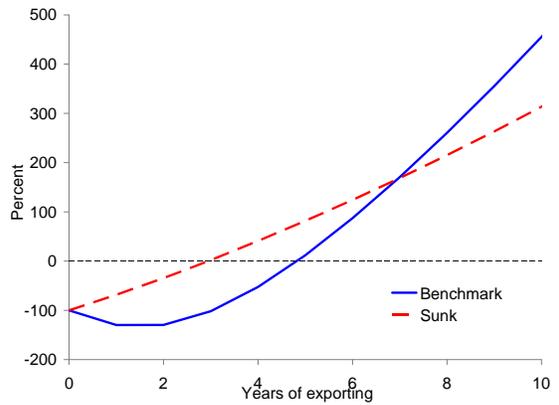


Figure 3: Benchmark Model Elimination of 10 percent Tariff

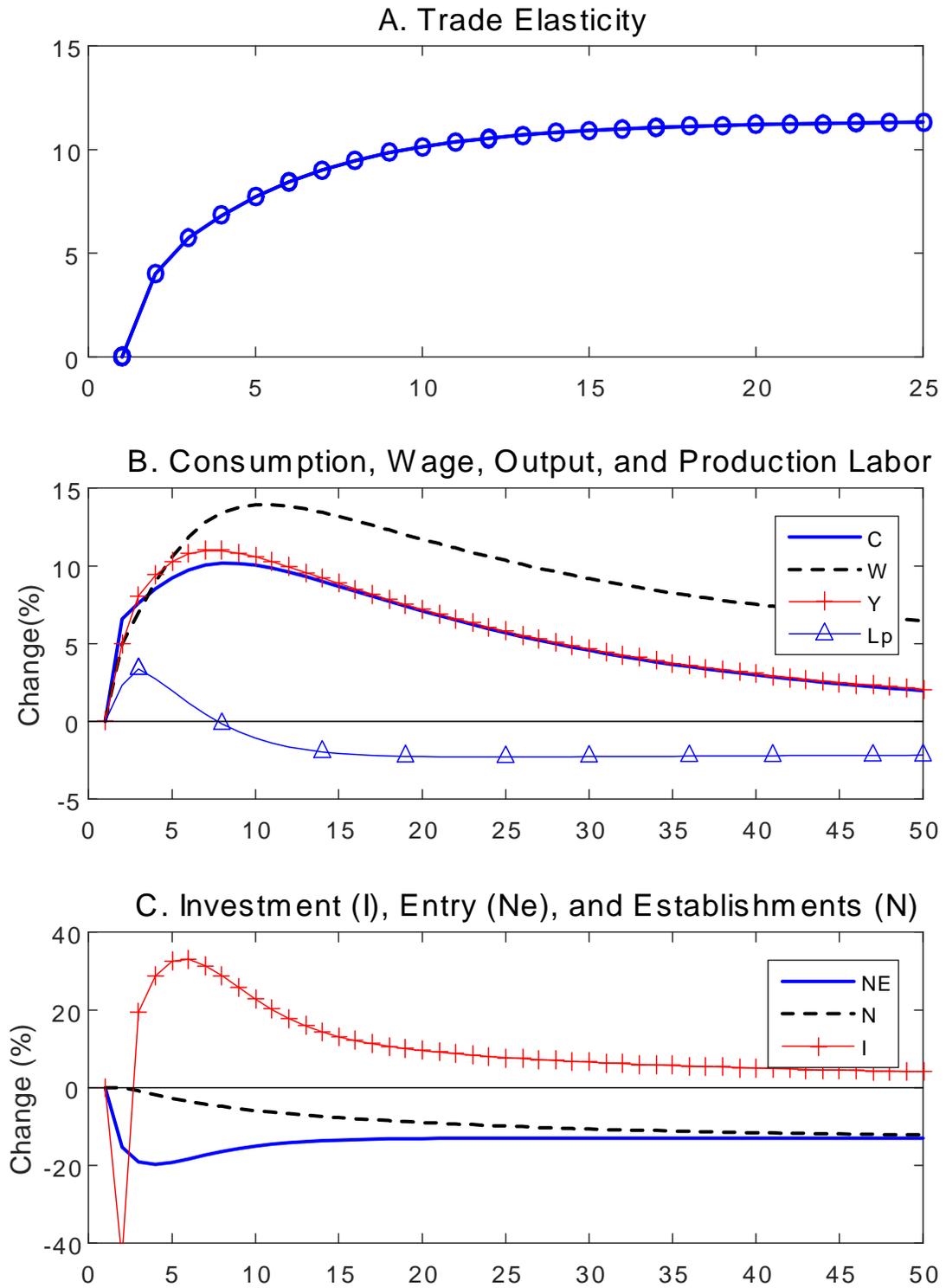


Figure 4: Role of Entry Adjustment on Trade and Consumption

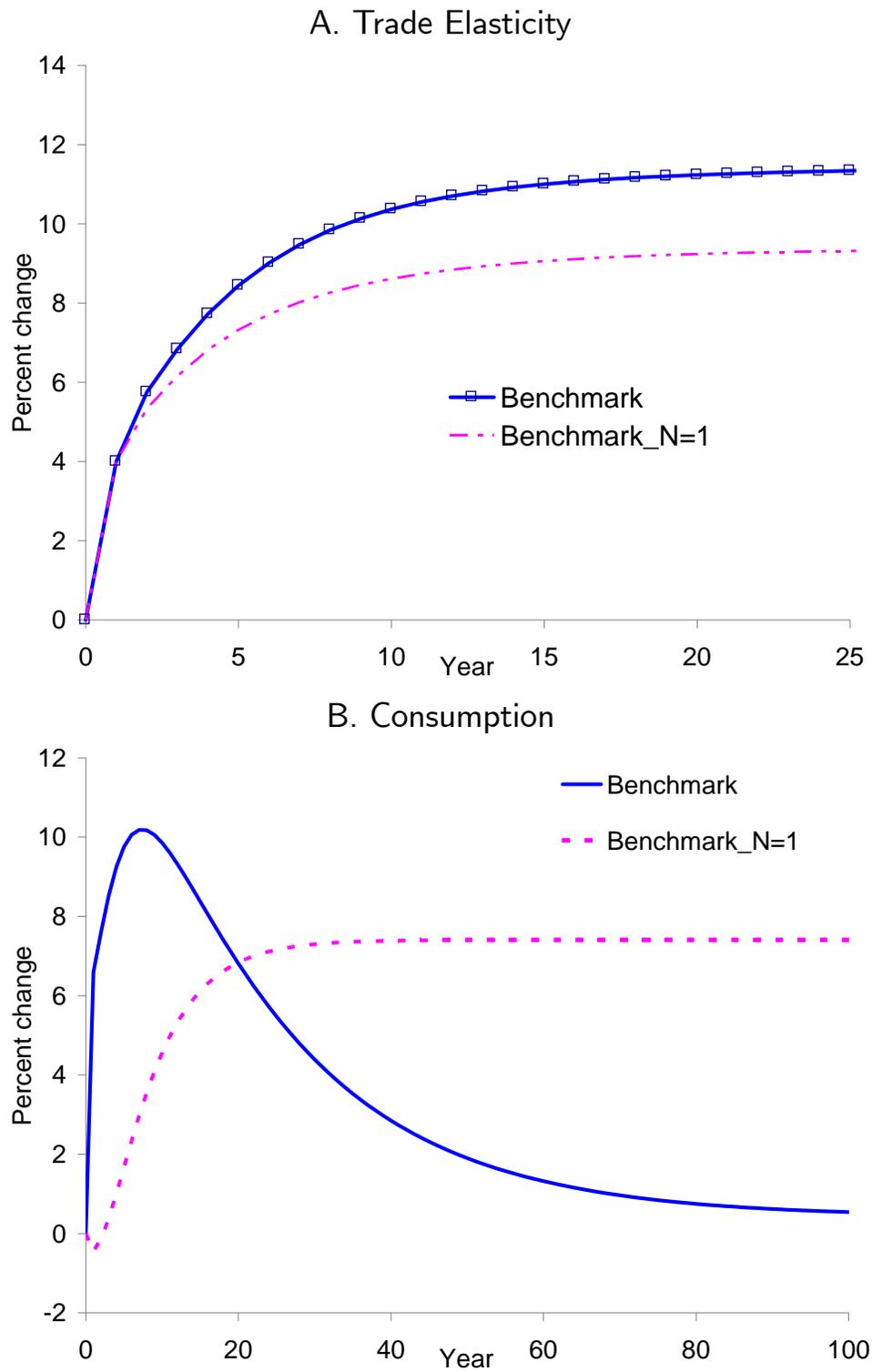


Figure 5: Comparison of Trade Dynamics

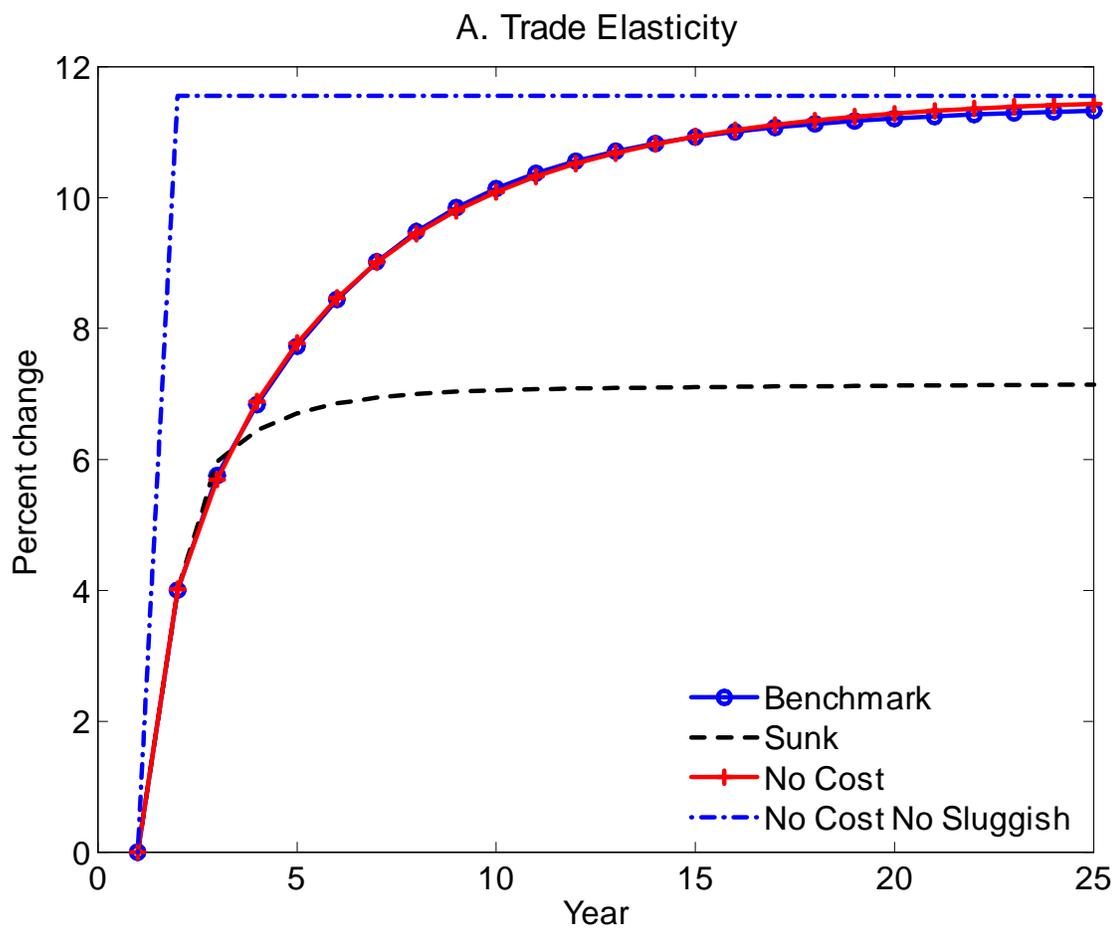


Figure 6: Comparison of Consumption, Wage, and Output Dynamics

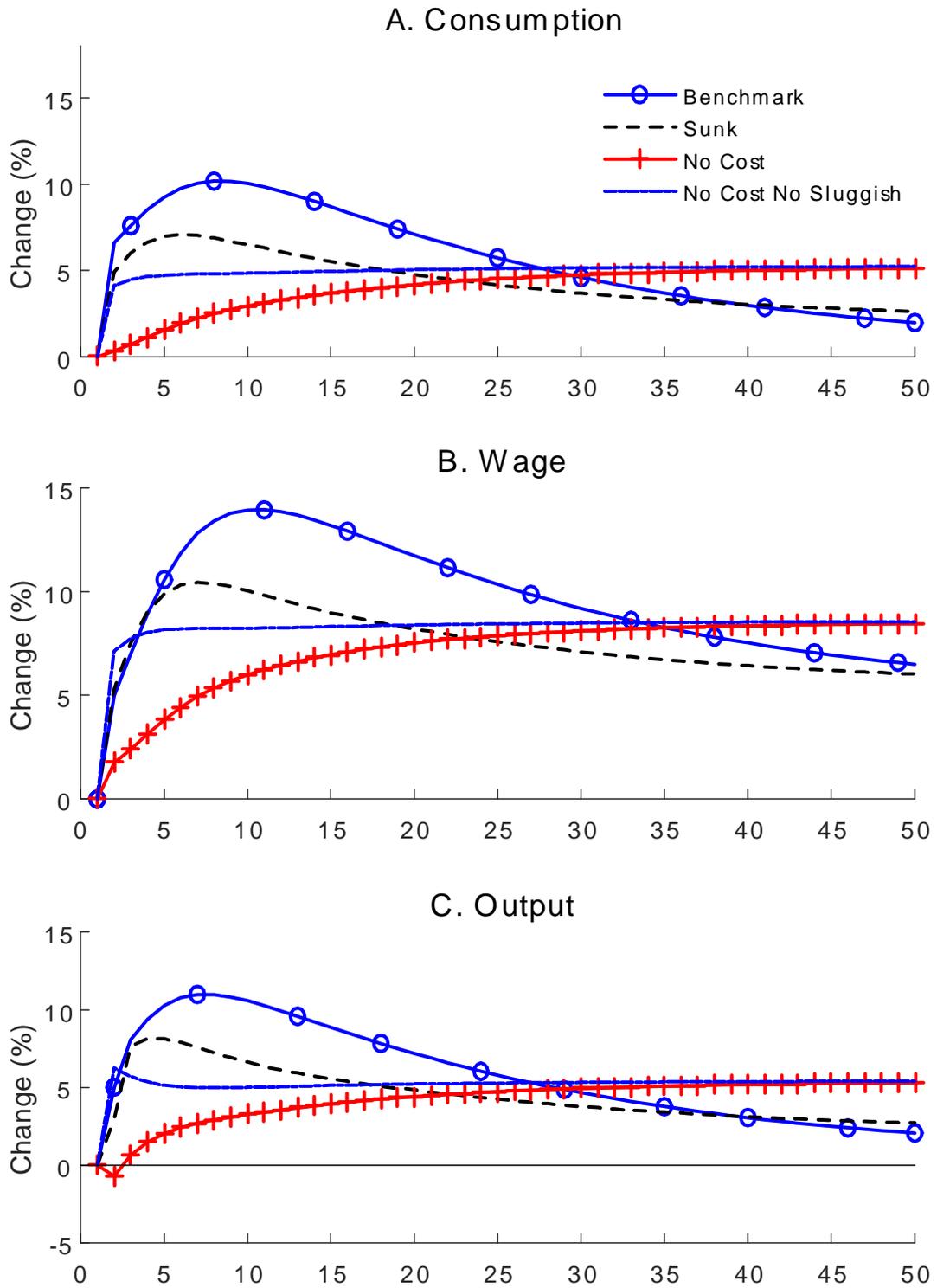


Figure 7: Comparison of Investment, Entry, Labor Dynamics

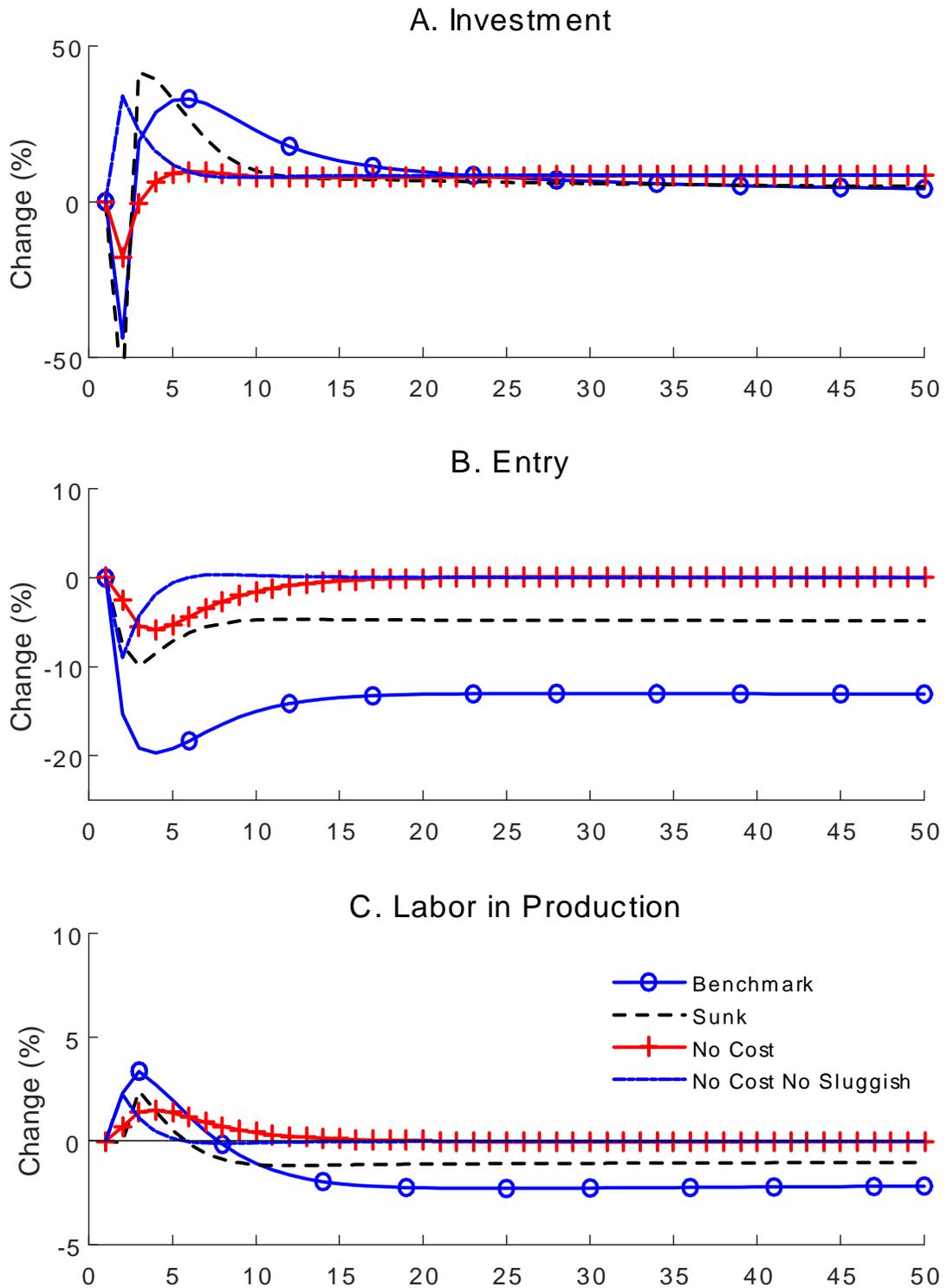


Figure 8: Decomposition of Consumption for Simple Model

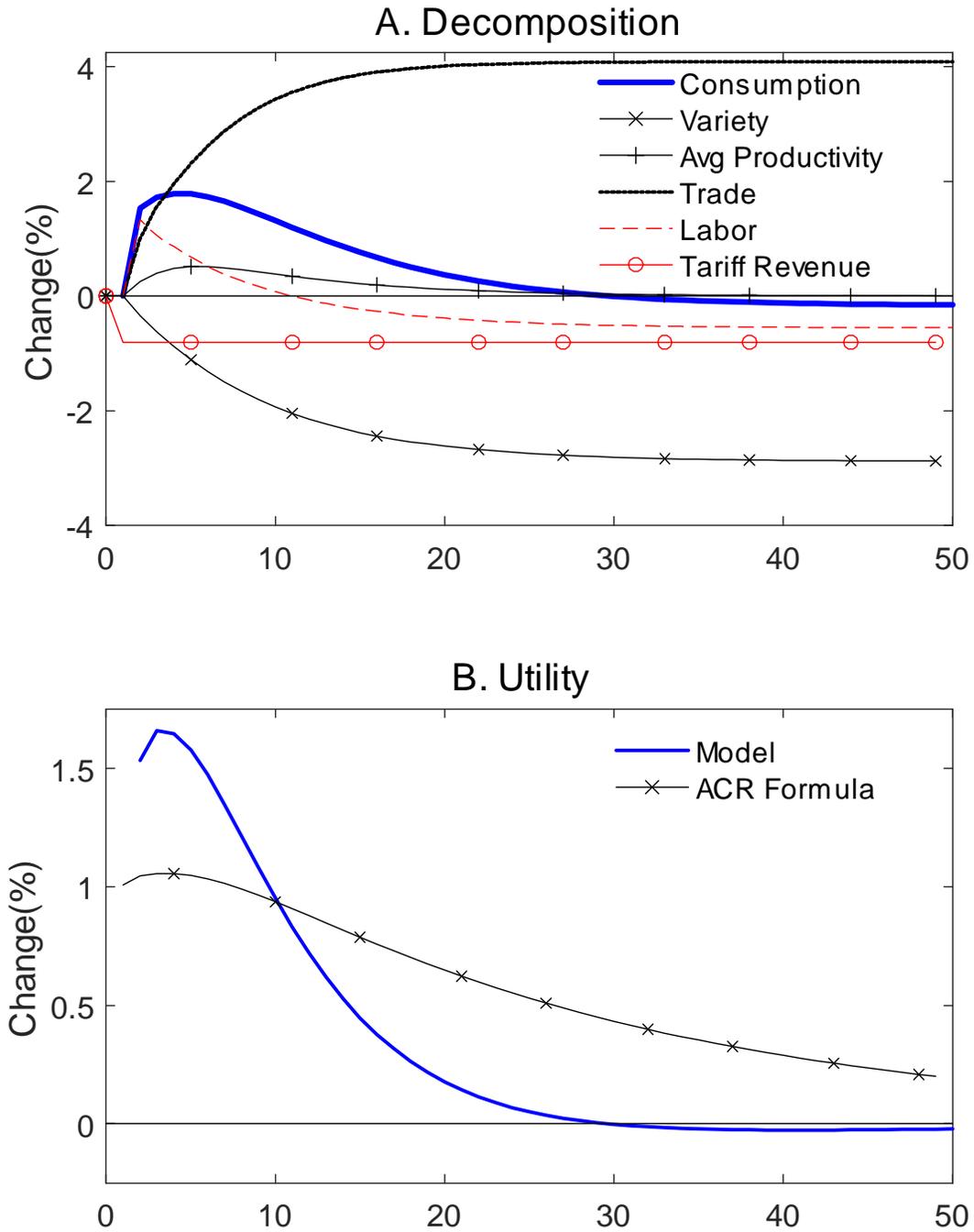


Figure 9: Dynamics following Home Tariff Reduction

