# The Exporter and Productivity Dynamics: The Effect of Trade Liberalization*

Kazuma Inagaki†

August 27, 2024

**Abstract**

This paper studies how R&D and export investment magnifies the welfare gain from trade liberalization. I develop a dynamic heterogeneous firm international trade model with investment in productivity-enhanced R&D and export technology. I find that the R&D with a dynamic export technology enhances the welfare gain from trade liberalization, in contrast to the canonical model with static firms' export decisions. I quantitatively demonstrate that the welfare gain from trade liberalization in the dynamic trade model with R&D is higher than that without R&D by 40%, compared to 2% at a static trade model. These findings suggest that static trade models are an even worse approximation of dynamic trade models than we thought.

Keywords: Trade liberalization, Firm dynamics, Heterogeneous firms, Innovation

*I am very grateful to my advisor, George Alessandria, for his continued guidance. I thank Kim Ruhl for his helpful comments. I also thank Yan Bai, Gaston Chaumont, Hamid Firooz, Rafael Guntin, Matias Moretti, Mark Bils, Narayana Kocherlakota, Christopher Sleet, and many seminar and conference participants for thoughtful discussions and helpful suggestions. I gratefully acknowledge the financial support of the Joint Usage/Research Centers at the Institute of Social and Economic Research (ISER).

†University of Rochester, *E-mail address:* kinagaki@ur.rochester.edu

## 1 Introduction

A growing body of literature supports the positive effect of exports on a firm's productivity. Motivated by this fact, researchers extend the canonical heterogeneous firm international trade model such as Melitz (2003) to allow firms' R&D investment (e.g., Costantini and Melitz (2008); Atkeson and Burstein (2010); Rubini (2014); Impullitti and Licandro (2018)). Although these studies discuss the importance of the firms' R&D activity with firm heterogeneity, the interaction of the firm's export dynamics and productivity dynamics has not been examined enough.

This paper quantifies welfare gain from trade liberalization by incorporating two key aspects: the firm's dynamic export decision (exporter dynamics) and the endogenous R&D investment in firm productivity (productivity dynamics). I introduce the three assumptions into the heterogeneous firm international trade model. The first two assumptions are sunk export entry cost and a lag before exporting, which is discussed in Dixit (1989); Das et al. (2007); Impullitti et al. (2013); Alessandria and Choi (2014); Alessandria et al. (2021). These two assumptions generate firm dynamics in the export market and gradual trade expansion. The other assumption is the firms' R&D investment in their productivity. The assumption of endogenous productivity is motivated by the empirical findings of Alvarez and López (2005); Aw et al. (2007, 2011); Bustos (2011); Loecker (2013); Bloom et al. (2016) that show a positive relationship between trade and R&D or productivity.

I develop a continuous-time general equilibrium international trade model with heterogeneous firms. Firms face persistent productivity shocks that are endogenously determined by the R&D investment. This R&D investment generates the productivity dynamics. Trade liberalization has distinct effects on exporters' and non-exporters' investment in R&D. Exporters can access larger foreign markets, which may increase their investment in R&D, while non-exporters face competition from productive foreign exporters and may decrease their investment. As a result, the benefit from trade liberalization is larger for the exporters than non-exporters.

For the exporter dynamics, the model includes the sunk export entry cost and lag before exporting. Firms pay irreversible costs to start exporting and decide on future export status; i.e., firms invest in their future export state, not today's export decision. To start exporting, firms pay the startup export costs, which are higher than the continuation costs. The high startup sunk cost makes exporting a persistent decision since exporters want to avoid incurring the high startup cost again. Additionally, I introduce the assumption of a lag before exporting to account for the gradual adjustment of exporting enhanced expansion after trade liberalization. This assumption is inherently embedded in the discrete-time model, but it is newly assumed in the continuous-time model. Because of these assumptions, in the Sunk-cost model, the entrants start their business as non-exporters. In the following discussion, I refer to the Sunk-cost model as the model with the sunk cost and lag before exporting, while the model with the fixed cost is referred to as the Fixed-cost model.

Adding on R&D decisions to the Sunk-cost model boosts the welfare gain by about 40%. By calibrating the model to fit the U.S. data, I show that the Sunk-cost model with R&D generates about 75% larger long-run consumption and about 40% larger welfare gain than the Sunk-cost model without R&D, when R&D elastic to the trade liberalization. On the other hand, R&D raises welfare gain by about 2% when R&D elasticity is low. This finding contrasts with the Fixed-cost models. In the Fixed-cost model, the assumption of R&D enhances the welfare gain from trade liberalization by only 2% regardless of R&D elasticity.

This result is derived from the difference in the free entry condition between the Sunk-cost and Fixed-cost models. In the Sunk-cost model, the exporters' profit enhanced by R&D is not fully offset in the equilibrium since the entrants start their business as non-exporters. That is, the entrants do not fully internalize the profit of exporting, and the increase in the number of entrants satisfying the free entry condition is weak. Indeed, the large decline in the mass of entrants leads to the labor substation toward production in the long run. On the other hand, in the Fixed-cost model, the profit of exporters from trade liberalization is offset in the equilibrium.

The incentive to enter is also associated with competition from foreign exporters and domestic firms. Since R&D enhances the average productivity of domestic firms after trade liberalization, entrants face severe competition, which reduces the incentive to enter. Also, the increase in the variety of imported goods enhances the competition and weakens the incentive to enter. In the long run, the increase in average productivity and imports is largely offset by the decline in investment in new products.

In addition to labor substitution, slow trade and productivity adjustment and a decline in investment in new products are important to understand the transition dynamics and welfare gain.

Slow trade adjustment leads to a gain from trade liberalization in the long run, while it reduces the short-run consumption and production labor due to the short-run investment in export technology. Slow productivity adjustment has a similar effect as slow trade adjustment since the labor is used to invest in R&D in the short run. Because of the short-run investment in R&D and export technology, the gap between welfare gain and long-run consumption change in the Sunk-cost model with R&D is smaller than the model without R&D.

The introduction of R&D has a small effect on trade dynamics. In the Sunk-cost model with high R&D elasticity, the share of continuation firms to startup firms increases compared to that without R&D. The increase in the number of continuation firms raises the exporter ratio, but it also reduces the exporter productivity premium. On the other hand, when R&D elasticity is low, the exporter ratio is smaller than in the model without R&D. The long-run trade elasticity of the Sunk-cost models is around 7.4, and that of the Fixed models is around 4.6. R&D increases the average productivity of exporters while it may reduce the incentive to start exporting because of competition.

This paper is related to several existing literature on international trade. The first relevant literature focuses on the aggregate effect of trade barriers like Arkolakis et al. (2012), based on Krugman (1980); Eaton and Kortum (2002); Melitz (2003). Some studies argue that the trade volume gradually expands following the reduction in trade cost, and the short-run trade elasticity is lower than the long-run trade elasticity (e.g., Baier and Bergstrand (2007); Yilmazkuday (2019); Boehm et al. (2023)). The general equilibrium models incorporating sunk cost explain this gradual expansion (e.g., Alessandria and Choi (2014); Alessandria et al. (2021)). This paper incorporates the assumption of R&D into this dynamic trade model and shows that the R&D investment enhances the gain from trade. Impullitti et al. (2013) also develops the continuous-time model with sunk cost, based on Dixit (1989); Das et al. (2007) without R&D.

The second relevant strand of literature focuses on the relationship between trade and innovation. The research using micro-level data indicates that international trade often has a positive effect on each firm's productivity and R&D investment. For instance, Alvarez and López (2005); Aw et al. (2007, 2011); Loecker (2013); Atkin et al. (2017) find that firms' productivity or R&D investment increases when they engage in exporting. Also, Lileeva and Trefler (2010); Bustos (2011) show that the reduction in trade costs increases the firms' investment and productivity. Bloom et al. (2016) reveals that the import competition raises the innovation of high-productivity firms and reduces the survival rate of low-productivity firms, which is consistent with my quantification result. Motivated by these micro-level findings, this paper develops the dynamic trade model with R&D investment. Atkeson and Burstein (2010) show that the R&D investment does not significantly contribute to the gain from trade in the general equilibrium model with heterogeneous firms. In contrast, I show that R&D investment enhances the welfare gain when the exporter dynamics are taken into account. Other studies, such as Sampson (2016); Impullitti and Licandro (2018); Perla et al. (2021), also find positive effects of trade cost reductions on the welfare gain when firms can invest in R&D in the static trade model with inefficiency. In addition to these findings, this paper emphasizes the importance of exporter dynamics for welfare gain. The other important perspective for trade and growth is technology diffusion with international trade (e.g., Grossman and Helpman (1993); Buera and Oberfield (2020)). This paper does not incorporate technology diffusion and the welfare gains that arise from domestic reallocation.

This paper is organized as follows. Section 2 presents the heterogeneous producer international trade model with the exporter and productivity dynamics. Section 3 shows the calibration and the model fit. In section 4, I study the model dynamics after trade liberalization and welfare gain. Section 5 concludes.

## 2 The model

I build a dynamic general equilibrium model with firm and export dynamics in the spirit of Alessandria and Choi (2014). I extend a simplified version of their model to continuous time and allow for the firms' R&D[1]. I introduce the lag before exporting when I extend their model to a continuous-time model in order to fill the discrepancy between the discrete-time and continuous-time Sunk-cost models. The lag before exporting is inherently embedded in discrete time, while the continuous-time model does not have this lag before exporting. Without the lag before exporting, firms do not face the uncertainty of export decisions since they can start exporting immediately. The lag before exporting is associated with the uncertainty of export investment and is important to generate a larger and more gradual export expansion.

[1] We do not consider capital, intermediate inputs, and non-tradable sector, while they include these assumptions.

There are two symmetric countries, *home* and *foreign*. Each country has identical, infinitely-lived consumers that supply $L$ units of labor inelastically. Each country also has representative final goods firms, heterogeneous intermediate goods firms, and a government. All intermediate goods firms sell the product to their own country, and some export. The intermediate goods firms are heterogeneous with respect to productivity, $z_t$, and export states, $m_t$. In addition, they are heterogeneous with respect to the state of waiting, $w_t$. The state of waiting means that intermediate goods firms cannot start exporting immediately, and there is a lag before exporting from their export decision, which generates a gradual trade adjustment as Alessandria and Choi (2014). Here, waiting firms represent the firms that decide to switch their export status, but the state, $m_t$ does not change. That is, it represents the firm waiting for a switch in their export state, $m_t$. The measure of home intermediate goods firms with productivity, $z_t$, export status, $m = 0$ for non-exporters and $m = 1$ for exporters, and waiting status, $w = 0$ for non-waiting firms, and $w = 1$ for waiting firms, is $g(z, m, w)$.

### 2.1 Consumers

Home consumers solve the following maximization problem:

$$\max_{C_t} \int_0^\infty e^{-\rho t} U(C_t) dt,$$

$$C_t \leq W_t L + \Pi_t + T_{g,t},$$

where $\rho \in (0, 1)$ is the subjective discount factor. Here, $C_t$ is the final goods consumption. In the budget constraint, $W_t$ is the real wage rate, $L$ is the inelastic labor supply, $\Pi_t$ is the real dividend from home producers, and $T_{g,t}$ is the real lump-sum transfer of local tariff revenue. I omit the final goods price, $P_t$, from the consumer's problem. The foreign consumer's problem is analogous. Foreign prices and allocations are denoted with an asterisk.

### 2.2 Final goods firms

Final goods are produced by combining home and foreign intermediate goods. A home final goods firm purchases inputs from all home intermediate goods firms and some foreign intermediate goods firms exporting to the home market. The aggregation technology is a CES function,

$$Y_t = \left\{ \int \sum_{m=0}^{1} \sum_{w=0}^{1} y_{H,t}(z,m,w)^{\frac{\theta-1}{\theta}} g_t(z,m,w)dz + \int \sum_{w=0}^{1} y_{F,t}(z,1,w)^{\frac{\theta-1}{\theta}} g_t^*(z,1,w)dz \right\}^{\frac{\theta}{\theta-1}} \quad (1)$$

where $y_{H,t}$ and $y_{F,t}$ are the inputs of intermediate goods purchased from home intermediate goods firms and foreign exporters, respectively. The elasticity of substitution between intermediate goods is $\theta > 1$.

The final goods market is competitive. A final goods firm maximizes the profit,

$$\begin{aligned} \max \Pi_{F,t} = P_t Y_t &- \int \sum_{m=0}^{1} \sum_{w=0}^{1} p_{H,t}(z,m,w) y_{H,t}(z,m,w) g_t(z,m,w)dz \\ &- \int \sum_{w=0}^{1} (1+\tau_t) p_{F,t}(z,1,w) y_{F,t}(z,1,w) g_t^*(z,1,w)dz \end{aligned} \quad (2)$$

subject to the production technology equation 1. Here, $p_{H,t}$ and $p_{F,t}$ are the price of intermediate goods produced by home goods firms with $(z,m,w)$ and foreign exporters with $(z,1,w)$, respectively. Solving the problem in equation 2 yields the input demand functions,

$$y_{H,t}(z,m,w) = \left( \frac{p_{H,t}(z,m,w)}{P_t} \right)^{-\theta} Y_t, \quad (3)$$

$$y_{F,t}(z,1,w) = \left( (1+\tau_t) \frac{p_{F,t}(z,1,w)}{P_t} \right)^{-\theta} Y_t, \quad (4)$$

where the price index is

$$P_t^{1-\theta} = \int \sum_{m=0}^{1} \sum_{w=0}^{1} p_{H,t}(z,m,w)^{1-\theta} g_t(z,m,w)dz + \int \sum_{w=0}^{1} \left[ (1+\tau) p_{F,t}(z,1,w) \right]^{1-\theta} g_t^*(z,1,w)dz.$$

I assume that the home final good is the numeraire and $P_t = 1$.

## 2.3 Intermediate goods firms

The intermediate goods firms produce their differentiated goods using labor. Exporting incurs fixed and variable costs. There is an ad valorem tariff, $\tau_t$, and an ad valorem transportation cost, $\xi$. Exporters pay the flow cost, $f_1$, to continue to export. When non-exporters start to export, they pay the flow startup cost, $f_0 > f_1$, while they are waiting, $w = 1$. The decision to change their state of waiting is irreversible. To resume exporting, firms have to pay $f_0$ again. These costs are valued in units of domestic labor. I also suppose that the intermediate goods firms exit the market with an exogenous death rate, $n_d(z)$, conditional on the current productivity. Incumbents receive an exogenous death shock that depends on a firm's productivity, $z_t$, $0 \leq n_d(z_t) \leq 1$. The intermediate goods firms are described by their technology and export status, $s = (z, m, w)$.

The incumbent's productivity, $z_t$ follows,

$$dz_t = \mu_t(s)dt + \sigma d\mathcal{W}_t, \tag{5}$$

where $\mu_t(s)$ is the endogenous drift, $\sigma$ is the standard deviation, and $\mathcal{W}_t$ denotes the Wiener process. Intermediate goods firms engage in the R&D activity and the drift of productivity, $\mu_t(s)$ is given by

$$\mu_t(s) = q_t(s) - \alpha z_t. \tag{6}$$

The incumbent firms invest $q_t(s)$ in their productivity by hiring $c_t(s)$ units of labor to increase future productivity.

Each period, they choose current prices for each market, $p_{H,t}(s)$ and $p^*_{H,t}(s)$, labor, $l_t(s)$, investment in R&D, $q_t(s)$, and timing to start waiting, $T_t(z, m, 0)$, to maximize the value function, $V_t(s)$, related to the profit, $\pi_t(s)$.

The firms have a linear production technology, $y_t(s) = e^{z_t} l_t(s)$. Non-waiting firms solve the following stopping time problem subject to equation (5),

$$V_0(z, m, 0) = \max_{p_{H,t}, p^*_{H,t}, l_t, q_t, T_t} \left\{ \mathbf{E}_0 \int_0^{T_t(z,m,0)} e^{-(\rho + \int n_d(z_v)dv)t} (\pi_t(z, m, 0))dt + e^{-(\rho + n_d(z))T_t(z,m,0)} \hat{V}_{T_t(z,m,0)} \right\}.$$

where $\hat{V}$ is the optimal value of switching the status. The first term on the right-hand side is value to continue the current state. The second term on the right-hand side is the value to switch status.

Waiting firms solve the following Hamilton-Jaccobi-Bellman equation,

$$(\rho + n_d(z))V_t(z,m,1) = \max_{p_{H,t},p^*_{H,t},l_t,q_t} \pi_t(z,m,1) + \mu_t(z,m,1)\frac{\partial V_t(z,m,1)}{\partial z} + \frac{\sigma^2}{2}\frac{\partial^2 V_t(z,m,1)}{\partial z^2}$$
$$+\gamma(V_t(z,-m,0) - V_t(z,m,1)).$$

The value of waiting firms, $V(z,m,1)$, corresponds to the optimal stopping value, $\hat{V}$. Here, $-m$ denotes the opposite export status of $m$. The second and third terms on the right-hand side represent the value of the change in their productivity. With the Poisson arrival rate, $\gamma$, waiting firms switch their export status, $m$. The fourth term on the right-hand side represents the probability of switching the export status.

The intermediate goods firms' profit, $\pi_t(s)$ is given by

$$\pi_t(s) = p_{H,t}(s)y_{H,t}(s) + m_t p^*_{H,t}(s)y^*_{H,t}(s) - W_t l_t(s) - W_t c_t(s) - m_t W_t f_1 - w_t(1-m_t)W_t f_0.$$

Both optimization problems are subject to the productivity process in equation 5, and the constraint that supplies to home and foreign goods markets, $y_{H,t}(s)$ and $y^*_{H,t}(s)$ with $y_t(s) = y_{H,t}(s) + m(1+\xi)y^*_{H,t}(s)$, are equal to demands by final good firms from equation 3 and the foreign analogue of equation 4. The firms with $m = 1$ pay the continuation cost to export, $f_1$, regardless of the state $w$. The firms with $m = 0$ and $w = 1$ pay the startup cost to export, $f_0$.

## 2.4 Entry

The new intermediate goods firms are created by hiring $f_E$ workers. The entrants draw their productivity from the distribution, $g_E(z)$. The entry condition is

$$V_t^E = -W_t f_E + \int V_t(z,0,0)g_E(z)dz \leq 0.$$

Entrants cannot export immediately after they start production; their export state is $m = 0$, and their waiting state is $w = 0$.

## 2.5 Government

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

$$T_{g,t} = \tau_t \int \sum_{w=0}^{1} p_{F,t}(z,1,w) y_{F,t}(z,1,w) g^*(z,1,w) dz. \tag{7}$$

## 2.6 Evolution of intermediate goods firms' distribution

The mass of entrants in period $t$ is $N_{E,t}$. The mass of intermediate goods firms is denoted as $N_t$. The mass of exporters equals $N_{1,t} = \int \sum_{w=0}^{1} g_t(z,1,w)dz$ and the mass of non-exporters equals $N_{0,t} = \int \sum_{w=0}^{1} g_t(z,0,w)dz$. The mass of intermediate goods firms 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 intermediate goods are available in the foreign country in period $t$. The starter ratio, the fraction of producers who start exporting among non-exporters, and the stopper ratio, the fraction of producers who stop exporting among exporters, are denoted by $n_{0,t}$ and $n_{1,t}$ respectively.

The dynamics of non-waiting and waiting firms' distribution are, respectively,

$$\partial_t g_t(z,m,0) = -\partial_z[\mu(z,m,0)g(z,m,0)] + \frac{1}{2}\partial_{zz}[\sigma^2 g(z,m,0)] - n_d(z)g(z,m,0) + \gamma g(z,-m,1) - \hat{\gamma} g(z,m,0),$$
$$\partial_t g_t(z,m,1) = -\partial_z[\mu(z,m,1)g(z,m,1)] + \frac{1}{2}\partial_{zz}[\sigma^2 g(z,m,1)] - n_d(z)g(z,m,1) - \gamma g(z,m,1) + \hat{\gamma} g(z,m,0),$$

where $\partial_z$ and $\partial_{zz}$ denotes the first and second order derivatives with respect to $z$, respectively. $\hat{\gamma}$ denotes the transition from $w = 0$ to $w = 1$. Since entrants begin their business as non-exporters, the dynamics of firms with $m = 0$ and $w = 0$ is

$$\partial_t g_t(z,0,0) = -\partial_z[\mu(z,0,0)g(z,0,0)] + \frac{1}{2}\partial_{zz}[\sigma^2 g(z,0,0)] - n_d(z)g(z,0,0) + \gamma g(z,1,1) - \hat{\gamma} g(z,0,0) + N_{E,t} g_E(z).$$

## 2.7 Aggregate variables

Nominal exports and imports equal

$$EX_t^N = \sum_{w=0}^{1} \int p_{H,t}^*(z,1,w) y_{H,t}^*(z,1,w) g_t(z,1,w) dz,$$
$$IM_t^N = \sum_{w=0}^{1} \int p_{F,t}(z,1,w) y_{F,t}(z,1,w) g_t^*(z,1,w) dz,$$

respectively. Home nominal GDP equals the sum of value added from intermediate goods producers and final goods producers, $Y_t^N = P_t Y_t + EX_t^N - IM_t^N$. The trade to GDP ratio is

$$TR_t = \frac{EX_t^N + IM_t^N}{2Y_t^N}.$$

Let $IMD_t$ be the expenditure on imported goods relative to that on home goods,

$$IMD_t = \frac{(1+\tau_t) \sum_{w=0}^{1} \int p_{F,t}(z,1,w) y_{F,t}(z,1,w) g_t^*(z,1,w) dz}{\sum_{m=0}^{1} \sum_{w=0}^{1} \int p_{H,t}(z,m,w) y_{H,t}(z,m,w) g_t(z,m,w) dz}.$$

I define the share of tradable expenditures on domestic goods and the trade elasticity as

$$\lambda_t = \frac{1}{1 + IMD_t}, \tag{8}$$
$$\varepsilon_{T,t} = -\frac{\ln(IMD_t / IMD_{-1})}{\ln((1+\tau_t)/(1+\tau_{-1}))}. \tag{9}$$

Production labor, $L_{P,t}$, and Research labor, $L_{R,t}$, are, respectively

$$L_{P,t} = \sum_{m=0}^{1} \sum_{w=0}^{1} \int l_t(z,m,w) g_t(z,m,w) dz, \tag{10}$$
$$L_{R,t} = \sum_{m=0}^{1} \sum_{w=0}^{1} \int c_t(z,m,w) g_t(z,m,w) dz.$$

The domestic labor hired by exporters to cover the fixed costs of exporting, $L_{X,t}$, and the domestic labor hired to create new firms, $L_{c,t}$, are, respectively,

$$L_{X,t} = f_0 \int g_t(z,0,1)dz + f_1 \int \sum_{w=0}^{1} g_t(z,1,w)dz,$$
$$L_{C,t} = f_E N_{E,t}.$$

Aggregate profits equal profits minus fixed costs,

$$\Pi_t = \Pi_{F,t} + \int \sum_{m=0}^{1} \sum_{w=0}^{1} \pi_t(z,m,w) g_t(z,m,w)dz - W_t L_{C,t}.$$

### 2.8 Equilibrium

In an equilibrium, variables satisfy several resource constraints. The market clearing conditions are:

1. Final goods market $Y_t = C_t$.

2. Labor market $L = L_{p,t} + L_{r,t} + L_{X,t} + L_{C,t}$.

3. Government budget constraint given by equation 7.

The foreign analogues also hold. Firm's profits are distributed to the shareholders, $\Pi_t$, and foreign analogue. Writing the budget constraints in local currency units allows us to normalize the consumption price in each country as $P_t = P_t^* = 1$.

An equilibrium is a collection of allocations for home and foreign consumers, $C_t$, $C_t^*$; allocation for home and foreign final good firms; allocations, prices, and export decisions for home and foreign intermediate good firms; labor used for exporting costs at home and foreign; labor used for entry costs at home and foreign; transfers, $T_t$, $T_t^*$ by home and foreign governments; real wages, $W_t$, $W_t^*$ that satisfy the following conditions: (i) the consumer allocations solve the consumer's problem; (ii) the final good firms' allocation solves their profit maximization problem; (iii) the intermediate good firms' allocations, prices, and export decisions solve their profit maximization problems; (iv) the entry conditions for intermediate good firms hold; (v) the market clearing conditions hold; and (vi) the transfers satisfy the government budget constraint.

## 3 Calibration

This section first describes the functional forms and parameter values. The instantaneous utility function equals $U(C) = \log(C)$. The cost function of R&D investment is $c_t = e^{(\theta-1)z_t+\phi q_t}/\phi$, where $1/\phi$ is the elasticity of R&D. An entrant draws productivity from the unconditional distribution, $z = \mu_E + \varepsilon_E,\ \varepsilon_E \overset{iid}{\sim} N\left(0, \frac{\sigma^2}{2\hat{\alpha}}\right)$, where $\mu_E < 0$ is the entrants' disadvantage and set to match the fact that entrants are smaller than incumbents, and $\hat{\alpha}$ denotes the productivity persistence of the models without R&D. The model with R&D has a heterogeneous productivity persistence, and, for simplicity, I use the common $\alpha$ for the entrant's distribution that remains unchanged over time to exclude the knowledge diffusion.

The subjective discount factor is 4% in annual frequency, $\rho = 0.04$, and labor supply, $L$, is set to 1. The elasticity of substitution, $\theta$, is set to 5, which yields a producer markup of 25% and is consistent with Broda and Weinstein (2006). The entry cost, $f_E$, is chosen to set the mass of the establishments of the initial steady state to be 1. The Poisson arrival rate, $\gamma$, is set to 1, which implies that the average waiting time to start and stop exporting is one year. The baseline tariff rate, $\tau$, is set to 8%.

The R&D elasticity, $\phi$, is the important parameter of the model, which determines how firms change their R&D investment after trade liberalization, but it is hard to identify. Here, I consider two cases: firms' R&D investment is elastic to the trade liberalization with $\phi = 20$, and firms' R&D investment is inelastic to the trade liberalization with $\phi = 100$. I refer to the model with $\phi = 20$ as the model with high R&D elasticity and the model with $\phi = 100$ as the model with low R&D elasticity. To make the initial steady state of all variants match the firm distributions of data, I calibrate $\alpha$. Hence, the models may have different R&D investments, $q_t$, but in the initial steady state, the different R&D elasticity, $\phi$, does not generate the different firm dynamics. In the model without R&D, $\alpha$, governs the whole productivity persistence and R&D investment, $q_t$, is eliminated from equation (6).

I internally calibrate the remaining eight parameters, $f_0$, $f_1$, $\xi$, $\lambda_D$, $n_{d0}$, $\mu_E$, $\alpha$, and $\sigma$ to match the six moments and two distributions for the United States:

1. An exporter rate of 22.3% (1992 Census of Manufactures (CM)).

2. A stopper rate of 17% as in Bernard and Jensen (1999) based on the Annual Survey of

Manufactures (ASM) of the Bureau of the Census 1984-1992.

3. Exporters' export sales to the total sale of 13.3% from 1992 CM.

4. Five-year exit rate of entrants of 37% (Dunne et al. (1989)).

5. Entrants' labor share of 1.5% reported in Davis et al. (1998) based on the ASM.

6. Shut down establishments' labor share of 2.3% (Davis et al. (1998)).

7. Employment size distribution as in the 1992 CM.

8. Establishment size distribution as in the 1992 CM.

Since there are more moments than parameters, the model fit is imperfect. The iceberg cost, $\xi$, is set to match exporters' export sales to total sales. I choose the rest of the seven parameters to minimize the sum of squared residuals between the data and model. The parameters and target moments are reported in table 1. I also calibrate the model, in which firms decide their current export status, $m$ and $f_0 = f_1$. This model is the dynamic variation of Melitz (2003), and I refer to it as the Fixed-cost model. I examine the role of R&D for the Fixed-cost model as well as the Sunk-cost model.

The size of the startup cost is about 6 times larger than the continuation cost across the Sunk-cost models. Aw et al. (2011) estimates the sunk export cost of the model with R&D investment in the discrete time using plane-level data of the Taiwanese electronic industry. They find that the startup export cost is about 5 times larger than the continuation cost.

The top-left and top-right panel of figure 1 plots the distribution of establishment and employment by employment size in the data and the models. The bar represents the data. Each line represents the Sunk-cost model with high R&D elasticity, the Sunk-cost model without R&D, the Sunk-cost model with low R&D elasticity, the Fixed-cost model with high R&D elasticity, the Fixed-cost model without R&D, and the Fixed-cost model with low R&D elasticity, respectively.

The share of establishments is decreasing in size in the data and the model. The distribution of the share of manufacturing employment is hump-shaped, and the establishments with 100-249 employees account for 20% of total employment in the data and model. The mean squared errors between the model and data of two distributions are reported in panel C of table 1.

The bottom-left panel of figure 1 plots the stationary distribution of intermediate goods firms of the Sunk-cost model with high R&D elasticity as a representative example. I plot the distributions of exporters (top blue line), non-exporters (bottom red line), and newborn firms (green chained line) by productivity level of the dynamic export model with high R&D elasticity. I also plot the exogenous shutdown probability of producers and the probability of starting and stopping exporting. The right yellow and left purple dashed lines represent the distribution of waiting non-exporters and waiting exporters, respectively. To match the low employment share and high shutdown rate of entrants, the average newborn productivity is about 25% lower than that of incumbents. Since the startup cost is higher than the continuation cost, the threshold to start export is larger than that to stop export. Also, the distribution shows that the decision to export is persistent, and there exist unproductive exporters and productive non-exporters.

The bottom-right figure 1 plots the producers' R&D investment cost by productivity, $z$ in the Sunk-cost model with high R&D elasticity. The dashed red line is the R&D cost of exporters, and the blue line is that of non-exporters. The R&D cost of productive firms is larger than the unproductive firms. The exporters invest in R&D more than non-exporters since the exporters can access the foreign market, and the return from R&D is larger than non-exporters.

[Table 1 about here.]

[Figure 1 about here.]

## 4 The effect of trade liberalization

In this section, I discuss the short-run and long-run effects of an unanticipated permanent global cut in tariffs from 8% to 0%. This estimates the expected change in the U.S. and the rest of the world from eliminating tariffs. I examine how R&D enhances welfare gain from trade liberalization in the Sunk-cost model. In particular, I decompose the log consumption change in the equilibrium and show that the labor is substituted toward production.

### 4.1 The change in the firms' R&D and export

Firstly, I describe how firms change their R&D investment and export decisions after trade liberalization. Figure 2 plots the difference in the R&D investment between the initial and new steady state. It also plots the threshold to start and stop exporting. The dot and dash lines denote the initial threshold and the new threshold, respectively. In the upper figures for the Sunk-cost model, the vertical line represents the thresholds to stop on the left-hand side, and that on the right-hand side represents the thresholds to start. The top two panels plot the change in R&D of the Sunk-cost model with high and low R&D elasticity. The bottom two panels plot those of Fixed-cost models.

In the Sunk-cost model, there are two spikes of change in investment since the startup cost and continuation cost are different. The threshold to start exporting is higher than that to stop exporting. In contrast to the model with low R&D elasticity, exporters near the threshold (marginal exporters) increase their investment more than marginal non-exporters in the model with high R&D elasticity. Hence, firms are more likely to continue to export in the Sunk-cost model with high R&D elasticity than the other models[2]. In the Fixed-cost model, there is one spike since the startup cost is equal to the continuation cost. The exporters and marginal non-exporter increase their R&D investment while the other firms weakly reduce their investment.

The threshold to export moves to the left-hand side in all models. Because of the decline in trade cost, more firms start and continue exporting. For the Sunk-cost models, the threshold to stop exporting moves larger than that to start exporting. This means that trade cost reduction makes export decisions more persistent.

[Figure 2 about here.]

### 4.2 Welfare and decomposition

I decompose the general equilibrium effect of the tariff reduction on consumption:

$$\hat{C} = \hat{L}_p + \frac{1}{\theta - 1}\left(\hat{N} + \hat{\bar{\Psi}} - \hat{\lambda}\right) + \hat{S}, \tag{11}$$

[2]The R&D investment is given by $q_t = \frac{1}{\phi} \log \frac{\partial_z V_t(z,m,w)}{W_t e^{(\theta-1)z_t}}$. The marginal value is converted to logarithm, which makes the different response of investment across productivity.

where $\hat{S} = -\hat{\lambda} + \hat{A}$, $A^{-1} = 1 + (1+\xi)^{1-\theta}(1+\tau)^{-\theta}\frac{\Psi_X}{\Psi}$, and $\lambda^{-1} = 1 + (1+\xi)^{1-\theta}(1+\tau)^{1-\theta}\frac{\Psi_X}{\Psi}$. $\lambda$ is derived from equation 8. If $\tau = 0$, $A = \lambda$. Here, $\Psi = \int \sum_{m=0}^{1}\sum_{w=0}^{1} e^{(\theta-1)z} g(z,m,w)dz$ and $\bar{\Psi}$ denotes the aggregate productivity and the average of aggregate productivity, respectively. $\Psi_x = \int \sum_{w=0}^{1} e^{(\theta-1)z} g(z,1,w)dz$ denotes the aggregate productivity of exporters. $\hat{x}$ denotes the log change of $x$ from the initial steady state. This equation is derived from the aggregate production labor, equation 10 and the aggregate technology of the final goods firm, equation 1,

$$L_{P,t} = \left(\frac{\theta}{\theta-1}W_t\right)^{-\theta} C_t\left(\Psi_t + (1+\xi)^{1-\theta}(1+\tau_t)^{-\theta}\Psi_{X,t}\right), \tag{12}$$

$$W_t = \frac{\theta-1}{\theta}\left(\Psi_t + (1+\xi)^{1-\theta}(1+\tau_t)^{1-\theta}\Psi_{X,t}\right)^{\frac{1}{\theta-1}}. \tag{13}$$

By eliminating $W_t$ in equation 12 with equation 13, the consumption, $C_t$ is decomposed into changes attributed to variations in labor, $\hat{L}_p$, the mass of producers, $\hat{N}$, average productivity, $\hat{\bar{\Psi}}$, $\hat{\lambda}$, $\hat{S}$.

Then, I define the manufacturing labor productivity, $Z_{p,t} = \frac{Y_t}{L_{p,t}}$ following Atkeson and Burstein (2010). Since $Y_t = C_t$ from the market clearing condition, by equation (11),

$$\begin{aligned}\hat{Z}_{p,t} &= \hat{C}_t - \hat{L}_{p,t},\\ &= \frac{1}{\theta-1}\left(\hat{N} + \hat{\bar{\Psi}} - \hat{\lambda}\right) + \hat{S}.\end{aligned} \tag{14}$$

This equation implies that manufacturing productivity depends on the firms' distribution and trade share.

Table 2 reports the welfare gain and long-run change in consumption. This table also reports the decomposition according to equation 11. The first row of panels A and B in table 2 shows the welfare gain and long-run consumption change from the trade liberalization of each model, respectively. From the second row to the fifth row, the consumption decomposition is shown. I also report the manufacturing productivity in the sixth row of each panel. Here, the discount value of $x_t$ is defined as $\rho\int_0^\infty e^{-\rho t}\log(x_t)dt$, which is shown in percent.

The R&D raises the welfare gain in the Sunk-cost model, but it does not in the Fixed-cost model when the R&D elasticity is high. The R&D enhances the welfare gain by about 40% in the Sunk-cost model, while it increases the welfare by about 2% in the Fixed-cost model. The Sunk-cost model with low R&D elasticity shows a similar change as the Fixed-cost model with low

R&D elasticity, which is around 2%.

The decomposition clarifies the important factor in raising the welfare in the Sunk-cost model. By comparing the Sunk-cost model with high R&D elasticity to that without R&D, I find that the production labor contributes to raising welfare and long-run change in consumption. For detail, panel A of table 3 reports the discounted level change in the labor of production, research, firm creation, and exports. Introducing R&D reduces the labor for new firm creation in the Sunk-cost model and the labor is substituted for production, while it does so only weakly in the Fixed-cost model.

The difference in the amplification by R&D arises from the difference in the free entry condition. In the Sunk-cost model, entrants start their business as a non-exporter, and the amplified gain of exporters by R&D is not fully offset by the change in the mass of entrants. In the Sunk-cost model, the entrants do not internalize the amplified gain by R&D, and the competition reduces the incentive to enter more than in the Fixed-cost model.

Across all models, manufacturing productivity remains almost unchanged by R&D after trade liberalization. The reason why the manufacturing productivity does not change largely by R&D is explained by the competition. Trade liberalization raises the R&D investment and the productivity of domestic firms, especially exporters. On the other hand, the rise of them enhances the competition and reduces the incentive to enter. As a result, the decline in the mass of establishment offset the increase in the investment in R&D.

I also examine the long-run changes in consumption. In the Sunk-cost model, R&D doubles the consumption change, while it is relatively constant in the Fixed-cost model when R&D elasticity is high. When the R&D elasticity is low, the R&D has a small effect on the change in consumption of both models. As for welfare gain, the increase in production labor accounts for the difference in the models, but manufacturing productivity does not.

[Table 2 about here.]

[Table 3 about here.]

### 4.3 Transition dynamics

Figures 3 plot the transition of consumption after trade liberalization of the models for the first 50 years. Figures 4 illustrate the transition dynamics after trade liberalization of the models with high R&D elasticity and the models without R&D. Figures 5 illustrate the transition dynamics of models with low R&D elasticity, and I plot the transition dynamics of the models without R&D for reference. The blue line and red dashed line denote the Sunk-cost model with high R&D elasticity and without R&D, respectively. The yellow dot and purple chain lines denote the Fixed-cost model with high R&D elasticity and without R&D, respectively. The blue line with a circle and the yellow line with an asterisk denote the Sunk-cost model with low R&D elasticity and the Fixed-cost model with low R&D elasticity, respectively.

Figures 3a and 3b plot the transition dynamics of the consumption of each model. The R&D increases the consumption, both in the long run and short run, by about 0.4 points across times in the Sunk-cost model with high R&D elasticity relative to that without R&D. In the Sunk-cost model, short-run and long-run consumption contribute to the increase in welfare gain. Also, the Sunk-cost models show the delayed overshoot of consumption dynamics. The consumption gradually increases, reaching a peak after 8 periods of trade liberalization, which is about 0.4 points higher than the long-run change. The consumption of the Sunk-cost model with low R&D elasticity shows a similar transition to that without R&D.

In the Fixed-cost model, the R&D has a small effect on the long-run consumption. The R&D increases the short-run change in consumption in the Fixed-cost model, but it has a small effect in the long run. The transition dynamics of the Fixed-cost model are flatter than the Sunk-cost model. Across the Fixed-cost models, the consumption at $t = 0$ is higher than the long-run consumption, and it gradually converges to the long-run level.

Manufacturing productivity and production labor are plotted in figure 4a and 4b, respectively. Those figures of the model with low R&D elasticity are illustrated in the figure 5. I will not mention the figure number of the model with low elasticity since their figures are in the same order as figures 4. The shape of the transition dynamics is similar to the consumption both in the Sunk-cost and Fixed-cost models. On the other hand, the size of change is different from the consumption, and R&D does not raise manufacturing productivity over time across models. The manufacturing productivity of the Sunk-cost model also shows the delayed overshoot, and it achieves the peak after 8 periods of trade liberalization. In contrast to the consumption, the manufacturing productivity does not increase at $t = 0$ since it is the state variable. The production labor increases in the initial period and gradually converges to the new steady-state level. Two transition dynamics reveal that production labor accounts for the increase in consumption by R&D as I discussed in the previous section.

Both consumption and manufacturing productivity grow gradually and show the overshoot in the Sunk-cost model. The short-run investment in R&D and export technology generates this shape of transition. Figures 4c illustrate the transition dynamics of research labor. In the short run, research labor increases and gradually converges to a new steady state. Hence, introducing R&D generates a new channel that reduces the short-run increase in production labor and consumption. Compared to the Sunk-cost model, the research labor weakly changes in the Fixed-cost model.

Figure 4d plots the trade to GDP ratio. The trade to GDP ratio of the Sunk-cost models gradually grows, which is not observed in the Fixed-cost model as shown in Alessandria and Choi (2014). It takes about 20 years to reach the long-run level after trade liberalization. Figure 4e plots the transition dynamics of trade elasticity. Trade elasticity also gradually increases after trade liberalization. In the Sunk-cost model, the long-run trade elasticity is about 7, while the short-run trade elasticity is about 4. This gradual trade expansion means a short-run increase in the investment in export technology, which reduces the short-run production of labor and consumption. The short-run and long-run trade elasticity of the Fixed-cost models is almost constant over time. The imported and domestic variety shows a similar transition as trade elasticity, which is shown in figure 4f[3].

Trade elasticity is decomposed into the trade cost change, productivity premium, $\frac{\bar{\Psi}_X}{\bar{\Psi}}$, and exporter ratio, $n_x$. Trade elasticity 9 is the change in imported goods share,

$$IMD = (1+\xi)^{1-\theta}(1+\tau)^{1-\theta}\frac{\bar{\Psi}_X}{\bar{\Psi}}\frac{N_x}{N}. \tag{15}$$

The change in the trade cost is the same across the models, while the change in the exporter ratio and productivity premium are different across the models. Figures 4g and 4h illustrate the exporter

[3] Because of the gradual decline in the mass of establishment in figure 4k, the variety also gradually decreases after it reaches the peak.

ratio and productivity premium, respectively. In contrast to trade elasticity, the long-run change in the exporter ratio of the Sunk-cost model with R&D is larger than that without R&D. The larger change in the exporter ratio arises from the increases in the persistence of productivity of continuing exporters in the Sunk-cost model with high R&D elasticity. Since continuing exporters are less productive than starting exporters, the productivity premium is small relative to the Sunk-cost model without R&D after trade liberalization.

Figure 4i plots the share of waiting firms of the Sunk-cost model with high R&D elasticity and that without R&D, which is the proxy of starter and stopper. The assumption of sunk cost and delayed exporting generates the gradual trade adjustment after trade liberalization. Since the firms start exporting rapidly, the labor used for the export cost also increases initially, which prevents the jump in consumption, and the consumption gradually reaches the peak after period 0. By contrast, the Fixed-cost models generate constant export dynamics, and the adjustment to trade liberalization occurs immediately.

The change in the share of waiting firms that start exporting in the Sunk-cost model with R&D is smaller than that without R&D. On the other hand, the change in the share of waiting firms that stop exporting in the model with R&D is smaller than that without R&D. Because of this, the labor demand for the startup is smaller, and that for the continuation is larger in the Sunk-cost model with high R&D elasticity than that without R&D. In the Sunk-cost model, individual firms' R&D changes the labor allocation related to the export extensive margin.

As I discuss, R&D enhances welfare gain from trade liberalization in the Sunk-cost model, but it reduces the gap between welfare gain and long-run consumption change. In addition to the short-run investment in export technology, the investment in R&D reduces the short-run production labor and consumption.

R&D has a small effect on aggregate productivity as well as manufacturing productivity. Figures 4j, 4k, and 4l illustrate the transition dynamics of the average productivity, mass of establishment, and aggregate productivity, respectively. In the Sunk-cost model with high R&D elasticity, the average productivity increases, and the mass of the establishments declines largely relative to the other models. Those large changes offset each other, and the aggregate productivity is similar to the Sunk-cost model without R&D. In the models without R&D, the average productivity converges to zero in the long run since the productivity dynamics are exogenous.

The change in the mass of establishments is important to understand the transition of consumption. In all models, the mass of establishments declines after trade liberalization. The R&D amplifies the decline of the mass of establishment both in the Sunk-cost and Fixed-cost models. The gradual decline in the mass of establishments implies the economy utilizes the over-accumulated capital soon after the trade liberalization. Thus, the initial several periods of consumption are larger than the long-run consumption, and we observe an overshoot of consumption.

The weak contribution of R&D to welfare gain in the Fixed-cost model is also discussed in Atkeson and Burstein (2010). On the other hand, their setup of numerical simulation assumes that the firms start as a non-exporter unlike the Fixed-cost model in this paper. In particular, entrants receive a small common productivity, and firms start their business as a non-exporter. They find that the difference in R&D elasticity matters to the long-run consumption change, but unlike the Sunk-cost model, it does not contribute to welfare gain. They show that it takes 100 periods for exports to reach the new steady-state level, and trade expansion has a small effect on welfare gain. In the Sunk-cost model, it takes about 20 years because of the persistent export decision and it has a significant effect on welfare gain.

Arkolakis et al. (2012) show that the gain from trade cost reduction is expressed by the trade elasticity, $\hat{C} = \hat{\lambda}/\varepsilon_T$. Here, I discuss the effect of R&D investment on their ACR formula. In the Sunk-cost model with high R&D elasticity, the ACR formula predicts 0.910% gain from trade liberalization, while it is 0.801% in the Sunk-cost model without R&D[4]. Hence, the ACR formula overstates welfare gain less than 10% when R&D is elastic unlike the model without R&D. This result shows that the ACR formula does not overstate the gain from trade liberalization than we expect when the economy has an elastic R&D against trade liberalization.

[Figure 3 about here.]

[Figure 4 about here.]

[Figure 5 about here.]

[4]Trade elasticity for the Sunk-cost model with high R&D elasticity is 7.403, for the Sunk-cost model without R&D is 7.342, for the Sunk-cost model with low R&D elasticity is 7.045, for the Fixed-cost model with high R&D elasticity is 4.687, for the Fixed-cost model without R&D is 4.626, and for the Fixed-cost model with low R&D elasticity is 4.637.

### 4.4 The flow startup cost

The continuous-time model with flow startup cost and lag generates a non-monotonic increase in consumption after trade liberalization. In figure 3a and 3b, the consumption increases at $t = 0$ when the agents realize the trade liberalization, which is higher than in the following several periods. Also, the production labor increases in the initial period, as shown in figure 4b and 5b. This feature is not observed if I assume the stock startup cost as Impullitti et al. (2013). Also, it is not observed in the discrete-time model as Alessandria and Choi (2014). With the flow startup cost and lag, the firms do not pay the startup cost when they decide to start exporting, while the firms pay the cost in the following periods until they start exporting. Thus, in period 0, the firms do not use the labor for startup costs. Instead, the economy utilizes labor to produce goods, raising consumption in period 0.

## 5 Conclusion

This paper develops a dynamic heterogeneous firm international trade model with two firm-level investments in export and productivity. I introduce three assumptions whose importance is emphasized in the literature: sunk export cost, delayed exporting, and endogenous innovation. I calibrate the model to fit the U.S. data and study the aggregate effect of an unanticipated tariff reduction. I find that adding elastic R&D to the Sunk-cost model boosts welfare gain by about 40%, while it is only about 2% in the Fixed-cost models. I decompose the welfare gain from trade liberalization and show that the increase in production labor accounts for the difference between the Sunk-cost model and the Fixed-cost model. R&D raises the gain of the exporters from trade liberalization, while it is weakly offset in the equilibrium in the Sunk-cost model. This result suggests that the lack of exporter dynamics underestimates the importance of R&D investment for the gain from trade liberalization.

## References

Alessandria, George, and Horag Choi (2014) 'Establishment heterogeneity, exporter dynamics, and the effects of trade liberalization.' *Journal of International Economics* 94(2), 207–223

Alessandria, George, Horag Choi, and Kim J Ruhl (2021) 'Trade adjustment dynamics and the welfare gains from trade.' *Journal of International Economics* 131, 103458

Alvarez, Roberto, and Ricardo A López (2005) 'Exporting and performance: evidence from chilean plants.' *Canadian Journal of Economics/Revue canadienne d'économique* 38(4), 1384–1400

Arkolakis, Costas, Arnaud Costinot, and Andrés Rodríguez-Clare (2012) 'New trade models, same old gains?' *American Economic Review* 102(1), 94–130

Atkeson, Andrew, and Ariel Tomas Burstein (2010) 'Innovation, firm dynamics, and international trade.' *Journal of political economy* 118(3), 433–484

Atkin, David, Amit K Khandelwal, and Adam Osman (2017) 'Exporting and firm performance: Evidence from a randomized experiment.' *The Quarterly Journal of Economics* 132(2), 551–615

Aw, Bee Yan, Mark J Roberts, and Daniel Yi Xu (2011) 'R&d investment, exporting, and productivity dynamics.' *American Economic Review* 101(4), 1312–44

Aw, Bee Yan, Mark J Roberts, and Tor Winston (2007) 'Export market participation, investments in r&d and worker training, and the evolution of firm productivity.' *World Economy* 30(1), 83–104

Baier, Scott L, and Jeffrey H Bergstrand (2007) 'Do free trade agreements actually increase members' international trade?' *Journal of international Economics* 71(1), 72–95

Bernard, Andrew B, and J Bradford Jensen (1999) 'Exceptional exporter performance: cause, effect, or both?' *Journal of international economics* 47(1), 1–25

Bloom, Nicholas, Mirko Draca, and John Van Reenen (2016) 'Trade induced technical change? the impact of chinese imports on innovation, it and productivity.' *The review of economic studies* 83(1), 87–117

Boehm, Christoph E, Andrei A Levchenko, and Nitya Pandalai-Nayar (2023) 'The long and short (run) of trade elasticities.' *American Economic Review* 113(4), 861–905

Broda, Christian, and David E Weinstein (2006) 'Globalization and the gains from variety.' *The Quarterly journal of economics* 121(2), 541–585

Buera, Francisco J, and Ezra Oberfield (2020) 'The global diffusion of ideas.' *Econometrica* 88(1), 83–114

Bustos, Paula (2011) 'Trade liberalization, exports, and technology upgrading: Evidence on the impact of mercosur on argentinian firms.' *American economic review* 101(1), 304–340

Costantini, James A, and Marc J Melitz (2008) *The dynamics of firm-level adjustment to trade liberalization* (Harvard University Press)

Das, Sanghamitra, Mark J Roberts, and James R Tybout (2007) 'Market entry costs, producer heterogeneity, and export dynamics.' *Econometrica* 75(3), 837–873

Davis, S.J., Haltiwanger J.C., and Schuh S. (1998) *Job Creation and Destruction* (MIT Press)

Dixit, Avinash (1989) 'Entry and exit decisions under uncertainty.' *Journal of political Economy* 97(3), 620–638

Dunne, Timothy, Mark J Roberts, and Larry Samuelson (1989) 'The growth and failure of us manufacturing plants.' *The Quarterly Journal of Economics* 104(4), 671–698

Eaton, Jonathan, and Samuel Kortum (2002) 'Technology, geography, and trade.' *Econometrica* 70(5), 1741–1779

Grossman, Gene M, and Elhanan Helpman (1993) *Innovation and growth in the global economy* (MIT press)

Impullitti, Giammario, Alfonso A Irarrazabal, and Luca David Opromolla (2013) 'A theory of entry into and exit from export markets.' *Journal of International Economics* 90(1), 75–90

Impullitti, Giammario, and Omar Licandro (2018) 'Trade, firm selection and innovation: The competition channel.' *The Economic Journal* 128(608), 189–229

Krugman, Paul (1980) 'Scale economies, product differentiation, and the pattern of trade.' *The American Economic Review* 70(5), 950–959

Lileeva, Alla, and Daniel Trefler (2010) 'Improved access to foreign markets raises plant-level productivity… for some plants.' *The Quarterly journal of economics* 125(3), 1051–1099

Loecker, Jan De (2013) 'Detecting learning by exporting.' *American Economic Journal: Microeconomics* 5(3), 1–21

Melitz, Marc J (2003) 'The impact of trade on intra-industry reallocations and aggregate industry productivity.' *econometrica* 71(6), 1695–1725

Perla, Jesse, Christopher Tonetti, and Michael E Waugh (2021) 'Equilibrium technology diffusion, trade, and growth.' *American Economic Review* 111(1), 73–128

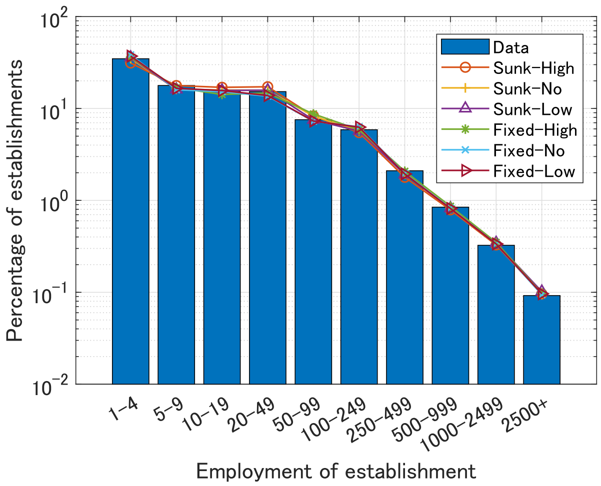
Rubini, Loris (2014) 'Innovation and the trade elasticity.' *Journal of Monetary Economics* 66, 32–46

Sampson, Thomas (2016) 'Dynamic selection: an idea flows theory of entry, trade, and growth.' *The Quarterly Journal of Economics* 131(1), 315–380

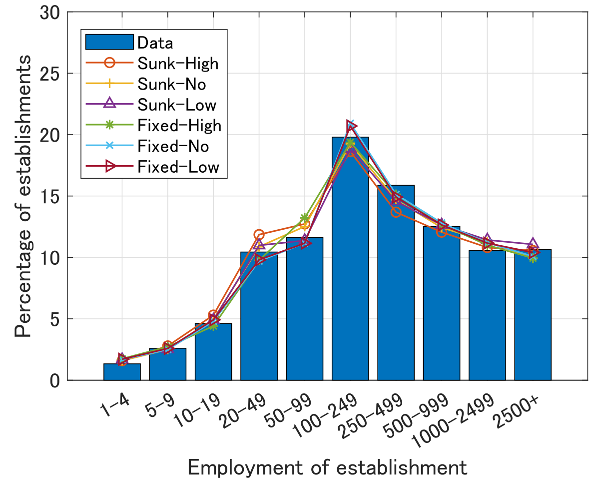
Yilmazkuday, Hakan (2019) 'Estimating the trade elasticity over time.' *Economics Letters* 183, 108579

Figure 1: Steady state distribution and policy function

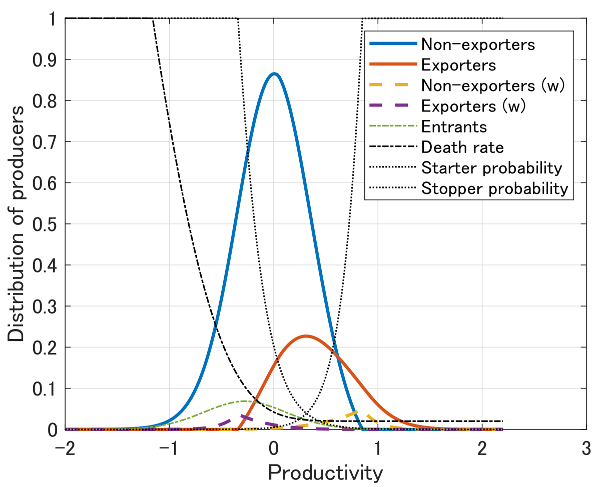
(a) Distribution of establishment




(b) Distribution of employment




(c) Stationary distribution




(d) R&D cost

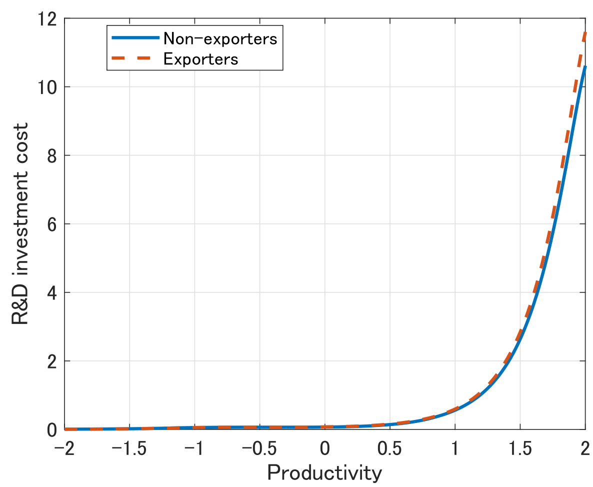
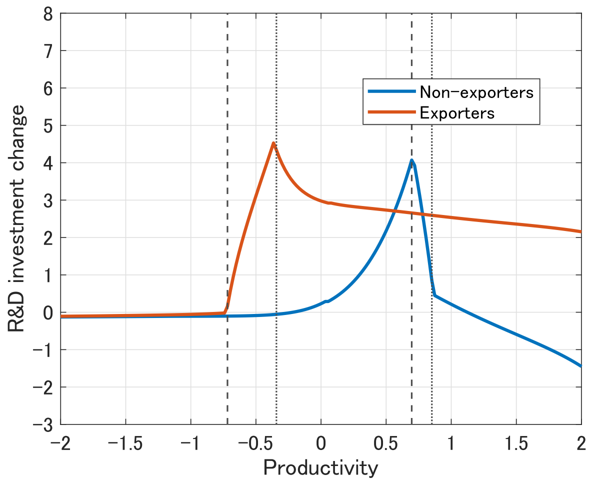
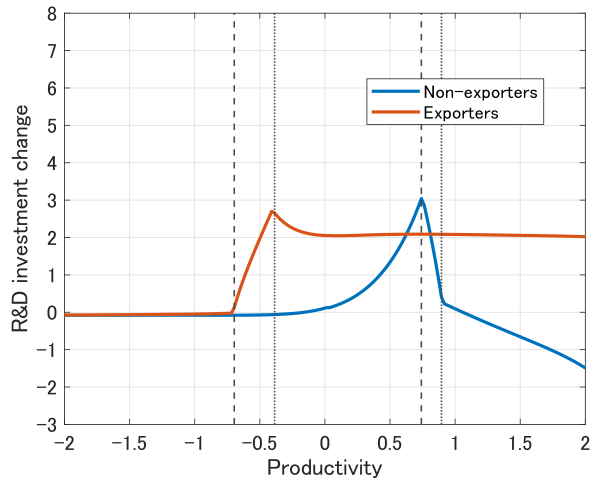


Figure 2: Change in the R&D investment

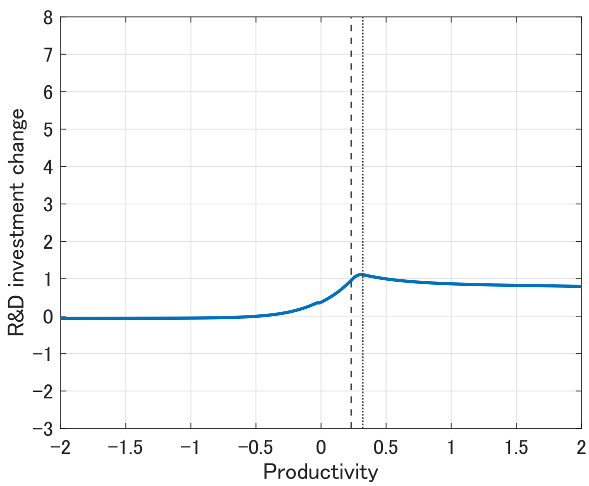
(a) Sunk-cost (High)




(b) Sunk-cost (Low)




(c) Fixed-cost (High)




(d) Fixed-cost (Low)

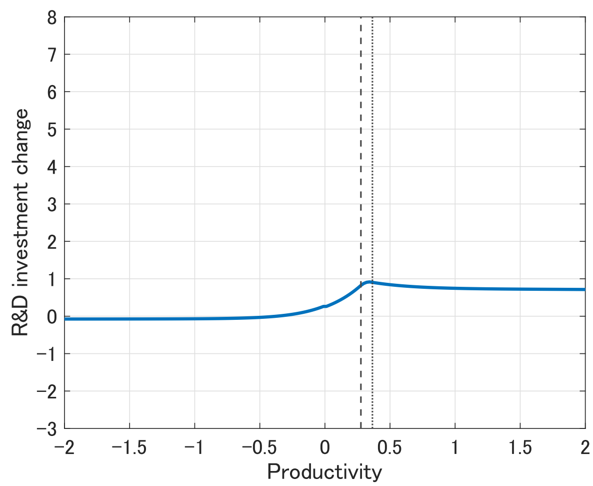
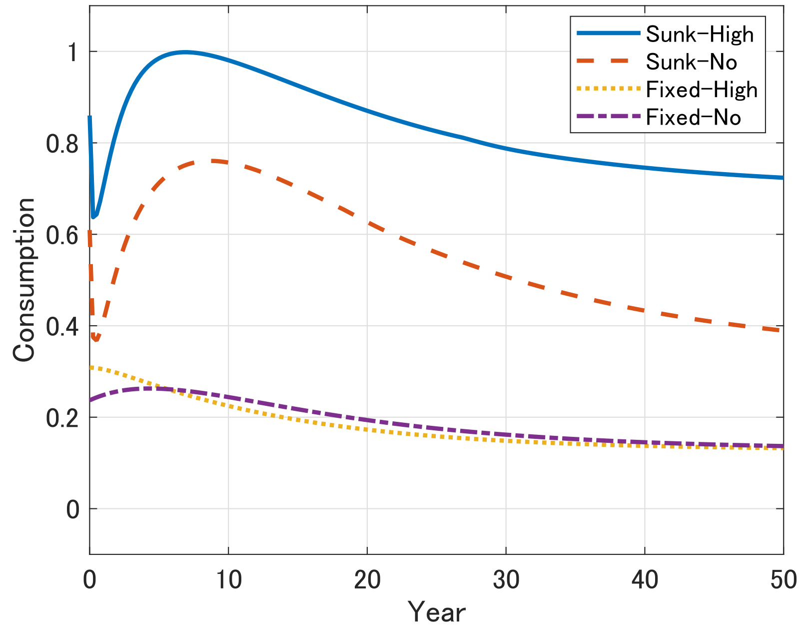


Figure 3: Transition of consumption after 8% tariff reduction

(a) High R&D elasticity




(b) Low R&D elasticity

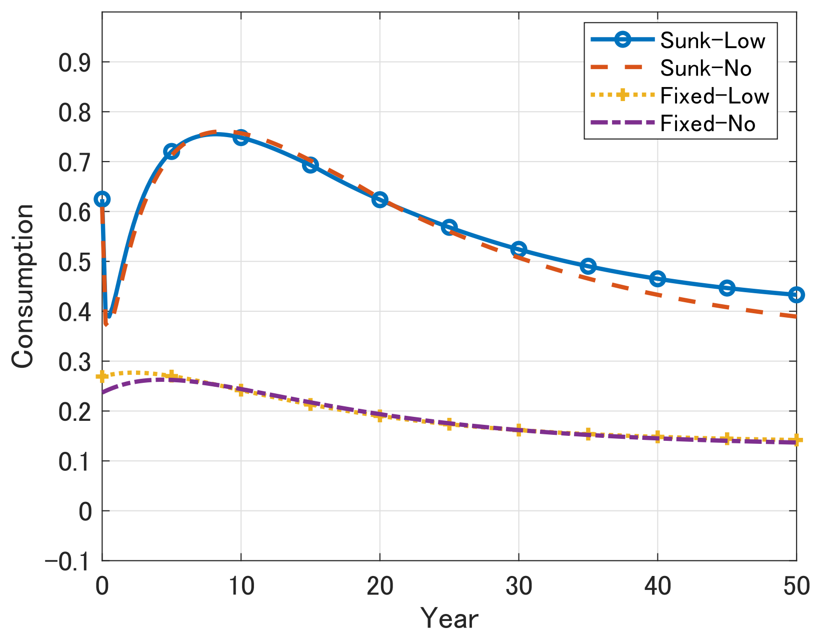


Figure 4: Transition dynamics after 8% tariff reduction

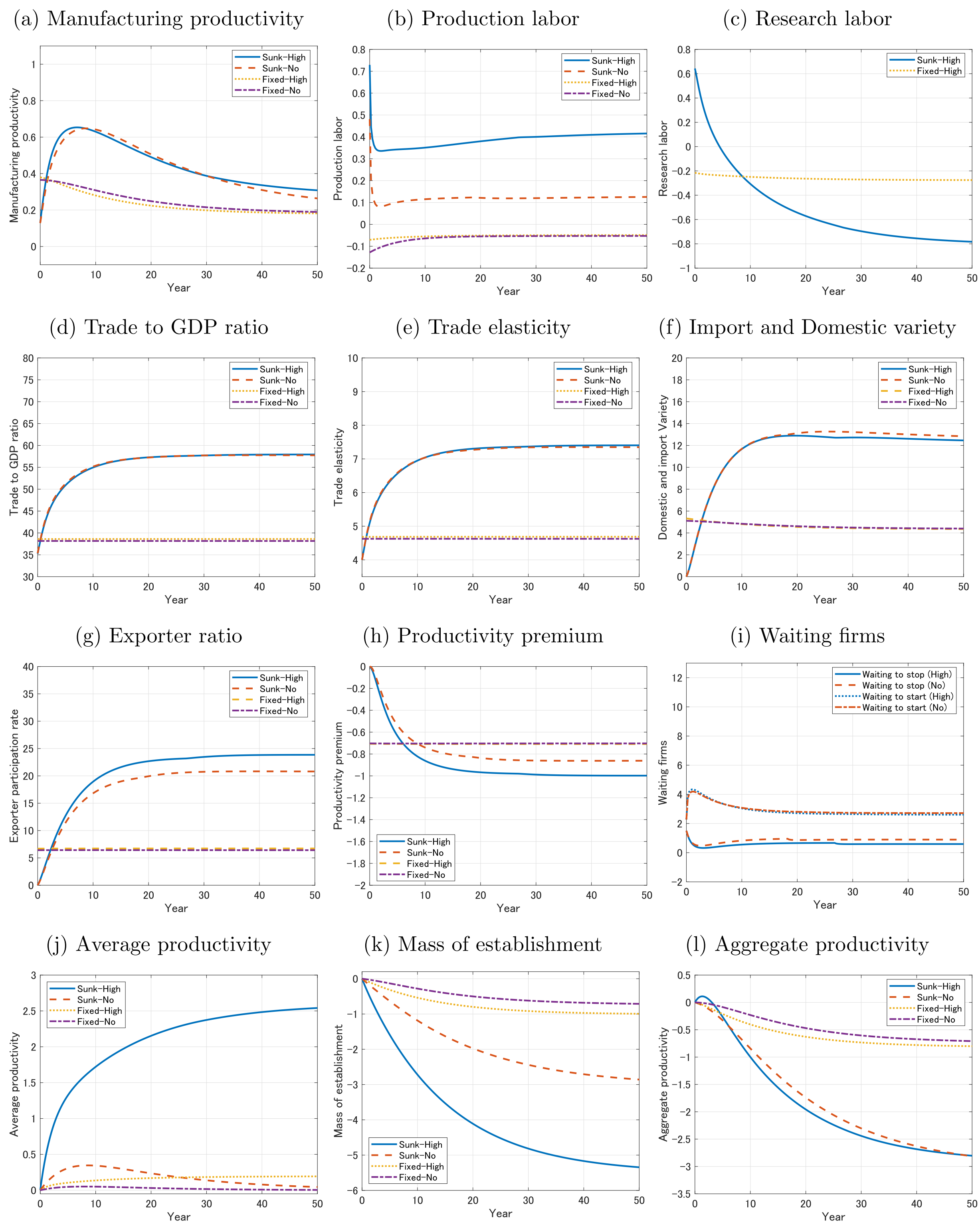


Figure 5: Transition dynamics after 8% tariff reduction with low R&D elasticity

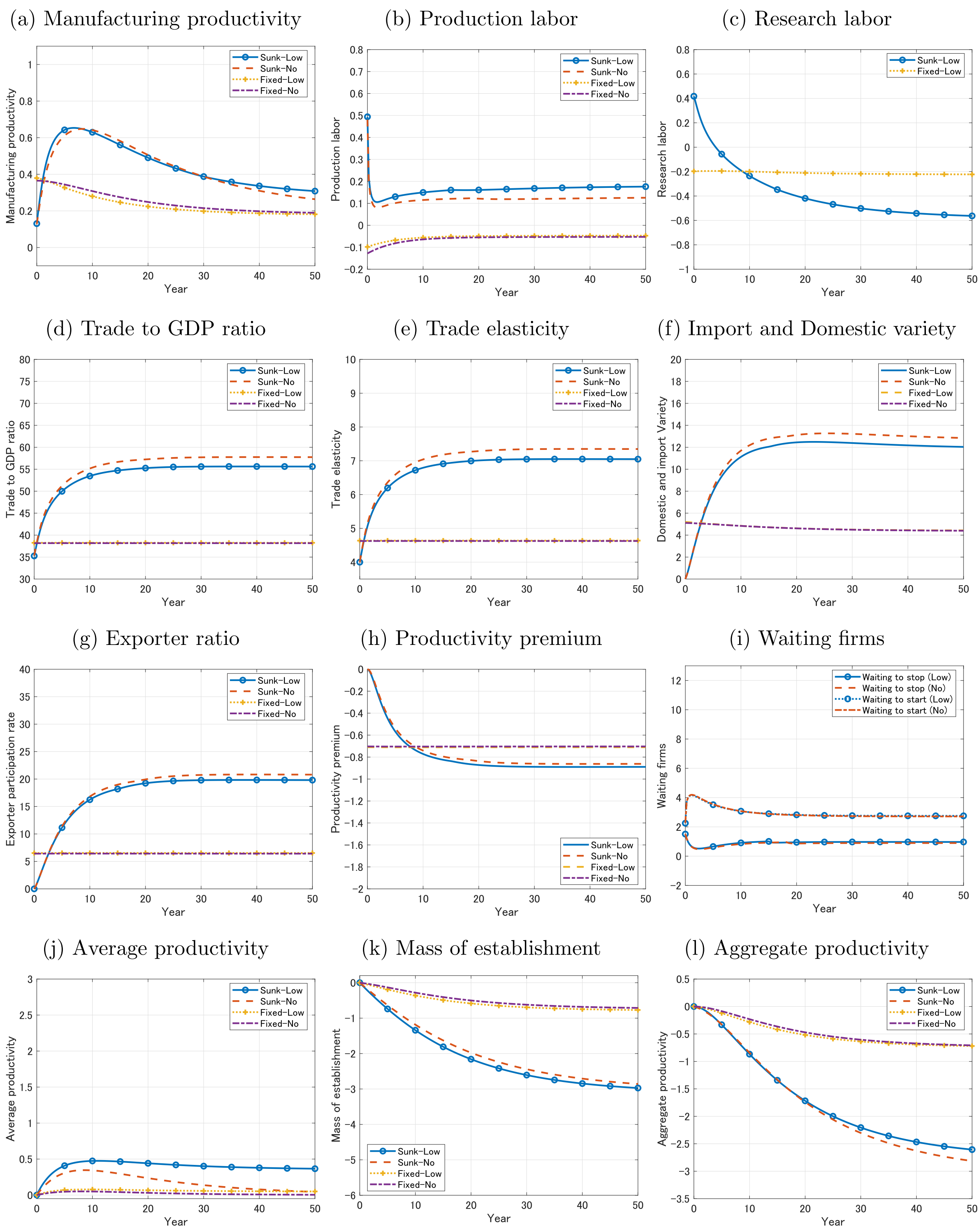


Table 1: Parameter values and Target moments

| A. Common Parameters | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | $\rho$ | $\theta$ | $\gamma$ | $\tau$ | | |
| | | 0.04 | 5.0 | 1 | 0.08 | | |
| **B. Model Parameters** | | | | | | | |
| | | Sunk | Sunk | Sunk | Fixed | Fixed | Fixed |
| R&D elasticity | | High | No | Low | High | No | Low |
| Startup cost | $f_0/f_1$ | 7.158 | 7.476 | 7.947 | - | - | - |
| Continuation cost | $f_1$ | 0.019 | 0.021 | 0.019 | 0.023 | 0.023 | 0.022 |
| Iceberg cost | $\xi$ | 0.451 | 0.451 | 0.451 | 0.451 | 0.451 | 0.451 |
| Death rate | $\lambda_D$ | 5.520 | 6.650 | 5.787 | 6.081 | 6.372 | 5.712 |
| | $n_{d0}$ | 0.020 | 0.023 | 0.019 | 0.021 | 0.022 | 0.021 |
| Entry disadvantage | $\mu_E$ | -0.277 | -0.369 | -0.249 | -0.406 | -0.424 | -0.237 |
| Entry cost | $f_E$ | 1.626 | 2.822 | 2.446 | 1.120 | 1.635 | 1.418 |
| Productivity persistence | $\alpha$ | 0.165 | 0.292 | 0.242 | 0.610 | 0.722 | 0.442 |
| Productivity SD | $\sigma_z$ | 0.307 | 0.332 | 0.324 | 0.512 | 0.528 | 0.427 |
| **C. Target moments** | Data | | | | | | |
| 5-year exit rate | 37.0 | 36.8 | 37.0 | 37.0 | 37.0 | 37.0 | 37.0 |
| Startups' labor | 1.5 | 1.4 | 1.5 | 1.8 | 1.6 | 1.4 | 1.6 |
| Exiters' labor | 2.3 | 2.1 | 2.4 | 2.4 | 2.4 | 2.4 | 2.3 |
| Stopper rate | 17.0 | 17.0 | 17.1 | 16.9 | 65.2* | 65.1* | 56.4* |
| Exporter ratio | 22.3 | 22.4 | 22.4 | 22.3 | 22.3 | 22.3 | 22.3 |
| Trade share | 13.3 | 13.3 | 13.3 | 13.3 | 13.3 | 13.3 | 13.3 |
| Distribution | | | | | | | |
| Establishments | | 1.417 | 0.630 | 0.639 | 0.766 | 1.354 | 0.971 |
| Employment | | 1.014 | 0.612 | 0.696 | 0.686 | 0.594 | 0.550 |

Note: Sunk and Fixed denote the Sunk-cost model and the Fixed-cost model, respectively. The value with * denotes the non-target moments. High represents the model with $\phi = 20$, Low represents the model with $\phi = 100$, and No represents the model with the exogenous productivity process.

Table 2: Consumption decomposition

| R&D elasticity | Sunk High | Sunk No | Sunk Low | Fixed High | Fixed No | Fixed Low |
|---|---|---|---|---|---|---|
| A. Discounted | | | | | | |
| $\hat{C}$ | 0.841 | 0.570 | 0.583 | 0.196 | 0.200 | 0.204 |
| $\hat{L}_p$ | 0.375 | 0.118 | 0.156 | -0.054 | -0.066 | -0.056 |
| $\frac{1}{\theta-1}\hat{\bar{\Psi}}$ | 0.463 | 0.048 | 0.096 | 0.036 | 0.007 | 0.015 |
| $\frac{1}{\theta-1}\hat{N}$ | -0.845 | -0.415 | -0.447 | -0.162 | -0.102 | -0.118 |
| $\frac{1}{\theta-1}\hat{\lambda}$ | -1.513 | -1.470 | -1.444 | -1.269 | -1.266 | -1.265 |
| $\hat{S}$ | -0.665 | -0.647 | -0.666 | -0.893 | -0.904 | -0.901 |
| $\hat{Z}_p$ | 0.466 | 0.452 | 0.425 | 0.265 | 0.247 | 0.272 |
| B. Long-run | | | | | | |
| $\hat{C}$ | 0.701 | 0.331 | 0.396 | 0.128 | 0.128 | 0.136 |
| $\hat{L}_p$ | 0.422 | 0.129 | 0.180 | -0.049 | -0.053 | -0.047 |
| $\frac{1}{\theta-1}\hat{\bar{\Psi}}$ | 0.650 | 0.000 | 0.088 | 0.049 | 0.000 | 0.012 |
| $\frac{1}{\theta-1}\hat{N}$ | -1.380 | -0.764 | -0.779 | -0.253 | -0.186 | -0.198 |
| $\frac{1}{\theta-1}\hat{\lambda}$ | -1.684 | -1.623 | -1.582 | -1.287 | -1.283 | -1.282 |
| $\hat{S}$ | -0.674 | -0.656 | -0.675 | -0.905 | -0.916 | -0.913 |
| $\hat{Z}_p$ | 0.279 | 0.202 | 0.216 | 0.177 | 0.181 | 0.183 |

Note: $Z_p$ represents the manufacturing productivity, where $Z_p = C/L_p$. Welfare gain is give by the value of $x$ that satisfies $\int_0^\infty e^{-\rho t}U(C_{-1}e^x)dt = \int_0^\infty e^{-\rho t}U(C_t)dt$, where $C_{-1}$ is the consumption level in the initial steady state. The values are shown in percent.

Table 3: Change in the labor allocation

| | | Sunk High | Sunk No | Sunk Low | Fixed High | Fixed No | Fixed Low |
|---|---|---|---|---|---|---|---|
| A. Discounted | | | | | | | |
| $\hat{L}_p$ | production | 0.288 | 0.094 | 0.123 | -0.045 | -0.057 | -0.048 |
| $\hat{L}_r$ | research | -0.045 | - | -0.009 | -0.015 | - | -0.004 |
| $\hat{L}_x$ | firm creation | -0.668 | -0.542 | -0.522 | -0.090 | -0.083 | -0.084 |
| $\hat{L}_e$ | export | 0.426 | 0.451 | 0.409 | 0.151 | 0.140 | 0.137 |
| $\hat{L}_0$ | startup | 0.100 | 0.123 | 0.122 | - | - | - |
| $\hat{L}_1$ | continuation | 0.326 | 0.328 | 0.287 | - | - | - |
| B. Long-run | | | | | | | |
| $\hat{L}_p$ | production | 0.324 | 0.103 | 0.141 | -0.041 | -0.046 | -0.041 |
| $\hat{L}_r$ | research | -0.093 | - | -0.018 | -0.016 | - | -0.004 |
| $\hat{L}_x$ | firm creation | -0.686 | -0.582 | -0.555 | -0.093 | -0.094 | -0.092 |
| $\hat{L}_e$ | export | 0.455 | 0.479 | 0.432 | 0.151 | 0.140 | 0.137 |
| $\hat{L}_0$ | startup | 0.045 | 0.069 | 0.076 | - | - | - |
| $\hat{L}_1$ | continuation | 0.410 | 0.410 | 0.356 | - | - | - |

Note: In the equilibrium, $L = L_p + L_r + Lx + L_c$. The export labor is the sum of startup and continuation labor, $L_e = L_0 + L_1$. The values are shown in level.