Technology, Geography, and Trade Over Time: The Dynamic Effects of Changing Trade Policy*

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Carter Mix
University of Rochester

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Abstract
I develop a multi-country heterogeneous firm model to study the aggregate effects of multilateral trade policy over time. The model captures the slow evolution of production and trade networks in response to trade policy as firms make durable and irreversible investments in source-specific productive capacity and destination-specific exporting capacity. It also incorporates capital, international assets, firms, and endogenous labor supply while still matching world geography. The model is calibrated to match size and trade flows of the US and its major trade partners as well as the split of trade between consumption, capital, and material goods. I find that the short run fluctuations in the economy following a policy change are a key determinant of the overall gains from trade and that transitions are not simply represented by gradual convergence to a new steady state. Futhermore, I find that the long-run effects of trade are poorly approximated by quantitative models without dynamics. While all the model features are important, the behavior of the domestic economy in the short- and long-run relies most on the semi-fixed trade networks and intertemporal trade incentives. The model is used to evaluate the effects on the US of being left out permanently or temporarily from a world trade liberalization. Being left out is quite costly, with losses in utility concentrated in the initial periods of the liberalization.

JEL classifications: F12, F13, F6.
Keywords: Trade policy, Heterogeneous firms

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1 Introduction

Given the current backlash against trade and the proposed unilateral and multilateral changes in trade policy, it has never been more important to understand these changes' aggregate effects on the macroeconomy. In this paper I study the dynamic impact of changes in trade policy in a multi-country model with non-trivial transitions arising from durable firm-level investments in productive and export capacity that is consistent with firm-level data on firm and export dynamics. My key contribution is to develop a parsimonious framework of firm dynamics, export destination investments, and trade policy that can capture the rich cross-country trade linkages while also incorporating the key features of macro models – capital accumulation, intertemporal borrowing and lending from incomplete financial markets, and endogenous labor supply - necessary for quantitative work. The model delivers dynamics that differ both qualitatively and quantitatively from existing trade models. To illustrate this, I use the model to show that trade liberalizations among foreign trade partners lower US welfare but generate short run strength in output. Temporary exclusion from foreign liberalizations, on the other hand, is recessionary in the short run.

A dynamic model of trade is useful for the analysis of trade policy in at least two ways. First, we know that economies take time to build up capital and productive or exporting capacity in response to policy. The model in this paper takes this into account and gives predictions not only about the overall effects of trade, but also how these effects change over time as the economy adjusts. Policymakers want to know how a certain policy will affect the economy in the next five years, ten years, etc. A dynamic model allows for that kind of analysis. Indeed, in this paper, we will see that the economic response in the short run can be much different than the long run response and that these adjustment margins are essential determinants in the overall gains from trade. Second, trade policy is not static. In a dynamic model, we can think carefully about the different effects of permanent and temporary changes in trade policy or changes that occur gradually. Indeed, the model presented here is general enough to consider the dynamic effects of any multilateral trade policy.

Contrary to previous multi-country models in the literature, my dynamic model of firm creation and exporting captures the idea that production and trade networks are mostly fixed in the short-run and involve substantial investments to reorganize. Specifically, the pattern of trade is determined by trade barriers and firms' investments to build factories around the world and then use these factories to export to many markets. It is well known that these investments in productive capacity and export linkages are long-lived with large upfront costs. While changing trade policy is costless, relocating factories and establishing new export patterns is costly and takes time. Previous work in two-country models emphasizes an important role of transitions from the dynamic firm creation and exporting margins and that long-run outcomes look different in a static model.[1] I build on these insights by introducing a much richer and realistic geography and more features common to business cycle analyses. This allows me to consider a broader range of unilateral and multilateral policies and adjustment margins and also accounts for the importance of asymmetries in size and trade flows on the quantitative effects.

To set ideas on the need for models with investment in productive and export capacity, it's useful to consider the automotive industry in Mexico and the United States. Before 1990, there were 8 active assembly plants in Mexico and in 1993, one year prior to NAFTA, they produced 2.7% of the total cars sold in the US. In 2014, the number of plants had grown to 18 and they supplied 17.4% percent of the US market. In the US, on the other hand, 20 automobile manufacturing plants have shut down since 1992 leaving 46 plants in operation and the fraction of cars bought and produced in the US has fallen from 76.4% to 72.8%.[2] Obviously, auto plants involve large upfront and somewhat irreversible investments over the

[1] See, for example, Alessandria and Choi (2014).

[2] See Klier et al. (2017) for more on the growth of the Mexican auto industry under NAFTA.

course of many years. So, a rise in trade barriers between Mexico and the US is likely to have a small impact on trade flows initially but have a large impact on the incentive to invest in new factories and reinvest in the capital stock of existing factories.

The effect of higher barriers with the US on Mexican auto plants depends on how Mexican exports to other countries such as the EU and South America will expand. These investments are quite destination-specific. In 2017, Mexican auto exports to the US accounted for 75% of total auto exports. Plants often produce only one model of car and those models are in higher demand in certain destinations. Reorganizing the Mexican auto industry to shift exports to Canada, Germany, or South America would require significant destination-specific investment. These costs imply that Mexican auto plants will be stuck exporting to the US in the short run in spite of higher costs.

These two channels - durable investments in productive capacity and destination-specific exporting capacity - are captured in the model with firms that make long-lived decisions regarding entry and exporting to each market. New firms must pay an initial fixed cost to begin producing. Investments to produce have been used to explore the importance of firm dynamics since Hopenhayn (1992), including trade models starting with Melitz (2003). Nonexporting producers similarly face high sunk costs to begin exporting in each destination market and lower costs to continue exporting in that market. These sunk costs have been studied extensively in the micro literature starting with a series of papers by Baldwin, Dixit, and Krugman.[3] The simplicity of the fixed cost structure across firms is crucial to keeping the model tractable. Even with these assumptions, the model has N^2 state variables related to firms and exporting relationships between countries. Long-lived decisions for entrants and potential exporters introduce additional margins to adjust in reaction to trade policy. Because these adjustments require real resources, they affect other macroeconomic variables

[3] In particular, see Baldwin (1988), Baldwin (1989), Baldwin and Krugman (1989), Dixit (1989a), and Dixit (1989b).

such as labor and consumption. It is precisely this mechanism that generates short run fluctuations so different from long run steady states.

The ability of the model to capture the relative size and trade flows of various countries is crucial to the macroeconomic response to changes in trade policy. To illustrate its importance, I perform a global liberalization under three different representations of the world: two-country symmetric, two-country asymmetric, and six-country asymmetric. In a symmetric world, each country experiences the same dynamics and has identical gains from trade. In the two-country asymmetric world, the smaller of the two countries experiences larger increases in both welfare and income as they import a larger share of total output and gain access to a larger market. This is consistent with other trade models with asymmetric countries such as Alvarez and Lucas (2007). The gains premium for small countries combined with the gradual accumulation of assets and exporters gives small countries an incentive to borrow initially. Thus, consumption and output grow faster relative to a world in financial autarky. Although the small country experiences lower welfare in the eventual steady state as it pays back debts accrued in the initial periods, the redistribution of consumption and leisure to initial periods results in higher overall gains. Compared to the symmetric case, both countries have lower gains from trade. The small country's gains decrease because of the lack of feedback. The large country has a low import share and its marginal cost is not affected much by the liberalization. As a result, their prices don't fall by much and the trade elasticity response for the small country is much weaker, generating smaller gains.

The two-country asymmetric model shows that country size relative to the world is important. The six-country asymmetric model shows that country size relative to average country size is also important. As the rest of the world is split into smaller countries, each of these countries experiences larger gains from the liberalization and wants to borrow initially. The higher world demand for debt raises interest rates and makes borrowing less attractive for a relatively large economy like the US, lowering the positive impact on output and welfare.

In addition, the global liberalization in the multi-country model introduces trade diversion, which further lowers the gains of any one country.

The effects of changing trade policy in the dynamic model are also strongly influenced by the inclusion of macroeconomic features such as matching end-use trade flows and endogenous labor.Matching end-use trade implies that trade is intensive in capital goods. With capital-intensive trade, the price of investment responds strongly to tariff decreases, amplifying capital deepening after a trade liberalization. Consumption responds less on impact but increased capital in the future leads to higher consumption in the long run. Endogenous labor allows the economy to respond to the increased demand for labor in a liberalized economy. As the number of exporters increase, the demand for labor for the fixed cost increases and agents respond by supplying more labor. With inelastic labor, the economy substitutes labor away from the production sector towards these fixed costs, lowering long run production and consumption. Both capital-intensive trade and endogenous labor increase the positive impact of a liberalization on both production and welfare.

After explaining the impact of model features in a global liberalization, I use the model to quantify the macroeconomic effect on the US of being left out of a world trade liberalization. Given the current administration's protectionist view toward further liberalization and the reaction of foreign countries, it's possible that the US will miss out on the next major liberalization of trade barriers. Indeed, in 2017, the US withdrew from the Trans Pacific Partnership (TPP), a proposed trade deal that included Canada, Mexico, and several important trade partners across the Pacific. The remaining member countries immediately drafted TPP-11, a similar trade deal that excludes the US. I show that such liberalizations yield welfare losses for the US but generate temporary booms in output and investment.

I calibrate a six-region version of the model to match the US and its major trading partners and assume 10% bilateral tariffs between all country pairs. The world trade liberalization is simulated by immediately and permanently eliminating tariffs between all country pairs that do not include the US. When tariffs drop, liberalization participants recognize that future wealth is high. In the current period, there are strong incentives to consume, take leisure, and invest in both capital and the stock of exporters in other liberalizing countries. They free up resources by disinvesting in domestic varieties and exporting capacity to the US, and by borrowing.

Large world demand for debt makes the real interest rate increase and the US saves on impact. The US also takes advantage of the fixed trade network to invest more today, recognizing that prices will increase in the future as liberalization participants shift resources to building export capacity between each other. Initial lending and investment lead the US to produce more but to forego consumption and leisure on impact, with consumption falling by about 1%. Continued lending in the medium run keeps consumption low and it only begins to recover after about six years. Overall, the consumption equivalent cost to the US of being left out of the liberalization is 0.17%, or about $1500 of present value consumption for each consumer. This loss is equivalent to that generated by unilaterally raising tariffs on all trade partners from 10% to 14%. Despite overall losses, high lending in the short run increases US bond holdings and allows for higher welfare in the long run. Comparing welfare across steady states yields a welfare *gain* of 0.16%. In other words, the reduction in utility is concentrated in initial periods, with higher utility moving from one steady state to another. A similar calibration in a static Eaton-Kortum model yields a welfare cost of 0.07%, about 40% of the dynamic cost, with no information on when these losses occur. I analyze the relative importance of various model features in generating the observed dynamics. The reversal in welfare implications is driven by risk-free bonds and foreign demand for debt. The persistence and magnitude of losses is driven by the dynamic exporting decision as it slows down the growth of trade and production in foreign countries and extends the time for which they borrow. A key takeaway from this analysis is that although US inward and outward trade costs do not change, there are substantial effects on the macroeconomy that a static model ignores. Foreign trade policy affects the domestic economy.

Lastly, I show that expectations about future changes in trade policy can have large effects on the current US economy. Taking advantage of the dynamic nature of the model, I consider the effects of temporary exclusion from a worldwide liberalization under perfect foresight. Because agents know they will be included and therefore have higher wealth in the future, they act today to take full advantage of the liberalization. For example, domestic agents know that the price of investment will be low in the future and therefore delay capital investment to the future and take more leisure today, generating a recession in the short run. Investment in exporters and disinvestment in domestic varieties, on the other hand, starts immediately. Thus, when the liberalization occurs consumption and output grow much faster as the economy substitutes towards the cheaper foreign goods more quickly. Compared to immediate and permanent inclusion, temporary exclusion can be somewhat costly but it is less costly in a model with firm and exporter dynamics as these margins adjust in anticipation of inclusion.

1.1 Related Literature

The model relates to three branches in the literature: static trade, dynamic trade, and international real business cycles (IRBC). The static trade literature embodies the prevailing *modus operandi* for studying the aggregate effects of trade policy. A seminal paper in this literature is Eaton and Kortum (2002) (EK), which introduces a static model of trade in which world asymmetries in size and trade flows can easily be modeled and illustrates how this heterogeneity matters for the effects of trade policy. Since then, several variations of the model have been developed to explore variation in the gains from trade across sectors, workers, regions, etc. Analysis of policy in these models are done from one equilibrium to another, with no notion of time or a transition of the economy.

The IRBC literature recognizes that the dynamics prevalent in the macroeconomics literature are important for aggregate fluctuations in the open economy. Backus et al. (1992) introduce capital and financial markets between countries into an otherwise Armington-type model and find that the model can capture several empirical regularities in the data. Several papers have been written that incorporate IRBC dynamics into otherwise static models of trade such as EK. Alvarez (2017), Eaton et al. (2016) and Ravikumar et al. (2018) show that endogenous capital accumulation generates larger gains from trade than a purely static model. Furthermore, they predict a gradual transition of the economy such that the gains from the initial to the terminal steady state overstate the gains from trade that account for the transition. Eaton et al. (2016), Fitzgerald (2012), Ravikumar et al. (2018), and Reyes-Heroles (2016) incorporate financial markets into an EK model. Reyes-Heroles (2016) shows that changes in trade costs are an importance source of changes in trade imbalances. I also find that capital accumulation increases the gains from trade and that trade policy has strong effects on trade imbalances both in the short run and the long run. To these papers, I add heterogeneous firms and firm dynamics, which leads to very different dynamics. I also add other elements from the IRBC literature such as capital-intensive trade[4] and endogenous labor. I find that both of these elements increase the overall gains from a trade liberalization. These papers mostly focus on how dynamic elements change long-run or overall outcomes (gains from trade) of a global liberalization. My paper instead focuses on the dynamic transition in response to policy and considers different types of policy experiments.

The dynamic trade literature studies both empirically and methodologically the effects of trade policy and trade costs on trade over time. Baier and Bergstrand (2007) show that the increases in trade from trade agreements are large, but that they can take 10 to 15 years to materialize. Jung (2012) shows that the long run response of trade to a

[4]Capturing the split of trade between capital and consumption goods has been shown to be important for macroeconomic flucations. See Boileau (1999), Boileau (2002), and Engel and Wang (2011).

trade agreement is about three times the response on impact, even controlling for tariff phaseouts. Das et al. (2007) find evidence of large "sunk costs" paid by firms to produce in foreign markets. These sunk costs generate exporter hysteresis and make entry into exporting more difficult. Alessandria and Choi (2007) add this sunk cost into a Melitz-type (Melitz (2003)) general equilibrium heterogeneous firm model of trade to generate a dynamic trade elasticity and examine the implications for business cycles. Alessandria and Choi (2014) use the same sunk cost and show that a dynamic trade elasticity changes the macroeconomic effects of trade policy. In particular, a global liberalization of tariffs leads to large gains initially as economies substitute away from domestic varieties and towards foreign varieties. The models with dynamic trade elasticities are generally confined to only two symmetric countries, ignoring the impact cross-sectional heterogeneity and making analysis of many multilateral trade policies impossible.[5] My paper generalizes a dynamic trade model to include multiple countries and to match asymmetries in size and trade flows. The multi-country generalization is useful to examine the importance of asymmetries and third-party effects, and to explore a wider range of relevant trade policy changes. I also add endogenous labor and capital-intensive trade to these frameworks, which have important implications both for dynamics and for the overall impact of trade policy.

All of these papers mainly focus on a few types of trade policy: global, multilateral, or unilateral liberalizations of tariffs or trade costs. The model in this paper opens the door to studying more relevant and modern changes in trade policy. Because it is dynamic with semi-fixed production and trade networks, the model can be used to study the dynamic effects of changes in trade policy that are expected or unexpected, permanent or temporary, phased-in or sudden, etc. Because it can include multiple countries, it can be used to study multilateral changes in trade policy and third-party effects. In this paper, for instance, I

[5] An important exception to this is Steinberg et al. (2017) which introduces a three country model of exporting to analyze the impact of Brexit and trade uncertainty on the UK. My model is instead for an arbitrary number of countries.

explore the effects of being excluded from a foreign trade liberalization either permanently or temporarily. To my knowledge, such an experiment has not been performed in a dynamic setting and the results are much different than those from a static EK model.

2 Model

Let $\mathbb{C}$ be the set of countries in the world. Each country i in $\mathbb{C}$ has a representative consumer that chooses her optimal labor supply, capital investment, and holdings of an internationally-traded risk-free bond in each period subject to a budget constraint.

In each country nontraded final goods are produced by competitive firms that combine domestically produced and imported intermediate inputs and domestic labor. The CES aggregation technology differs in the intensity with which foreign inputs and domestic labor are used. For consumption goods, more labor and less foreign intermediates are required while investment and material inputs will require less labor and more foreign intermediates. Thus, the model replicates the empirical feature documented by Boileau (1999) that trade is intensive in capital. Indeed, in the calibration of the model I match end use trade shares of capital, consumption, and intermediate goods.

In each country a mass of monopolistically competitive firms produce differentiated varieties using domestic labor, capital, and materials. To export a firm must pay a destination-specific fixed cost denominated in domestic labor. The fixed costs faced by current exporters to a specific destination is lower on average than the fixed costs for current nonexporters. To keep the model tractable, I assume that firms are homogeneous in productivity but differ in the portfolio of fixed costs they face to export their goods to foreign countries. Firms draw these fixed costs for each period and for each destination from an iid distribution. To capture the persistent nature of the exporting decision and durable investments in exporting capacity, I assume that current exporters to a destination draw from a distribution that is first order stochastic dominated by the distribution for nonexporters as in Alessandria et al. (2013). This type of shifting distribution is present in nearly all structural analyses of producer level exporter dynamics.

The mass of firms in each country is determined by a free entry decision and an exogenous exit probability. Entrants pay a fixed cost denominated in labor and begin producing starting in the next period. Exporting fixed costs are not drawn until the period production starts, so firms cannot export in their first period of production. The mass of entrants is determined by a free entry condition that equates the fixed cost of entry with the expected lifetime profit of the firm. All intermediate goods producers face an exogenous probability of survival less than one in each period. Previous work finds that the aggregate effects of trade policy are quite similar in models of exogenous and endogenous exit (see Arkolakis et al. (2012)).

2.1 Consumers

Each country i has a representative consumer that chooses labor L_i, investment X_i, and holdings of a risk-free bond B_i to maximize expected discounted utility

$$\sum_{t=0}^{\infty} \beta^t U(C_{it}, \bar{L}_i - L_{it})$$

subject to a budget constraint and the capital law of motion

$$P_{it}C_{it} + P_{Xit}X_{it} + Q_t B_{i,t+1} \leq W_{it}L_{it} + R_{it}K_{it} + B_{it} + \Pi_{it} + T_{it}$$

$$X_{it} = K_{i,t+1} - (1-\delta)K_{it}$$

where β is the discount factor; C_{it} is consumption; P_{it} is the price of consumption for country i; P_{Xit} is the price of investment; Q_t is the worldwide price of the bond; B_{it} is the amount of the bond carried into period t in units of the country 1 consumption good; W_{it} and R_{it} denote the wage rate and rental rate of capital; K_{it} is capital; Π_{it} is profits from home producers; T_{it} are lump sum transfers from tariff revenues; and δ is the depreciation rate.

The solution to the problem includes an intratemporal condition for labor

$$\frac{U_C}{P}W = U_L$$

and two intertemporal conditions for investment in capital (Euler condition) and the risk free bond

$$\frac{U_C}{P}P_X = \beta\mathbb{E}\frac{U_{C'}}{P'}[R' + P'_X(1-\delta)]$$
$$\frac{U_C}{P}Q = \beta\mathbb{E}\frac{U_{C'}}{P'}[1 - \phi(B' - \bar{B_C})]$$

where U_x denotes the derivative of the utility function with respect to x. We introduce a small adjustment costs on bond holdings, $\phi(B' - \bar{B_C})$, to keep the model stationary. Additionally, we can calibrate the cross-country distribution of net foreign assets. The no arbitrage condition is obtained by realizing that the bond price Q is the same across countries in time t.

2.2 Final Goods Firms

Each country consists of three types of final goods firms with each type having a continuum of firms of mass one. Each type of final goods firm produces either consumption C, investment X, or materials M using domestic and foreign intermediates and domestic labor. The mix of inputs allows me to be consistent with the ratio of gross output to value added for different final goods. I assume that these firms act competitively and present the problem for a representative firm. Consider a representative final good producer of good $G \in \{C, X, M\}$ in country i. The firm chooses labor L_{Gi} and intermediates $\{\{G_{ji}(f)\}_{\Omega_{ji}}\}_{j\in\mathbb{C}}$ where f indexes firms and Ω_{ji} is the set of firms in country j that export to country i to maximize

$$P_{Gi}G_i - \sum_{j\in\mathbb{C}} \tau_{ji}P_{ji}G_{ji} - W_iL_{Gi}$$

subject to the following aggregation technologies

$$G_i = \left[\left(\sum_j \omega_{Gji}^{\frac{1}{\gamma}} G_{ji}^{\frac{\gamma-1}{\gamma}} \right)^{\frac{\gamma}{\gamma-1}} \right]^{\alpha_G} L_{Gi}^{1-\alpha_G}$$

$$G_{ji} = \left[\int_{f \in \Omega_{ji}} G_{ji}(f)^{\frac{\theta-1}{\theta}} df \right]^{\frac{\theta}{\theta-1}}$$

where $\tau_{ji} - 1$ is the tariff imposed on goods moving from j to i and I assume τ_{ii}=1; ω_{Gji} is the Armington weight country i places on goods of type G from country j and $\sum_j \omega_{Gji} = 1$; γ is the elasticity of substitution between bundles of intermediates from different countries (the Armington elasticity); θ is the elasticity of substitution between varieties within the same country and I assume $\theta > \gamma$; and $G_{ji}(f)$ is the quantity of goods shipped from j to i by firm f. Note that the Armington weights differ by the type of good being produced. In the calibration, I use these weights to make capital and material final goods require a higher share of foreign inputs. The Cobb-Douglas share for intermediates in production α_G also varies by type of good to match gross output to value added for different final goods.

The firm will choose labor so that the wage bill is equal to the share $1 - \alpha_G$ of total revenue. Demand for a bundle of intermediates from country j is given by

$$G_{ji} = \left(\frac{\tau_{ji} P_{ji}}{\tilde{P}_{Gi}} \right)^{-\gamma} \omega_{Gji} \tilde{G}_i$$

where

$$\tilde{P}_{Gi} = \left[\sum_j \omega_{Gji} (\tau_{ji} P_{ji})^{1-\gamma} \right]^{\frac{1}{1-\gamma}}$$

is the standard CES price index and

$$\tilde{G}_i = \left(\sum_j \omega_{Gji}^{\frac{1}{\gamma}} G_{ji}^{\frac{\gamma-1}{\gamma}} \right)^{\frac{\gamma}{\gamma-1}}$$

is the bundle of intermediate goods from all countries used by country i. Demand for individual goods sold by firm f is given by

$$G_{ji}(f) = \left[\frac{P_{ji}(f)}{P_{ji}} \right]^{-\theta} G_{ji}$$

where

$$P_{ji} = \left[\int_{f \in \Omega_{ji}} P_{ji}(f)^{1-\theta} df \right]^{\frac{1}{1-\theta}}.$$

The aggregate price of good G can be determined by recognizing that expenditure on intermediates is a constant fraction α_G of total revenues and will be a function of the price of intermediates $\tilde{P}_{Gi}$ and the wage W_i.

2.3 Intermediate Goods Firms

Let f index an intermediate goods (IG) firm in country i. Production of IG firm f is

$$y(f) = z_i(k(f)^{\alpha} l(f)^{1-\alpha})^{1-\alpha_m} m(f)^{\alpha_m}.$$

IG firms are monopolistically competitive and face the downward-sloping demand curve from the final goods firms. Firms choose prices in each destination where they produce so that total demand is equal to supply. Though intermediates are destined for various end uses, I assume that there is nothing different about the intermediates when they are shipped.

In each period, IG firms face both a static and a dynamic problem. At the beginning of the period, firms in country i are differentiated by their export status $e_{ij}(f)$ in each destination j and by the vector of exporting fixed costs $\{\kappa_{ij}(f)\}_{j \neq i}$ that they draw. Given today's export status, firms make a static decision choosing capital $k_i(f)$, labor $l_i(f)$, materials $m_i(f)$, and destination-specific prices $p_{ij}(f)$ to maximize current profits. The firm must then decide whether to pay any of the destination-specific fixed costs to export tomorrow. To capture the persistence of the exporting decision we see in the data, I assume that firms exporting to destination j today draw fixed costs from a distribution $F_{1,ij}$ that is first order stochastic dominated by the distribution from which the nonexporters draw $F_{0,ij}$. In other words, exporters draw lower fixed costs on average and are thus more likely to export in the future. This added benefit to exporting introduces a tradeoff where firms may choose to have negative net profits from exporting to be more likely to export in the future. I assume

$F_{1,ii}$ is degenerate at $\kappa = 0$; all firms produce domestically.

The recursive problem for an IG firm f in country i is

$$V(\{\kappa_{ij}(f), e_{ij}(f)\}_j) = \max_{l_i(f), k_i(f), m_i(f), \{p_{ij}(f), e_{ij}(f)'\}_{j \neq i}} \left[\sum_{j \in \mathbb{C}} e_{ij}(f) p_{ij}(f) \sum_{G} G_{ij}(f) - e_{ij}(f)' W_i \kappa_{ij}(f) \right]$$
$$-W_i l_i(f) - R_i k_i(f) - P_{M,i} m_i(f) + \beta n_s \mathbb{E} D_{t+1} V(\{\kappa_{ij}(f)', e_{ij}(f)'\}_{j \neq i})$$

subject to the demand functions from final goods firms throughout the world and the production technology. D_{t+1} denotes the subjective discount factor $u_{C'}/u_C$ and n_s is a constant probability of survival. Recall that $\kappa_{ij}(f)$ is drawn from the distribution $F_{e_{ij}(f),ij}$.

Since the production function is constant returns to scale, we can break up the problem into a separate problem for each destination. This is a key assumption for tractability. Without it, firm input decisions depend on the export status vector with 2^{J-1} possibilities where J is the total number of countries in $\mathbb{C}$. As written, the model implies that for each destination j, firm f in country i chooses inputs $l_{ij}(f)$, $m_{ij}(f)$, and $k_{ij}(f)$, price $p_{ij}(f)$ and future export status $e_{ij}(f)'$ to maximize the discounted present value of profits earned by selling to destination j.

The first order conditions of the static problem are familiar. Prices p_{ij} are a constant markup over the marginal cost

$$p_{ij}(f) = \frac{\theta}{\theta - 1} MC_i = \frac{\theta}{\theta - 1} \frac{1}{z_i} \left(\frac{R_i}{\alpha(1 - \alpha_m)} \right)^{\alpha(1-\alpha_m)} \left(\frac{W_i}{(1-\alpha)(1-\alpha_m)} \right)^{(1-\alpha)(1-\alpha_m)} \left(\frac{P_{M,i}}{\alpha_m} \right)^{\alpha_m}.$$

Since firms are homogeneous in productivity, all firms have the same marginal cost and the same prices in each market, conditional on producing in said market. Inputs are chosen so that

$$W_i l_{ij}(f) = MC_i (1 - \alpha)(1 - \alpha_m) y_{ij}(f)$$
$$R_i k_{ij}(f) = MC_i \alpha (1 - \alpha_m) y_{ij}(f)$$

and

$$P_{M,i}m_{ij}(f) = MC_i\alpha_m y_{ij}(f)$$

where $y_{ij}(f) \equiv \sum_G G_{ij}(f)$. Adding up over all destinations in which a firm produces would gives the total inputs of the firm, which will vary based on the markets in which the firm produces. The static problem solves for the optimal profit net of fixed costs π_{ij} of a country i firm operating in country j.

In the current period, the firm also chooses tomorrow's export status. Let $V_{e_{ij},ij}$ be the value of a firm with current export status e_{ij}. Since exporting cannot begin until the next period, the current profits are unaffected by the export decision and the dynamic problem can be written

$$V^d(\kappa_{ij}) = \max\{n_s\mathbb{E}D'V'_{0,ij}, -W_i\kappa_{ij} + n_s\mathbb{E}D'V'_{1,ij}\}.$$

In words, you choose to either pay the fixed cost and begin next period as an exporter or you begin the next period as a nonexporter. Since exporting yields positive profits and a higher chance of positive profits in the future, we know $V'_1 > V'_0$ so there exists κ^*_{ij} such that

$$W_i\kappa^*_{ij} = n_s\mathbb{E}D'(V'_{1,ij} - V'_{0,ij}).$$

In words, κ^*_{ij} is the fixed cost that would make a country i firm indifferent between exporting and not exporting to country j. Firms f that draw $\kappa_{ij}(f) \leq \kappa^*_{ij}$ will find it optimal to pay the fixed cost and begin exporting in the next period.

Furthermore, we can derive the ex ante expectation of $V_{1,ij}$ and $V_{0,ij}$ as

$$\mathbb{E}V_{1,ij} = \mathbb{E}\pi_{ij} - W_i\int_0^{\kappa^*_{ij}} \kappa dF_{1,ij}(\kappa) + n_s\mathbb{E}D'[F_{1,ij}(\kappa^*_{ij})V'_{1,ij} + (1 - F_{1,ij}(\kappa^*_{ij}))V'_{0,ij}]$$

and

$$\mathbb{E}V_{0,ij} = -W_i\int_0^{\kappa^*_{ij}} \kappa dF_{0,ij}(\kappa) + n_s\mathbb{E}D'[F_{0,ij}(\kappa^*_{ij})V'_{1,ij} + (1 - F_{0,ij}(\kappa^*_{ij}))V'_{0,ij}].$$

The difference is then

$$\mathbb{E}(V_{1,ij}-V_{0,ij}) = \mathbb{E}\pi_{ij} - W_i \int_0^{\kappa^*_{ij}} \kappa[dF_{1,ij}(\kappa) - dF_{0,ij}(\kappa)] + n_s \mathbb{E}D'[F_{1,ij}-F_{0,ij}](V'_{1,ij}-V'_{0,ij}),$$

a first difference equation in $V_1 - V_0$. Solving the difference equation gives the κ^*_{ij} thresholds.

It is worth noting that while the exporting threshold is independent of export status, the likelihood of exporting is not. Moreover, assuming we are in steady state we can derive a simple equation relating the gain in firm value from exporting to the discounted export profits minus the extra expected expenses in fixed costs:

$$\mathbb{E}(V_{1,ij}-V_{0,ij}) = \frac{\mathbb{E}\pi_{ij} - \frac{W_i \kappa^*_{ij}}{\nu}[F_{1,ij}(\kappa^*_{ij}) - F_{0,ij}(\kappa^*_{ij})]}{1 - n_s \beta [F_{1,ij}(\kappa^*_{ij}) - F_{0,ij}(\kappa^*_{ij})]},$$

where the distribution $F_{s,ij}$ is given as

$$F_{s,ij} = \left(\frac{\kappa}{f_s \nu}\right)^{\frac{1}{\nu-1}}$$

for $\kappa \in \{0, f_s\nu\}$ and 0 otherwise.

2.4 Free Entry

IG firms die with probability $1 - n_s$ in each period. New firms can pay a fixed cost f_e denominated in labor to begin producing and drawing exporting fixed costs in the next period. New producers only sell in the domestic market. New firms in country i enter when the fixed cost is less than the expected discounted value of profits. The free entry condition is

$$W f_e = n_s \mathbb{E}D'_i \left[V'_{1,i} + \sum_{j \neq i} V_{0,ij} \right]$$

where

$$V_{1,i} = \pi_{ii} + n_s \mathbb{E}D'_i V'_{1i}$$

and $V_{0,ij}$ as previously defined. The mass of entrants in country i is denoted N_{ei}.

2.5 Aggregation

In this model the distribution of fixed export costs is endogenous because they depend on past behavior. However, because the draws of fixed costs are iid across firms and across time and only depend on export status, we can easily integrate over individual choices of firms to get aggregate variables. By doing this, we only need to keep track of the number of exporters in each market instead of keeping track of the distribution of fixed costs in each period for each pair of countries.

Let N_{ij} be the mass of IG firms in country i that produce for country j (N_{ii} is the total mass of producing firms in i). Using the CES price index, we have

$$P_{ij}^{1-\theta} = \int_{\Omega_{ij}} P_{ij}(f)^{1-\theta} df = N_{ij} \left(\frac{\theta}{\theta - 1} MC_i \right)^{1-\theta}$$

where the second equality uses the fact that all exporting firms make the same pricing decision. Then prices can be written

$$P_{ij} = N_{ij}^{\frac{1}{1-\theta}} \frac{\theta}{\theta - 1} MC_i.$$

The price of the bundle of goods from country i in country j is decreasing in N_{ij}. This reflects a love of variety among consumers.

Now we move on to solve the aggregate inputs used by the economy. Using the individual firms' production function and the first order conditions from the static problem, it is easy to show that $k_{ij}(f) = \frac{\alpha(1-\alpha_m)MC_i}{R_i} y_{ij}(f) \equiv \Psi_i y_{ij}(f)$. Using the CES demand faced by each firm, we can solve for the capital used by each firm in exporting from i to j

$$k_{ij} = \frac{\int_{\Omega_{ij}} k_{ij}(f) df}{N_{ij}} = \frac{\Psi_i}{N_{ij}} \left(\sum_G G_{ij} \right) \int_{\Omega_{ij}} \left(\frac{P_{ij}(f)}{P_{ij}} \right)^{-\theta} df = \Psi N_{ij}^{\frac{\theta}{1-\theta}} \sum_G G_{ij}.$$

Once we have capital, we also know labor l_{ij} and materials m_{ij} used by each firm from

$$l_{ij} = \left(\frac{R_i}{\alpha} \frac{1 - \alpha}{W_i} \right) k_{ij}, \qquad m_{ij} = \left[\frac{R_i}{\alpha(1 - \alpha_m)} \frac{\alpha_m}{P_{M,i}} \right] k_{ij}.$$

We also want to know the profits earned by each firm in each market. We have

$$\pi_{ij} = \frac{\int_{\Omega_{ij}} \pi_{ij}(f)df}{N_{ij}} = \frac{1}{N_{ij}} \int_{\Omega_{ij}} \frac{1}{\theta} P_{ij}(f) \left(\frac{P_{ij}(f)}{P_{ij}} \right)^{-\theta} df \sum_G G_{ij} = \frac{P_{ij} \sum_G G_{ij}}{\theta N_{ij}}$$

which tells us that the aggregate profits coming from country j are split equally among firms that sell to country j.

We need to keep track of the number of producers for each market in each period. For $i \neq j$, the number of exporters today is equal to the number of exporters and nonexporters yesterday that survive and draw a sufficiently low fixed cost. The law of motion is

$$N_{ij,t} = n_s N_{ij,t-1} F_{1,ij}(\kappa^*_{ij,t-1}) + n_s (N_{ii,t-1} - N_{ij,t-1}) F_{0,ij}(\kappa^*_{ij,t-1}).$$

For $i = j$, the number of domestic producers today is equal to the number of surviving producers from yesterday plus surviving entrants that paid the fixed cost to export yesterday

$$N_{ii,t} = n_s (N_{ii,t-1} + N_{ei,t-1}).$$

2.6 Equilibrium

In equilibrium, several markets must clear. Total capital supplied by consumers is equal to the capital demanded by firms

$$K_i = \sum_{j \in \mathbb{C}} N_{ij} k_{ij}.$$

Similarly, total materials supplied by final goods firms are demanded by IG firms so that

$$M_i = \sum_{j \in \mathbb{C}} N_{ij} m_{ij}.$$

Total labor supplied by consumers is used by firms for production and for the payment of fixed costs

$$L_i = N_{ii} l_{ii} + \sum_G L_{G,i} + N_{ei} f_e + \sum_{j \neq i} N_{ij} l_{ij} + N_{ij} \int_0^{\kappa^*_{ij}} \kappa dF_{1,ij}(\kappa) + (N_{ii} - N_{ij}) \int_0^{\kappa^*_{ij}} \kappa dF_{0,ij}(\kappa).$$

Aggregate profits Π_i that supplement consumer's income is total operation profits minus the fixed costs

$$\Pi_i = N_i\pi_{ii} - W_i N_{ei} f_e + \sum_{j\neq i} N_{ij}\pi_{ij} - W_i \left[N_{ij} \int_0^{\kappa_{ij}^*} \kappa dF_{1,ij}(\kappa) + (N_{ii} - N_{ij}) \int_0^{\kappa_{ij}^*} \kappa dF_{0,ij}(\kappa). \right]$$

Tariff revenue is rebated lump sum to consumers

$$T_i = \sum_{j\in\mathbb{C}} (\tau_{ji} - 1) P_{ji} \sum_G G_{ji}.$$

Finally, international bonds are in zero net supply

$$\sum B_{i\in\mathbb{C}} = 0.$$

An equilibrium is a set of prices and allocations such that

1. Consumers maximize utility given prices,

2. Final goods firms maximize profits given intermediate good prices and wages,

3. IG firms maximize the expected discounted value of profits given prices,

4. and all markets clear.

3 Model to Data

To analyze trade policy, I need a calibration of the model that reflects the data. In this section, I show how I discipline the parameters of the model to match macro and micro data. First, we need functional forms for utility and for the distribution of fixed costs. Utility takes the form

$$U(C, L) = \bar{L}^\sigma \frac{\left[C^\mu(\bar{L} - L)^{1-\mu}\right]^{1-\sigma}}{1 - \sigma}$$

where $1/\sigma$ is the intertemporal elasticity of substitution. The distribution of fixed costs is

$$F(\kappa) = \left(\frac{\kappa}{f_n\nu}\right)^{\frac{1}{\nu-1}} \quad \text{if } 0 \leq \kappa \leq f_n\nu$$

where $f_n \in \{f_0, f_1\}$ depends on the firm's current export status. The parameters f_0 and f_1 determine the mean of the distribution and therefore the average fixed cost. The parameter ν changes the curvature of the distribution and therefore the elasticity of the extensive margin to changes in trade costs.

The values for the parameters are shown in Table 1. Panel A includes parameters for which standard values are used and calibration is external to the model. The model is an annual model. To generate a 4 percent interest rate we set the discount factor β=0.96. Capital depreciation rate δ=.1 and the capital share of value added α=0.36 are set at common values in the literature. Recognizing that the gross output to value added ratio is higher for consumption goods, I set $\alpha_C = 0.8$ and $\alpha_X = \alpha_M = 1$. This implies that the production of the final consumption good requires both intermediate goods and domestic labor while the final investment and material good production uses only goods. The elasticity of substitution across intermediates θ is set to 6 so that firms charge a twenty percent markup. I set the Armington elasticity $\gamma = 4$ as in Simonovska and Waugh (2014). This implies a short run trade elasticity of close to 3 and long-run trade elasticity of close to 8 in a bilateral liberalization of symmetric countries. I let $n_s = .98$ so that 2% of firms die each year. Since firms are homogeneous, this is set to match the share of labor in exiting firms (Alessandria and Choi (2014)).

Cobb-Douglas parameters α_m and α_G for $G \in \{C, X, M\}$ determine the gross output to value added ratio in intermediate goods and in each final good. I use BEA GDP by industry data to separately calculate gross output to value added ratios in investment, materials, and consumption. I group investment and materials together and get a value of about 2.2. For consumption, I get a value of 1.65. I set $\alpha_X = \alpha_M = 1$ and $\alpha_m = 0.65$ as gross output to value added in the intermediates sector can be written as $1/(1 - \alpha_m \frac{\theta-1}{\theta})$. I set α_C=0.8, which approximately matches the gross output to value added ratio for consumption in the United States.

The labor endowment for each country $\bar{L}_i$ is a key element in determining aggregate gains from trade. Here, I normalize $\bar{L}_{US} = 1$ and then set $\bar{L}_i$ so that $\bar{L}_i/\bar{L}_{US}$ matches the relative population for the two regions in 2014. I normalize technology $z_{US} = 1$.

Panel B of Table 1 gives the values for parameters that are calibrated jointly and are internal to the model.[6] These include parameters in the distributions of fixed costs $f_{0,i}, f_{1,i}, \nu$, country-specific technology z_i and preferences for sources $\{\omega_{ij}^G\}_{G\in\{C,X,M\}}$, the share of materials in the total costs of firms α_m, and relative preferences for consumption and leisure μ. They are chosen to match the following moments:

1. $L_{US}/\bar{L}_{US} = 1/4$

2. Annual exiting firms exports/total exports = 4%

3. Fraction of firms that export = 45%

4. Trade elasticity 92% phased in at 10 years.

5. Relative GDP of regions in 2014

6. Bilateral trade shares + end use trade in 2014

The first moment, $L_{US}/\bar{L}_{US} = 1/4$, is the share of time spent working and is largely determined by μ, the relative preference for consumption and leisure. I do not let this parameter vary by country.

The rest of the moments can be broken into three general categories: micro moments on export participation (2 and 3), macro dynamic trade elasticities (4), and aggregate cross-sectional features (5 and 6). Below I give some intuition on how these moments inform various parameters.

[6] Table 2 gives the values for country-specific parameters and data.

3.1 Micro moments on export participation

By choosing f_0 and f_1 for each country, I pin down the fraction of firms that export and the relative probability with which exporters and nonexporters can enter in the next period. I set the fraction of exporters in each country to 45%. This is close to the fraction of manufacturing firms that export in a number of developed countries and I see little evidence that the number of exporters varies across countries by size based on data from the EFIGE database (see Altomonte and Aquilante (2012)). Furthermore, the results are not significantly affected by this choice. Next, I need to choose what fraction of today's exporters will continue exporting in the steady state. This will determine the ratio of f_0 and f_1.

We know that the exporting decision is persistent. Bernard and Jensen (1999) show that lagged exporting status is an important predictor of current status and that only 13% of exporters stop exporting in a given year. We also know a lot about the exporter life cycle. Ruhl and Willis (2017) show that survival rates among new exporters are low and that new exporters take several years to export the same amount as incumbent exporters both in terms of volume and as a fraction of total sales. Alessandria et al. (2018) incorporate the exporter life cycle into a general equilibrium model using heterogeneous productivity and iceberg costs with sunk costs paid by new exporters. The heterogeneity that I've assumed across firms does not allow for the explicit modeling of the exporter life cycle. The question that I face is how best to capture it with the margins I can control. One approach would be to match the average fraction of exporters that stop exporting each year. However, in a model with firms that are homogeneous in productivity, this ignores the fact that these exiting exporters and the new exporters that replace them don't export as much as incumbents, inflating the value of firms relative to the data. Entrants and nonexporters see a relatively high probability of becoming an exporter which affects today's value more than it should. As a result, I choose to match instead the fraction of total exports contributed by exiting exporters. Bernard et al.

(2017) show that, controlling for partial-year effects, exiting exporters export 68% less in the year that they exit than in a baseline year of exporting. A back of the envelope calculation implies these stopping exporters represent about 4% of aggregate exports in the year they stop. This is roughly consistent with numbers reported in Alessandria et al. (2018) on exit rates and export levels for exiters in Chile and Colombia. Matching this moment lowers the probability of exporting and the value of entry is much less affected by the potential gains from exporting. This becomes especially important when we look at dynamic responses to trade liberalizations as it dictates how economies substitute away from domestic varieties in trade liberalizations. It also is an important factor for the long run trade elasticity, as will be shown in the next section.

Figure 1 shows the evolution of export participation in a cohort of surviving new firms over time. In the initial period of production $t = 0$, firms cannot export and export participation (number of exporters/number of firms) is equal to zero by constraint. In this first period, firms draw their fixed cost and decide whether or not to export in the next period. Drawing a fixed cost low enough to export is unlikely, and only 5% of firms begin exporting in the next period. At $t = 1$, firms draw fixed costs again. Now, those firms that are already exporting draw lower fixed costs on average and are very likely to export again. As a result, the number of exporters grows as they include most of the previously exporting firms and some new ones. Export participation continues to grow in subsequent periods and slows down over time. Eventually, the number of exiting and entering exporters equalize and export participation levels out at about 55%. This link between export participation and firm age is consistent with the data.[7]

The shape of export participation by firm age is similar to the shape of export participation for the whole economy after a reduction in trade costs. Such a policy increases the fixed cost threshold for exporting κ^* on impact. This makes current exporters more likely

[7]See, for example, Roberts and Tybout (1997) and Wagner (2015).

to continue and nonexporters more likely to be able to enter. The economy responds with the same slow increase in export participation and the exporter persistence shown here is crucial to that response. I discuss this further in the next section.

3.2 Dynamic Trade Elasticity

To get some intuition on how the parameters of the model determine the trade elasticity, consider a two-country version of the model with only one final good. The trade elasticity is the change in the ratio of imports to expenditure on domestic intermediates (IDR) relative to a change in tariffs. This ratio is equal to

$$IDR_1 = \frac{\tau_{21} p_{21} y_{21}}{p_{11} y_{11}} = \frac{(\tau_{21} p_{21})^{1-\gamma} \omega_{21}}{p_{11}^{1-\gamma} \omega_{11}} = \frac{\left[\left(\frac{N_{21}}{N_2} \right)^{\frac{1}{1-\theta}} N_2^{\frac{1}{1-\theta}} \tau_{21} MC_2 \right]^{1-\gamma} \omega_{21}}{\left(N_1^{\frac{1}{1-\theta}} MC_1 \right)^{1-\gamma} \omega_{11}}$$

where the first equality comes from the CES demand of final goods firms and the second equality uses the optimal price aggregate across firms. Taking logs and differencing yields

$$\Delta \ln IDR_1 = (1-\gamma) \left(\Delta \ln \tau_{21} + \Delta \ln \frac{MC_2}{MC_1} \right) + \frac{1-\gamma}{1-\theta} \left(\Delta \ln \frac{N_{21}}{N_2} + \Delta \ln \frac{N_2}{N_1} \right)$$

and the trade elasticity is

$$TE = \frac{\Delta \ln IDR_1}{\Delta \ln \tau_{21}} = 1 - \gamma + (1-\gamma) \frac{\Delta \ln \frac{MC_2}{MC_1}}{\Delta \ln \tau_{21}} + \frac{1-\gamma}{1-\theta} \left(\frac{\Delta \ln \frac{N_{21}}{N_2}}{\Delta \ln \tau_{21}} + \frac{\Delta \ln \frac{N_2}{N_1}}{\Delta \ln \tau_{21}} \right).$$

Since capital, the stock of exporters in each country, and the number of producing firms are predetermined, the short run elasticity is approximately $1-\gamma$. In the long run, the elasticity depends on the differential change in the marginal cost between countries, the change in the fraction of country 2 firms that export, and the relative change in the number of producing firms in countries 1 and 2. The two elastiticities of substitution θ and γ determine the impact of the extensive margin (firms and exporters) on the trade elasticity in the long run.

Jung (2012) claims that following bilateral trade liberalizations and controlling for gradual phaseouts of tariffs, trade increases by about three times as much in the long run as it does on impact. Furthermore, the growth in trade occurs slowly, with 92% of the increase occurring in the first 10 years. This is the moments I target in calibration. In bilateral trade liberalizations, we might expect that the log changes in the marginal costs and the number of domestic varieties are similar (at least qualitatively) in both countries so that the main driver of the long run changes in the trade elasticity come from the exporter margin. To see which parameters drive changes in this margin, consider the law of motion for the number of exporters in a two-country version of the model. Taking logs and a linear approximation yields

$$\Delta \ln \frac{N_{21,t}}{N_{2,t}} \approx -\Delta \ln N_{2,t} + [F_1(\bar{\kappa}^*_{21}) - F_0(\bar{\kappa}^*_{21})]\Delta \ln N_{21,t-1} + \frac{\bar{N}_2}{\bar{N}_{21}} F_0(\bar{\kappa}^*_{21}) \Delta \ln N_{2,t-1} + \frac{1}{\nu - 1} \Delta \ln \kappa^*_{21,t-1}.$$

This equation is quite intuitive. It says that the growth of the fraction of firms that export depends on the growth in the total number of firms in the economy, lagged changes in the number of firms and exporters, and changes in profits from exporting represented in the threshold fixed cost for exporting κ^*_{21}. The first term simply captures that if the number of firms drops for reasons external to exporting, the fraction of exporters will increase. The second term gives the persistence in the growth of exporters which is determined by the difference between the steady state probabilities of drawing a sufficiently low fixed cost for exporters and nonexporters. Holding all else constant, the larger this difference (i.e. the more persistent the exporting decision), the larger will be the overall change in the fraction of exporting firms. The third term captures the lagged effect of losing or gaining firms in the economy. If a liberalization decreases the number of domestic varieties, then there are fewer firms that have the possibility of exporting in the future.

The last term tells us the response of the extensive margin to a change in the threshold fixed cost for exporting κ^*_{21}. The effect of this change is summarized by the parameter ν. In a liberalization, κ^*_{21} first increases as exporting to the foreign country has become more profitable. As more firms begin exporting, however, the profits for each firm decrease and

κ_{21}^{*} will fall over time before settling at some point above its initial steady state. Thus, given values for f_1 and f_0 which were chosen to match micro moments, ν determines the transition of the extensive margin of trade and, through it, the transition of the trade elasticity.

3.3 Cross-regional features

A key advantage in static models is the ability to match cross-sectional features such as size, technology, and bilateral trade flows. In the dynamic model I consider, much of this flexibility is retained. It was mentioned previously that the labor endowment $\bar{L}$ in each country is calibrated to match population relative to the US. In this section, I further discuss how data on relative GDP and end use trade flows are used to determine technology z and trade preferences ω_G.

By changing the form of heterogeneity across firms and assuming iid distributions, the model is tractable in multiple countries. However, there are still several state variables. For each country, we must keep track of capital, bond holdings, the number of domestic varieties, and the number of exporters to each destination. Let $J = |\mathbb{C}|$ be the number of countries. Then we have $J(J+2)$ state variables in each period. For this reason, I will calibrate the model to match cross-sectional features for six regions, many of which are a combination of several countries. I choose regions based on their importance in US trade, size, and geographic similarity between countries within a region. The six regions are: the United States (US), China, Canada and Mexico (rest of NAFTA), the European Union (EU), an East Asia aggregate (EA)[8], and the rest of the world (ROW). China,the rest of NAFTA, EU, and EA account for about 80% of US trade flows in 2014.

I normalize $z_{US} = 1$ and let z_i vary so that relative GDP between country i and the US is the same in the data and the model. The technology parameters should not be taken

[8]The East Asia aggregate includes Japan, South Korea, Hong Kong, Vietnam, Thailand, Malaysia, Singapore, Indonesia, and the Philippines.

seriously as a calibration of relative technologies in different regions. The regions I consider are often made up of two or more countries with nonzero trade frictions. I do not model these trade frictions explicitly and instead let trade costs within a region be reflected instead in a lower productivity. Data on GDP for 2014 is taken from the Penn World Tables.

I choose Armington weights $\omega_{G,ij}$ to match bilateral end use trade between regions. End use trade data is aggregated manually into capital, materials, and consumption from Comtrade BEC classification bilateral data. Appendix C shows how I classify BEC codes into the three categories in the model.

In matching bilateral trade shares in the steady state, I'm taking a stand on trade imbalances and, by implication, net foreign asset positions. In steady state we have

$$Exports_i - Imports_i = -(1-\beta)B_i.$$

A country can only maintain a trade deficit, for example, if they have a positive net foreign asset position and are receiving interest payments every period which allow them to spend more than they earn domestically. The large deficit that the US ran in 2014 implies a net foreign asset position greater than 100% of GDP. Data from the BEA, on the other hand, shows a US net foreign asset position of -40% of GDP. I will perform all trade policy experiments in the model both with trade imbalances as in the data in steady state and adjusting Armington weights so that trade is balanced for each bilateral pair in steady state. Doing so also adjusts the import share for each country and can change the results significantly. On occasion, I will perform experiments under the assumption of financial autarky, for which the balanced trade steady state will be used.

4 Global Tariff Liberalization

The model includes key features common in international macro models with the rich heterogeneity in geography of quantitative trade models and a non-trivial transition coming from firm life-cycle. To understand how these features affect the transition from a change in trade policy, I now consider the response to a global liberalization that eliminates a 10 percent tariff in variations that abstract from some alternative margins of adjustment. First, I explore the role of capital intensive trade, endogenous labor and endogenous entry by considering a liberalization in a two country symmetric world. With two symmetric countries, there are no borrowing and lending motives. Next, I move to a two-country asymmetric world (US vs rest of world (ROW)) to illustrate the importance of size relative to the world for dynamics. Gains for both countries decrease, but as the small country, the US has larger gains and has an incentive to borrow from the ROW. Finally, I consider what happens when I match the geography in the ROW. In this case I go from two countries to six countries to show how the number and relative size of countries matters for dynamics and overall gains.

In each representation of the world, I compare the dynamics of my model with those in a similar model with no firms. This model is similar to recent developments in the trade literature such as Alvarez (2017), Eaton et al. (2016), Ravikumar et al. (2018), and Reyes-Heroles (2016) which add capital, bonds, or both to a static EK model with multiple countries and no firms. We will see that the addition of heterogeneous firms and long-lived decisions about exporting and production yield very different results about the effects of trade in both the short-run and the long-run. Each new representation also shows the importance of asymmetries or rest of world structure on the dynamics relative to the two-country symmetric case, highlighting my contribution to the existing dynamic trade literature.

4.1 Symmetric 2-country World

Previous work with sunk costs in exporting are done in either a partial equilibrium (Das et al. (2007)) or symmetric 2-country general equilibrium framework (Alessandria and Choi (2014)). Simplifying the world allows for more intricate modeling of firm heterogeneity.

For example, Alessandria and Choi (2014) model heterogeneity across firms in productivity and fixed costs to match employment distributions and export participation. The multi-country macro approach of this paper abstracts from the richer firm heterogeneity in these frameworks, but we will see here that the model generates the same general dynamics. In addition, the two-country symmetric framework abstracts from any borrowing and lending incentives in a tariff liberalization. So we use it to focus on the importance of capital-intensive trade, endogenous labor, and firms for the results of a global liberalization.

To replicate the two-country symmetric world, I set $z_1 = z_2 = 1$, $\bar{L}_1 = \bar{L}_2 = 1$ and choose Armington weights $\omega_{G,ij}$ so that expenditure on imports is 14% of GDP (the US imports to GDP ratio in 2014), assuming a 10% tariff between the two countries. The relative weights for different final goods is chosen so that 20% of intermediates go to consumption, 20% to capital, and 60% to materials. Consider an economy in steady state for time $t < 0$ and suppose there is an unanticipated drop in tariffs at time $t = 0$ from 10% to 0%. Tariffs remain at 0% permanently.

Aggregate responses to the liberalization are shown in Figure 2. As in Alessandria and Choi (2014), consumption overshoots its long run steady state. The same mechanism drives overshooting in both models. Namely, when trade is liberalized, firms invest fewer resources in domestic varieties. The number of entrants falls by as much as 40% in the short run, freeing up resources previously used in paying fixed costs to be used in production, consumption, and building up the stock of exporters. Eventually the stock of domestic firms evens out and the number of entrants increases to converge to a level 10% below the initial steady state. Furthermore, the economy now supports a larger fraction of firms that export. Increased payment of fixed costs for exporters and new producers lowers the amount of resources available for consumption and production, generating the overshooting behavior.

The amount of overshooting and the gains from trade are highly sensitive to the inclusion of capital-intensive trade and endogenous labor. Eliminating either of these features lowers the gains from trade and, especially in the case of inelastic labor, leads to more exaggerated overshooting.[9] Why does this happen?

In the benchmark model with endogenous labor, labor falls in the short run as consumers want to take leisure in response to learning about higher future wealth. Over time, firms demand more workers both for production and to pay fixed costs of exporting. The wage increases and workers supply more labor. In the new steady state, there are more workers and they are allocated between paying fixed costs and producing goods. These added workers keep production high so there is less overshooting. When labor is inelastic, workers do not increase their supply of labor so increases in production after a liberalization are driven by reallocation of labor from paying the fixed costs of entrants to producing goods. Once labor is once again reallocated towards fixed costs, production and consumption fall, generating steep overshooting.

Eliminating capital-intensive trade is done by redefining Armington weight to be equally across categories $\omega_{C,ij} = \omega_{X,ij} = \omega_{M,ij}$. With capital-intensive trade, each country's aggregate investment good has a larger share of foreign goods. As a result, a liberalization causes a larger fall in the price of investment. Agents invest more both in the transition and the new steady state. With higher capital stocks, both countries produce and consume more with approximately the same amount of labor.

Table 3 shows the gains from trade for several specifications of the model. For the dynamic model, gains are computed using both consumption equivalence and by comparing the initial and terminal steady states. Consumption equivalence is the preferred measure as it properly accounts for the transition. To get the consumption equivalent gain from trade, we first find the η that solves

$$\frac{u(\eta C^*, L^*)}{1-\beta} = \sum_{t=0}^{\infty} \beta^t u(C_t, L_t)$$

[9] Indeed, Alessandria and Choi (2014) ignore these features in their analysis and find much more extreme overshooting.

where C^* and L^* represent the initial steady state values for consumption and leisure and $\{C_t, L_t\}$ represents the paths they take after the change in trade policy. In words, η represents the change in consumption in the initial steady state needed to make the agent indifferent between staying at the initial steady state or experiencing the policy change. The consumption equivalent gain from trade is then represented as $(\eta - 1) \cdot 100$ (Lucas (1987)).

Similar to Alessandria and Choi (2014), Table 3 shows that the discounted gains are larger than steady state gains in a model with dynamic exporting decisions and free entry of firms. The amount of overshooting in the model determines how much higher the discounted gains will be. Thus, the model with inelastic labor has discounted gains that are over twice as large as the steady state gains while the benchmark case reports discounted and steady state gains that are almost identical.

Both capital-intensive trade and endogenous labor significantly increase the gains from trade. Capital-intensive trade increases overall gains relative to the model without capital-intensive trade by 31% due to larger reduction in investment prices and increased capital deepening. Endogenous labor increases gains relative to the inelastic labor case by 21% as consumers are allowed to optimally choose the tradeoff between leisure and consumption.

Figure 2 and Table 3 also show the results for a model with no firms. I eliminate firms by letting $\gamma = \theta$, making the distribution over fixed costs degenerate at zero, and removing entry decisions. Since firms are homogeneous in productivity and all firms export, they act as a single aggregate firm. I set the elasticity $\gamma = 7.75$ to match the discounted change in the world domestic expenditure share from the benchmark model. All other parameters are adjusted to match the 2-country symmetric world setup with identical trade flows as in the dynamic model.

The model without firms is similar to more recent developments in the trade literature such as Eaton et al. (2016) and Ravikumar et al. (2018). Adding capital and bonds gives the model a dynamic element but the trade elasticity itself remains mostly static, as is shown in Figure 2. Substitution towards foreign varieties and away from domestic varieties occurs immediately, ignoring any semi-fixed trade networks that take time to adjust. Capital accumulates gradually and the economy invests and works a lot on impact. Consumption jumps on impact because of cheaper foreign goods and grows slowly as the capital stock grows. The model without firms exhibits no overshooting behavior in consumption. Since leisure and consumption are both increasing monotonically over time, the gains from trade that account for the transition are 26% smaller than a comparison of welfare across steady states. This is consistent with results in Ravikumar et al. (2018) and the static version of the model in Alessandria et al. (2018). Gains are higher both overall and across steady states in the model with firms since it gives the economy another margin of adjustment to allocate production efficiently.

4.2 Asymmetric 2-country World

Now we keep the assumption of a 2-country world but add asymmetries. I recalibrate the model to the US and a rest of world aggregate in 2014. The US accounts for roughly 1/6 of world GDP and 1/20 of world population so the rest of world aggregate is quite large in this experiment. In the data, the import to GDP ratio is 14% in the US and is only 1.7% in the rest of the world as only trade with the US is counted as international trade. These trade shares imply trade imbalances and nonzero net foreign asset positions in the initial steady state (see section 3.3). I ignore this here by calibrating the model so that imports for each country is equal to the average of imports for both countries. Figure 3 shows the response for several aggregate variables in the asymmetric and symmetric models.

It is immediately clear that the gains from trade both in terms of welfare and income are much larger for the small economy, in this case the US. Total gains in the US are 5.3 times higher than total gains in the rest of world aggregate (see Table 4). This is consistent with the static trade literature. The smaller country benefits more than the large country for several reasons. First, given that trade is balanced in the initial steady state, expenditure on foreign goods in the small economy is a much larger share of total expenditures. When the tariff drops, this means a larger drop in aggregate prices. In addition, the small country is gaining improved access to a much larger market, which is more advantageous for its potential exporters. Unlike a static model, however, the dynamic model does not assume that trade is balanced in the transition. Because the smaller country has larger gains from the liberalization and because those gains are not realized immediately, the small country would like to borrow initially against future wealth. The large country experiences only small gains and the borrowing incentives of the small country raise the interest rate, so they are willing to lend. In this way the small economy grows faster than in a world with balanced trade but will eventually converge to a new steady state that is worse off as they need to repay their debts.

The first two columns of Table 4 compute the gains from trade for the 2-country asymmetric world using consumption equivalence and comparing steady states under different assumptions about financial markets and initial trade balances. Going from financial autarky to the bond economy with a balanced initial steady state raises gains from 3.22% to 3.39%, about a 5% increase. However, with the bond economy, the economy converges to a new steady state with welfare that is 9% lower than new steady state welfare in the financial autarky case. The increased gains in the bond economy, then, come from a redistribution of gains from the later periods to the initial periods.

The US gains are large, but they are smaller than the gains from a symmetric world (see Table 3). This is largely explained by the weaker response of the trade elasticity as seen in Figure 3. In Section 3.2, we saw that the long run trade elasticity is partly determined by the relative changes in the marginal cost in the two countries. In the symmetric model, these changes are equal and cancel out. In the asymmetric model, the larger country has a much smaller import share and thus, a trade liberalization has a smaller effect on its marginal cost. In other words, in the asymmetric case foreign prices for the small country fall by less and thus, they substitute less towards foreign goods. The crossing in the dynamic path of consumption and leisure in the asymmetric and symmetric model is driven by US borrowing in the initial periods to consume more and take more leisure. Figure 4 shows the paths of consumption and leisure in the symmetric model and in the asymmetric model with financial autarky. In this case, the paths do not cross.

We have assumed in this discussion that the rest of the world is made up of one enormous country and have seen that this implies small gains. Of course in reality, the rest of the world is made up of many countries, all of which are smaller than the United States in terms of GDP, and most of which are smaller in terms of market size. In the next section, I break up the rest of the world into the five smaller regions discussed above and investigate the impact on the gains from a worldwide trade liberalization for the US.

4.3 Asymmetric 6-country World

Now we move to the full calibration of the model. Using the calibration described above, I simulate the same global trade liberalization of 10% bilateral tariffs. How much does adding countries matter for dynamics? Figure 5 shows the evolution of US consumption, labor, the trade balance, and the domestic expenditure share λ[10] under different assumptions about financial markets and the initial trade balance for the 2-country and 6-country calibrations. The first row shows the response under financial autarky (balanced trade). In this case, the dynamics of the aggregate variables are all similar, only the magnitudes have changed, and the smaller magnitudes can be explained by the smaller response in the domestic ex-

[10] The domestic expenditure share λ is common in the international trade literature and in this model is defined as the share of total intermediate goods expenditure on domestically produced goods. It is a key component in determining the gains from trade in the sufficient statistic approach (see Arkolakis et al. (2012)).

penditure share. Why does the domestic expenditure share fall by less in the six-country model? The countries that make up the rest of the world are now experiencing a larger trade liberalization, generating a larger decline in the number of domestic varieties and freeing up more resources to build trade relationships. However, these countries are now strengthening trade relationships with five other countries rather than one, and the relationship with the US gets less resources than it did in the two-country world. In other words, a 6-country model introduces trade diversion that is nonexistent in a 2-country model.

The second row of Figure 5 shows the responses of the same variables but comparing the two models under the assumption of incomplete markets with trade balanced in the steady state. In this case, we see that not only are the magnitudes different, but the path of these variables over time has also changed. The differential in consumption across the 2- and 6-country models is high on impact and decreasing with time. What is driving this change? In the 2-country model, the US is by far the smallest country and experiences the largest gains. They want to borrow a lot initially by running large trade deficits and the large rest of world is willing to lend to them. In the 6-country world, the US is no longer the smallest country and several of the other countries will experience larger gains from the liberalization. This leads to high demand for borrowing on impact, pushing up the real world interest rate and making borrowing less attractive for the US. In fact, Figure 5 shows that the US becomes a lender in the short run. As a result, the US will consume less and work more in the short run. In the long run, they receive interest payments from borrowing countries which they use to consume more and work less. Table 4 gives the gains from trade for the US in both models under different assumptions. With financial autarky, gains fall by about 5%, all of which is due to trade diversion. With incomplete markets, gains fall by 8% because of both trade diversion and to the redistribution of welfare towards the more discounted future.

4.3.1 Trade imbalances and NFA positions

In the analysis so far, I have assumed that bilateral trade is balanced in the steady state. This implies two major changes relative to the case where bilateral and aggregate trade imbalances in 2014 are matched in the steady state. First, matching trade imbalances implies nonzero net foreign asset (NFA) positions. A large trade deficit in steady state can only be achieved with a large and positive NFA position. For the US, this may be counterfactual (see Section 3.3). Assuming bilaterally balanced trade in steady state instead assumes NFAs of zero for all countries. Second, balanced trade in the steady state changes the structure of trade for each country. The US will import less and export more and the smaller import share in the balanced steady state case should dampen the impact of a trade agreement. However, US deficits are not uniform across countries and assuming balanced trade makes US imports less concentrated in countries with whom they run larger deficits, like China. We saw in the previous section that the gains from trade are sensitive to changes in the marginal cost of production across countries. In a multi-country model, what matters for the US is some import-weighted average of the marginal cost of its trading partners. If imports are less concentrated in large and more closed economies like China, this should increase the gains from trade.

Figure 6 compares the responses under both assumptions about initial trade imbalances and NFAs for the US. As expected, changing the structure of trade and NFA position can have significant consequences on the dynamics. What is clear is that welfare for the US is lower in the case with nonzero NFA positions in steady state. Indeed, the third row of Table 4 reports gains that are 7% smaller. We would like to know whether this is due to the altered structure of trade or initial NFAs. To answer this question, I recalibrate the steady state with zero NFAs for all countries but with constant country-specific wealth endowments that generate the same trade imbalances. This is similar to Dekle et al. (2007) and, for our purposes, is useful as it isolates the structure of trade from initial NFAs. The last row of Table 4 reports that these gains are even smaller. This implies that the positive NFA position of the US increases gains and that the structure of trade that generates trade imbalances (imports more concentrated in China) lowers gains.

It is intuitive that holding more NFAs increases the gains from trade. As the real interest rate increases, countries holding NFAs are receiving higher interest payments from foreign countries. This extra wealth can be used in transition to consume more or work less and increase welfare. Relative to the model with zero NFAs and trade imbalances, gains increase by 6%.

4.3.2 The importance of N countries

The quantitative changes in both the overall gains from trade and dynamics that occur going from the two- to six-country models may make us wonder if the 2-country model is useful to quantify the impact of trade liberalizations. Here, I show that it can be.

A global liberalization in a six-country model is not the same as that of a two-country model. In the two-country model, we are leaving out liberalizations that occur within the rest of world aggregate. Suppose that we do the same liberalization in each world. That is, perform a global liberalization in the two-country world and a series of bilateral liberalizations with the US in the six-country world. In other words, assume that all countries liberate trade with the US but with no other country. The results for the six-country experiment are reported in the last two columns of Table 3 and show that the gains from trade are identical to the two-country global liberalization. Because the liberalizations are all bilateral, there is no trade diversion. Also, foreign countries gain by less since the US represents a smaller portion of their total trade. As a result, they borrow less and the intertemporal incentives for the US are unchanged.

This is a useful result as it tell us that strategically choosing the countries we explicitly model can be as good as modeling multiple countries. If we only care about how a liberalization affects the US, two countries is enough to do that analysis.

5 The Cost of Being Left Out

In this section, I analyze a specific relevant trade policy. As the US administration continues to reaffirm its isolationist ideology and the rest of the world extols globalization, I answer the question: What are the dynamic effects of being excluded from a global trade liberalization?

Using the 6-region calibration with 10% tariffs between all bilateral country pairs, I consider an unanticipated shock that eliminates tariffs between all countries except the United States. Exclusion of the US is permanent and agents have perfect foresight after the initial drop in tariffs. This experiment can easily be done in a static model. However, I show that the losses to the US are larger in a dynamic model and that these losses are distributed unevenly over time. Specifically, all of the losses for the US occur in the short run. In the long run, they converge to a better steady state than the initial one. I will also show that the dynamic exporting decision generates unique dynamics in investment, value added, and the trade balance relative to a model with a static trade elasticity.

To understand the dynamic effects of being left out, it is useful to think about the incentives of the participant countries of the liberalization. Figure 7 shows the responses to the tariff decrease for Europe. When tariffs drop, participants feel richer as they can now buy foreign goods at a cheaper price. The wealth effect makes them want to consume more and work less today. They also want to invest in capital and in the number of exporters that export to other participating countries. Where do they get the resources for more investment, consumption, and leisure in the short run when production is still low relative to the future? They get it from three sources. First, domestic varieties will be less valuable in the future as more foreign varieties enter. Since the benefits of exporting are far removed from the minds of potential entrant firms, the number of entrants drops, freeing up resources that were previously used for fixed costs to be used in production, consumption, and to pay exporting fixed costs. This is similar to the selection effect in Melitz (2003). In Europe, the number of domestic varieties drops by 6.5% over 35 years. Second, exporting to the US becomes less valuable relative to exporting to other liberalizing countries. Participating countries will substitute away from the US in the short run, using those fixed costs to instead export to other liberalization participants. With a dynamic exporting decision, substitution away from the US takes time and exporters leave the US slowly. Trade networks are somewhat fixed in the short run. Finally, countries will want to borrow by selling internationally traded bonds today. The trade balance in Europe drops by about 0.5 percentage points on impact and about 1 percentage point relative to the initial steady state after two periods. Later on, the incentives to borrow switch as Europe overshoots its new steady state. At this point, they foresee being poorer and want to lend. This also explains the reversal in the number of exporters to the US in the medium run. In the long run, European net foreign assets decrease and they converge to a steady state with a higher trade balance where they pay interest on the debt accrued in transition.

How does this affect the US? Figure 8 gives the impulse response functions for the US. When the tariffs decrease, US consumers know that foreign exporters will soon substitute towards other countries. The effect of the substitution can be seen in the increase in the terms of trade in the first three periods. Since capital is intensive in investment, this means that the price of investment is low today relative to the next few periods. Anticipating this increase in prices, US consumers increase investment by 2% today and then decrease investment substantially in subsequent periods, with a trough at 6% below the initial steady state. Investment recovers quickly after that as the terms of trade drops. Foreign demand for debt increases the world interest rate, making lending attractive for the US. On impact, the trade balance increases by 1 percentage point. The demand for debt in foreign countries is persistent as it takes time for participants to increase their stock of exporters. Knowing this, the US first invests in exporters and substitutes away from domestic firms, which increases the trade balance so that 2 years after the agreement, the trade balance is 1.5 percentage points above the initial steady state. When the rest of the world wants to lend, the US takes advantage of the low interest rate and borrows to increase consumption and the number of domestic varieties while also using resources freed up by decreasing the number of exporters. Finally, the US converges to a steady state with a higher net foreign asset position and lower trade balance, receiving interest payments from the liberalizing countries.

The initial increases and later reversals in saving and investment lead to a U-shaped response in GDP (value added). On impact, the US works 0.57% more and produces more goods. As these extra goods are all either invested in capital or the risk-free bond, the US chooses to save at the cost of current consumption, which falls by 0.95% on impact and only begins to recover during the reversal in the trade balance five years later. Being left out is quite costly in the short run! In the long run, consumption is only 0.04% below the initial steady state. Labor, on the other hand, converges to a steady state 0.3% below the initial steady state and a welfare comparison across the two steady states yields a 0.16% gain from being left out! Accounting for the transition, on the other hand, yields a 0.17% loss in welfare. This loss is equivalent to the loss generated by unilaterally raising tariffs on all trade partners from 10% to 14%.

How does the US consume the same amount with less production in the new steady state? First of all, the liberalization in the rest of the world lowers the price of foreign goods, as seen in the terms of trade. In a world where trade is balanced, this does little good for the US. Foreign countries use fewer US exports so the US uses fewer imports. This is accompanied by a decrease in wage and welfare decreases. With unbalanced trade, however, the US uses the initial periods to improve its net foreign asset position, allowing them to import more of these cheaper goods in the new steady state despite lower exports.

Figure 9 shows how the losses from trade are distributed over time in the dynamic model. For each period s since the liberalization, I calculate the losses assuming that the path for consumption and leisure are as in the model up to period s, and then return to steady state for all time periods $t > s$. The figure shows these counterfactual losses as a fraction of the total discounted loss. Increases in this measure from $s-1$ to s indicate that period s contributes to losses whereas decreases occur when period s consumption and leisure represent gains relative to the initial steady state. The measure initially increases quickly before slowing down when consumption and leisure increase. It peaks at year 12 and the paths for consumption and leisure up to this period imply losses that are 66% larger than the actual losses that account for the rest of the paths. After year 12, consumption and leisure imply utility higher than the initial steady state. Figure 9 also shows the same evolution of losses for a static model. In this case, losses in welfare are constant so there can be no overshooting in losses.

5.1 Static vs Dynamic

How important are the dynamic elements of the model? In this section, I compare the results from the dynamic model with a standard EK model with tariffs. Using the "hat algebra" developed by Jones (1965) and popularized again more recently starting with Dekle et al. (2007), the general equilibrium conditions for the EK model can be written as

$$\hat{P}_i^{-\theta_{EK}} = \sum_j s_{ji} (\hat{\tau}_{ji} \hat{w}_j)^{-\theta_{EK}}$$

$$\hat{s}_{ji} = \frac{(\hat{\tau}_{ji} \hat{w}_j)^{-\theta_{EK}}}{\sum_k s_{ki} (\hat{\tau}_{ki} \hat{w}_k)^{-\theta_{EK}}}$$

$$\sum_j s'_{ji} X'_i - D_i = \sum_j s'_{ij} X'_j$$

$$X'_i = \hat{w}_i w_i L_i + \sum_j (\tau_{ji} - 1) s_{ji} X_i + D_i$$

where $\hat{x}$ denotes x'/x, x denotes the equilibrium value for x under initial tariffs τ and x' denotes the equilibrium value of x under counterfactual tariffs τ'. s_{ji} is the share of country i expenditure on goods from country j, X_i is expenditure of country i, and D_i represents an exogenous trade deficit to match the data.

Computing the model requires values for the trade shares, value added, and expenditure, for which I use the 2014 data. I calculate initial expenditure assuming 10% tariffs. I use the same six regions and the same data on GDP and international trade flows to discipline the model. Because capital and materials are excluded from the model, trade is assumed to be in consumption goods only. The static trade literature generally assumes that the trade balance and net foreign asset position are exogenous to trade policy. To compare with the most common model, I maintain this assumption but later compare the results to a model with trade imbalances. In a similar fashion, I also assume that labor is inelastic and relax this assumption later.

The trade elasticity in the EK model is, of course, static and is equal to θ_{EK}. It's not immediately clear how this parameter should be calibrated in order to compare the EK model with the dynamic model for which the trade elasticity changes over time. In general, we want to compare models using the same trade elasticity. Indeed, Arkolakis et al. (2012) shows that for a large class of static trade models, equilibrating trade elasticities generates equivalent gains from trade for equivalent changes in the domestic expenditure share. Since matching trade elasticities across models is not possible, I match the discounted average value of the world domestic expenditure share.

Let λ_W be the world share of intermediate goods that are purchased domestically in the dynamic model

$$\lambda_W = \frac{\sum_j P_{jj}(C_{jj} + X_{jj} + M_{jj})}{\sum_j \sum_i P_{ij}(C_{ij} + X_{ij} + M_{ij})}$$

and λ_W^{EK} the same measure in the EK model. I choose the trade elasticity θ_{EK} in the EK model so that

$$\sum_{t=0}^{\infty} \beta^t \hat{\lambda}_W = \frac{\hat{\lambda}_W^{EK}}{1-\beta}.$$

where $\hat{\lambda}$ is the log difference in λ from the initial steady state. In words, the trade elasticity in the EK model is calibrated so that the discounted world expenditure share is the same in the two models. This implies a value of $\theta_{EK} = 5.2$, well within the range of estimates for trade elasticies in static models.

The first two rows of Table 5 show the losses from trade in the dynamic model and the static EK model for the United States. The loss to US welfare implied by the EK model is 0.07%, about 40% of the discounted loss in the dynamic model. I also try an alternate parameterization of θ_{EK} by choosing it to generate a static change in λ_W^{EK} that matches the long run change in λ_W in the dynamic model. Then $\theta_{EK} = 6.1$ and the losses from trade are 0.08%, still far below the dynamic model. Of course, in addition to missing the magnitudes, the EK model also misses out on any changes in welfare over time, which are significant in this example.

Why are the losses larger in the dynamic model? Essentially, for the same reasons that the gains for liberalizers are bigger in the dynamic model. Decreases in tariffs reduce the price of foreign goods leading to more consumption. This is true in both the static and dynamic model. In the dynamic model, however, the reduction in prices also leads to more investment, a mechanism that is amplified once capital-intensive trade is incorporated in the model. In the non-liberalizing country, the opposite occurs. As foreign exporters leave, the price of foreign goods increases, generating similar increases in the price of consumption, investment, and material goods. As a result, capital and material good purchases fall. Indeed, the dynamic model predicts long run output that is 0.5% below the initial steady state. In the long run, the price of foreign goods falls again, but the higher net foreign asset position makes it optimal to produce less and take more leisure, buying foreign goods instead of using domestic goods.

The implications of being left out of a trade agreement in the dynamic model developed in this paper differ from a static EK model both in magnitude and in the distribution over time. In the next section, I examine the importance of several model elements by removing them from the benchmark model.

5.2 Sources of US Dynamics

In this section, I show how several elements of the model affect the aggregate dynamics and gains from trade after being left out of a trade agreement. In comparing models, I recalibrate parameters as in the previous section so that the discounted change in λ_W is consistent with the benchmark model. I analyze the importance of five different elements: heterogeneous firms, financial markets, elastic labor, capital-intensive trade, and free entry of firms. The model without heterogeneous firms I call "No Firms." In this case, I let $\gamma = \theta$ and impose that fixed costs are zero for all firms. Since firms are homogeneous in productivity, this is the same as a representative firm model. I impose financial autarky by requiring $B_{i,t} = 0$ for each country i and for all periods t. Of course, the results under financial autarky assume a balanced steady state. Results for the model with a balanced steady state are also included for reference. I impose inelastic labor by removing leisure from the utility function (setting $\mu = 1$). To get rid of capital-intensive trade (called "No KIT" in the results), I recalibrate Armington weights so that $\omega_{C,ij} = \omega_{X,ij} = \omega_{M,ij}$ for all i and j. Fixed entry of firms is imposed by replacing the free entry condition for firms with

$$N_{ei} = (1 - n_s)N_{ii}.$$

Figures 10 and 11 show the response of several macro variables in each model for the US and Europe, respectively. What follows is a discussion of how eliminating each element of the model affects the results.

No Firms. The no firms model is similar in many ways to a standard EK model modified to include capital and financial markets, such as the models in Eaton et al. (2016) or Ravikumar et al. (2018). A key difference is that the no firms model still has elastic labor and capital intensive trade which are missing from these papers.

In the benchmark dynamic model, investing in the stock of exporters in any country takes time. As a result, tariff liberalizing countries cannot substitute away from US and domestic varieties right away. Without firms, this friction is gone and trade adjusts immediately, as illustrated by the domestic expenditure share, which drops about 6% on impact and stays roughly the same over time. Europe and other liberalization participants demand higher consumption, more leisure, and more investment goods in the initial periods. The only way to get more resources is to borrow. The demand for debt from liberalizing countries raises the interest rate, and the US lends a lot on impact. Unlike the dynamic model, there are no firms so the US does not need to build up exporters in order to lend more.

Unlike the dynamic model, the terms of trade for the US is not increasing over the first few periods, so there is no incentive to invest today to avoid higher future prices and investment falls by 8% on impact. Higher lending and less investment on impact result in a decrease in consumption similar to that in the benchmark model. However, lending is not persistent so consumption recovers much more quickly with the initial drop diminished by half in only 6 years. The half-life for the drop in consumption in the benchmark model by contrast is 11 years. The aggregate discounted welfare loss is about half of the loss in the benchmark model and the long run steady state gain is about double in the no firms case.

Financial Autarky. The effects of financial autarky on the liberalizing countries are similar to those discussed in section 4.2. Without the extra resources that come from borrowing, countries have slower growth in consumption and capital but converge to a steady state with higher welfare. This redistribution of welfare to more discounted periods lowers overall welfare.

When foreign countries cannot borrow, the response of the US macroeconomy is basically static. Consumption, leisure, investment, and GDP all fall on impact and remain basically constant over time. Because foreign demand is tempered by the inability to borrow, the terms of trade responds by less both on impact and over time. Importantly, the financial autarky case results in losses overall but also losses in the long run. Indeed, the risk-free bond is the key ingredient of the model that allows the US to trade current welfare for future welfare. Without it, the results on the losses from trade for the US are quite similar to the static EK model.

No KIT. Without capital-intensive trade, liberalization participants have less incentive to invest in capital in the transition because the price of investment is less affected by the liberalization. As previously discussed, the gains from trade are lower when trade is not intensive in capital since it results in less capital deepening overall. Because of this, the world demand for debt is low relative to the benchmark model. This means the US lends less on impact. As a result, US consumption drops by about 0.5% on impact, about half the initial drop in the benchmark model and leisure does not drop at all. In the medium run, no capital intensive trade means higher overshooting of welfare for liberalization participants. When they are at the peak of welfare (about year 10), they have strong incentives to save, pushing down the interest rate and incentivizing US borrowing. The reversal in the trade balance for the US is thus even stronger in this model than in the Benchmark model. The US borrows a lot in the medium run, and actually sees a net decrease in net foreign assets betweens steady states. As a result, the long run steady state also implies an even bigger loss than in the transition. GDP and investment have an even more distinct U shape due to the bigger reversal.

Inelastic Labor. Inelastic labor restricts liberalizing countries abilities to grow in terms of GDP and lowers the gains from trade. As in the No KIT case, less is borrowed initially, meaning that the US lends less initially and consumption drops by less. Inelastic labor also generates more overshooting than the No KIT case. As a result, the reversal in the trade balance is even stronger. In the long run, the US must export much more than it imports, which results in much lower long run welfare.

Fixed Entry. When entry is fixed, liberalizing countries cannot substitute workers away from creating domestic varieties and into production or building export capacity. However, the growth of the economy depends on these factors so workers are indeed needed. Thus, the wage responds much more strongly generating big increases in both labor and consumption. Hiring labor is very expensive, and more borrowing is required to do it. The US lends more both on impact and over the short run than in the benchmark case and consumption and leisure fall by more. Labor in the US rises over 1% on impact and consumption falls by almost 1.5%.

There is no reversal in the fixed entry model. The reversal in the Benchmark model came from liberalizing countries converging to the new steady state in the number of domestic varieties. The number of entrants increases and requires more of the labor that was used in production. Fixed entry makes the number of entrants constant in each period so there is no reversal. The high lending of the US in the initial periods increases their net foreign assets, and they end up much better off in the new steady state.

Conclusion from various models. Exploring these variations of the model tell us a few key things about the sources of US dynamics. The short run and long run welfare effects of being left out of a trade agreement depend crucially on the availability of financial markets. Financial markets allow the US to build up assets while the interest rate is high, sacrificing present welfare and increasing welfare in the long run. The amount of overshooting in foreign countries with regards to consumption, investment and GDP has important implications for the US trade balance. Strong overshooting generates larger reversals in the US trade balance as foreign countries sell bonds at a very low interest rate. This increases US growth in the medium run but lowers long run welfare in the long run relative to a case with no overshooting. Higher overshooting also generates more distinctly U-shaped patterns in investment and GDP. Lastly, heterogeneous firms and the dynamic exporting decision are crucial to generate U-shaped patterns in investment and make the initial changes in the trade balance and decrease in consumption more persistent.

5.3 The Cost of Being Left Out... Temporarily

The dynamic model allows us to examine the impact of changing the timing of the policy. In this section, I explore the effects of being left out of a trade agreement temporarily. The analysis is done assuming perfect foresight, so that the excluded country knows it will later be included and acts appropriately. While this assumption may seem heroic for longer time horizons, it is innocuous for shorter time horizons since negotiations on free trade agreements or joining existing trade blocks take time. Moser and Rose (2012) gather data on 88 trade agreements and conclude that negotiations take 28 months on average.

Regional trade agreements are common. Often countries are initially left out only to be included a few years later. The European Union for instance, originally included only six countries. In 2013, Croatia joined as the 28th member of the organization. In 1989, Canada and the US signed the Canada-United States Free Trade Agreement. Five years later, the North American Free Trade Agreement extended tariff reductions to Mexico. In the dynamic model, we can look at the effects of temporary exclusion from a trade liberalization. To compare the results with those above, I consider the same elimination of 10% bilateral tariffs in the same six regions. Initially the US is excluded. However, all agents know that in either two or six years, the US will join the liberalization and all worldwide tariffs will be eliminated. I use this experiment to investigate how the economy responds differently based on their expectations about future inclusion. Also, we can examine how costly being temporarily excluded is relative to a case in which there is no exclusion initially.

Figure 12 compares US responses under four different assumptions on the period of exclusion: (1) permanent exclusion, (2) 2-year exclusion, (3), 6-year exclusion, and (4) immediate and permanent inclusion. Similar to Alessandria and Mix (2018), expectation of a future liberalization is recessionary in the short run. A 2-year exclusion period reduces real GDP by about 2% on impact and 3.5% in the period before the US joins the agreement. A 6-year exclusion period has little effect on GDP on impact, but then GDP decreases over the next five periods with a trough at 5% below the initial steady state right before the US is included. What can explain these dynamics? Knowing that the future price of investment goods will fall dramatically, the economy runs down its capital stock and instead uses its output to consume more and lend to the rest of the world. Leisure increases on impact and the increase is larger with longer exclusion due to reduced investment in the form of fixed cost to export and produce in the initial years. Indeed, labor used in production actually decreases more in the 2-year exclusion case. The initial reduction in GDP is therefore due to agents taking more leisure in the short run and reallocation of labor from production to fixed costs of exporting.

When the US is temporarily excluded, it uses the exclusion period to build up its stock of the risk-free bond by lending to the liberating countries and to invest in exporting capacity. Upon entering the trade agreement, the US then uses those accumulated bonds and borrows to finance its large investment in capital and increases in consumption. Due to previous investment in the stock of exporters, substitution away from the domestic variety occurs quickly. Table 6 shows the growth rates of consumption and output in the first five years after the US is included in the liberalization. The growth of both consumption and output following the inclusion of the US is faster for longer periods of exclusion due to more borrowing and a more evolved trade network. Indeed, we see that the 5-year growth rates of consumption and output relative to immediate inclusion are 63% and 21% larger with a 2-year exclusion and 100% and 64% faster with a 6-year exclusion. Also included in Table

6 are the gains from trade under the various timing restrictions. Being left out of a trade agreement for two years reduces the gains by 5% and being left out for 6 years reduces the gains by about 17%.

This experiment can't be done in a purely static model without capital, bonds, or heterogeneous firms. We can, however, repeat the experiment omitting two key margins of adjustment: bonds and firms. We saw in the benchmark model that the temporarily excluded country used both of these margins to prepare for the liberalization. I repeat the experiment in the dynamic model assuming financial autarky and again in a model without firms as previously explained. Table 7 shows the gains from trade with immediate inclusion and a 6-year exclusion period under the various model specifications. In financial autarky, the overall gains from being excluded for six years are still only 19% smaller. Eliminating bonds as a margin of adjustment for the US does not make exclusion much more costly relative to the benchmark model. In the model without firms, on the other hand, the overall gains with a 6-year exclusion period are 28% smaller than with immediate inclusion. The forward-looking decision for exporters and entrant firms is a useful tool in preparing for future liberalizations and is the key margin to capture the relative gains under exclusion.

In summary, being temporarily excluded from a trade agreement affects both short-run and long-run outcomes. Agents take more leisure today, causing a recession that is steeper for longer periods of exclusion. Trade networks begin to evolve immediately, preparing for the liberalization and consumption and output grow faster after liberalizing. Being left out of the agreement temporarily lowers the gains from trade relative to being included initially, but being able to adjust trade and production networks through long-lived firm decisions alleviates the relative loss.

5.4 Multi-Country Analysis

So far, the focus has been on the effect of liberalizations on the US economy. The multi-country model can also tell us how other economies are affected. Table 8 reports the consumption equivalent gains from trade for each country in a global liberalization that includes the US, excludes the US permanently, and excludes the US for six years. As expected, NAFTA gains the most in a global liberalization as it is the smallest country and the ROW, as the largest country, gains least. When the US is left out, gains for all countries fall, and the amount that they fall is closely linked to how much they rely on the US in trade. For NAFTA, 56% of total imports come from the United States. Thus, gains for NAFTA when the US is permanently left out are less than a quarter of the gains when the US is included. Countries that are more closed to the US such as the ROW and China suffer less; gains only fall by about 10%. When the US is left out temporarily, gains for the other countries fall by much less; about 11% for NAFTA and only 2-4% for others.

6 Conclusion

I develop a tractable multicountry general equilibrium model with semi-fixed trade networks in the short run that can match world geography. This addition generates nontrivial transitions and significant fluctuations in the short run that affect the overall gains from trade. The model is used to analyze the effects on the US of being left out of a world trade liberalization over time. The benchmark model produces total losses from the liberalization that are 2.5 times bigger than those predicted by a static EK model and are equivalent to the losses from unilaterally raising tariffs from 10% to 14%. Furthermore, these losses are not distributed equally over time, with all of the losses occurring in the first 12 years and gains thereafter. Intertemporal trade (financial markets) in the model is the key driver of the uneven distribution of gains. Firm dynamics and the dynamic exporting decision increase losses as the initial losses are more persistent. In addition, because foreign countries substitute slowly and trade is intensive in capital goods, there is an incentive for the US to invest more on impact. High initial investment and later reversals in the trade balance generate a U-shaped GDP response, so that being left out is initially expansionary, then recessionary before converging to a level slightly below the initial steady state. Temporary exclusion from a foreign trade agreement is also costly relative to immediate inclusion, but it is less so in the dynamic model due to forward-looking firm decisions.

The model is general enough to analyze any multilateral trade policies and can be used in many other applications. It is well suited to Bayesian estimation over a period of time. Such an estimation could be used to understand the macroeconomic effects of the global trade integration on individual countries over time including the effects of direct changes in trade costs, foreign liberalizations, and expectations about future changes with each trading partner. For a further discussion of estimation in dynamic trade models, see Alessandria and Mix (2018). The model is also amenable to the introduction of sectoral heterogeneity, which may change the implications presented here (see Levchenko and Zhang (2014)). A simpler form of productivity heterogeneity across firms could also be added, allowing for closer study of the firm-level effects of trade policy, although, as shown in this paper, it will have little effect on aggregate dynamics. Future work will address these topics.

References

Alessandria, G. and Choi, H. (2007). Do sunk costs of exporting matter for net export dynamics? *The Quarterly Journal of Economics*, pages 289–336.

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

Alessandria, G., Choi, H., and Ruhl, K. (2018). Trade adjustment dynamics and the welfare gains from trade. Technical report, National Bureau of Economic Research.

Alessandria, G. and Mix, C. (2018). Trade policy is real news: A quantitative analysis of past, present, and future trade costs.

Alessandria, G., Pratap, S., and Yue, V. Z. (2013). Export dynamics in large devaluations.

Altomonte, C. and Aquilante, T. (2012). The eu-efige/bruegel-unicredit dataset. Technical report, Bruegel working paper.

Alvarez, F. (2017). Capital accumulation and international trade. *Journal of Monetary Economics*, 91:1–18.

Alvarez, F. and Lucas, R. E. (2007). General equilibrium analysis of the eaton–kortum model of international trade. *Journal of monetary Economics*, 54(6):1726–1768.

Arkolakis, C., Costinot, A., and Rodríguez-Clare, A. (2012). New trade models, same old gains? *American Economic Review*, 102(1):94–130.

Backus, D. K., Kehoe, P. J., and Kydland, F. E. (1992). International real business cycles. *Journal of Political Economy*, 100(4):745–775.

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

Baldwin, R. (1988). Hysteresis in import prices: The beachhead effect. *The American Economic Review*, pages 773–785.

Baldwin, R. (1989). Sunk-cost hysteresis.

Baldwin, R. and Krugman, P. (1989). Persistent trade effects of large exchange rate shocks. *The Quarterly Journal of Economics*, 104(4):635–654.

Bernard, A. B., Boler, E. A., Massari, R., Reyes, J.-D., and Taglioni, D. (2017). Exporter dynamics and partial-year effects. *American Economic Review*, 107(10):3211–28.

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

Boileau, M. (1999). Trade in capital goods and the volatility of net exports and the terms of trade. *Journal of international Economics*, 48(2):347–365.

Boileau, M. (2002). Trade in capital goods and investment-specific technical change. *Journal of Economic Dynamics and Control*, 26(6):963–984.

Das, S., Roberts, M. J., and Tybout, J. R. (2007). Market entry costs, producer heterogeneity, and export dynamics. *Econometrica*, 75(3):837–873.

Dekle, R., Eaton, J., and Kortum, S. (2007). Unbalanced trade. *American Economic Review*, 97(2):351–355.

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

Dixit, A. (1989b). Hysteresis, import penetration, and exchange rate pass-through. *The Quarterly Journal of Economics*, 104(2):205–228.

Eaton, J. and Kortum, S. (2002). Technology, geography, and trade. *Econometrica*, 70(5):1741–1779.

Eaton, J., Kortum, S., Neiman, B., and Romalis, J. (2016). Trade and the global recession. *The American Economic Review*, 106(11):3401–3438.

Engel, C. and Wang, J. (2011). International trade in durable goods: Understanding volatility, cyclicality, and elasticities. *Journal of International Economics*, 83(1):37–52.

Fitzgerald, D. (2012). Trade costs, asset market frictions, and risk sharing. *American Economic Review*, 102(6):2700–2733.

Hopenhayn, H. A. (1992). Entry, exit, and firm dynamics in long run equilibrium. *Econometrica: Journal of the Econometric Society*, pages 1127–1150.

Jones, R. W. (1965). The structure of simple general equilibrium models. *Journal of political Economy*, 73(6):557–572.

Jung, B. (2012). Gradualism and dynamic trade adjustment: Revisiting the pro-trade effect of free trade agreements. *Economics Letters*, 115(1):63–66.

Klier, T. H., Rubenstein, J. M., et al. (2017). Mexico's growing role in the auto industry under nafta: Who makes what and what goes where. *Economic Perspectives*, (6):1–29.

Levchenko, A. A. and Zhang, J. (2014). Ricardian productivity differences and the gains from trade. *European Economic Review*, 65:45–65.

Lucas, R. E. (1987). *Models of business cycles*, volume 26. Basil Blackwell Oxford.

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

Moser, C. and Rose, A. K. (2012). Why do trade negotiations take so long? *Journal of Economic Integration*, pages 280–290.

Ravikumar, B., Santacreu, A. M., and Sposi, M. (2018). Capital accumulation and dynamic gains from trade.

Reyes-Heroles, R. (2016). The role of trade costs in the surge of trade imbalances. *Princeton University, mimeograph.*

Roberts, M. J. and Tybout, J. R. (1997). The decision to export in colombia: an empirical model of entry with sunk costs. *The American Economic Review*, pages 545–564.

Ruhl, K. J. and Willis, J. L. (2017). New exporter dynamics. *International Economic Review*, 58(3):703–726.

Simonovska, I. and Waugh, M. E. (2014). The elasticity of trade: Estimates and evidence. *Journal of international Economics*, 92(1):34–50.

Steinberg, J. et al. (2017). Brexit and the macroeconomic impact of trade policy uncertainty. In *2017 Meeting Papers*, number 216. Society for Economic Dynamics.

Wagner, J. (2015). A note on firm age and the margins of exports: First evidence from germany. *The International Trade Journal*, 29(2):93–102.

A Tables

Panel A: Externally calibrated parameters			
Parameter	Description	Value	Target
β	Discount factor	0.96	
δ	Capital depreciation rate	0.1	
α	Capital share in value added	0.36	
α_C	Share of materials in C production	0.8	
α_M, α_X	Share of materials in X and M production	1	
γ	Armington elasticity	4	SR Trade Elasticity = 3
$\bar{L}_i$	Labor endowment	varies	Population in i, $\bar{L}_{US} = 1$
n_s	Firm survival rate	0.98	Surviving labor share
Panel B: Internally calibrated parameters			
μ	Relative preference C vs L	0.33	$L_{US} = 1/4$
f_e	Entry cost	1.64	$N_{US} = 1$
α_m	Cobb-Douglas share for materials	0.6	Gross Output=2·Value added
θ	Elasticity of substitution	6	LR Elasticity ≈ 8
ν	Fixed cost distribution curvature	4	92% phase in 10 years
f_{0i}	Average fixed cost (nonexporters)	varies	Fraction exporters = 0.45
f_{1i}	Average fixed cost (exporters)	varies	Exiters export share = 4%
z_i	Productivity	varies	$\frac{GDP_i}{GDP_{US}}$, $z_{US} = 1$
$\omega_{G,ij}$	Armington weights for good G	varies	End-use trade flows

Table 1: Calibrated values for model parameters. Panel A includes parameters for which values are chosen externally and Panel B includes parameters for which values are chosen jointly to match moments in the data. The targets listed for Panel B are the moments that are most informative for that parameter. Country-specific parameter values can be found in Table 2.

Region	$\bar{L}_i$	z_i	f_{0i}	f_{1i}	$\omega_{C,ji}$	$\omega_{X,ji}$	$\omega_{M,ji}$
US	1	1	685	0.009	(0.55,0.03,0.03,0.12,0.06,0.19)	(0.16,0.06,0.07,0.23,0.11,0.37)	(0.3,0.05,0.05, 0.19, 0.1, 0.31)
NAFTA	0.5	0.84	1573	0.03	(0.05,0.53,0.04,0.15,0.07,0.16)	(0.09,0.14,0.08,0.28,0.12,0.3)	(0.07,0.28 0.06,0.23,0.1,0.25)
EU	1.6	0.73	828	0.012	(0.01,0.01,0.64,0.08,0.04,0.21)	(0.02,0.02,0.22,0.18,0.09,0.46)	(0.02,0.01,0.39,0.14,0.07,0.36)
China	4.3	0.34	1043	0.014	(0.00,0.00,0.01,0.88,0.03,0.08)	(0.01,0.01,0.03,0.57,0.09,0.29)	(0.01,0.01,0.02,0.74,0.05,0.17)
EA	2.3	0.49	1147	0.016	(0.01,0.00,0.02,0.09,0.73,0.15)	(0.02,0.01,0.05,0.23,0.28,0.41)	(0.02,0.01,0.03,0.17,0.48,0.3)
ROW	12.7	0.23	606	0.009	(0.00,0.00,0.01,0.02,0.01,0.96)	(0.01,0.01,0.03,0.07,0.04,0.84)	(0.00,0.00,0.02,0.04,0.02,0.92)

Table 2: Country-specific parameters. Armington shares may not add to one due to rounding.

Model	Gains from Trade		
	Consumption Equiv.(%)	Steady State(%)	Static Equil.(%)
Benchmark	3.75	3.73	-
Inelastic L	3.08	1.45	-
No KIT	2.86	1.85	-
No Firms	2.2	2.96	-
Eaton-Kortum	-	-	0.23

Table 3: Gains from trade in a 2-country symmetric world under different model specifications. Consumption equivalence computes gains from trade that include the transition using Lucas consumption equivalence. Steady state compares welfare across steady states in a dynamic model and static equilibrium compares welfare across equilibria in a static model.

Model	Two country		Six country		Six - US lib	
	CE(%)	SS(%)	CE(%)	SS(%)	CE(%)	SS(%)
FA	3.22	3.2	3.05	2.97	3.19	3.14
$B_0 = 0$	3.39	2.91	3.04	3.04	3.35	2.89
$B_0 > 0$	3.07	2.62	2.82	2.8	3.05	2.64
Exo TB	-	-	2.66	2.65	-	-

Table 4: Gains from trade in 2-country and 6-country asymmetric models under different assumptions about financial markets and initial NFA positions. FA denotes financial autarky, $B_0 = 0$ denotes a bond economy with balanced trade in the initial steady state, $B_0 > 0$ denotes a bond economy with trade imbalances from the data in 2014 which implies a large positive NFA position for the US, Exo TB denotes a version of the model with zero NFAs for all countries but permanent endowment shocks that keep the structure of trade the same. The last two columns are the gains assuming that only the US liberalizes tariffs bilaterally with each country but foreign countries do not liberalize with each other.

Model	US Gains from Trade when left out		
	Consumption Equiv.(%)	Steady State(%)	Static Equil.(%)
Benchmark	-0.17	0.16	-
Eaton-Kortum (EK)	-	-	-0.07
EK high θ_{EK}	-	-	-0.08
No Firms	-0.09	0.27	-
Financial Autarky	-0.09	-0.11	-
$B_0 = 0$	-0.23	0.15	-
Inelastic L	-0.13	-0.62	-
No KIT	-0.09	-0.18	-
Fixed Entry	-0.2	0.94	-

Table 5: US gains from being left out of a worldwide trade liberalization. See text for description of various models.

Model	Consumption Growth (%)	Output Growth (%)	US Gains	
			CE(%)	SS(%)
Benchmark (Permanent exclusion)	-	-	-0.17	0.16
Immediate inclusion	2.4	4.7	2.8	2.82
2-Year Exclusion	3.9	5.7	2.68	2.74
6-Year Exclusion	4.8	7.7	2.33	2.55

Table 6: US gains and aggregate dynamics from being temporarily left out of a worldwide trade liberalization. Consumption and output growth are the 5-year growth rates of consumption and output after joining the liberalization.

Model	Global Lib		6-Year Exclusion		Gains Discount (6YE/GL)
	CE(%)	SS(%)	CE(%)	SS(%)	
Benchmark Model	2.8	2.82	2.33	2.55	0.83
Financial Autarky	3.05	2.97	2.47	2.97	0.81
No Firms	1.51	2.19	1.09	1.89	0.72

Table 7: US gains from being temporarily left out of a worldwide trade liberalization in various models.

Country	Global Lib (GL) CE(%)	US Left Out (LO) CE(%)	USLO/GL	US Ex 6 Y (TLO) CE(%)	TLO/GL
US	2.82	-0.17	-	2.33	0.83
China	3.24	2.84	0.88	3.14	0.97
EA	4.48	3.82	0.85	4.38	0.98
EU	3.34	2.82	0.84	3.24	0.97
NAFTA	6.4	1.51	0.24	5.69	0.89
ROW	2.23	1.99%	0.9	2.15	0.96

Table 8: Gains from trade for all countries in a global liberalization, with the US left out permanently, and with the US excluded for six years. The table also shows the discount on the gains for each country when the US is excluded either temporarily or permanently.

B Figures

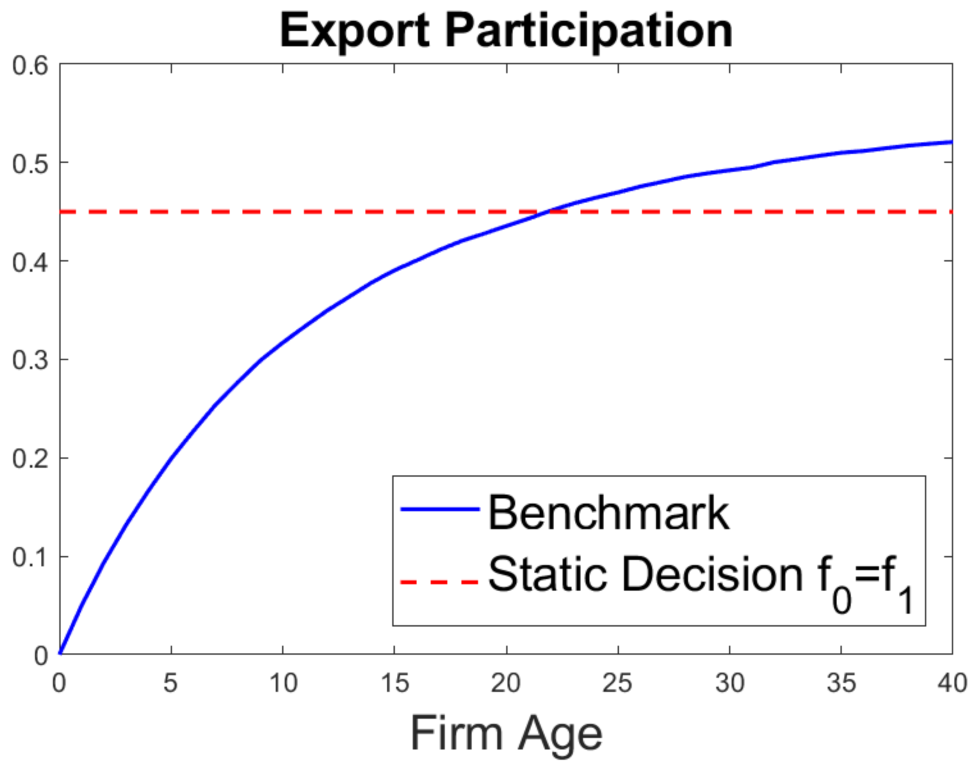

Figure 1: Export participation by firm age in a cohort of 100,000 surviving firms.

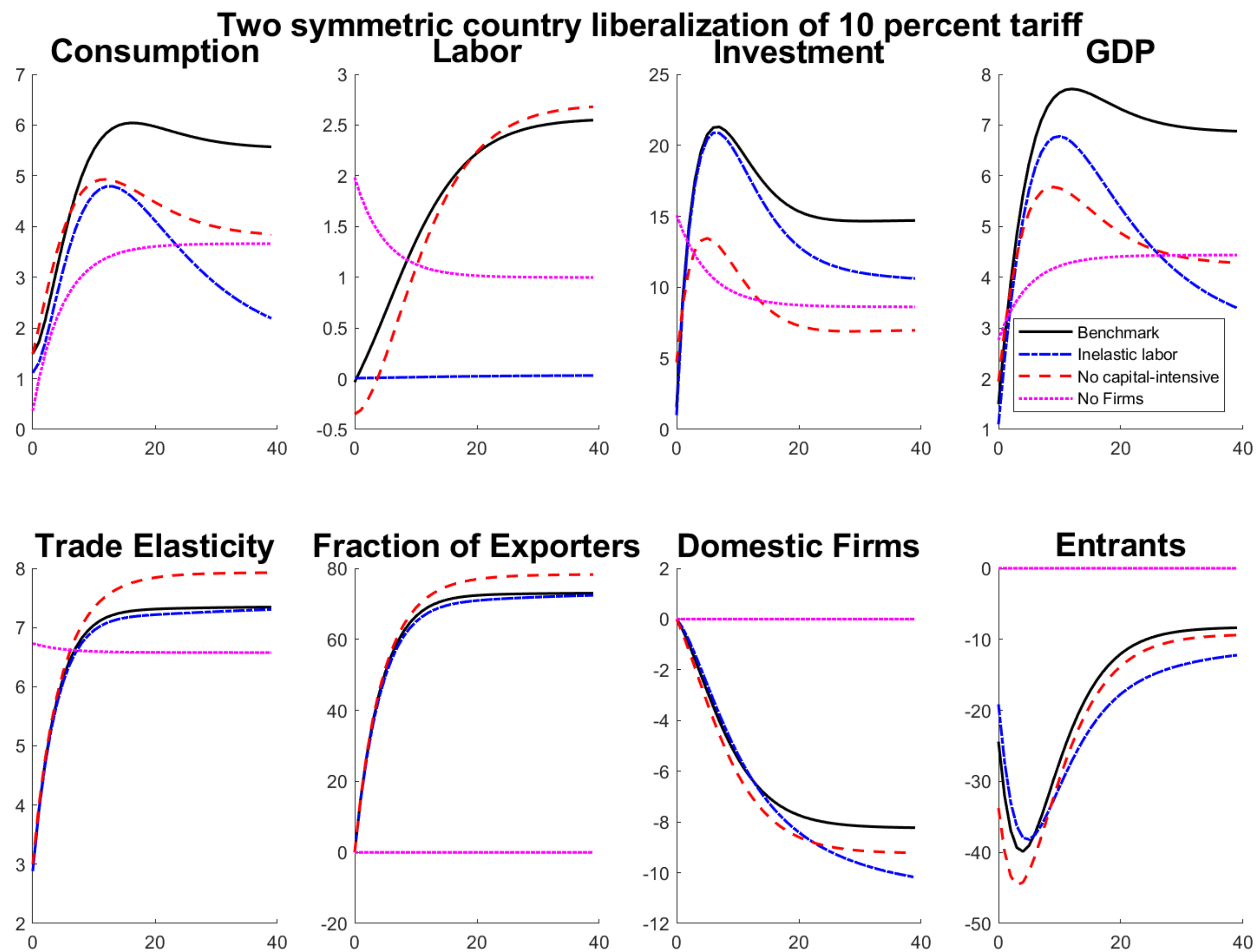

Figure 2: Transition dynamics following a 10% tariff elimination in a symmetric two-country world.

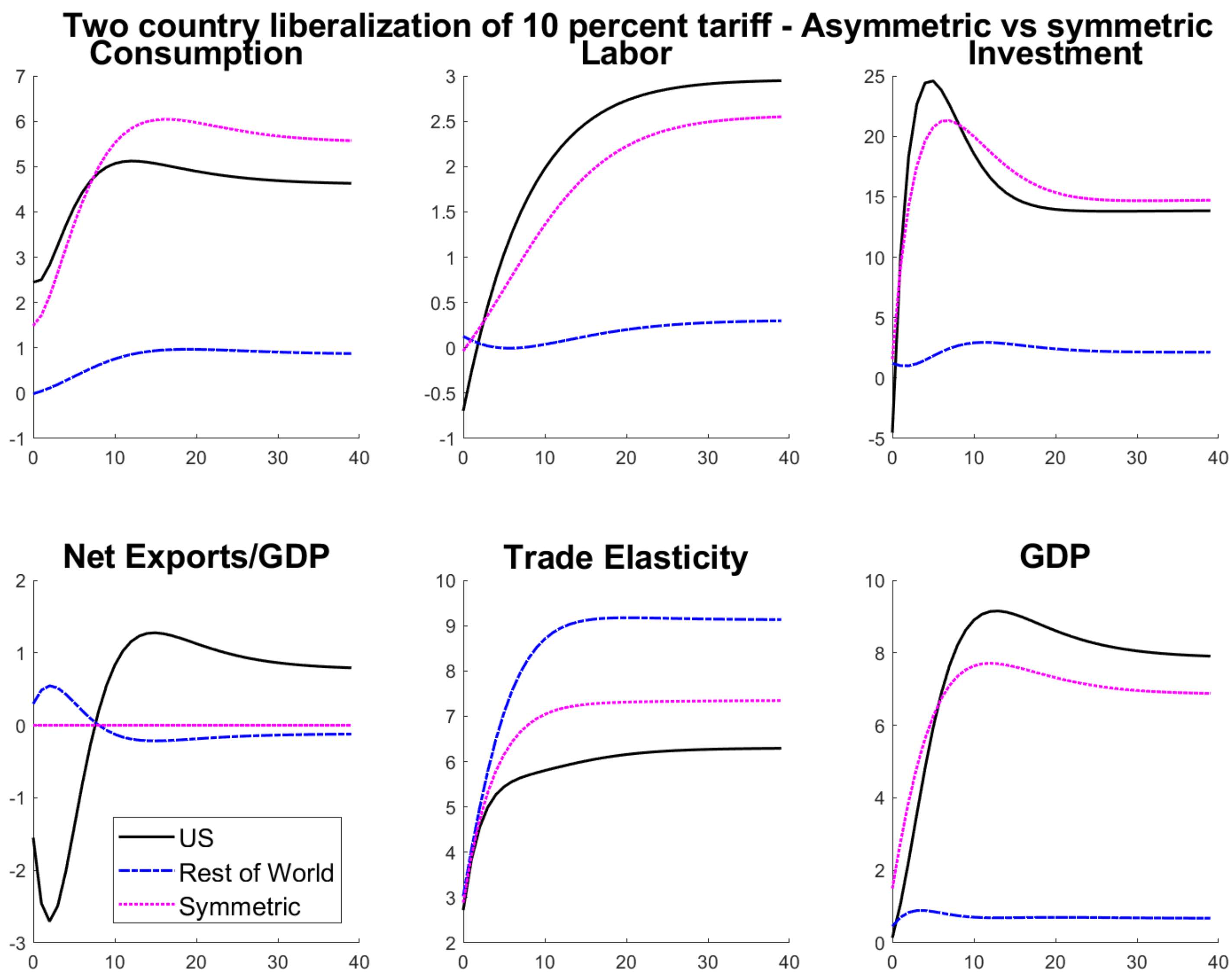

Figure 3: Transition dynamics following a 10% tariff elimination in an asymmetric two-country world compared to the symmetric two-country world

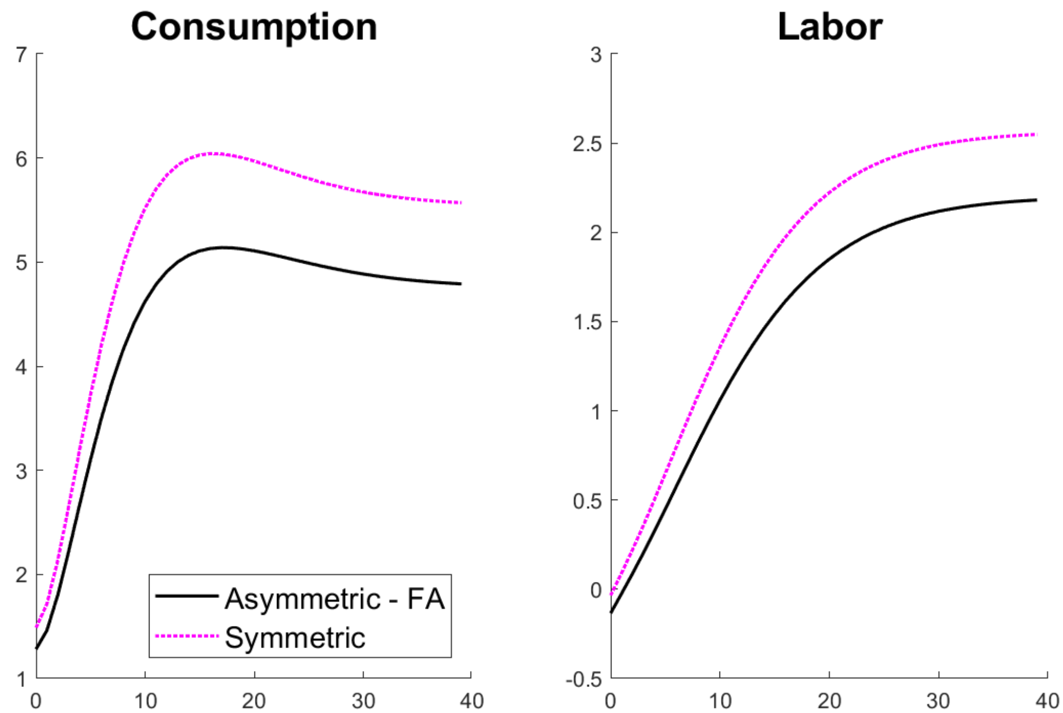

Figure 4: Welfare components in a two-country asymmetric world in financial autarky and the symmetric two-country world. Without financial autarky, the paths of consumption and leisure do not cross.

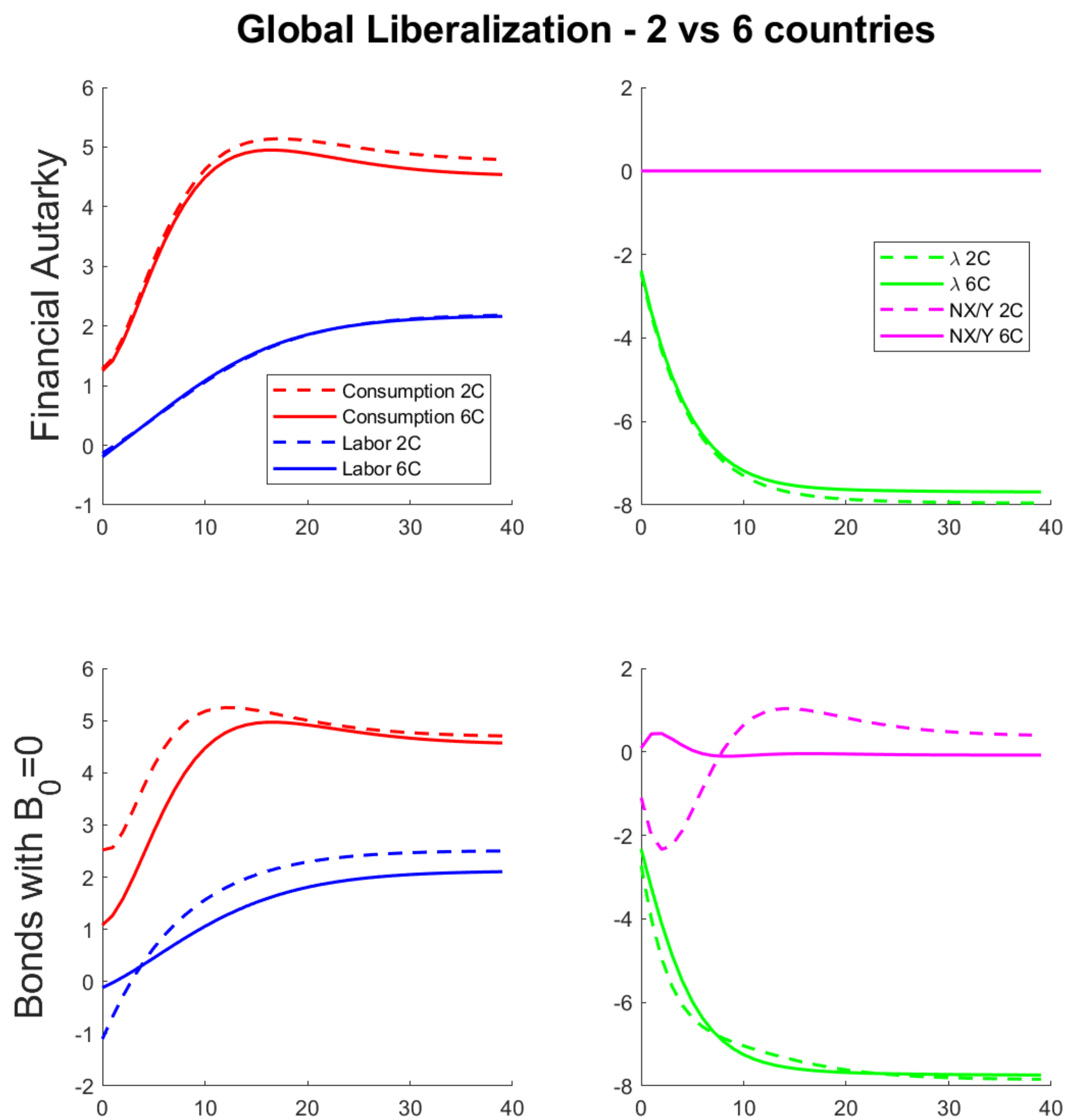

Figure 5: Responses of consumption, labor, the trade balance and the domestic expenditure share (λ) to a global liberalization in a 2-country and 6-country calibration. 2C = 2-country, 6C = 6-country.

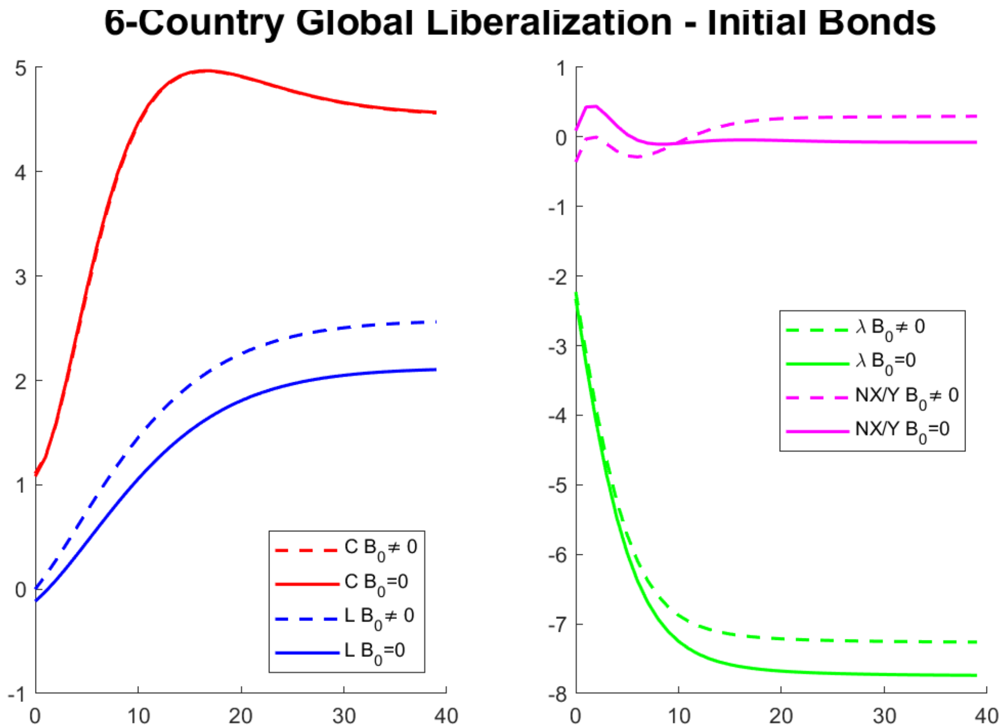

Figure 6: This figure compares economy responses to a global liberalization in a 6-country economy when $B_0 = 0$ and when $B_0 > 0$ to match US trade balances in 2014.

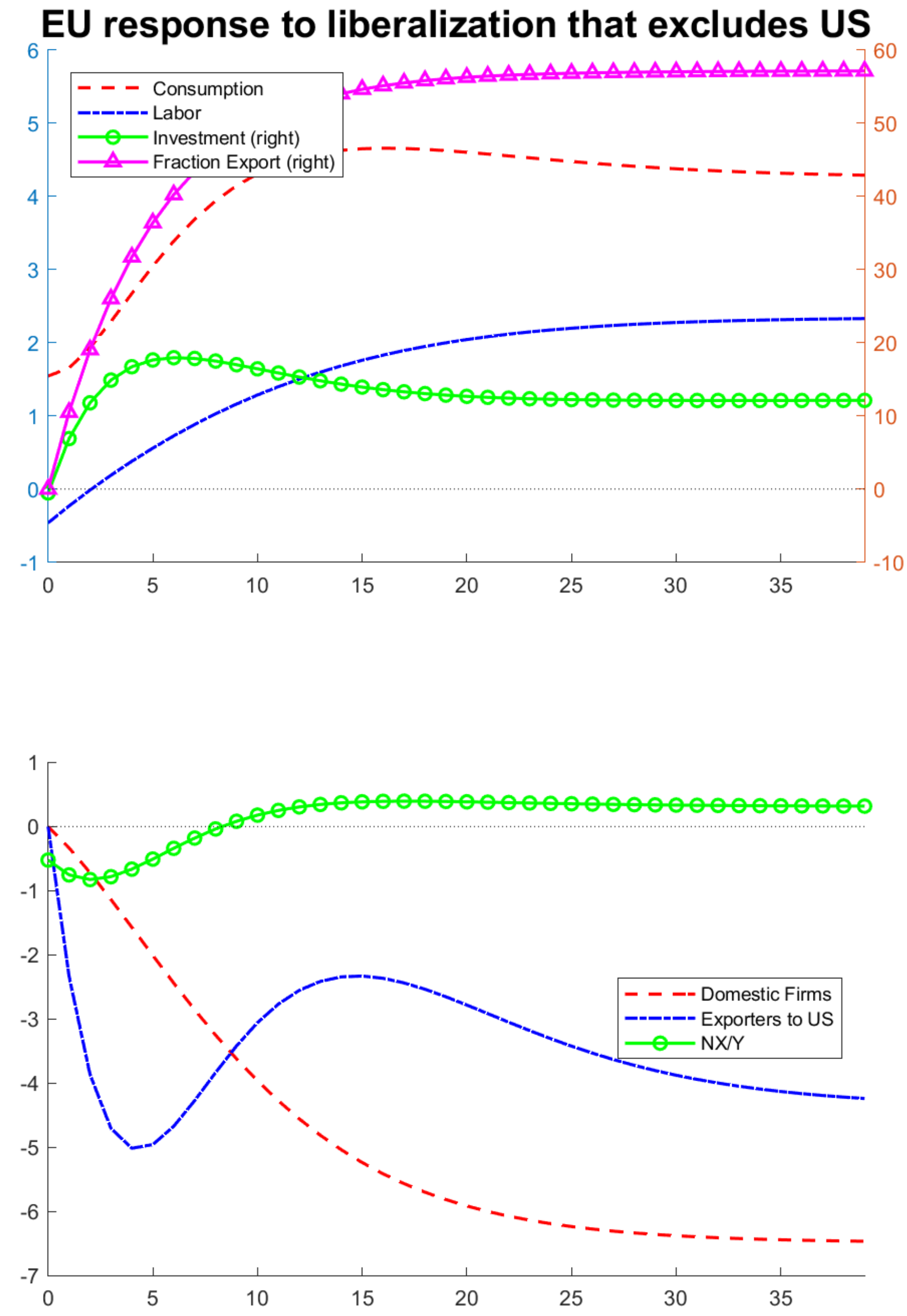

Figure 7: Macroeconomic responses for the European Union to a liberalization of 10% tariffs that excludes the US. Values represent log point differences from the initial steady state.

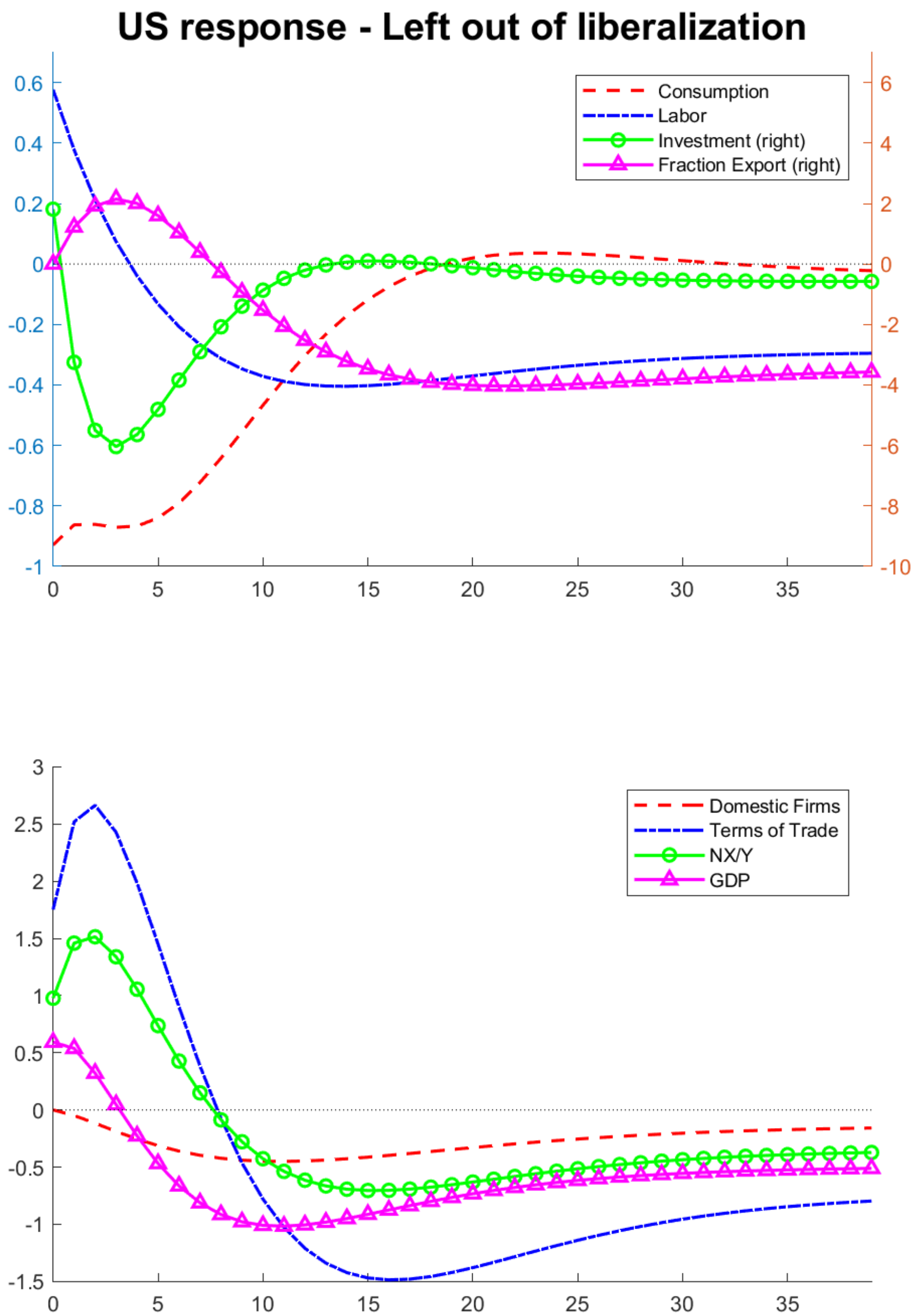

Figure 8: Macroeconomic responses for the United States when left out of a liberalization of 10% tariffs. Values represent log point differences from the initial steady state.

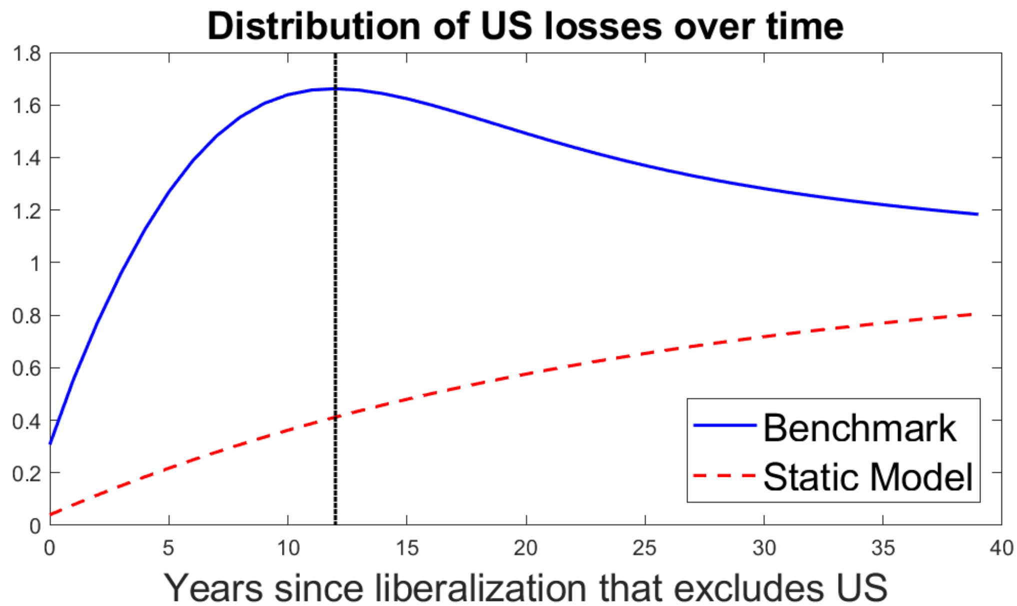

Figure 9: This figure graphs the losses assuming an immediate return to the initial steady state from $t+1$ onward as a fraction of the losses that account for the whole path. Increases at t imply $U_t < U_{-1}$ and decreases imply $U_t > U_{-1}$.

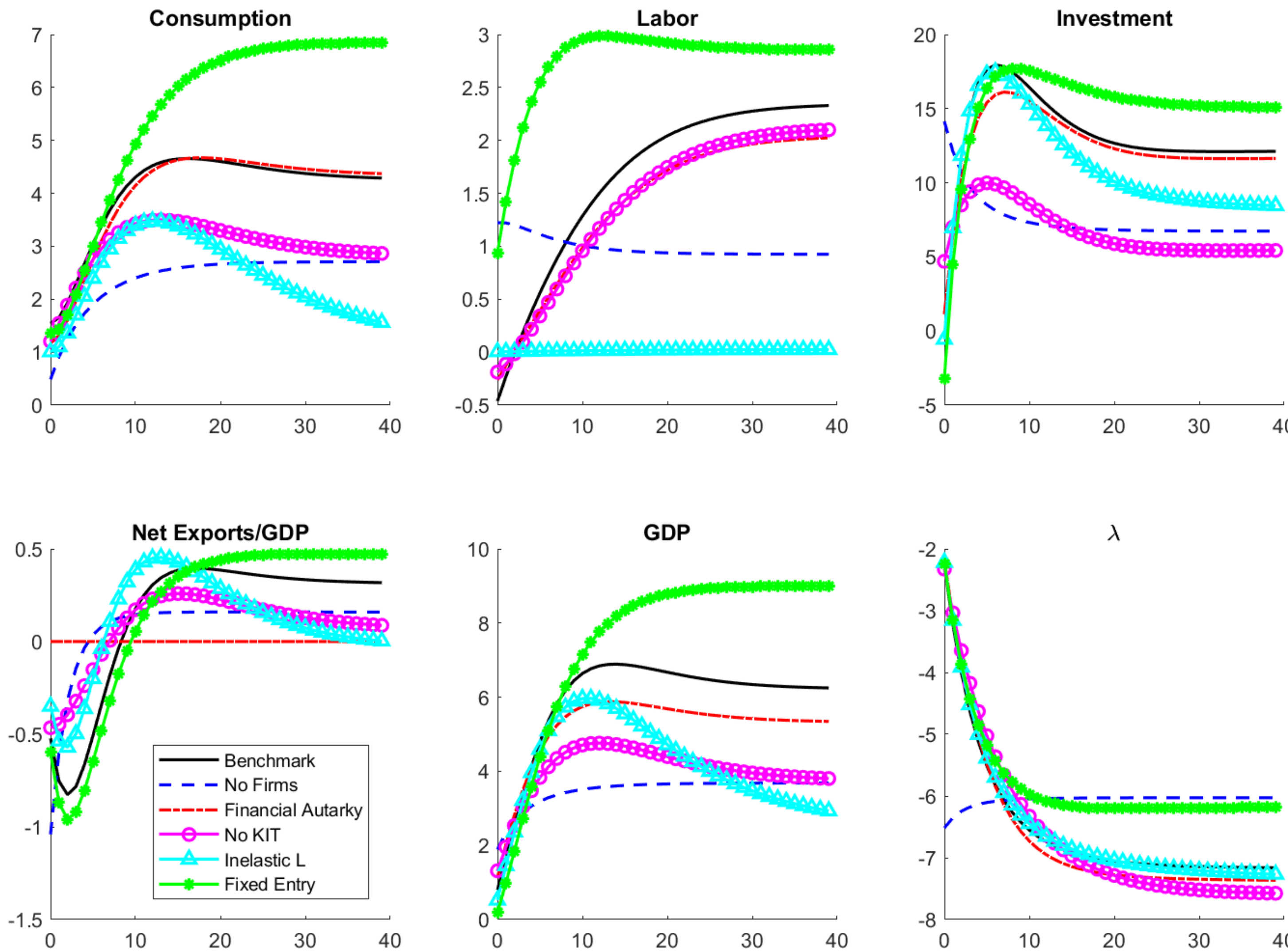

Figure 10: Macroeconomic responses for the European Union when left out of a liberalization of 10% tariffs. See text for description of various models.

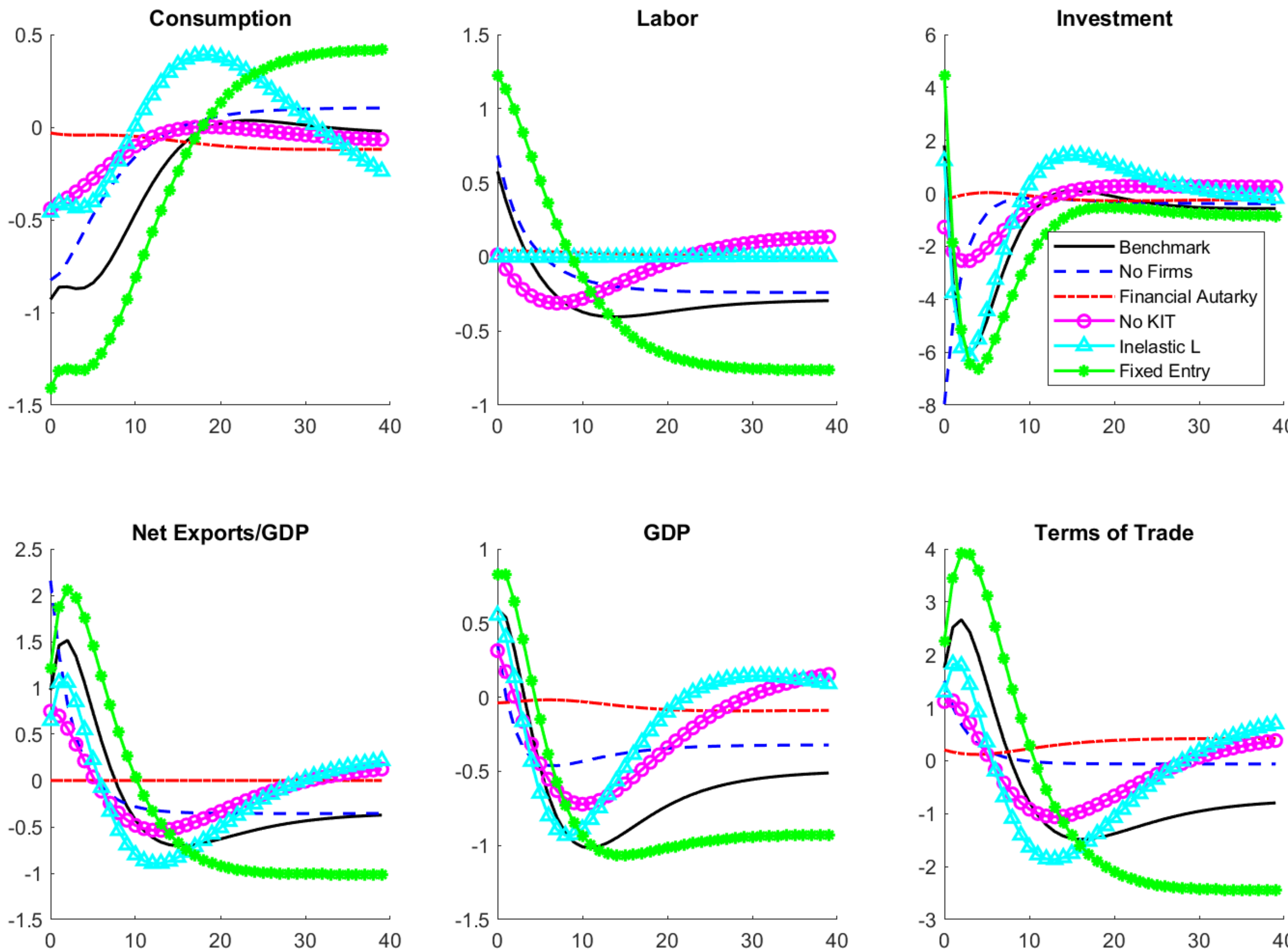

Figure 11: Macroeconomic responses for the United States when left out of a liberalization of 10% tariffs. See text for description of various models.

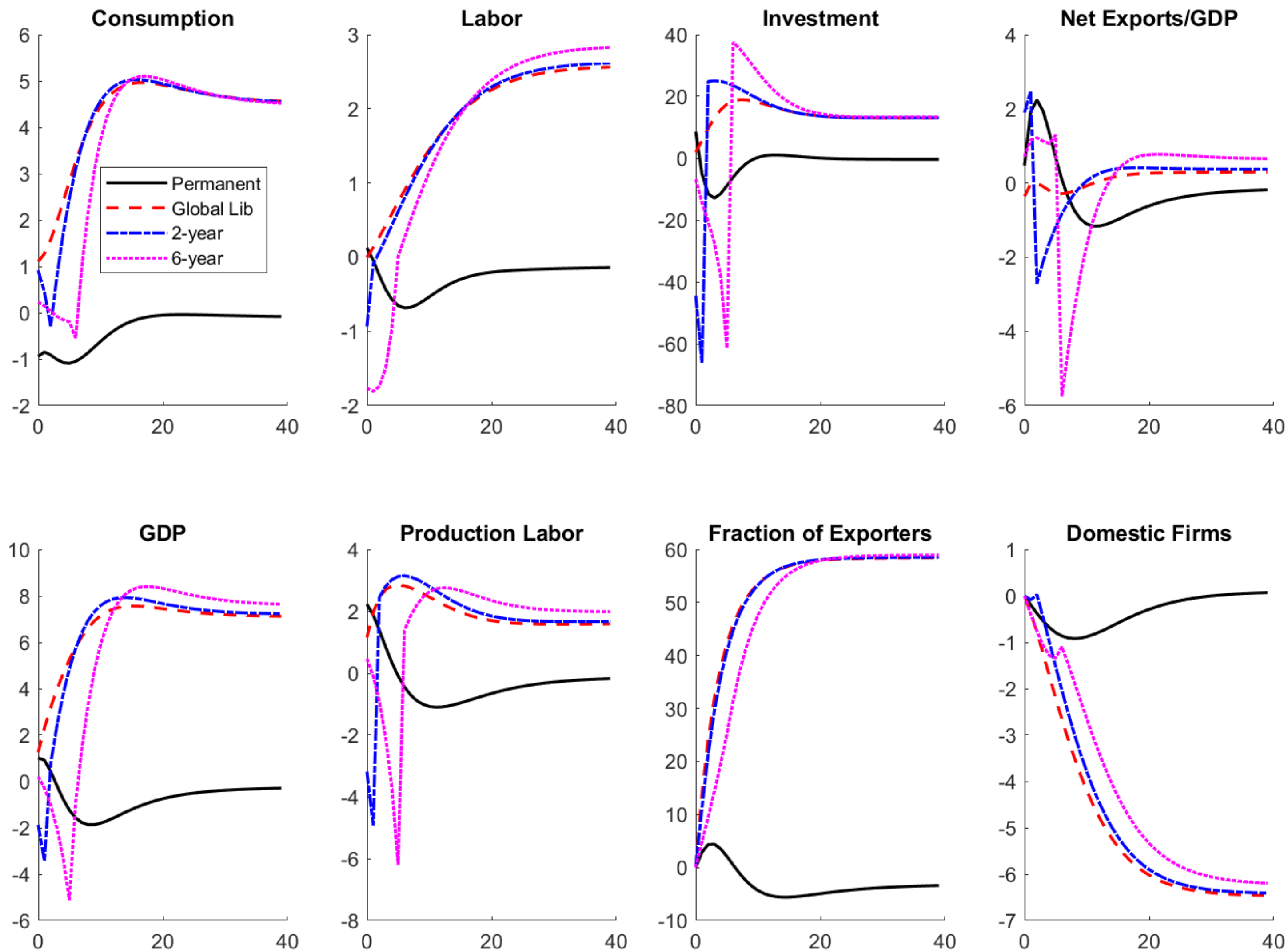

Figure 12: Macroeconomic responses for the United States when temporarily left out of a liberalization of 10% tariffs. Permanent refers to permanent exclusion of the US (the benchmark experiment). Global Lib refers to a global liberalization at time 0, 2-year and 6-year refer to the US being left out for the first 2 or 6 years of the agreement.

C End-Use Trade

I gather UN Comtrade data on bilateral trade by Broad Economic Categories (BEC) for the six regions in the model. Trade that is not specified (BEC=7*) and trade in petroleum (BEC=321*) are excluded. The remaining BEC classifications are split into capital, intermediate, and consumption goods as suggested by UN Comtrade in the following way:

Capital goods:

- 41* Capital goods (except transport equipment)
- 521* Transport equipment, industrial

Intermediate goods:

- 111* Food and beverages, primary, mainly for industry
- 121* Food and beverages, processed, mainly for industry
- 21* Industrial supplies not elsewhere specified, primary
- 22* Industrial supplies not elsewhere specified, processed
- 31* Fuels and lubricants, primary
- 322* Fuels and lubricants, processed (other than motor spirit)
- 42* Parts and accessories of capital goods (except transport equipment)
- 53* Parts and accessories of transport equipment

Consumer goods:

- 112* Food and beverages, primary, mainly for household consumption
- 122* Food and beverages, processed, mainly for household consumption
- 522* Transport equipment, non-industrial
- 61* Consumer goods not elsewhere specified, durable
- 62* Consumer goods not elsewhere specified, semi-durable
- 63* Consumer goods not elsewhere specified, non-durable

The sum over each category in capital goods, for instance, represents aggregate trade in capital goods.