Trade Policy is Real News: A Quantitative Analysis of Past, Present, and Future Trade Costs*

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Abstract

We evaluate the aggregate effects of changes in trade barriers when trade responds gradually to changes in trade policy from a dynamic exporting decision and trade policy changes can be implemented with a lag. Our model offers insights into how the timing of changes in trade barriers affect the economy and how business cycle shocks affect trade. We find a fall in current trade barriers is expansionary while a decline in future trade barriers is recessionary on impact. Furthermore, canceling agreed upon declines in future trade barriers is expansionary in the short-run but substantially lowers medium-run growth. We capture the growth and trade factors driving the economy with movements in productivity, investment efficiency, the labor wedge, and trade costs. Business cycle shocks generate persistent fluctuations in trade flows as trade lags the demand for tradables, making trade-based approaches to measure trade costs suspect. We estimate the model to match US aggregate fluctuations and trade integration since 1970. Our estimation yields a time series of trade costs and expected future trade costs. Forward-looking variables such as export participation help to identify future trade costs. Our model is well-suited to studying alternative unilateral and bilateral changes in current and future trade barriers being contemplated.

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1 Introduction

Declines in policy and non-policy trade barriers have generated a dramatic liberalization of trade over the past 60 years. Now that this liberalization is slowing and protectionism is on the rise, it is more important than ever to understand the impact that trade integration has had on the aggregate economy. In this paper, we recognize that the reduction in trade costs of the past several decades comes from both expected and unexpected changes. For example, trade agreements such as GATT rounds follow long periods of negotiation and specify a phaseout for tariffs so that agents predict a decreasing path for future trade costs. Of course, anticipated and unanticipated changes in trade costs may have very different aggregate effects. Therefore, knowing the source of the trade cost decline is important for understanding the impact that the recent trade integration has had on the US economy.

This paper makes three main contributions. First, we study the aggregate effects of changes in trade barriers in a general equilibrium model in which trade responds gradually to changes in trade policy and future trade costs can be expected by firms and consumers. The model confirms that agents' expectations about future trade costs have important implications for aggregate outcomes. Second, we use OECD panel data and the timing of GATT round negotiations and implementation to validate the aggregate predictions of the model. Third, we provide a methodology by which a series for trade costs and their expected path can be extracted from data. Different subsets of simulated data are used to perform Bayesian estimation and Kalman filtering to back out an estimated series for expected and unexpected trade costs. The results suggest that both aggregate macro and forward-looking trade variables are necessary to separately identify the sources of trade cost variation. These three contributions represent an important step towards calculating the aggregate effects of trade integration. Each contribution is summarized in more detail below.

A model that can be used to analyze the aggregate effects of trade policy must have at least three key features. First, the adjustment of trade to changes in trade policy must be slow. A Robust empirical literature provides evidence that trade adjustments take time.[1] Having a slow adjustment of trade implies that other variables like aggregate prices and output also respond slowly to changes in trade costs, giving us a more clear picture of the persistent effect of past trade cost changes. Second, the model must have a specification of trade costs that allows for both anticipated and unanticipated changes. Finally, the model should correctly capture the composition of traded goods. In particular, trade is intensive in capital-goods. Including this feature in a model yields investment prices that are more sensitive to changes in trade costs. During a liberalization, the price of investment relative to consumption should fall, leading to more capital deepening.

We begin with the general equilibrium model of Alessandria and Choi (2007). The model features heterogeneous firms that pay a sunk cost to export. The sunk cost generates exporter hysteresis and slows down the export participation response to trade cost shocks. This gives the slow adjustment of trade that we want. To this framework, we add a stochastic process for trade costs with a persistent unanticipated component and an anticipated trend component. A liberalizing trend shock reduces trade costs in the next period and gives a decreasing path for trade costs into the future. This is meant to be similar to a trade agreement. We also add capital-intensive trade by requiring that final investment goods require a larger share of foreign goods as inputs in production. Finally, we also include shocks to productivity growth, Hicks-neutral productivity, and investment-specific technology. A calibration of the model is used to show that the aggregate response to trade cost changes depends on whether they were anticipated.

The model predicts that unanticipated reductions in trade costs are expansionary. The declining price of capital goods induces increased investment for firms and increasing the marginal product of labor. Higher wages and lower goods prices encourage consumers to substitute towards consumption and away from leisure, increasing labor supply and therefore GDP. The substitution effect dominates the income effect that induces agents to both

[1] For example, see Baier and Bergstrand (2007) and Jung (2012). Baier et al. (2014) claims that the slow adjustment is most prominent in the extensive margin of trade.

consume more and take more leisure as real income increases.

Anticipated reductions in trade costs, on the other hand, are recessionary. The income effect that encourages consumers to consume more and work less due to higher future income has no offsetting substitution effect until trade costs actually change. In the period of anticipation, agents would rather work less. Furthermore, firms delay investment since they recognize that it will be cheaper in future periods. Forward-looking firm variables such as the number of exporters and firm value also react to news of future liberalizations before any actual change in trade costs. The differential effect of anticipated and unanticipated trade shocks in the model suggest that the aggregate impact of a trade liberalization will depend critically on the source of the trade cost reduction.

To see this, we model a trade liberalization in two ways: as a one-time expected trend shock and as a series of unanticipated declines in the trade cost. Since the expected shock is recessionary, a gap between the GDP response under the two cases forms immediately. This gap persists for many periods as firms are always anticipating even lower investment prices in future periods, keeping investment low relative to the unanticipated case. Investment, consumption, and labor also differ along the transition. In addition to showing the importance of the source of the trade cost movements, these results also suggest that fluctuations of macro variables may be useful in backing out each component of trade costs. We will return to this later.

Next, we turn to the data to validate the aggregate consequences predicted by our model for expected trade liberalizations. We report consumption, investment, and trade behavior of OECD countries both before and after GATT round implementations. GATT rounds are useful as they are global agreements with timing that is exogenous to any one country's state of the business cycle and the negotiation periods are well documented. The data exercise confirms that investment and trade fall relative to economic activity in the periods directly preceding implementation. Consumption increases during the same period as would be consistent with a wealth effect driven by news of the liberalization. Thus, the data outcomes are qualitatively consistent with our stylized model.

Having provided evidence that the sources of trade cost variation are important for aggregate outcomes, we suggest a methodology to separately identify them. The model is simulated for 1000 periods. The last 250 observations of a subset of the simulated variables are treated and data and are used to reconstruct an estimated series for the path of trade costs using Bayesian techniques for estimation and Kalman filtering to identify shocks that fit the data. A comparison between the estimated series and the simulated series for trade costs and the expected component of trade costs can be used to evaluate the success of the method.

Multiple approaches to choosing data could be used. One option is to use only macro data, as this is the most freely available. We use GDP growth in the home and foreign country as well as investment and trade data in the home country in a first attempt at identifying the actual trade cost series. The aggregate data does a good job of capturing trade costs, but less well at separately identifying which are expected by agents. Taking this into account, one might want to use forward-looking variables such as export participation and the differential stock price of exporters against nonexporters. Using these two series and aggregate trade data gives a better approximation of both the expected and unexpected trade costs. However, by using both macro and forward-looking data, we achieve the best fit. We conclude that a proper estimation of trade costs and their aggregate effects over the last 60 years will require both aggregate and forward-looking data, and we leave this exercise to future work.

1.1 Relevant Literature

We contribute to a literature on the interaction between trade policy and business cycles. A recent group of papers motivated by the Great Trade Collapse also identify and measure the change in trade costs and understand their aggregate implications (Levchenko et al. (2010), Alessandria et al. (2010a), Alessandria et al. (2010b), Alessandria et al. (2011), Alessandria et al. (2013), Eaton et al. (2016b)). Unlike these papers, and the Gravity Literature that inspired them, we allow trade to respond with a lag to aggregate shocks and show that these lags strongly influence estimates of changes in trade barriers. Alessandria and Choi (2019) also propose a dynamic framework to decompose the US trade balance into trade and business cycle shocks, but abstract from capital accumulation. Eaton et al. (2016b), Eaton et al. (2016a) and Reyes-Heroles et al. (2016) use multi-country multi-industry static trade models to study the role of anticipated changes in common trade barriers and other aggregates in the distribution of trade imbalances and aggregate fluctuations under perfect foresight. Our approach differs from these papers by introducing a much richer dynamic model with forward-looking trade reforms and dynamic trade adjustment. Mix (2019) builds a multi-country model with a dynamic exporting decision for firms to consider the aggregate effect of multilateral tariff changes but does not consider the phaseout structure of tariffs in trade agreements.

Our paper contributes to the literature on the delayed impacts of free trade agreements and globalization. Baier and Bergstrand (2007) argue that the full impact of free trade agreements on trade can take up to 10 to 15 years to be realized. Besedeš et al. (2015) argue that some of this is coming from gradual phase out of tariffs while Baier et al. (2014) show that the extensive margin of trade response is more delayed than the intensive margin. In addition, there is a large literature in international economics which attempts to explain the empirical observation that trade responds more to changes in the terms of the trade in the long run than in the short run.[2] The model we develop will capture both of these observations and will therefore allow for the impacts of a liberalization episode to become stronger over time.

Our paper also contributes to the literature on news as a source of business cycle fluctuations. Most work in this spirit has considered either predictable changes in productivity or fiscal policy,[3] with much debate about how to identify future changes in these variables.

[2]See, for example, Alessandria et al. (2015), Ruhl et al. (2008), and Rabanal and Rubio-Ramirez (2015).
[3]See, for example, Beaudry and Portier (2006), Barsky and Sims (2012), Schmitt-Grohé and Uribe (2012),

There is little doubt that trade agreements (and disagreements) contain important predictable components. We use generalized information about tariff phaseouts to discipline trade policy news in our model. In our estimation, we use the model to infer these changes.

In Section 2, we discuss frequently observed patterns of globalization and gradualism. In Section 3, we describe the model in detail. In Section 4, we describe our calibration of parameters. In Section 5, we explore the impact of productivity and trade policy shocks on the aggregate economy. In Section 6, we estimate the model and discuss the importance of forward-looking behavior in the model. Finally, we conclude in Section 7.

2 Data

In this section, we review four salient features of US trade and trade policy since 1960. First, trade relative to economic activity has grown persistently. Second, over the same period, both trade policy and trade costs have also fallen gradually. Third, these gradual declines in trade policy are a key feature of trade agreements. This component of trade policy requires a model with agents forming expectations over future trade costs. And fourth, changes in inward and outward barriers may display strong asymmetries over time.

Figure 1 plots real US trade (exports plus imports) as a share of GDP. Since 1960, this ratio has grown four-fold from 7.5 percent to 31 percent. Growth has been a bit uneven over time as evident by the gaps between data and the trend line. One view of the data is the US transitioned from a low-level of trade integration in the 60's to a high-level in the 2010 period. The transition period from 1967 to 2010 was a bit uneven with rapid expansion from 67 to 75 and then again from the mid-80s to late 90s.

The gradual adjustment of the trade to GDP ratio over time arises from two well known features of trade policy and trade: (1) trade policy changes gradually, and (2) the response of trade to changes in trade policy or trade costs is gradual. Baier and Bergstrand (2007) show

Ramey (2011), Mertens and Ravn (2010) and Mertens and Ravn (2012). For a full survey of the literature, see Beaudry and Portier (2014).

that a trade agreement triples bilateral trade, but that this growth in trade takes between 10 and 15 years. Baier et al. (2014) and Alessandria and Choi (2014) find that the adjustment of trade is more gradual at the extensive margin of products or firms. Jung (2012) finds that trade expansion is delayed beyond the slow phaseouts in tariffs. Using product-level tariff and trade flows from Nafta, Khan and Khederlarian (2019) find that the trade response to a tariff change in 8 years is nearly 3 times the impact effect.

The model will capture both sources of gradual adjustment in trade. Because exporters face a sunk cost to begin exporting, the extensive margin of trade adjusts slowly in response to changes in trade costs, thus slowing down the trade response. Trade shocks can gradually raise or lower trade costs over several periods.

We now consider the changes in trade policy and trade costs. We emphasize that trade costs and trade policy have fallen gradually with a predictable component. In measuring trade policy, we initially ignore nontariff measures such as quotas, licensing restrictions, etc and focus instead on tariffs.[4] Figure 2 plots customs duties scaled by non-oil imports since 1960.[5] Tariffs fell gradually from about 8 percent in the late 1960s to less than 2 percent in the late 1990s. Unlike trade, however, the decreases are more concentrated in particular periods surrounding global and regional trade agreements. The most recent period of fast liberalization was from 1995 to 2000, a period in which global tariffs decreased due to the Uruguay Round of the WTO and the US implemented the North American ree Trade Agreement (NAFTA). Since 2000, tariffs were relatively low until increasing in 2018.

We include two more general measures of trade policy in Figure 2 to account for the downward bias in trade-weighted tariff since prohibitively high tariffs are given very little weight. The first is an average manufacturing tariff from Yi (2003) and the second is a trade restrictiveness index (TRI). The Yi measure is based on average tariff measures collected from various trade studies around particular trade liberalizations and finds tariffs are almost

[4]For a discussion on calculating the ad valorem equivalent of nontariff measures, see Kee et al. (2008a).

[5]We scale by non-oil imports to remove the effects of rising oil prices on measures of tariffs. The three spikes on tariffs arise from the President Nixon's 1971 import surcharge of 10 percent across all goods, President Ford's 1975 temporary oil import fees, and President Trump's 2018 tariffs on Chinese goods.

double our aggregate measure. A consensus is that average tariffs were about 15 percent at the start of the Kennedy round (Bown and Irwin (2015)).

The trade restrictiveness index Anderson and Neary (1994) and Anderson and Neary (1996) is defined as the uniform tariff that, when replacing the current structure of tariffs, would keep welfare the same for the representative agent. Kee et al. (2008b) show that this measure can be decomposed into the following form:

$$TRI = (\bar{t}^2 + \sigma^2 + \rho)^{1/2}$$

where $\bar{t} = \sum_n s_n t_n$, $\sigma^2 = \sum_n (t_n - \bar{t})^2$, and ρ is the covariance between the import demand elasiticy of product n and it's squared tariff. s_n represents the import weights of product n and t_n is its tariff. Thus, the TRI is a properly weighted average of the import weighted tariff from above, the import weighted variance of tariffs, and the covariance of squared tariffs and import demand elasticities. Prohibitively high tariffs (especially those with high demand elasticities) have a larger effect on the measure of tariffs.

Lacking good estimates for import demand elasticities at the product level, we create a simpler measure $T\tilde{R}I = (\bar{t}^2 + \sigma^2)^{1/2}$. Fortunately, the covariance term is generally second order to the other two terms as showed by Irwin (2010). We construct this measure using product level tariff data from Feenstra (1996) (from 1974-1988) and Schott (2008) (from 1989-2015). These series are found in 2. Consistent with the literature, we find that the series are highly correlated with the simpler import weighted tariff (0.52 for the first period and 0.91 for the latter period). Also consistent with the literature, the TRI implies a much higher level of tariffs. In general, these series tell a very similar story for aggregate tariffs in the last 60 years.

Now consider a broader measure of trade costs using a Gravity trade model.[6] We follow Jacks et al. (2011) to calculate the geometric average of US inward and outward barriers.

[6]The gravity trade model essentially infers trade costs by inverting our trade-to-GDP ratio after making an adjustment for a country's size relative to the rest of the world

These costs are derived from the model of Anderson and Van Wincoop (2003) by recognizing that the model implies

$$x_{ij}x_{ji} = x_{ii}x_{jj}\left(\frac{t_{ij}t_{ji}}{t_{ii}t_{jj}}\right)^{1-\sigma}$$

and then defining

$$\tau_{ij} = \left(\frac{t_{ij}t_{ji}}{t_{ii}t_{jj}}\right)^{1/2} = \left(\frac{x_{ii}x_{jj}}{x_{ij}x_{ji}}\right)^{\frac{1}{2(\sigma-1)}}$$

where x_{ij} refers to bilateral trade from country i to country j (and x_{ii} represents intranational trade). We approximate intranational trade using GDP minus exports.[7] ROW GDP is calculated as World GDP - US GDP. We assume the somewhat standard value of 4 for the Armington elasticity σ although a constant elasticity is inconsistent with the idea that trade grows gradually following a trade agreement. A higher (lower) value implies smaller (larger) trade cost declines over time.

The trade cost series is plotted in Figure 3 and confirms the gradual and sometimes inconsistent decrease in trade costs over the past 60 years. Now we move on to showing that many of the changes in trade policy are predictable.

We now discuss the large predictable component in the declines in trade barriers. Tariffs fall sharply following the completion of GATT negotiations in the Kennedy Round (1967), the Tokyo Round (1979) and the Uruguay Round (1994). Tariff declines following these negotiations occurred over a period of between five and eight years. Table 1 reports the negotation periods and tariff phaseout periods for each of these GATT rounds. The table also gives the tariff phaseout period for the Agreement on Textiles and Clothing (ATC) that was implemented with the Uruguay Round.[8] These liberalizations point to the two ways in which trade policy is at least somewhat predictable. First, negotiations took place over several years in all cases. Agents in the economy knew that global liberalizations in tariffs

[7] Production would be a better series but as long as the GDP to output ratio is roughly constant over time, this only affects the level and not the changes. Indeed, Jacks et al. (2011) also use GDP for the same reason.

[8] The ATC itself was the fourth agreement within GATT since 1961 to address the short-term impact of growing North-South trade in textiles.

were likely to occur in the future. Second, agreements include tariff phaseout schedules. Thus, even if the success of the negotation was a surprise, the change in future tariffs was known.

This pattern of long negotiation and extended phaseouts is not only true for global negotiations. Table 1 also shows that two bilateral trade agreements, NAFTA and the US Korea FTA, followed long negotiation periods with long phaseouts of tariffs. Besedeš et al. (2015) look at NAFTA's scheduled phase-outs at the HS10 product level. Of the products they consider, 18% were already duty free at the commencement of NAFTA and an additional 42% were made duty free on impact. All other products took at least 5 years for tariff cuts to phase in, and about 7% of all products became duty free in 10 equal annual tariff cuts. Less than 1% of all products had a tariff phase in longer than 10 years.

Figure 4 shows the world export weighted and simple average weighted scheduled US tariff phaseouts on Korean goods resulting from the US Korea Free Trade Agreement.[9] The schedules tariffs dictate, at the aggregate level, a very smooth decrease in bilateral tariffs. Figure 5 shows tariffs for autos shipped between the US and Korea. It is clear from this picture that tariff phaseouts differ both in their duration and in the timing of when they begin. The US, for example, secured a 25% tariff on Korean trucks that would not begin to phase out until 2018, 6 years after the agreement.This phaseout has been pushed out once again, currently scheduled to begin in 2041. The 10% tariff on Korean cars, on the other hand, were scheduled to drop immediately. Korean tariffs on US cars were cut in half at the beginning of the agreement, held constant over the next three years, and then dropped to 0.

These phaseouts combined with the long negotiations highlight the forward-looking aspect of trade policy. Consumers and firms may know whether to expect tariff decreases in the future and know the schedule of these decreases over the next several years.

Although changes in trade policy are often bi- or multilateral, changes in inward and outward barriers for the US are asymmetric. Figures 6 and 7 show import and export tariffs

[9]We thank Kristy Buzard for sharing this data with us.

in the US and a few of its major trading partners. The movements in these tariffs are far from uniform. Figure 8 shows the number of antidumping investigations initiated by the US and by other countries against the US.[10] The US generally exhibits lower average inbound tariffs relative to the rest of the world, and this may explain why the US uses antidumping more intensively. The difference between the number of investigations initiated by or against the US can be quite large, with a maximum of almost 40. The asymmetry in inward and outward barriers will be captured in the model with differential shocks on trade costs.

3 Model

We develop a two-country dynamic stochastic general equilibrium model with heterogeneous firms to study the short- and long-run effects of changes in trade costs and other aggregate shocks. We extend the IRBC model with heterogeneous firms and a sunk cost of exporting from Alessandria and Choi (2007) to include trade intensive in durable/capital goods and a broader set of shocks including neutral and investment-specific technology, a labor wedge, and a shock to international risk-sharing. The extended model fully captures the key moments of the US and ROW on openness, business cycles, and relative prices.

There are two countries, Home and Foreign, each populated by a continuum of identical and infinitely lived consumers. Consumers make consumption and labor decisions and trade a non-contingent bond across countries. In each period t, the economy experiences an event s_t. The history of these events is denoted $s^t \equiv (s_0, ..., s_t)$ where s_0 is given. We denote the probability of a history s^t as $\pi(s^t, s_0)$.

Each country has a continuum (unit mass) of monopolistically competitive firms that produce differentiated intermediate goods. A firm is the unique producer of a single variety. The firms are indexed by $i \in [0, 1]$. Intermediate goods producers use capital and labor to produce. Firm productivity has both an aggregate component and an idiosyncratic com-

[10]The figure counts antidumping cases only involving major US trade partners: Mexico, Canada, Japan, Korea, China, and any countries in the European Union.

ponent. The aggregate component Γ generates balanced growth as in King et al. (1991) and Aguiar and Gopinath (2007) such that $\Gamma_t(s^t) = g_0(s_0)g_1(s^1)...g_t(s^t)$ where $g_t(s^t)$ is the growth rate of aggregate productivity at time t. Aggregate productivity across the two countries is assumed to be cointegrated of order C(1,1) as in Rabanal et al. (2011). Aggregate technology is also subject to transitory Hicks-neutral shocks.

All intermediate goods firms sell their variety in the domestic market, but only some export. To export a firm pays an iceberg cost and a fixed cost which depends on their export status in the last period. New exporters pay a higher fixed cost than continuing exporters, as is common in the literature. These fixed costs are denominated in units of labor.

Competitive final good producers in each country use intermediate goods produced in the domestic and foreign market to produce consumption and investment goods. Use of intermediates in production follows the familiar CES structure. To capture the empirical observation noted by Boileau (2002) and others that trade is intensive in durable goods, we assume that the bias in production for home goods is different for consumption and investment goods. In addition, final goods producers face an adjustment cost in the ratio of domestic goods to foreign goods used in production as in Erceg et al. (2005) and Rabanal and Rubio-Ramirez (2015). This provides more flexibility to capture the slow adjustment of trade to aggregate shocks observed in the data than through the dynamics of exporting.

3.1 Consumers

Consumers are endowed with one unit of time which they can use for leisure or labor $L(s^t)$. Consumers choose labor, consumption, and a one-period bond to maximize utility subjective to a budget constraint. The representative consumer's objective function is

$$\max \sum_{t=0}^{\infty} \sum_{s^t} \beta^t \pi(s^t|s_0) U\left(C(s^t), 1 - L(s^t)\right)$$

where $C(s^t)$ denotes aggregate consumption at time t given history s^t, β is the discount factor, and $\pi(s^t|s_0)$ is the probability of achieving history s^t at time t given state s_0 at $t=0$. The budget constraint is

$$P_C(s^t)C(s^t) + Q(s^t)B(s^{t+1})\left(1+\Omega(B(s^{t+1})\right) \leq \chi_l(s^t)P_C(s^t)W(s^t)L(s^t) + B(s^t) + \Pi(s^t)$$

where $P_C(s^t)$ is the price of consumption goods relative to the home currency, $W(s^t)$ is the real wage, $Q(s^t)$ is the price of a bond $B(s^{t+1})$ that pays one unit of the home currency in the next period, and $\Pi(s^t)$ denotes profits from home intermediate goods producers. $\chi_l(s^t)$ is an exogenous labor wedge that evolves according to an AR(1) process so that

$$\ln \chi_l(s^{t+1}) = \rho_l \ln \chi_l(s^t) + \varepsilon_l(s^t+1)$$

and $\varepsilon_l \sim \mathcal{N}(0,\sigma_l^2)$. There is also a portfolio adjustment cost determined by the function $\Omega(B)$. Notice that the budget constraint is written in terms of the home currency. Similarly, the foreign budget constraint is

$$P_C^*(s^t)C^*(s^t)+\frac{Q(s^t)}{e(s^t)}B^*(s^{t+1})\left(1+\Omega(B^*(s^{t+1})\right) \leq \chi_l^*(s^t)P_C^*(s^t)W^*(s^t)L^*(s^t)+\frac{B^*(s^t)}{e(s^t)}+\Pi^*(s^t)$$

where asterisks denote prices and allocations in Foreign and $e(s^t)$ represents the nominal exchange rate.

From now on, we abstract from state dependence and write all variables with only time subscripts unless it is likely to be confusing. The first order conditions from the Home consumer's problem are:

$$-\frac{U_{L,t}}{U_{C,t}} = \frac{W_t}{P_C\chi_l} \tag{1}$$

$$Q_t\left(1+\Omega(B_{t+1})+B_{t+1}\Omega'(B_{t+1})\right) = \beta\mathbb{E}_t\frac{U_{C,t+1}}{U_{C,t}}\frac{P_{C,t}}{P_{C,t+1}} \tag{2}$$

where U_x denotes the marginal utility with respect to $x \in (C, L)$. We add a risk premium shock *a la* Smets and Wouters (2007) so that the Foreign Euler equation for bonds expresses the bond price as

$$Q_t \left(1 + \Omega(B^*_{t+1}) + B^*_{t+1}\Omega'^*_{t+1})\right) = \beta \mathbb{E}_t \frac{U_{C^*,t+1}}{U_{C^*,t}} \frac{P^*_{C,t}}{P^*_{C,t+1}} \frac{e_t}{e_{t+1}} \pi_{risk,t} \tag{3}$$

where π_{risk} follows an AR(1) process with persistence ρ_{risk} and shock $\varepsilon_{risk} \sim \mathcal{N}(0, \sigma^2_{risk})$.

Arbitrage yields the expected growth rate version of the Backus-Smith condition,

$$\mathbb{E}_t \frac{U_{C,t+1}}{U_{C,t}} \frac{P_{C,t}}{P_{C,t+1}} = \mathbb{E}_t \frac{U_{C^*,t+1}}{U_{C^*,t}} \frac{P^*_{C,t}}{P^*_{C,t+1}} \frac{e_t}{e_{t+1}} \pi_{risk,t}.$$

Without loss of generality we normalize the consumption price level to 1 in each country so that e_t denotes the real exchange rate.

3.2 Final Goods Producers

In each country, there are many final goods producers that engage in perfect competition. Home final goods producers use all Home- and a subset of Foreign-produced intermediate goods as inputs to create consumption and investment goods with CES production technologies[11]

$$C^p(s^t) = \left[\int_0^1 y^C_h(i, s^t)^\theta di^{\frac{\rho}{\theta}} + \omega_C^{1-\rho} \left(\phi(TR^C(s^t), TR^C(s^{t-1})) \int_0^1 y^C_f(i, s^t)^\theta di^{\frac{1}{\theta}} \right)^\rho \right]^{\frac{1}{\rho}} \tag{4}$$

$$I^p(s^t) = \left[\int_0^1 y^I_h(i, s^t)^\theta di^{\frac{\rho}{\theta}} + \omega_I^{1-\rho} \left(\phi(TR^I(s^t), TR^I(s^{t-1})) \int_0^1 y^I_f(i, s^t)^\theta di^{\frac{1}{\theta}} \right)^\rho \right]^{\frac{1}{\rho}} \tag{5}$$

where $y^X_n(i, s^t)$ is the quantity of intermediate goods produced by firm i in country n used in the production of good X. Parameter θ determines the elasticity of substitution between within country varieties while ρ determines the elasticity of substitution between Home- and

[11] Foreign final goods producers also use intermediates from both economies and have analogous production technologies, holding constant elasticities of substitution and home bias parameters.

Foreign-produced goods. ω_C and ω_I capture home bias in production of consumption and investment, respectfully. It is equivalent to allowing for a different shipping cost for goods depending on their final use. We allow these to be different, and in particular we impose $\omega_I > \omega_C$ to capture the empirical observation that trade is intensive in durable goods. Define the consumption and investment trade ratios as

$$TR^C(s^t) = \frac{Y_f^C(s^t)}{Y_h^C(s^t)} \quad \text{and} \quad TR^I(s^t) = \frac{Y_f^I(s^t)}{Y_h^I(s^t)}.$$

where

$$Y_j^C(s^t) = \int_0^1 y_j^C(i,s^t)^\theta di^{\frac{1}{\theta}} \quad \text{and} \quad Y_j^I(s^t) = \int_0^1 y_j^I(i,s^t)^\theta di^{\frac{1}{\theta}}.$$

Then the adjustment cost $\phi(\cdot,\cdot)$ takes the form

$$\phi\left(TR(s^t), TR(s^{t-1})\right) = \left[1 - \frac{\iota}{2}\left(\frac{TR(s^t)}{TR(s^{t-1})} - 1\right)^2\right]. \tag{6}$$

This adjustment cost has been used by Rabanal and Rubio-Ramirez (2015) and Erceg et al. (2005). It causes firms to optimize by adjusting the trade ratio gradually, thereby capturing a low short-run and high long-run trade elasticity.

The adjustment cost on the import share makes the decision regarding today's purchases of intermediates dynamic. This will be particularly important when we consider shocks that change future trade costs in a predictable way. In order to minimize movements in the import share, firms will gradually make changes to their purchases of foreign intermediates.

Final goods producers produce consumption goods and investment goods separately and maximize profits over each type of final good. That is, they choose intermediates to maximize two profit functions

$$\sum_{t=0}^{\infty}\sum_{s^t} Q(s^{t+1}|s^t)P(s^t)C(s^t) - \int_0^1 p_h(i,s^t)y_h^C(i,s^t)di - \int_0^1 p_f(i,s^t)y_f^C(i,s^t)di \tag{7}$$

$$\sum_{t=0}^{\infty}\sum_{s^t} Q(s^t|s^{t-1})P_I(s^t)I(s^t) - \int_0^1 p_h(i,s^t)y_h^I(i,s^t)di - \int_0^1 p_f(i,s^t)y_f^I(i,s^t)di \tag{8}$$

with (7) subject to equations 4 and 6; (8) subject to equations 5 and 6. The firm treats these as distinct problems. Notice that while final goods producers buy intermediates for the production of consumption and investment goods separately, the intermediate goods producers only produce one type of intermediate and charge the same price for it, regardless of its final use.

Demand for aggregates of foreign $Y_f^X(s^t)$ and home intermediates $Y_h^X(s^t)$ are determined implicitly from the first order conditions

$$P_h(s^t) = \frac{\partial X(s^t)}{\partial Y_h^X(s^t)} + \frac{\partial X(s^{t+1})}{\partial Y_h^X(s^t)} \tag{9}$$

$$P_f(s^t) = \frac{\partial X(s^t)}{\partial Y_f^X(s^t)} + \frac{\partial X(s^{t+1})}{\partial Y_f^X(s^t)} \tag{10}$$

where $P_h(s^t)$ and $P_f(s^t)$ are the aggregate home price levels for home and foreign intermediates, respectively, and can be expressed as

$$P_h(s^t) = \left(\int_0^1 p_h(i,s^t)^{\frac{\rho}{\rho-1}} di\right)^{\frac{\rho-1}{\rho}}$$

$$P_f(s^t) = \left(\int_0^1 p_f(i,s^t)^{\frac{\rho}{\rho-1}} di\right)^{\frac{\rho-1}{\rho}}$$

which is the usual Dixit-Stiglitz price index.

Given demand for $Y_h^X(s^t)$, the demand faced by an individual Home firm i in the Home market is

$$y_h^{X,d}(i,s^t) = \left(\frac{p_h(i,s^t)}{P_h}\right)^{\frac{1}{\theta-1}} Y_h^X \tag{11}$$

and the demand faced by an individual Foreign firm i in the Home market is Home firm i in the Home market is

$$y_f^{X,d}(i,s^t) = \left(\frac{p_f(i,s^t)}{P_f}\right)^{\frac{1}{\theta-1}} Y_f^X \tag{12}$$

Prices for consumption and investment goods are determined through the zero profit conditions. In particular, P_X is pinned down by $P_X(s^t)X(s^t) = P_h(s^t)Y_h^X(s^t) + P_f(s^t)Y_f^X(s^t)$ for $X \in \{C, I\}$. Since trade is intensive in investment goods, P_I will be more responsive to changes in foreign prices.

3.3 Intermediate Goods Producers

Each country has a continuum of intermediate goods producers of measure unity. These firms each produce a unique variety and engage in monopolistic competition. Intermediate goods producers produce with capital and labor. Firm productivity has an aggregate and idiosyncratic component.

The production technology of the firm is

$$y_h^C(i,s^t) + \xi^*(s^t)y_h^{*C}(i,s^t) + \frac{y_h^X(i,s^t) + \xi^*(s^t)y_h^{*X}(i,s^t)}{\psi(s^t)} = e^{z(s^t)}k(i,s^{t-1})^{\alpha}\left(A(i,s^t)l(i,s^t)\right)^{1-\alpha} \tag{13}$$

where $y_h^X(i,s^t)$ and $y_h^{*X}(i,s^t)$ represent domestic and export sales of intermediates for the production of final good X, $k(i,s^t)$, $l(i,s^t)$, and $e^{z(s^t)}A(i,s^t)^{1-\alpha}$ represent firm specific capital stock, labor, and productivity, respectively, $\psi(s^t)$ denotes aggregate investment specific productivity, and ξ^* represents a stochastic iceberg cost of exporting to the Foreign market. Firm productivity $e^{z(s^t)}A(i,s^t)^{1-\alpha}$ has two aggregate components and one idiosyncratic component. In particular, $z(s^t)$ is at the aggregate level and

$$\ln A(i,s^t) = \ln \Gamma(s^t) + \eta(i,s^t).$$

The aggregate component $\Gamma(s^t)$ grows at rate g_t in every period with $\Gamma(s_{-1}) = 1$ so that $\Gamma(s^t) = g_0(s_0)...g_t(s^t)$. We follow Rabanal et al. (2011) in specifying the stochastic process for growth rates to make productivity across countries cointegrated of order C(1,1). We also include some persistence in the process. Thus, we have

$$\ln g(s^t) = c + \kappa(\ln \Gamma_{t-1} - \ln \Gamma^*_{t-1}) + \rho_g \ln g(s^{t-1}) + \varepsilon^c_g + \frac{1}{2}\varepsilon^d_g$$
$$\ln g^*(s^t) = c^* - \kappa(\ln \Gamma_{t-1} - \ln \Gamma^*_{t-1}) + \rho_g \ln g^*(s^{t-1}) + \varepsilon^c_g - \frac{1}{2}\varepsilon^d_g$$

where $\varepsilon^c_g \sim N(0, \sigma^{c2}_g)$ and $\varepsilon^d_g \sim N(0, \sigma^{d2}_g)$. Shocks to growth rates are either common or differential shocks and affect the growth rates of both economies. The process for $z(s^t)$ is

$$z_t = \rho_z z_{t-1} + \varepsilon^c_z + \frac{1}{2}\varepsilon^d_z$$
$$z^*_t = \rho_z z^*_{t-1} + \varepsilon^c_z - \frac{1}{2}\varepsilon^d_z$$

The idiosyncratic component of firm productivity, $\eta(i, s^t)$ is iid both across firms and across time with $\eta(i, s^t) \sim N(0, \sigma^2_\eta)$. Alessandria and Choi (2007) show that the aggregate properties of this model are similar when the idiosyncratic shock is persistent.

In addition to total firm productivity, producers also face an aggregate level of investment specific technology $\psi(s^t)$ (IST). Higher IST lowers the cost of production in terms of inputs and therefore also lowers the price of investment. IST shocks have been shown to be an important driver of business cycles and growth and help to explain the falling relative price of investment to consumption goods.[12] Boileau (2002) includes IST shocks in a BKK framework as modeled here. We let IST in each country follow an AR(1) process:

$$\ln \psi_t = \rho_\psi \psi_{t-1} + \varepsilon^c_\psi + \frac{1}{2}\varepsilon^d_\psi$$
$$\ln \psi^*_t = \rho_\psi \psi^*_{t-1} + \varepsilon^c_\psi - \frac{1}{2}\varepsilon^d_\psi$$

where $\varepsilon^c_\psi \sim N(0, \sigma^c_\psi)$ and $\varepsilon^d_\psi \sim N(0, \sigma^d_\psi)$.

Firms own the capital and choose investment $x(i, s^t)$ every period. The law of motion

[12]See, for example, Justiniano et al. (2010), Justiniano et al. (2011), Cavallo and Landry (2010), and Mandelman et al. (2011).

for capital is

$$k(i,s^t) = (1-\delta)k(i,s^{t-1}) + x(i,s^t). \tag{14}$$

At the beginning of a period, a firm is identified by its idiosyncratic productivity $\eta(i,s^t)$, undepreciated capital stock $k(i,s^{t-1})$ from the last period, and last period's export status $m(i,s^{t-1})$. The firm then chooses investment $x(i,s^t)$, labor $l(i,s^t)$, current export status $m(i,s^t)$, and prices $p_h^C(i,s^t)$, $p_h^I(i,s^t)$, $p_h^{*C}(i,s^t)$, and $p_h^{*I}(i,s^t)$ to maximize the present discount value of profits. Firm i's Bellman equation is [13]

$$V(\eta,k,m,s^t) = \max_{x,l,m',p_h^C,p_h^I,p_h^{*C},p_h^{*I}} \pi(i) + m'^*(i) \tag{15}$$

$$+ \sum_{s_{t+1}|s^t} \int Q(s^{t+1}|s^t) V(\eta',k',m'^{t+1}) dF(\eta')$$

where

$$\pi(i) = \sum_{X\in\{C,I\}} p_h^X y_h^X(i) - P_C W l - \Xi P_I x \tag{16}$$

$$\pi^*(i) = e\left[\sum_{X\in\{C,I\}} p_h^{*X} y_h^{*X}(i) - P_C W(m\tau_1 + (1-m)\tau_0)\right] \tag{17}$$

subject to the production technology (13), the law of motion for capital (14), and the downward sloping demand curves (11 and the Foreign analogue of 12). $F(\eta)$ is the cumulative distribution function of the normal distribution with variance σ_η^2. Ξ introduces capital adjustment costs in the model by taking the form

$$\Xi = 1 + \omega_{ac}\left(\frac{\bar{I}}{\bar{K}} - \delta\right)$$

where $\bar{I}$ and $\bar{K}$ denote aggregate investment and capital so that agents do not internalize the effect of their personal investment on the aggregate adjustment costs. The adjustment

[13] Dependence on the state s^t is not shown explicitly in the following exposition for convenience.

cost makes the price higher when aggregate net investment is positive and lower when net investment is negative, making adjustment in either direction more costly.

Let $V_1(\eta, k, m, s^t)$ be the value of a firm that chooses $m' = 1$. I.e. the firm chooses to export in the current period. Similarly, let $V_0(\eta, k, m, s^t)$ be the value of a firm that chooses $m' = 0$. Then we can rewrite the value of a firm as

$$V(\eta, k, m, s^t) = \max\{V_1(\eta, k, m, s^t), V_0(\eta, k, m, s^t)\}.$$

Clearly, V_1 and V_0 are both increasing functions of η. Also V_1 only crosses V_0 once for given (k, m, s^t). Thus, there exists a cutoff productivity level at which the firm is indifferent between exporting and not exporting. Above that level, the firm exports and below that level, they produce goods only for the domestic market. Because the fixed cost of exporting depends on the firm's export status in the last period, the cutoff also depends on the exporters previous export status. Let η_0 be the cutoff productivity level for firms that did not export in the last period and η_1 be the cutoff productivity for firms that did export. Then η_0 and η_1 satisfy

$$V_1(\eta_0, k, 0, s^t) = V_0(\eta_0, k, 0, s^t) \tag{18}$$

$$V_1(\eta_1, k, 1, s^t) = V_0(\eta_1, k, 1, s^t). \tag{19}$$

Since $\tau_0 > \tau_1$, we know that $\eta_0 > \eta_1$. That is, beginning to export requires a higher productivity shock than continuing to export.

With iid idiosyncratic shocks over time, all firms have the same expectations over their productivity in the next period. Then the only thing that determines a firms choice of capital for the next period is their export status in the current period. The distribution of capital is then determined by two mass points, weighted by the number of exporters and nonexporters.

The percentage of nonexporters that begin exporting in state s^t is just $1 - F(\eta_0(s^t))$. Similarly, the percentage of exporters that continue exporting is $1 - F(\eta_1(s^t))$. Let $N(s^t)$ be the measure of exporters in state s^t. Then we have

$$N(s^t) = (1 - N(s^{t-1}))[1 - F(\eta_0(s^t))] + N(s^{t-1})[1 - F(\eta_1(s^t))]. \tag{20}$$

Let $\Phi(s^t)$ ($\Phi^*(s^t)$) represent the set of Home (Foreign) firms that export. Then the measure of $\Phi(s^t)$ is $N(s^t)$, the number of exporters. The labor hired in Home for the purpose of paying the fixed cost L_{fc} is

$$L_{fc}(s^t) = \int_{i \in \Phi(s^t)} \tau_1 m(i, s^{t-1}) + \tau_0(1 - m(i, s^{t-1}))di. \tag{21}$$

3.4 Variable Trade Costs

The iceberg costs ξ^* and ξ faced by Home and Foreign intermediate goods producers, respectively, are stochastic. Each cost has a trend component and a transitory component. The trend component is captures the gradual changes in bilateral trade barriers. Because we use a linearization to solve the model, we choose a stochastic process for trade costs such that a trend shock to trade costs will still eventually return the steady state, but it will take a long time. The transitory component captures other deviations in the trade costs such as short term protection measures. The process for these trade costs is

$$\xi(s^t) = \xi_c(s^t) + \frac{1}{2}\xi_d(s^t)$$
$$\xi^*(s^t) = \xi_c(s^t) - \frac{1}{2}\xi_d(s^t)$$

where

$$\xi_d(s^t) = \rho_{\xi_d}\xi_d(s^{t-1}) + \varepsilon_\xi^d$$
$$\xi_c(s^t) = (1 - \rho_{\xi_c})\bar{\xi} + \rho_{\xi_c}\xi_c(s^{t-1}) + \Delta + \varepsilon_\xi^c$$
$$\Delta(s^t) = \rho_\Delta\Delta(s^{t-1}) + \varepsilon_\Delta^c$$

and $\varepsilon_a^b \sim N(0, \sigma_a^{b2})$ for all $a \in \{\xi, \Delta\}$ and $b \in \{c, d\}$. We use common and differential shocks instead of country specific shocks so that no assumptions about correlation of trade cost movements across countries need to be made. In addition, with this setup the responses to common shocks can be interpreted as responses to global movements in trade costs, such as those expected in times of rapid globalization.

3.5 Equilibrium

In equilibrium, there are several market clearing conditions that must be met. We must have $C^{(*)p}(s^t) = C^{(*)}(s^t)$ and $I^{(*)p}(s^t) = \int_0^1 x^{(*)}(i, s^t)$. All intermediate goods producers must set supply equal to demand from domestic final goods producers. Exporters must also meet the demand from foreign final goods producers. The market clearing conditions for labor are $L(s^t) = \int_0^1 l(i, s^t) + L_{fc}$ and $L^*(s^t) = \int_0^1 l^*(i, s^t) + L_{fc}^*$. All profits from intermediate goods producers are given to the representative agent. The market clearing condition for international bonds is $B(s^t) + B^*(s^t) = 0$, bonds are in zero net supply. Because budget constraints are written in terms of the domestic currency for each country, we can normalize one price in each country. Here, we choose $P_C(s^t) = P_C^*(s^t) = 1$ for all s^t.

We center our attention on a stationary equilibrium so that all allocations and prices are functions of the state s^t. Exogenous state variables have been described. Endogenous states are bonds, lagged final good trade shares, $\text{TR}^i\left(s^t\right)$, and distribution of (η, k, m) across intermediate firms. With iid idiosyncratic firm productivity the distribution can be summarized by the mass of exporters and the capital stock of exporters and non-exporters (N, K_0, K_1).

4 Calibration

Here we describe how we match the model to the data at the firm and aggregate levels. Our approach closely follows the international macro literature with and without firm heterogeneity (Engel and Wang (2011) and Alessandria and Choi (2007)).

The utility function is non-seperable between consumption and leisure

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

where the intertemporal elasticity of substitution is $1/\sigma$ and γ determines the share of consumption in the composite good.

The functional form of the convex portfolio adjustment cost is chosen to be consistent with a balanced growth path and equals

$$\Omega\left(\frac{QB}{Y^N}\right) = \frac{\omega_b}{2}\left(\frac{QB}{Y^N}\right)^2,$$

where the the term in parentheses is the ratio of expenditures on new debt to nominal output. As is customary, we set ω_b to be small but positive to induce stationarity but otherwise not affect the equilibrium dynamics of the model.

The assigned parameters are reported in Table 2. Many of these parameters are standard. A period is one quarter. We set β=0.99 to match a steady state real interest rate of 4%. We choose the share of consumption γ in the utility function so that time devoted to labor is 1/4 of the time endowment.[14] The intertemporal elasticity of substitution σ is set to 1/5. We set α=0.4 as is common in the literature to match the share of revenue that goes to labor. We set δ=0.025. The elasticity of substitution between varieties within a country is determined by θ. It also determines markups of intermediate firms. Here we set θ=0.8 which implies a markup of 25%. This is within the estimates in the literature which are summarized by Schmitt-Grohé (1997). The elasticity of substitution between home and foreign goods is determined by ρ. Here we choose an elasticity of 4 (ρ=3/4). This is a good bit higher than in most business cycle analyses Backus et al. (1994) but recent work suggests that when the gap in trade barriers moves systematically with the business cycle a model of this type can match aggregate fluctuations Alessandria and Choi (2019). The model yields a long-run

[14] This implies a Frisch elasticity of about 1.4, within the bounds of the estimates in the literature.

trade elasticity of close to 8 which is common in the trade literatureCaliendo and Parro (2014). The parameter on the adjustment cost of the trade share ι is initially set to 0.

We set κ, which determines how quickly country productivities converge after a shock, to 0.007 as in Rabanal et al. (2011). In this paper, we allow for persistence in the growth rates of productivity and assume countries are symmetric so that $c = c^*$. We set $c = c^* = 0.0025$ and set $\rho_g = 0.375$ to match a steady state growth rate of .004. For Hicks-neutral productivity shocks, we choose a persistence ρ_z of 0.9.

We calibrate the model to match aggregate and firm-level trade flows toward the end of the sample. Trade flows are determined by the taste parameters and the fixed and variable trade costs. The steady state iceberg cost is set to $\bar{\xi} = 2.0$. The parameters that remain to be calibrated are home bias for investment and consumption ω_I and ω_C, the fixed costs of exporting for incumbent and new exporters τ_1 and τ_0, and the volatility of idiosyncratic productivity shocks σ_η. We set $\omega_I = 1$ so that there is no home bias in investment goods and choose the other parameters to match the following four features from the data in steady state:

1. An aggregate import share of 15%,
2. 40% of all firms export,
3. 0.5% of exporters stop exporting every period,
4. Exporter sales are 1.5 times larger than nonexporter sales.

We assume variable trade costs are stationary but very persistent. The high persistence is necessary to capture the sustained rise in trade flows observed in the data. We set $\rho_\xi^d = 0.97$ and $\rho_\xi^c = 0.998$. We set ρ_Δ=0.93 so that the model generates the same average trade barrier over the next 10 years as with a 10 year linear phase-in.[15] This matches our empirical observations about free trade agreements. We set $\omega_{ac} = 2$ so that the investment response

[15]With our geometric trade costs this leads to a slightly higher trade barrier over a ten year window..

to a Hicks-neutral productivity shock is about three times as large as the GDP response. The standard deviation for all shocks apart from ε_η are set to 0.01.

Three model variations help to isolate how the nature of trade determine the aggregate effects of shocks to trade barriers and the usual business cycle shocks. In the first variation, denoted *Static*, we constrain τ_1=τ_0 so that the startup and continuation costs are identical. With a static exporting decision we give up on matching exporter persistence but lower productivity dispersion, σ_η, to match the same exporter size premium. This model has a higher short-run trade elasticity and lower long-run trade elasticity than our benchmark. In the second variation, denoted *Armington*, we eliminate the export decision by setting τ_1=τ_0=0. With no export decision the variance of idiosyncratic shocks is irrelevant. The Amington elasticity now equals the trade elasticity. This is the prototypical international business cycle model of Backus et al. (1994). The third variation, denoted no Capital intensive trade (*No KIT*), assumes imported goods have the same weight in the consumption and investment aggregators, ω_I=ω_C.

5 Model Results

We now analyze the dynamic effects of shocks to productivity and trade barriers on the aggregate economy. We consider some shocks that have not be studied elsewhere. We also contrast the benchmark model with some variations to clarify how the nature of trade barriers at the aggregate and firm-level affect the propagation of these shocks. This analysis clarifies which aggregate features we should look for in the data and how the model is identified when we move on to estimation.

Consistent with the findings in Alessandria and Choi (2007), across models, the differential effect of aggregate productivity shocks on output, employment, consumption, and investment are relatively minor while the effects on trade are much more substantial. Non-trade related variables primarily differ in that the benchmark dynamic exporting model generates smaller initial effects that are more persistent. These gaps are about 5-20 percent with the smaller differences in variables that are more directly affected by the shock. The more sizeable differences on trade flows occurs since the dynamic exporting model generates hump-shaped responses of exporting and trade to persistent and trend productivity shocks, which then leads to persistently low levels of trade in the recovery from recessions. With trend productivity shocks, in the benchmark model trade will move in the opposite direction from the static model.

For trade policy shocks, we show that anticipation of changes in trade costs can have important effects on the macroeconomy. We analyze the differential impact of anticipation at different time horizons and consider the effects of canceling or delaying anticipated trade agreements. Anticipation of future trade liberalizations is recessionary in the short run as agents forego investment to consume more and work less. The decrease in investment is driven by the wealth effect and also by the realization that the price of capital will be lower in the future. This is especially true when trade is intensive in capital. Canceling or delaying expected trade liberalizations generates an economic boom as agents work more and replenish their capital stock.

5.1 Productivity Shocks

The model considers three types of technology shocks: transitory and trend Hicks-neutral shocks and investment-specific shocks. Since the effect of these shocks on the international economy in a model with a dynamic exporting decisions has not been studied elsewhere, we take a moment to detail their effects. We focus on the impact of global technology shocks. As in Boileau (1999), Boileau (2002), and Engel and Wang (2011), allowing trade costs to differ on capital and consumption goods captures the high capital-intensity of trade and generates larger cyclical fluctuations in trade flows. Also, the slow entry and exit of exporters makes the trade response more persistent than in a static exporting model.

Figure 9 plots the impulse response functions of several macroeconomic variables to a global 1% recessionary Hicks-neutral productivity shock. As in the standard IRBC model, GDP, labor, investment, and consumption fall with the investment response being about three times larger than GDP. Trade and the number of exporters fall and recover gradually.

The trade response is driven by the export decision and trade being intensive in a cyclical sensitive good, capital. To account for this composition effect, we define trade-weighted demand D^{TW} as

$$D^{TW} = \frac{\bar{P}_f Y_f^c}{\bar{P}_f Y_f^c + \frac{\bar{P}_f}{\psi_f} Y_f^i} C + \frac{\frac{\bar{P}_f}{\psi_f} Y_f^i}{\bar{P}_f Y_f^c + \frac{\bar{P}_f}{\psi_f} Y_f^i} I.$$

The final panel in figure 9 shows that even controlling for the composition of demand, trade responds more than output.

The dynamics of trade are thus primarily driven by the dynamics of exporting. As the recession lowers the return to exporting more firms stop exporting and fewer start. Given the law of motion for the stock of exporters, these decisions only slowly reduce the share of exporters, with the peak impact 6 quarters and almost 2.5 times the impact effect. As the stock falls and the economy begins to recover the stock of exporters grows slowly. Even 5 years after the shock the stock of exporters is about as low as its impact effect. These dynamics of exporting lead to similar dynamics in trade.

Comparing the response of aggregate variables in our benchmark model to the variations with alternative export decisions, we see that the benchmark model leads to smaller but more persistent fluctations in output. The largest gap across models is in the labor response. Compared to the static model, labor falls 20 percent less on impact but is 15 percent lower two years on.

Modelling the trade costs by sector leads to a stronger response of trade and exporting as exporters are more exposed to the global recession. Without this effect, the impact of the shock would be less persistent.

The response to a global 1% recessionary productivity growth shock is shown in Figure 10. In this case, consumption drops more than investment as agents expect to be even poorer in the future and would like to save in the initial periods. Eventually, falling investment outpaces consumption.

Export participation and the trade share persistently rise in response to the trend shocks. The rise in export participation despite the recession arises because the wealth effect leads to more labor supply that makes it less costly to invest in the durable asset that is an exporter. This investment seems to explain the persistent increase in employment and the slow decline in investment. Again compared to models with a static or no export decision, the benchamrk model leads to more gradual dynamics in output and trade flows.

Finally, the response to a global 4% decrease in investment-specific technology is plotted in Figure 11 that yields a similar movement in output as the transitory Hicks-neutral shock. The decrease in ψ in both countries raises the relative price of investment to consumption and leads to a sharp drop in investment. Consumption increases a little on impact as agents substitute away from expensive investment towards cheaper consumption goods. As the capital stock shrinks and the price of investment goods returns to normal, consumption falls below steady state and recovers slowly.

With the stronger reduction in investment, trade and exporting fall by more on impact. As with Hicks-Neutral productivity, the drop and subsequent recovery in trade happen gradually.

The benchmark model leads to different effects on output and employment than the models with static or no export decision. Again, employment falls about 15 percent less in the benchmark model but returns more slowly. The dynamics of output are also much more persistent with the trough occurring in the fourth quarter compared to impact in the other models.

5.2 Trade Policy Shocks

We now analyze the effect of unanticipated and anticipated changes in trade barriers. The model response to an unanticipated persistent trade cost shock is similar to that of existing models in the literature. Anticipated shocks, on the other hand, have novel aggregate effects from large wealth and susbtitution effects given that trade is capital-intensive. After considering the effect of a single anticipated shock, we move on to consider other real-world trade policy changes such as canceling or delaying an anticipated trade liberalization.

Figure 12 shows impulse response functions in response to an unanticipated and persistent 1% decrease in trade costs. The reduction in trade costs lowers the price of foreign relative to domestic intermediate goods. As a result, trade responds strongly in the intial period and continues to grow in the transition as the extensive margin of trade grows slowly. The short-run impact effect on trade is about 1/3 of the effect 5 years on. These gradual effects on trade and exporting are unique to the benchmark dynamic exporting model.

Just as trade grows slowly so do aggregates. This aggregate gradualness arises because it takes time to accumulate the export capacity to fully benefit from this shock and to a much less extent the need to accumulate capital. The decrease in the price of traded goods also lowers the relative price of capital to consumption and investment grows by about 1% over the transiton. GDP and consumption both grow slowly over the transition.

The aggregate effect of a persistent trade cost shock depends strongly on the nature of trade barriers. With a static exporting decision, employment responds most strongly on impact while with a dynamic exporting decision it grows quite gradually. This primarily reflects the stronger incentive to expand investment as the effect of trade costs on investment prices is immediate in the static model. With no KIT we find a stronger response on cosumption and much weaker investment response.

Now we move on to anticipated changes in trade costs. Let $\varepsilon_{\Delta,t=0} = -0.005$. This shock is anticipated in two ways. First, it does not actually affect trade costs until time $t = 1$, but it enters agents information set today $t = 0$. Second, the shock implies not only a decrease in trade costs tomorrow, but also further decreases in the future. We can think about this shock as news of a future trade liberalization. Agents know that trade costs will drop when the agreement is implemented, but that tariffs will continue to fall in subsequent years. Figure

13 plots the impulse response functions for the aggregate economy in response to this shock.

The persistence of both trade costs and the trend component of trade costs imply that a 0.5% shock to the trend today decreases trade costs by over 7.5% in the long run. Perhaps surprisingly, we see that investment (and therefore trade) and GDP fall sharply in the initial periods. An anticipated trade liberalization is recessionary in the short run! Consumption, on the other hand increases immediately. Agents understand that tomorrow ($t = 1$) will be better than today because of lower trade costs. They also know that the next period ($t = 2$) will be better than tomorrow ($t = 1$). As a result, they would like to consume more and take more leisure today and save less. It is this wealth effect that drives the decrease in investment, trade, and GDP. Eventually, traded goods become cheap enough that agents begin to replenish and then increase their capital stock. Also, trade costs are a tax on goods. Agents respond to the lower tax on goods by consuming more and taking less leisure so that the labor response is positive in the long run. The increase in capital and labor translate to about a 7% increase in GDP after 10 years.

To make clear the role of expectations, suppose that we modelled an anticipated liberalization as a series of unanticipated persistent trade cost shocks. Figure 14 shows the macro responses for each liberalization. Of course, if each change in trade costs is unanticipated, the economy avoids the initial recessionary effects. Investment, GDP, and trade all increase on impact and continue to increase due to both past and current unanticipated decreases in the trade cost. Consumption follows a similar pattern, growing gradually and monotonically over the transition. The consumption response on impact is larger when agents anticipate the future path in trade costs. This is because they recognize the true extent of their long run wealth. In the anticipated case, consumption grows slowly over the first few periods as the capital stock initially deteriorates. Once the capital stock begins to grow again, consumption grows quickly throughout the rest of the transition. Despite the crossing of the two consumption paths, we know that welfare is higher when agents anticipate the agreement since expanding an agents information set cannot lower welfare. Indeed, the transition path for labor shows that agents are enjoying more leisure throughout the entire transition when the liberalization is anticipated.

The above experiment shows the importance of knowing the sources of trade cost variation in the data. Two identical trade costs paths with different sources yield entirely different outcomes for GDP, investment, consumption, and labor. Furthermore, these differences are persistent throughtout the first several years. Any analysis of the impact of trade integration on the economy must therefore differentiate between expected and unexpected movements in trade costs.

So far we have discussed the effects of an expected trade liberalization when agents know about it one period in advance. How does the time horizon at which agents expect the liberalization matter for aggregate effects? To compare liberalizations that are expected at different time horizons, we define a discounted average trade cost.[16]

$$\xi_{PV,t} = (1-\beta)\mathbb{E}_t \sum_{s=t}^{\infty} \beta^{s-t}\xi_s.$$

Consider three alternative trade liberalizations that are known one, four, and eight quarters before impementation and have the same $\xi_{PV,t}$. Figure 15 shows the impulse response functions of macroeconomic variables for these three liberalizations.

Regardless of the expectation time horizon, the announcement of a trade liberalization is initially rescessionary. In the case of four and eight quarter anticipation, the recession gets worse until the liberalization with a trough in output the period before liberalization in all cases. That trough is lower the longer the trade liberalization has been expected. Consumption increases on impact in all cases. Consumption growth after the news depends on the time horizon. When the liberalization is far in the future (8 quarters), consumption actually decreases over the initial 10 periods. This decrease is due to the strong disinvestment and high leisure leading up to the liberalization.

Despite decreases in economic activity, we see that the number of exporters in the econ-

[16] An ideal measure of the present value of trade costs would use the subject discount factor instead of β.

omy is growing over the entire transition, regardless of the expected wait before the liberalization occurs. This can only happen in a model with forward-looking firms. Agents understand that while exporting today might be unprofitable, the future is bright. If they receive a good productivity shock today, they use it to pay the sunk cost and begin exporting, recognizing that the likelihood of receiving another good shock like that after the liberalization is low. Of course, once the liberalization begins, growth in the extensive margin of trade increases.

We have explored the reaction of the economy to news about a future trade liberalization. Investment, consumption, labor, and the extensive margin of trade all move to take full advantage of the decrease in trade costs. Now suppose that these expectations are violated. In particular, suppose that agents receive news today that in eight periods, a trade liberalization will start. The period before it starts however, they receive news that the liberalization is either canceled or delayed an additional eight quarters.

Figure 16 compares the macroeconomic outcomes under these two situations. For the first seven quarters, the impulse response functions are the exact same as the anticipated trade liberalizations. Investment, labor, trade and output fall while consumption increases. When agents find out the agreement is canceled, all of these variables make a sharp recovery, with significant overshooting in consumption. Agents have been consuming more than they can afford assuming that they will be more wealthy in the future. The decrease in consumption that follows is very persistent, with consumption not returning to its original steady state within the first 10 years. In terms of output, investment, and employment, canceling a trade agreement looks like it generates a one-time boom in the economy at the date of cancellation. However, canceling an agreement also reduces the growth of GDP by about 1/3% per year over the next fifteen years. Indeed, if the recent slowdown in trade is assumed to come from cancellation of agreements such as TPP and TTIP, then these cancellations also explain some of the slowdown in GDP growth.

Delaying a trade agreement ameliorates all of these effects compared to canceling the agreement. Labor, investment, output, and trade recover a little before decreasing again prior to the liberalization. Consumption, on the other hand, experiences a significant change. Agents have been consuming more expecting a trade agreement in the not so distant future. When the agreement is delayed another two years, they are poorer than they thought and decrease consumption in the short and medium run. Prolonged low investment serves to exacerbate the dip in consumption in the medium run.

5.3 Variations in Assumptions

In this section, we analyze how alternative assumptions on the capital intensiveness of trade, the exporting decision of firms, and preferences affects the aggregate response to changes in future trade policy. Discussion frequently refer to the impulse response functions in Figures 10 through 13, all of which include dynamics for the Benchmark model and all variations of the assumptions below. Table 2 also includes the calibrated parameters for each alternate model.

Capital-intensive trade. The home bias parameters ω_c and ω_x determine how intensive trade is in capital vs consumption goods. We can eliminate capital-intensive trade by assuming that $\omega_c = \omega_x$. Without capital-intensive trade, trade becomes less volatile in response to a productivity shock. We still see that trade falls by more than output in a Hicks-neutral productivity driven recession. This is coming from the changing extensive margin of trade.

The effect of capital-intensive trade on macro dynamics can be more easily seen with changing trade costs. When trade costs decline and trade is intensive in capital, the price of investment drops by more than the price of consumption, inducing a larger investment response. With persistent trade cost decline, investment increases by 1% with capital intensive trade and 0.4% without it. Consumption increases by more on impact without capital-intensive trade as there is no change in relative prices and no substitution. In the long run, however, consumption is higher with capital-intensive trade since higher investment means higher long run capital stocks and more output.

Dynamic exporting decision. We calibrated the relative magnitude of the sunk and fixed costs of exporting by matching the churning of firms in and out of the export market. This resulted in a sunk cost that is about six times higher than the continuation cost so that it is much harder to become an exporter than to continue as an exporter. Now suppose that we assume there is no sunk cost of exporting. In that case, firms are no longer forward looking. If exporting today is unprofitable, then firms will not export as their cost of exporting tomorrow is independent of today's export decision.

How does changing the exporting decision of firms from static to dynamic affect aggregate outcomes? First, trade becomes more volatile. Since the extensive margin of trade responds immediately to an increase in expected profits for exporters, there is nothing to limit the trade response in the short run. Second, the trade response becomes less persistent. Take, for example, a recession from a persistent Hicks-neutral productivity shock. With a static exporting decision, trade responds by more on impact as exporters leave immediately. However, as productivity recovers, exporters reenter the market without any friction so that trade recovers quickly relative to the case in which reentering exporters must pay a large sunk cost.

With a persistent trade cost decline, we see that the trade response is immediate in a static exporter world. This does not match the slow adjustment of the extensive margin that we see in the data (see Baier et al. (2014)). It also results in higher investment and output in the initial periods.

Armington. We calibrate the model so that virtually all firms export (99.8%). Thus, the exporter margin is very inelastic. To have comparable responses in trade, we increase the elasticity of substitution between home and foreign goods from 4 to 9.

The response of trade to changes in trade costs closely mimics the response in the static exporter model. However, the higher substitutability between goods lowers the response of output, consumption, investment, and labor to a liberalization.

In the case of productivity shocks, an Armington model predicts far less movement in trade relative to output. Indeed, with a Hicks-Neutral productivity drop, trade only falls by half a percent relative to trade weighted demand. As in the static case, there is no U-shape in the response of trade.

The variations in the model we have presented represent some of the better known models in the trade and international macroeconomic literature. In the following section, we show some aggregate evidence on the response to anticipated trade liberalizations. This evidence seems to recommend the benchmark model of this paper.

6 Aggregate Evidence from GATT Rounds

We now present supporting evidence on the response of the aggregate economy to future changes in trade barriers that is consistent with the model. In particular, using a panel of OECD countries and the timing of GATT/WTO rounds, we show the investment rate and trade share fall in advance of a trade liberalization and then grow gradually with trade following a trade liberalization.

We consider a group of 27 countries[17] with data available from 1960 to 2008 from the OECD. For these countries, we collect annual data on real GDP, private and government consumption, gross fixed capital formation, exports and imports (of goods and services).

GATT and WTO liberalizations are useful events to validate the model. These are large, widely publicized and successful global negotiations with little scope for trade diversion from other countries to obfuscate the results. Negotiations for the Kennedy, Tokyo, and Uruguay Rounds (the three liberalizations that occur during the time span of the data) were negotiatied for about six years on average before implementation. All three liberalizations significantly decreased inward and outward tariffs for all member countries. The implementation year for each liberalization is the first year in which tariff reductions are experienced.

A concern is that the timing of negotiation and implementation may be endogenous. For example, negotiations might never conclude during a global recession. Thus, movements in country aggregates could be coming from the cycle and not the liberalization. To account

[17] A complete list of countries included in the analysis can be found in the Appendix.

for this, we include the cyclical component of the combined GDP of the G7 countries as a control. As these countries are world leaders in terms of production and political power, the timing of implementation is likely most heavily influenced by their cycle.

Another potential confounder is that seven of the countries were not GATT members over the entire period.[18] Joining the GATT often involved significant reformations to trade policy, including large unilateral liberalizations leading up to GATT accession. The regression includes controls for the timing of GATT accession for these countries to separate these effects from those of GATT liberalizations that occur around the same time.

The model estimated is

$$X_{it} = \alpha_i + \sum_{s=-q}^{r} (\beta_s FTA_{i,t+s} + \gamma_s JOIN_{i,t+s}) + \gamma_G GDP_{G7,t} + \gamma_{OP} \log \left(\frac{OilPrice}{CPI_{US}} \right)_t + \varepsilon_{it}$$

where X_{it} is some (theoretically) stationary aggregate variable of interest, α_i is a fixed effect, $FTA_{i,t}$ ($JOIN_{i,t}$) is an indicator variable taking the value of 1 if the country was part of an GATT round implemented at time t (joined the GATT/WTO at time t), q is the number of lagged periods, and r is the number of anticipation periods. We choose $q = r = 10$ and find that the results vary little with various specifications. The regression also includes a control for changes in the oil price which are likely to affect trade.

The coefficients of interest are $\beta_{-q}, \beta_{-q+1}, ..., \beta_r$ as they capture the lagged and forward looking effect of the liberalization. Below we report these coefficients for the (logged) real investment rate (I/Y), trade to GDP ratio ((EX+IM)/Y), consumption share (C/Y), and the cyclical component of GDP.

Figure 17a plots the β coefficients and their 95% confidence intervals before and after that time $t = 0$ liberalization. We see that the investment rate is stable until five years before implementation. This coincides with the early stages of GATT/WTO negotiations. Over the four years preceding implementation, investment drops by about 10 log points

[18] These countries include Iceland (joined in 1968), Ireland (1967), Korea (1967), Mexico (1986), Portugal (1962), Spain (1963), and Switzerland (1966).

consistent with the theory. A joint Wald test with null hypothesis $\beta_{-1} = \beta_{-2} = \beta_{-3} = \beta_{-5}$ yields a F-statistic of 4.38 (p-value=0.0045). In the two years following implementation, the investment rate completely recovers as predicted by the theory.[19]

Because trade is intensive in capital goods and investment falls prior to a liberalizations, the theory suggests that anticipation of a liberalization also reduces trade. Figure 17b plots the β coefficients over time. In the 10 years preceding the liberalization, the growth of trade is outpaced by that of GDP. In the 10 years after the liberalization, the trade to GDP ratio grows by about 50 log points on average. This growth is not all concentrated in one period or even in the initial four to six periods during which tariffs continue to drop. Rather, trade continues to grow even after tariffs have hit their new "steady state" value. The longest phaseout of tariffs of the three GATT liberalizations was 7 years in the Tokyo Round, which puts the final period with tariff drops at $t = 6$. A Wald test with null hypothesis $\beta_6 = \beta_{10}$ is strongly rejected with an F-statistic of 26.12. The point estimate grows by an additional 20 log points after period 6. Thus the evidence on gradual trade growth from these large multilateral agreements is consistent with the evidence from regional FTAs. We take this to be evidence of the slow adjustment of trade in response to changes in tariffs and note that our dynamic model of trade captures this margin where a static model of the exporting decision would fail.

Given that the expected reduction in foreign prices makes consumers wealthier, consumption should rise as a share of GDP. In Figure 17c we see that this is indeed the case. This figure plots the sum of consumption, government expenditures, and net exports (as we are comparing to a symmetric 2 symmetric country with zero trade imbalances in a global liberalization) as a share of GDP. Starting about six years before implementation, consumption begins to grow faster than GDP and a Wald test with null hypothesis $\beta_{-6} = \beta_{-1}$ delivers a p-value of 0.0002. The point estimate grows by just over five log points during this period. As investment catches up after the liberalization, the consumption share of GDP declines.

[19] A joint Wald test with null hypothesis $\beta_{-1} = \beta_{-2} = \beta_{-3} = \beta_3$ yields a p-value of 0.0086.

So far, we have discussed the empirical response to global liberalizations for macro variables as a share of GDP. Our model makes strong predictions about the movements of GDP itself. Figure 17d plots the cyclical component of GDP in response to future and past trade agreements. The recessionary effect of anticipation is clear. A Wald test comparing β_{-5} and β_{-1} is strongly rejected (p-value=0.005) and the point estimate falls by over one log point.

In the appendix, we explore various robustness measures including using different data, controls, or weighting schemes. The results are fairly robust to various specifications.

7 Simulation and Estimation

In previous sections, we have shown that the source of trade cost variation is important for aggregate effects both in the model and the data. Understanding the impact of the trade integration on aggregate variables in transition thus depends critically on the way trade costs fell. In this section, we discuss and illustrate one possible method to separately identify the expected and unexpected trade cost movements. The method relies on the structural model presented earlier to back out shocks consistent with a subset of observed data. To illustrate the accuracy of the method in identifying the source of trade cost variation, we use simulated data from the model so that we know the trade cost series and compare it with our estimated series.

We simulate the model for 1000 periods with shocks to productivity growth, Hicks-neutral productivity, investment-specific technology, unexpected trade costs, and expected trend trade costs. Using the last 250 observations, the proposed method is applied as follows. First, choose a subset of observed data to match using Bayesian estimation. Theoretical identification of shock processes in estimation can be tested using the method of Iskrev (2010). This test does not guarantee identification for any finite set of data. Rather, it confirms that the effects of each shock on the set of variables chosen are different enough that a sufficiently large data set could identify each shock. Any subset of observed data chosen for estimation should pass this test.

There are many approaches to choosing the data. In past sections, we have seen that the response of macro variables such as investment, GDP, and trade are different for unexpected shocks. One approach would be to use only this data as it is publicly available. Past sections have also shown that forward looking variables such as the number of exporters or firm values of exporters relative to nonexporters respond in anticipation to trade costs. Yet another approach would be to use these variables, which are harder to obtain or measure accurately. Since the data is simulated, all of these variables are available to us so we will employ three different methods. First, we use only macro variables: US and ROW GDP growth, US real and nominal investmenet rates, US real and nominal trade relative to GDP, and US nominal net exports over GDP. Second, we use aggregate trade and forward looking variables: the number of exporters, the relative firm value of exporters to nonexporters, US real and nominal trade to GDP, and real and nominal net exports to GDP. Finally, we use both macro and forward-looking variables in the last test. All of these subsets of data pass the identification test described above.

The next step is to perform Bayesian estimation and Kalman filtering to back out a series for trade costs (both expected and unexpected) implied by the estimation results.[20] These series can be compared to the actual series from simulation to see the relative usefulness of various sets of data.

Before examining the estimated series, we examine the accuracy of estimation of each shock variance. In this regard, each set of data does extremely well. Table 3 shows the actual parameter variables (same as the prior), the prior distribution and variance (purposely set to be very large), and the posterior means using the various sets of data. The posterior means in all three cases are very close to the actual parameter value. Indeed, it is clear that these values alone are not enough to decide which set of data is most useful in identifying the trade cost process.

[20] We assume that all parameters in the data generating process are known except the standard deviations of all shocks. These are the only parameters being estimated.

Figures 18 and 19 show the error in estimated trade costs (ξ_f) and anticipated trend trade costs (Δ) relative to the actual series for the three different sets of data. Errors are reported in standard deviations of the variable in the simulation.

In all three cases, the errors are not uniformly positive or negative. The estimated series seem to be mostly centered around the actual series. Indeed, this is expected as each set of data has information that allow it, given enough data, to identify trade cost shocks. The magnitudes or the error are very different, however. Using macro variables alone delivers the worst performance, with an average trade cost error of 0.48 standard deviations and an average trend trade cost error of 2.1 standard deviations. Errors in the trend trade cost are particularly important as errors indicate that the model, while able to closely estimate trade costs, cannot differentiate between expected and unexpected shocks.

Using forward-looking variables does much better in both dimensions. Trade cost errors now average only 0.21 standard deviations and average trend trade cost errors drop by almost half to 1.07 standard deviations. Despite this improvement, the next set of data illustrate that macro data still have additional information about trade cost variation. Using both macro and forward-looking data reduce the average error in trade costs by an order of magnitude to 0.02 standard deviations and the average error in trend trade costs to 0.3 standard deviations. In addition, the errors don't jump around as they do in the other two cases.

These results tell us two things. First, assuming that we know a particular structural model is correctly specified, the method proposed here using Bayesian estimation and Kalman filtering can separately identify expected and unexpected changes in trade costs. Second, both macro and forward-looking variables are useful in pinning down the relative contribution of each type of shock.

The difficulties we encountered using macro data to identify trade cost shocks do not arise under other models. Suppose that we assume two alternative data generating processes, one from a model with a static exporting decision, and one from a model with no anticipated trend shocks ($\sigma_\Delta = 0$). We simulate these two models and follow the same process that we followed for the benchmark model. In these cases, however, we will see that using macroeconomic variables alone is sufficient for accurate estimation of trade cost variation.

Before seeing the results, it's useful to consider the types of data that would be useful in estimating these models. In the benchmark model, forward-looking variables help to differentiate between anticipated and unanticipated trade cost changes. These are not helpful in the static exporter model, as exporting firms and domestic firms share the same future value. Furthermore, there is no future advantage to be gained from exporting today so news of future trade liberalization does not lead to an influx of exporters. Forward-looking variables are also not helpful when there are no trend trade costs, since their main purpose was to differentiate the two types of trade costs. Thus, using macro data is the only procedure that makes sense to identify trade costs in these alternative frameworks.

Figures 20 and 21 show the trade cost and trend trade cost errors in the estimated series. The average trade cost error falls from 0.48 standard deviations in the benchmark model to 0.17 standard deviations in the model without trend trade costs and to 0.08 standard deviations in the static exporter model. The average trend trade cost error falls from 2.1 standard deviations to 0.28 standard deviations in the static exporter model. The improvement in performance in the model without trend trade costs can likely be attributed to the fact that the same number of data series is being used to identify fewer shocks. Also, any persistent change in trade relative to output can be attributed to unanticipated changes in trade costs, with no confounding coming from anticipated changes.

The static exporter model performs better because it lacks any internal propagation of trade in response to trade cost shocks. The benchmark model features a gradual adjustment of trade to trade cost changes coming from the slowly adjusting extensive margin. Thus, a slow adjustment in trade could be coming from either a large unanticipated change in trade costs or a series of smaller anticipated movements. Because the static exporter model abstracts from the slow adjustment of trade, there is not such problem separately identifying the two sources of trade cost variation.

In this section we've proposed a method to identify the sources of trade cost variation in the data. If the data generating process is closer to our benchmark model, identifying trade cost changes requires both macro and forward-looking data. Data coming from a static exporter model or a model with no trend trade cost shocks do not benefit from the inclusion of forward-looking data and aggregate data is sufficient. The slow adjustment of trade in the data and evidence on consumer and firm anticipation of trade agreements seem to support a world closer to the benchmark model.

8 Conclusion

We have developed a quantitative general equilibrium model to study the effects of growth on trade and the effects of trade policy on growth. Our model accounts for the fact that changes in trade policy are often anticipated by firms and consumers and that these expectations over future change costs can potentially affect current macroeconomic behavior. We find that expected decreases in future trade costs are recessionary in employment, investment, and GDP due to the wealth effect and cheaper capital goods prices in the future. The recessionary impact of anticipated liberalizations is consistent across several specifications of the model. Future decreases in trade costs also induce entry of firms into the export market as firms recognize that the value of exporting will be high. This result depends crucially on the firm export decision being dynamic.

Encouraged by our quantitative work, we turn to the data and find that anticipation of GATT rounds lead OECD countries to decrease investment and trade while increasing consumption as a share of GDP. These findings are qualitatively consistent with the model.

Our findings lead us to conclude that changes in expectations about future trade costs can have important implications for the aggregate economy and for individual firm investment. WE propose a method to separately identify expected and unexpected trade costs using

Bayesian estimation and Kalman filtering. The results suggest that both macro and forward-looking variables should be used in estimation.

The method proposed here suggest two forward-looking variables that are helpful in separately identifying the sources of trade cost variation: the number of exporters and the relative firm value of exporters to nonexporters. Each of these variables could potentially be measured in the data. Firm value, for instance, may be related to the stock price. In future work, we hope to derive accurate measures for these variables from the data and perform our estimation of trade costs on the US data. Such an exercise would improve our understanding of how trade costs fell and move economists closer to understanding the aggregate impact of the most recent trade integration.

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A Tables

Name	Negotiation Period	Phaseout
Kennedy Round	1964-1967	1968-1972
Tokyo Round	1973-1979	1980-1986
Uruguay Round	1986-1993	1995-1999
ATC	-	1995-2005
NAFTA	1988-1993	1994-2004
US Korea FTA	2006-2012	-

Table 1: Tariff Phaseouts and Negotiations

	Model	Benchmark	No KIT	Static	Armington
Preferences	β	0.99	0.99	0.99	0.99
	γ	0.34	0.35	0.34	0.33
	σ	5	5	5	5
Production	θ	0.8	0.8	0.8	
	ρ	3/4	3/4	3/4	8/9
	ι	0	0	0	0
	ω_C	0.31	0.42	0.31	0.17
	ω_I	1	0.42	1	1
	δ	0.025	0.025	0.025	0.025
	α	0.4	0.4	0.4	0.4
	$c = c^*$	0.0025	0.0025	0.0025	0.0025
	κ	0.007	0.007	0.007	0.007
	ρ_g	0.3750	0.3750	0.3750	0.3750
	σ_η	0.9	0.9	0.2	0.2
	ω_{ac}	2	2	2	2
Trade Costs	$\bar{\xi}$	1.07	1.07	1.07	1.07
	ρ_ξ^c	0.998	0.998	0.998	0.998
	ρ_ξ^d	0.97	0.97	0.97	0.97
	ρ_Δ	0.93	0.93	0.93	0.93
	τ_1	0.039	0.039	0.036	0.0055
	τ_0	0.25	0.25	0.036	0.0068

Table 2: Calibrated Parameters

Parameter	Prior	Prior Dist	Prior Var	Macro Data	Forward-looking	Both
σ_g^c	0.01	Gamma	∞	0.0094	0.01	0.0097
σ_g^d	0.01	Gamma	∞	0.0102	0.0102	0.0101
$sigma_z^c$	0.01	Gamma	∞	0.0101	0.0106	0.0104
σ_z^d	0.01	Gamma	∞	0.0089	0.0089	0.0091
σ_ψ^c	0.01	Gamma	∞	0.01	0.0087	0.0102
σ_ψ^d	0.01	Gamma	∞	0.0125	0.0116	0.0103
σ_ξ^c	0.01	Gamma	∞	0.0096	0.0096	0.0098
σ_ξ^d	0.01	Gamma	∞	0.0102	0.0103	0.0103
σ_Δ	0.001	Gamma	∞	0.0011	0.00096	0.00098

Table 3: Estimation Results

B Figures

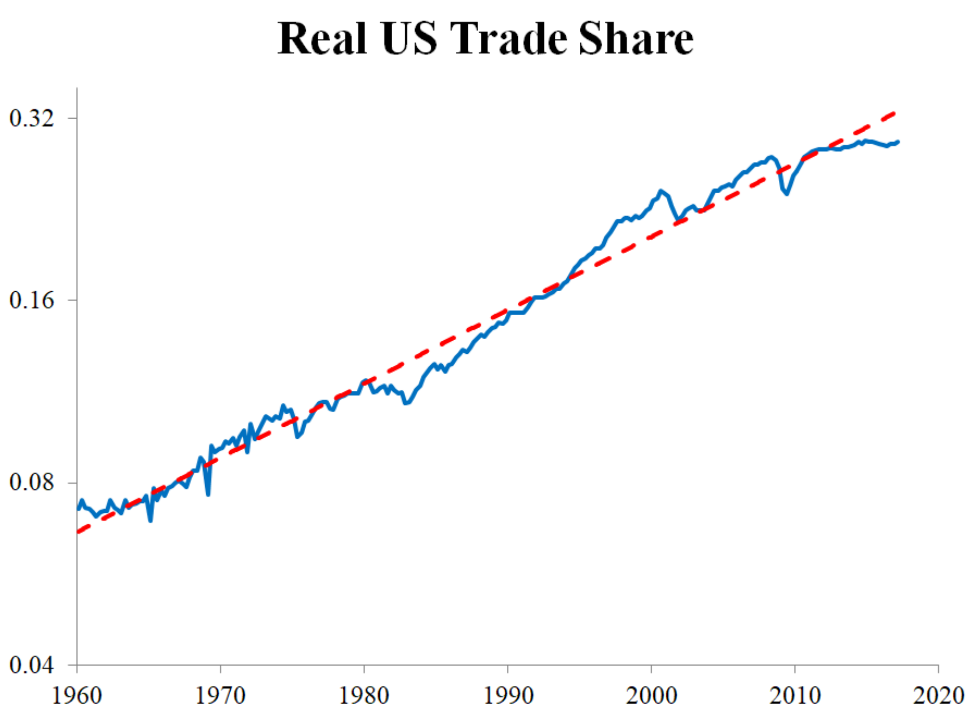


Figure 1: US Real Trade to GDP ratio

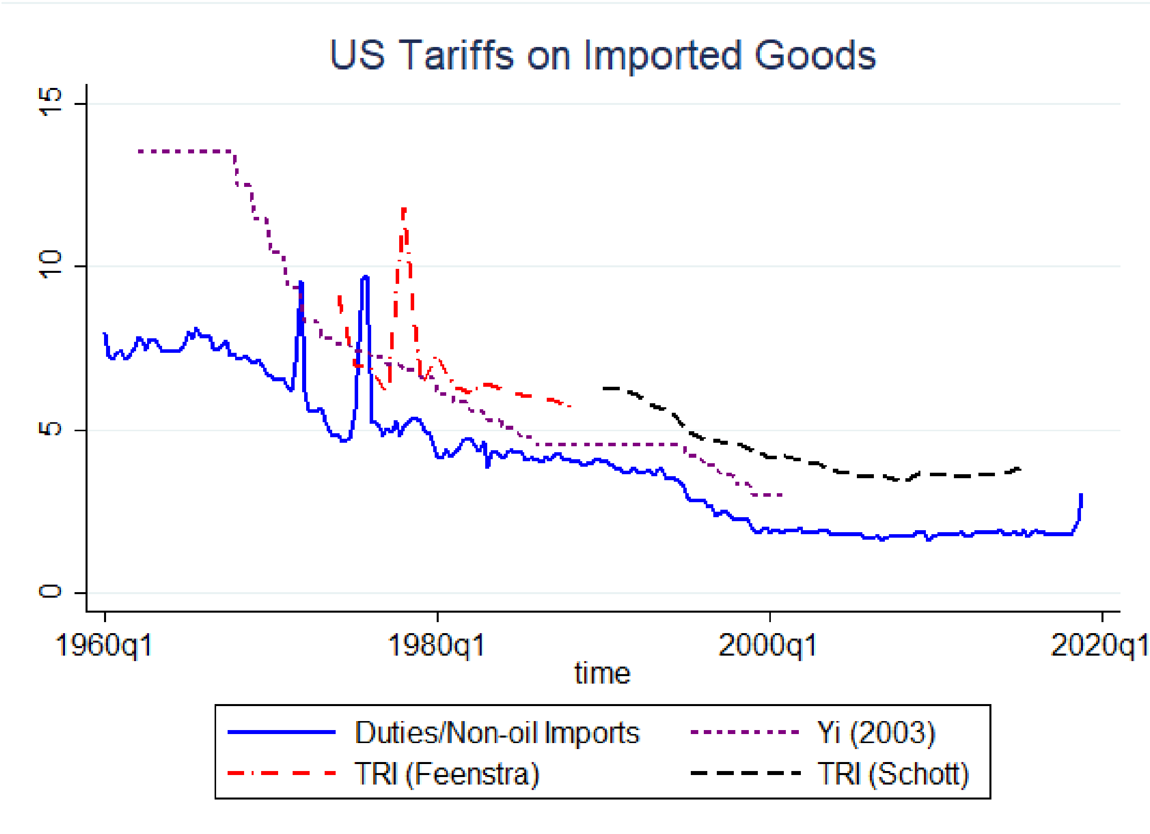


Figure 2: US Tariffs

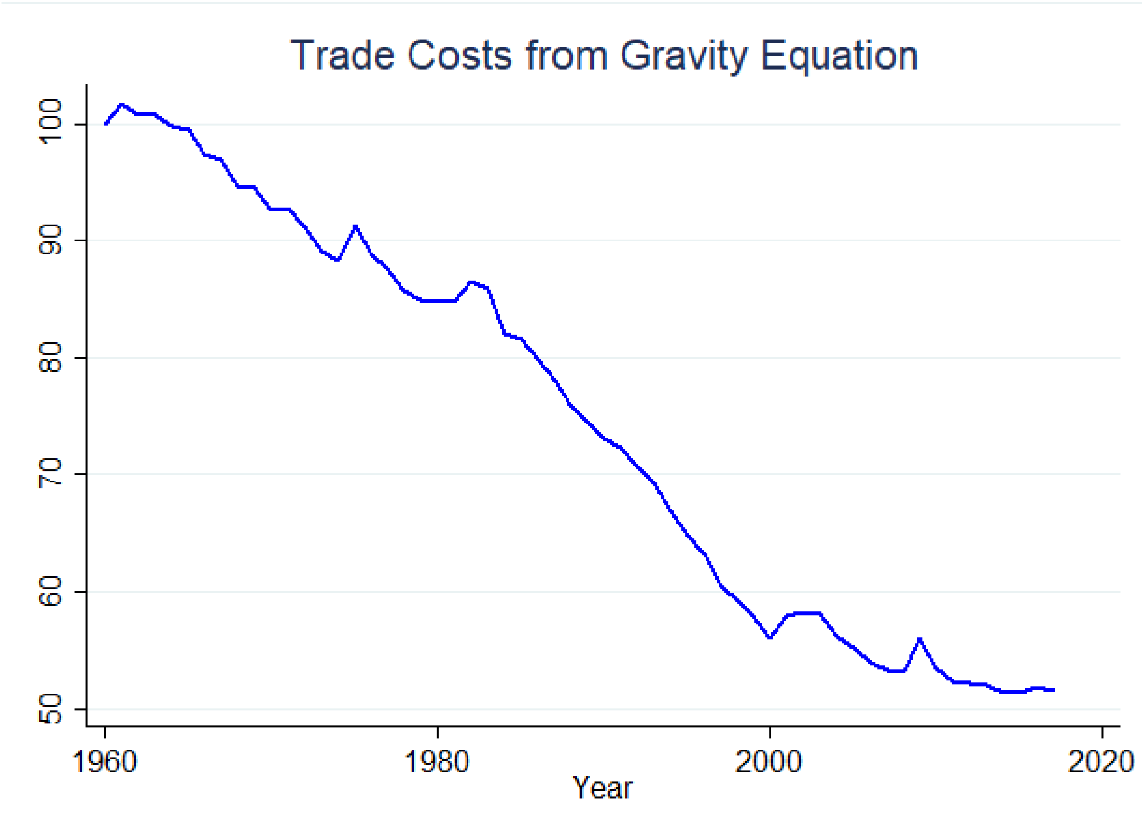


Figure 3: US Trade Costs

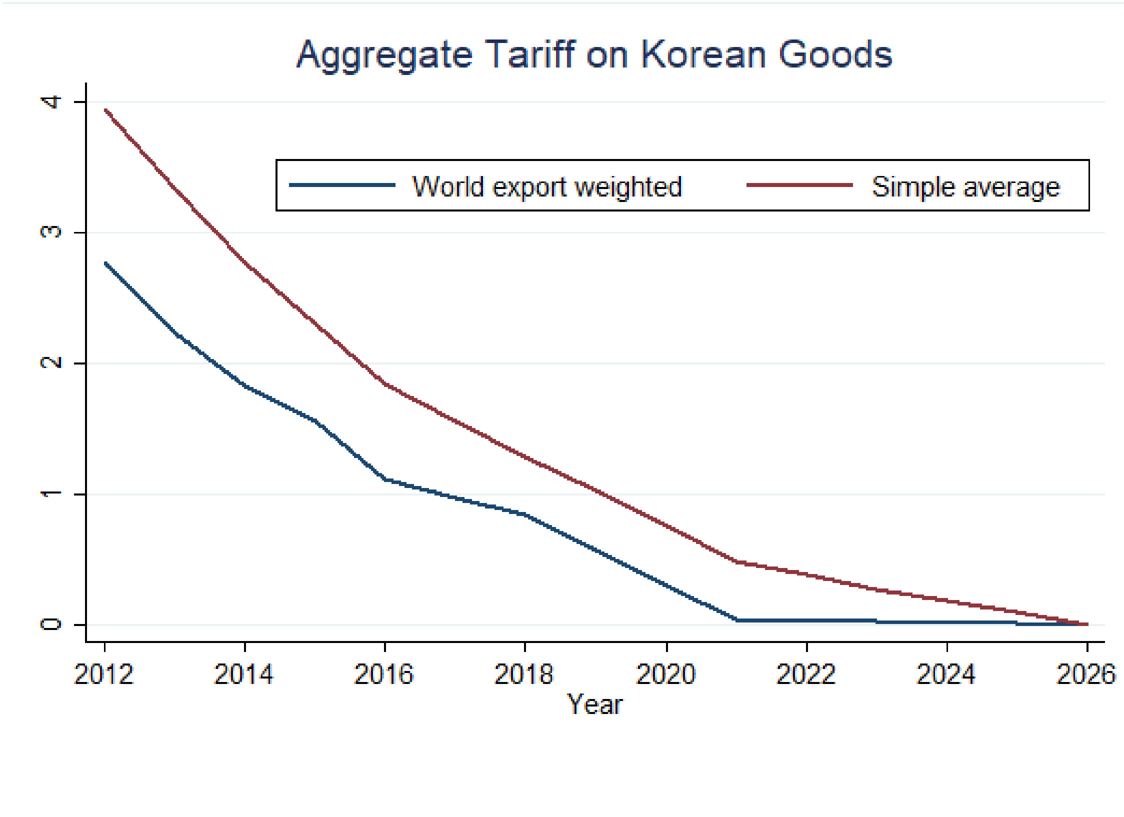


Figure 4: US Korea Bilateral Tariff Schedule

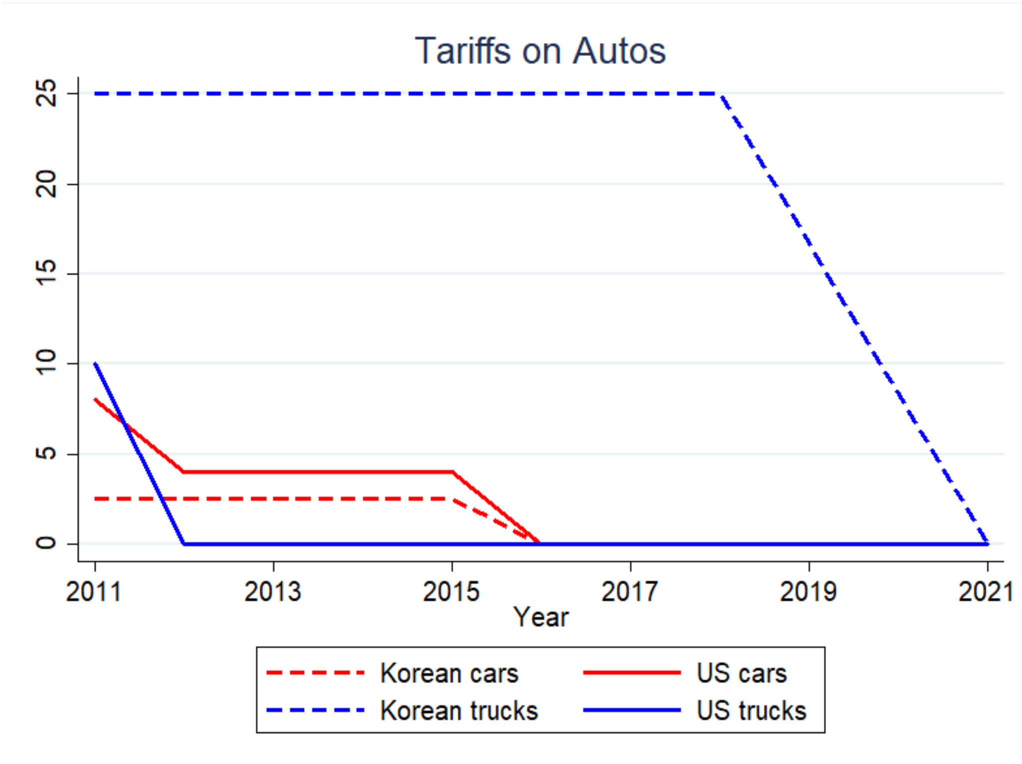


Figure 5: US Korea Auto Tariff Schedule

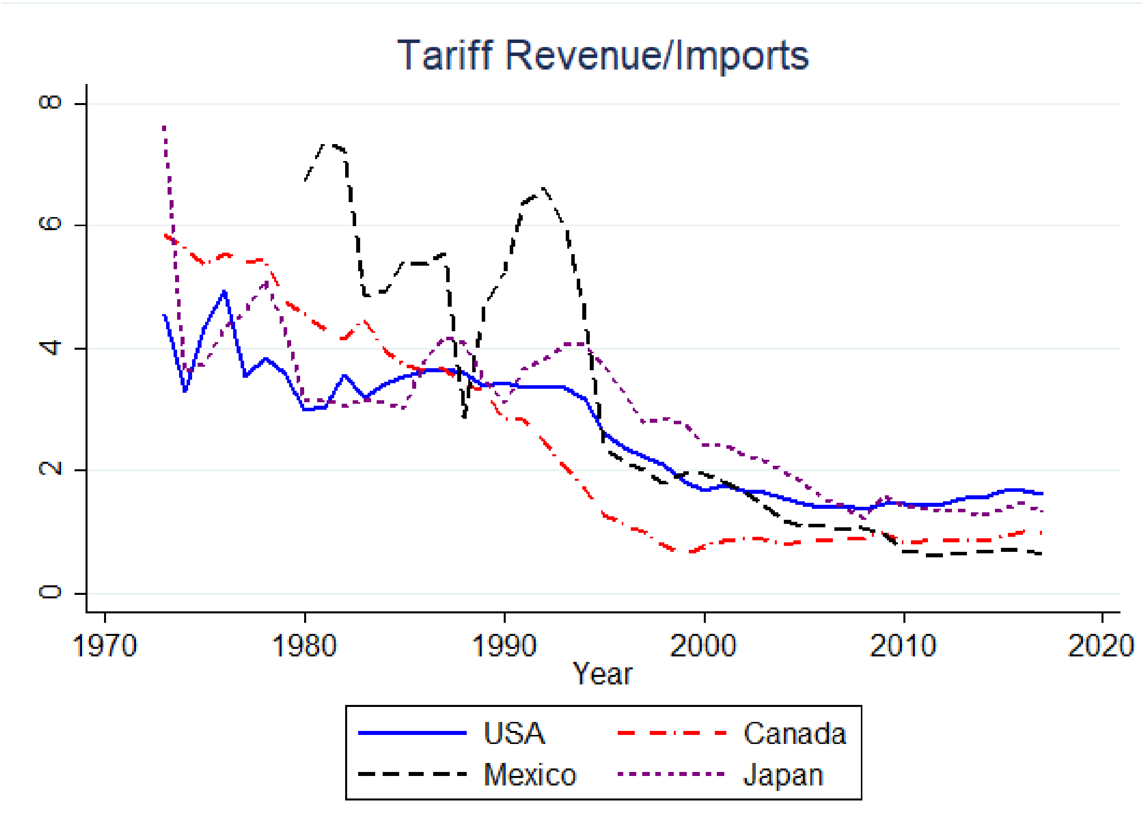


Figure 6: Import weighted tariffs for US and trade partners

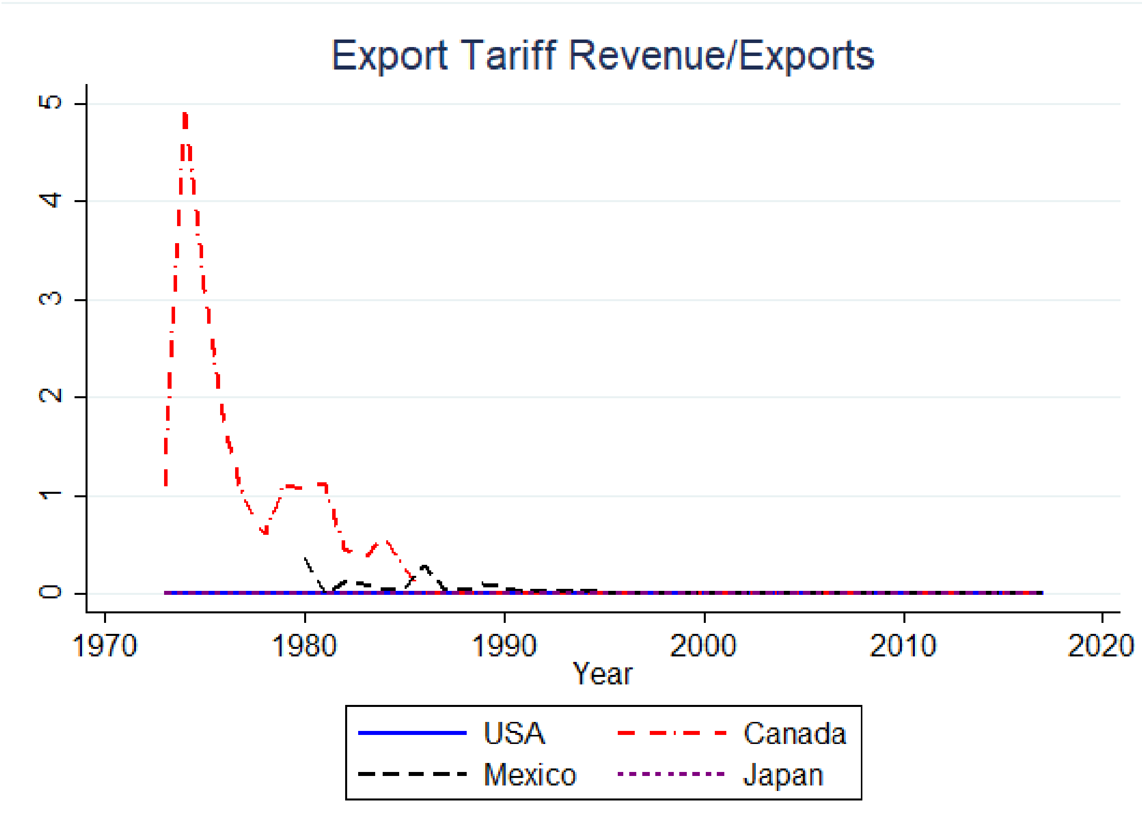


Figure 7: Export weighted export tariffs for US and trade partners

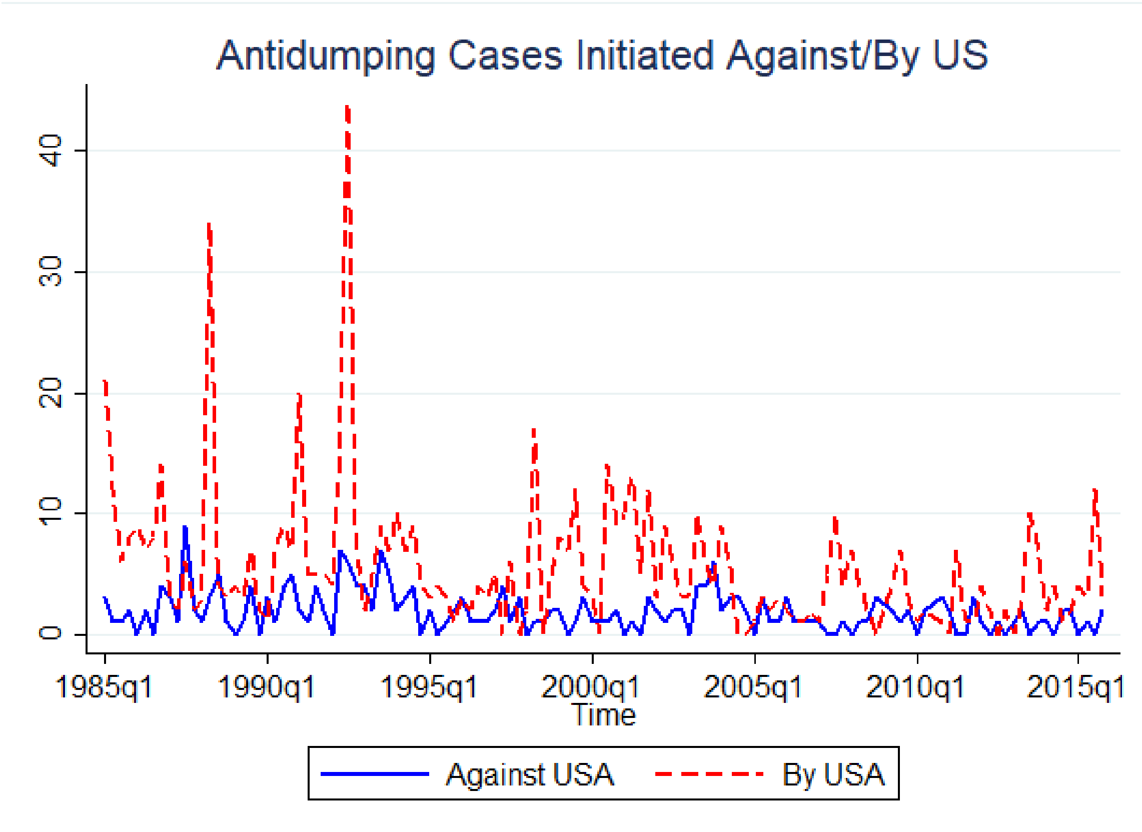


Figure 8: Antidumping cases for and against the US

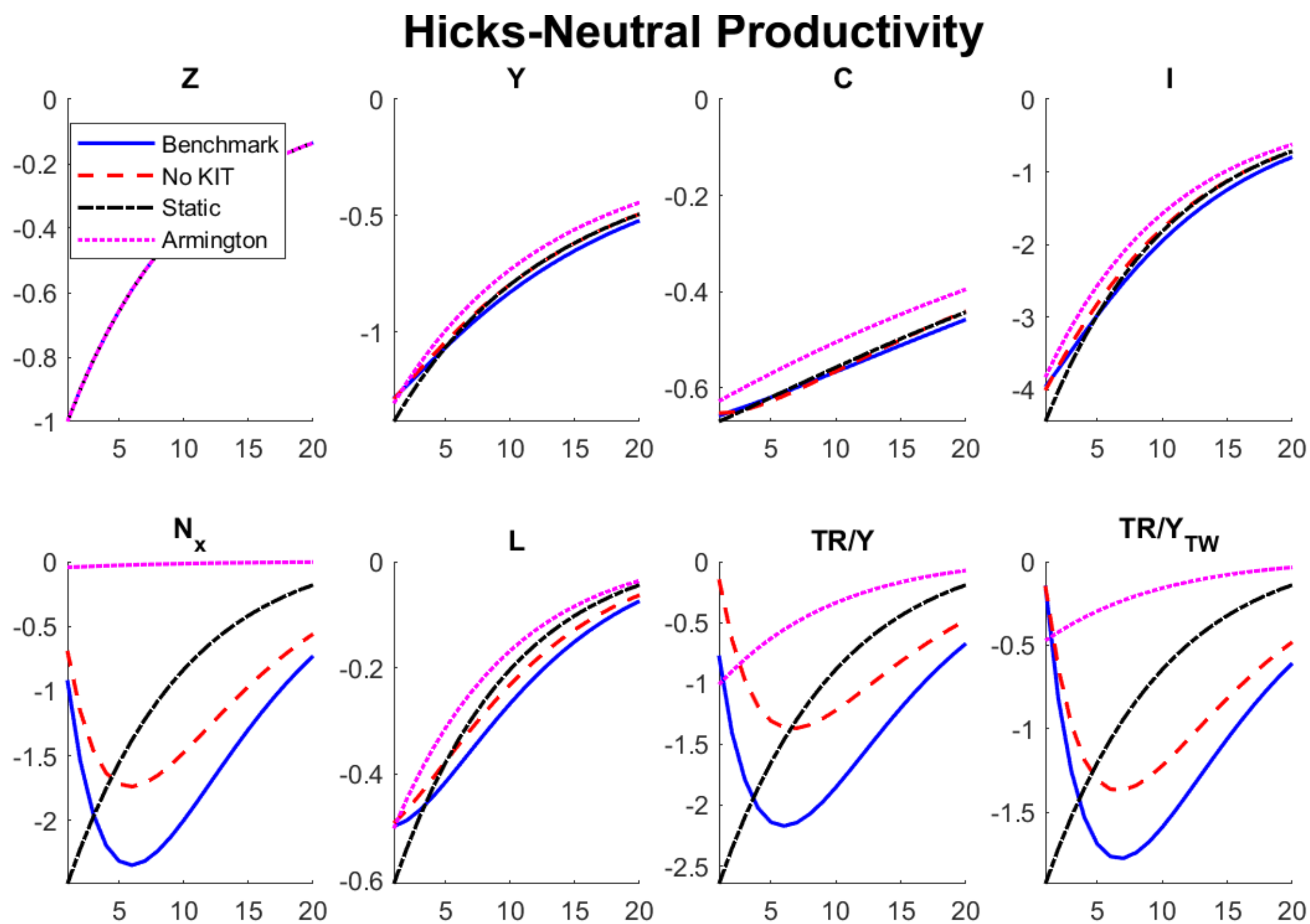


Figure 9: IRF Hicks-Neutral Productivity

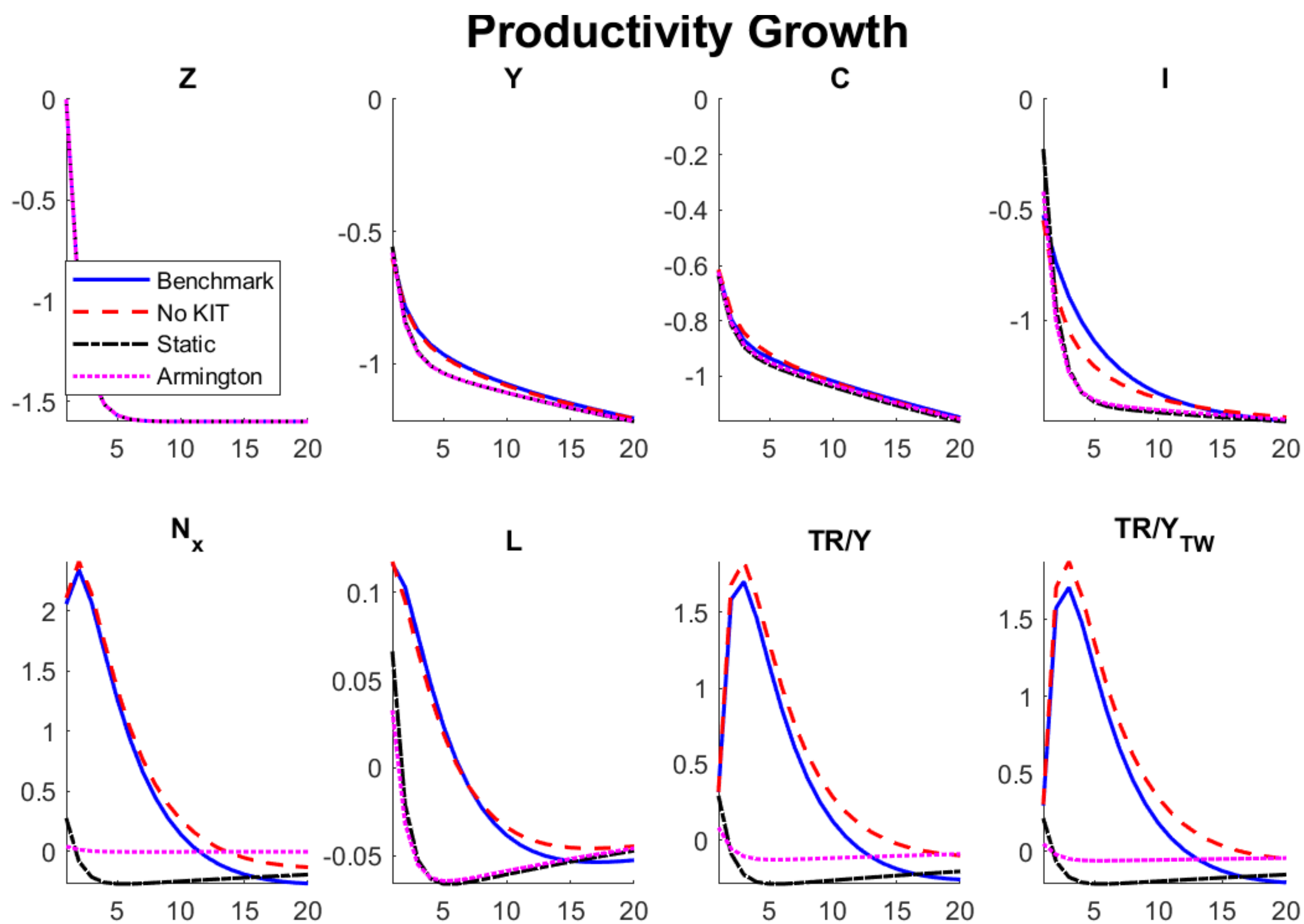


Figure 10: IRF Productivity Growth

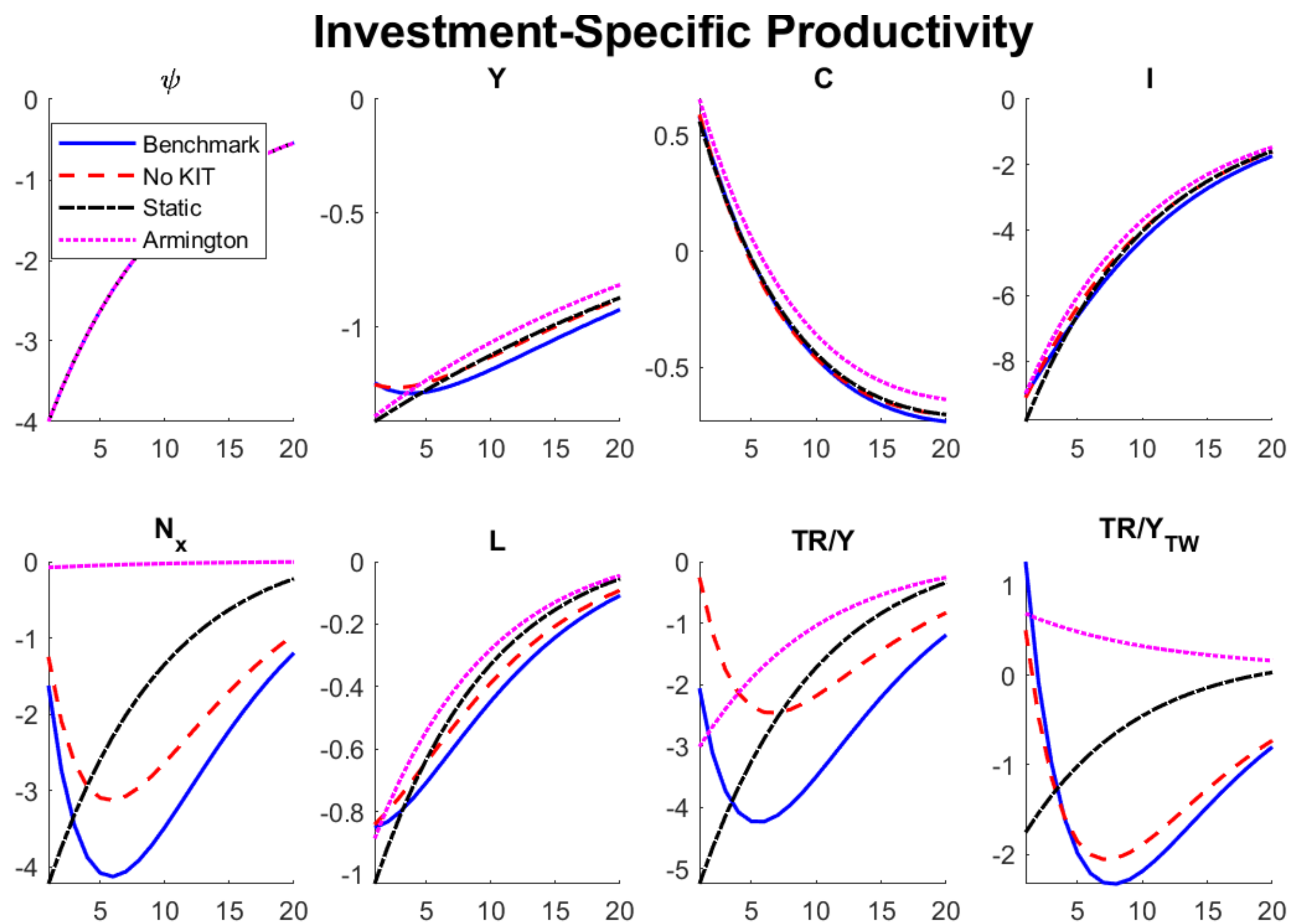


Figure 11: IRF Investment Specific Technology

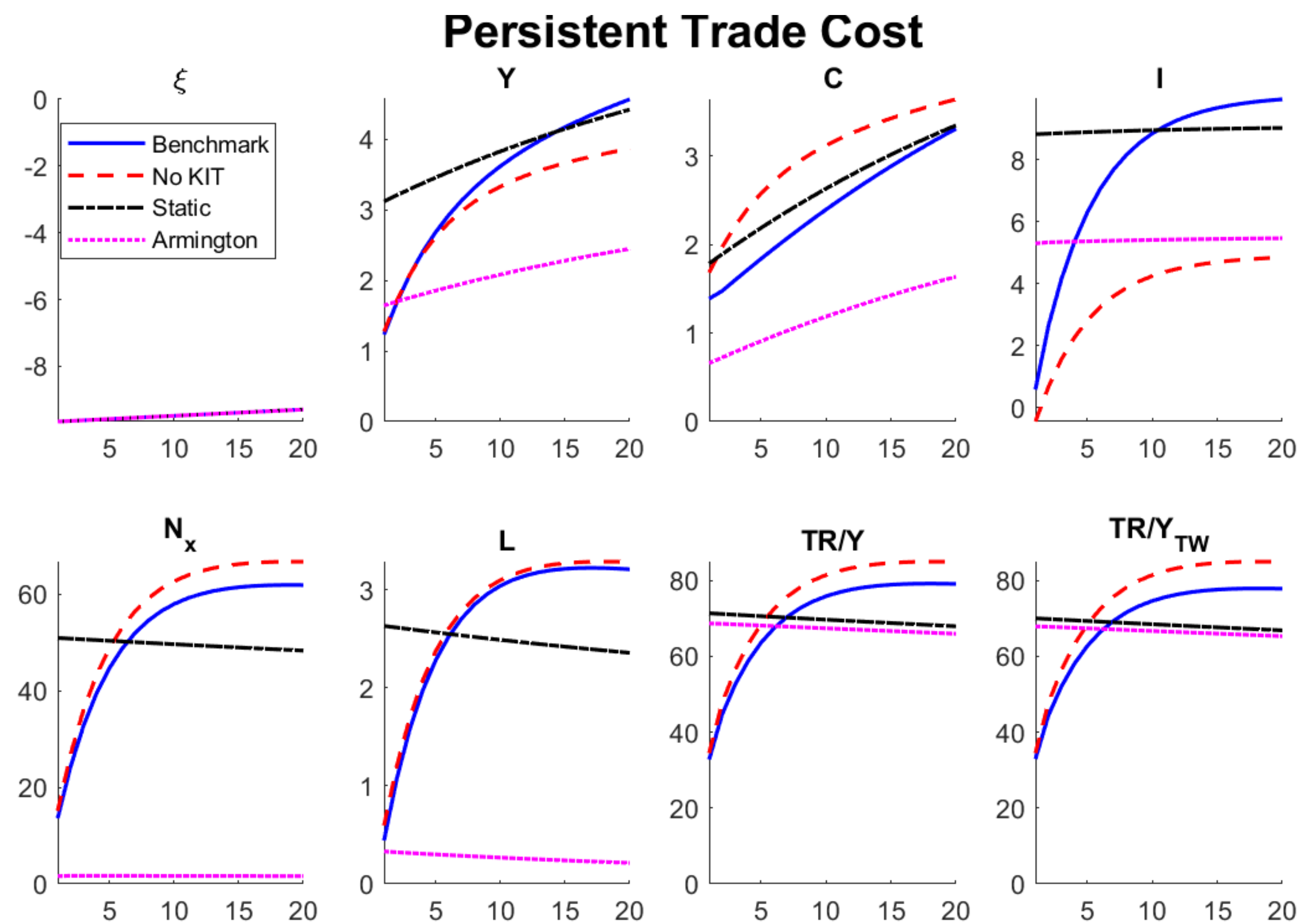


Figure 12: IRF Trade Cost

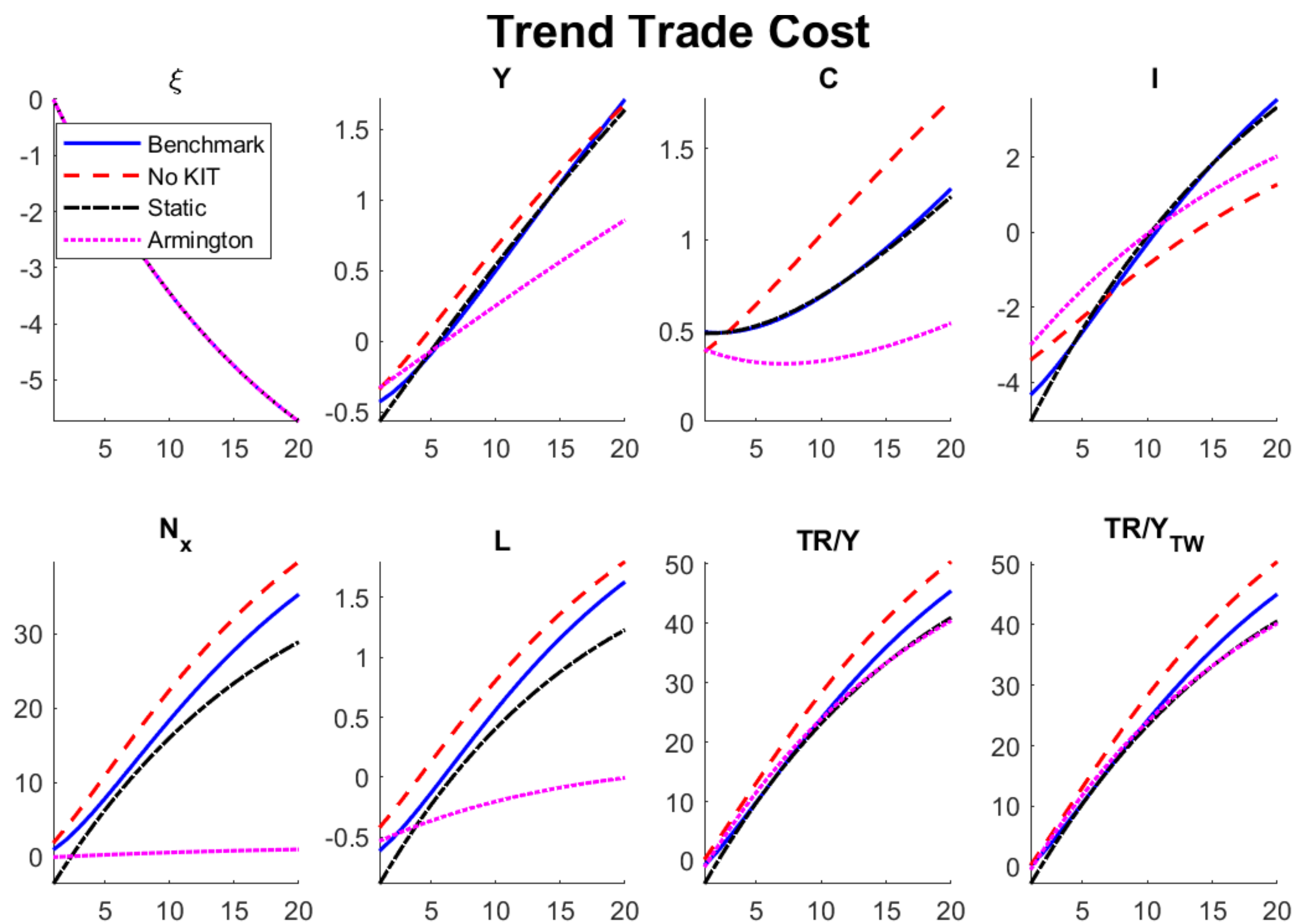


Figure 13: IRF Trend Trade Cost

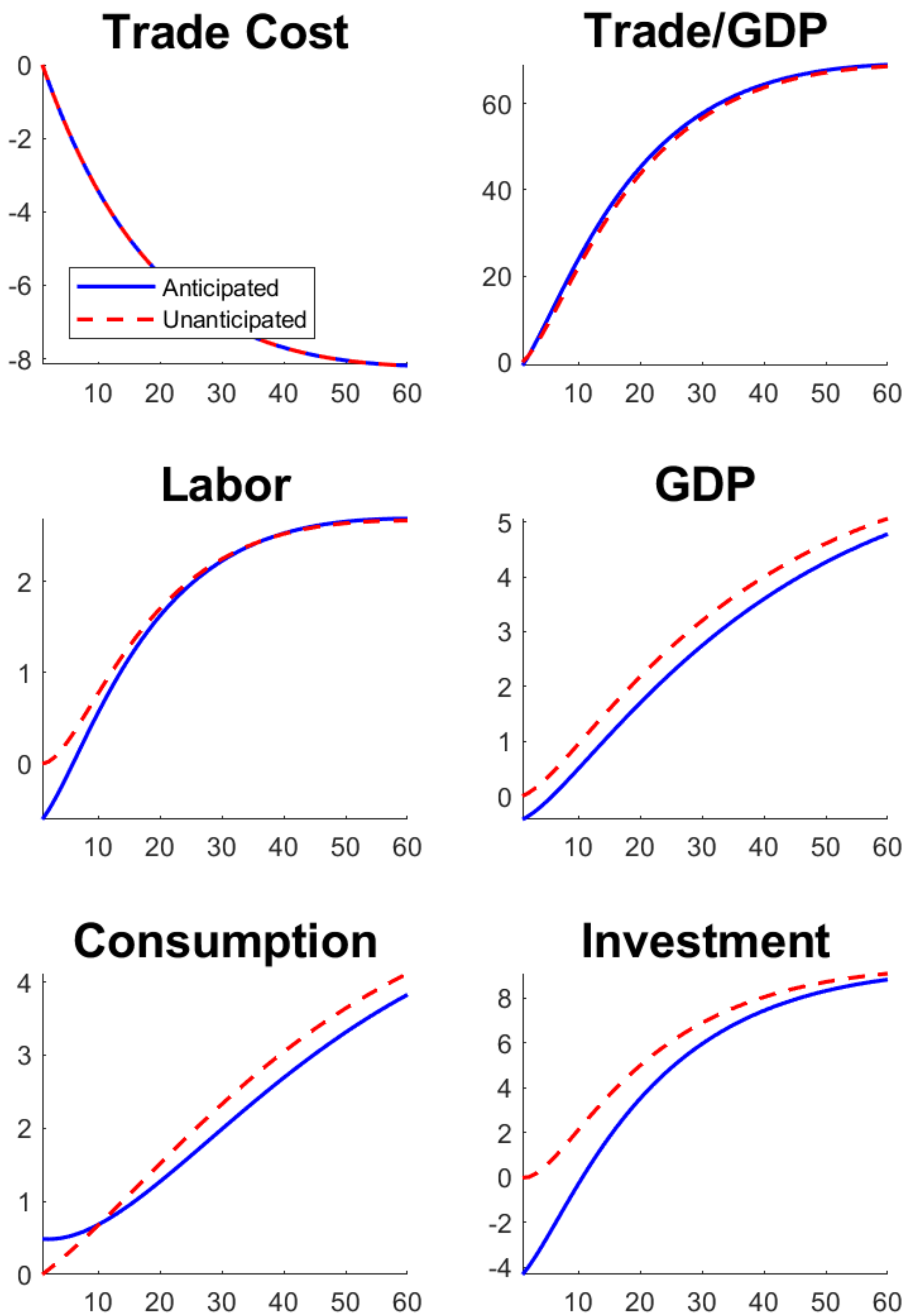


Figure 14: Anticipated vs Unanticipated Liberalization

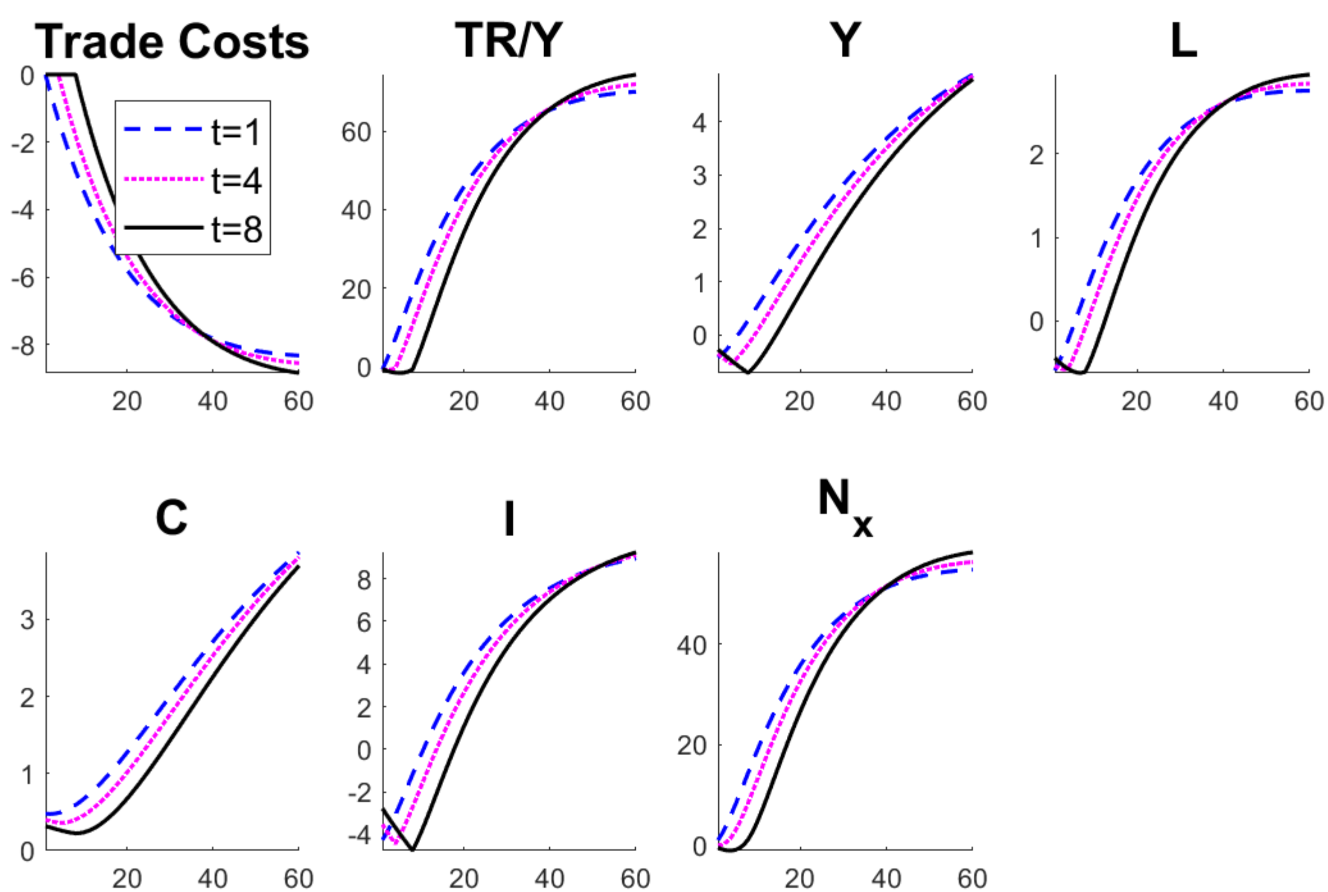


Figure 15: Trend Trade Cost - Lagged

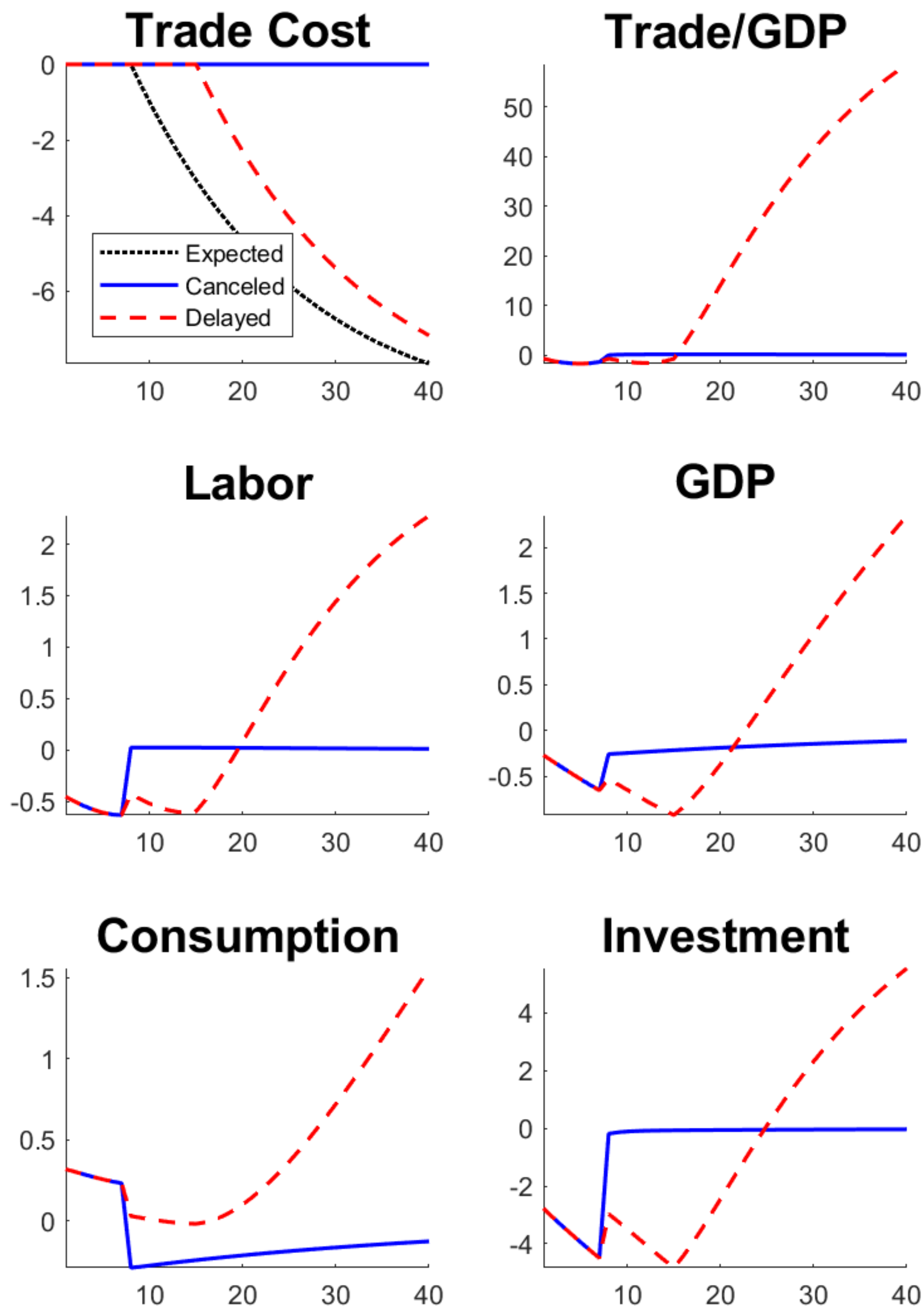
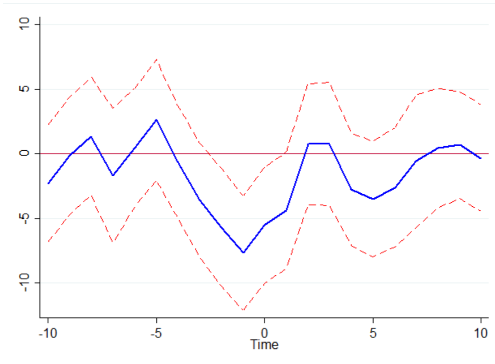
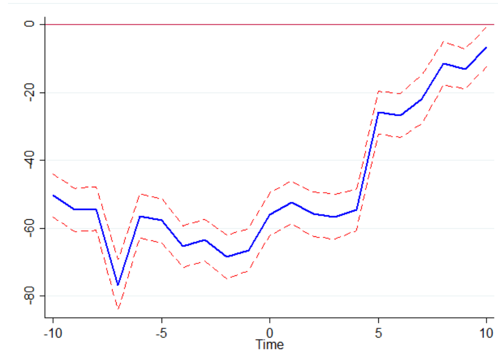


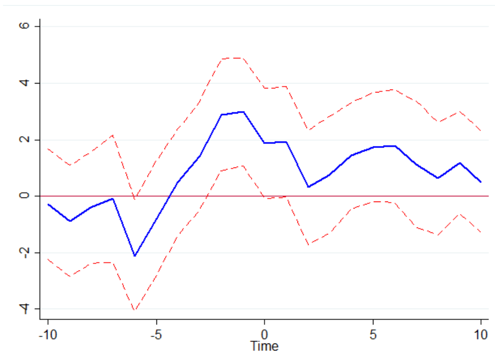
Figure 16: Canceled and Delayed Free Trade Agreements



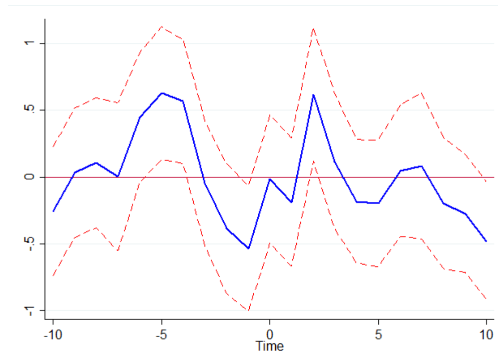
(a) I/Y



(b) (EX+IM)/Y



(c) C/Y



(d) Cyclical GDP

Figure 17: Aggregate Responses Before and After GATT Liberalizations

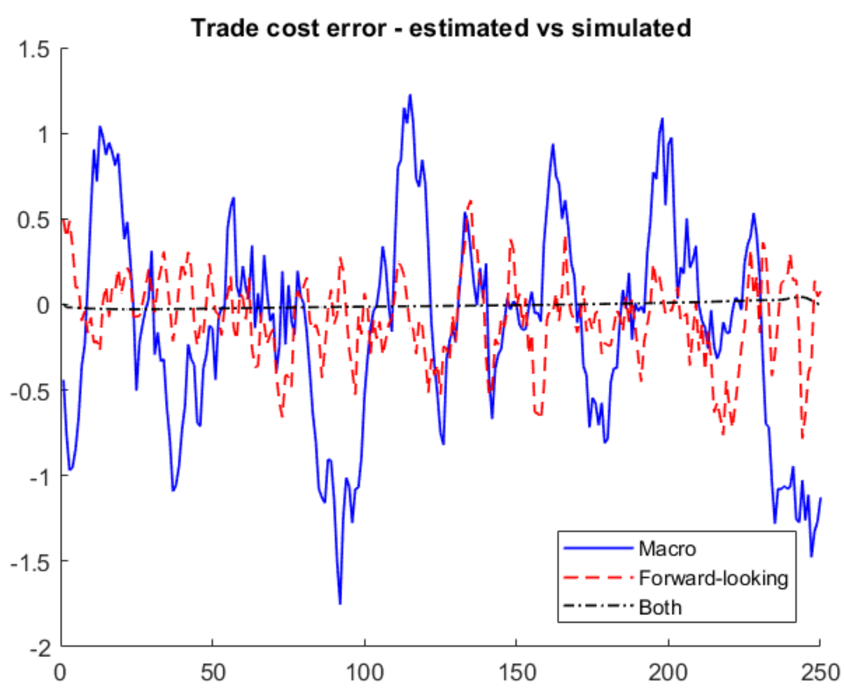


Figure 18: Trade Cost Error in Standard Deviations

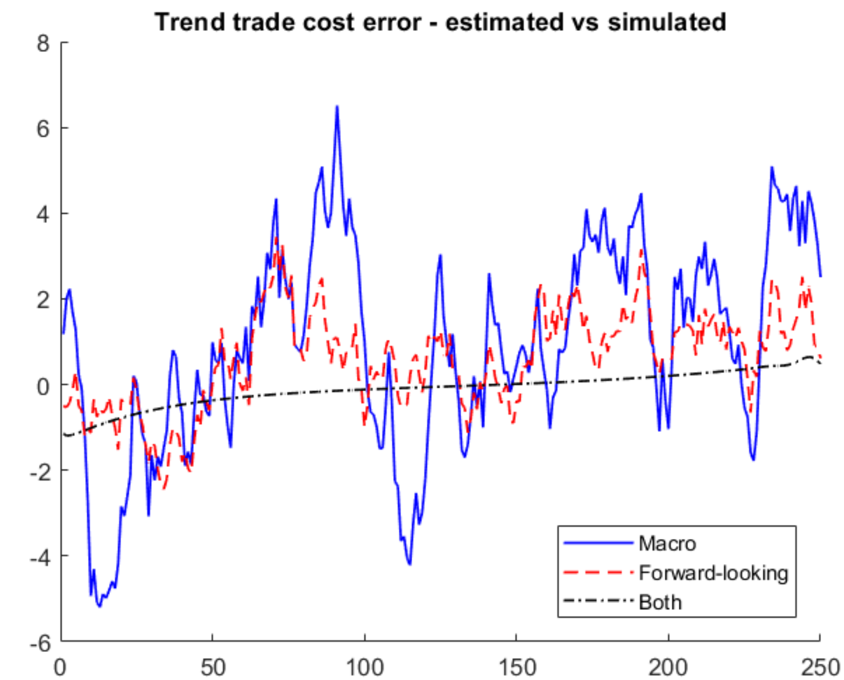


Figure 19: Trend Trade Cost Error in Standard Deviations

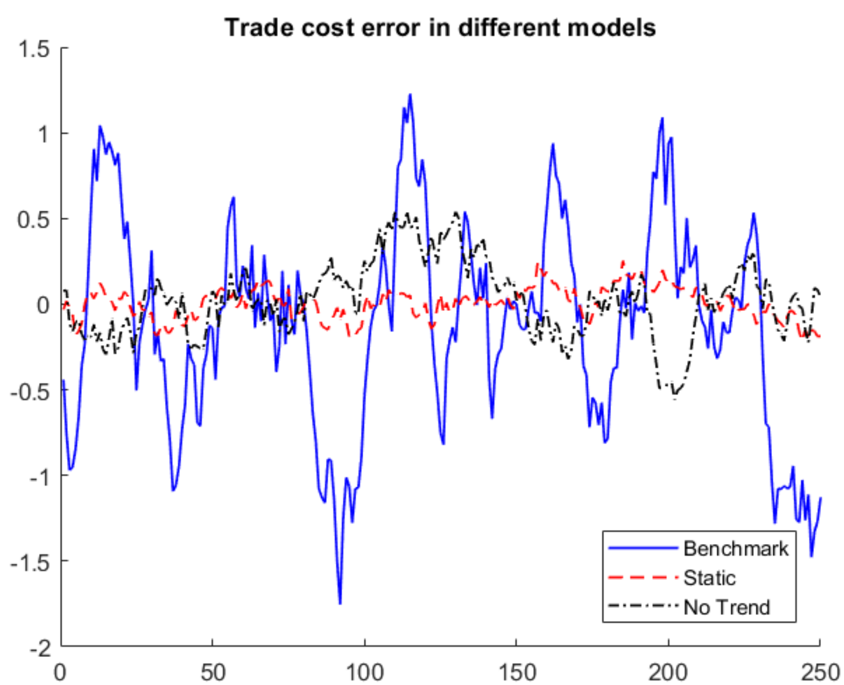


Figure 20: Trade Cost Error in Standard Deviations - Different Models

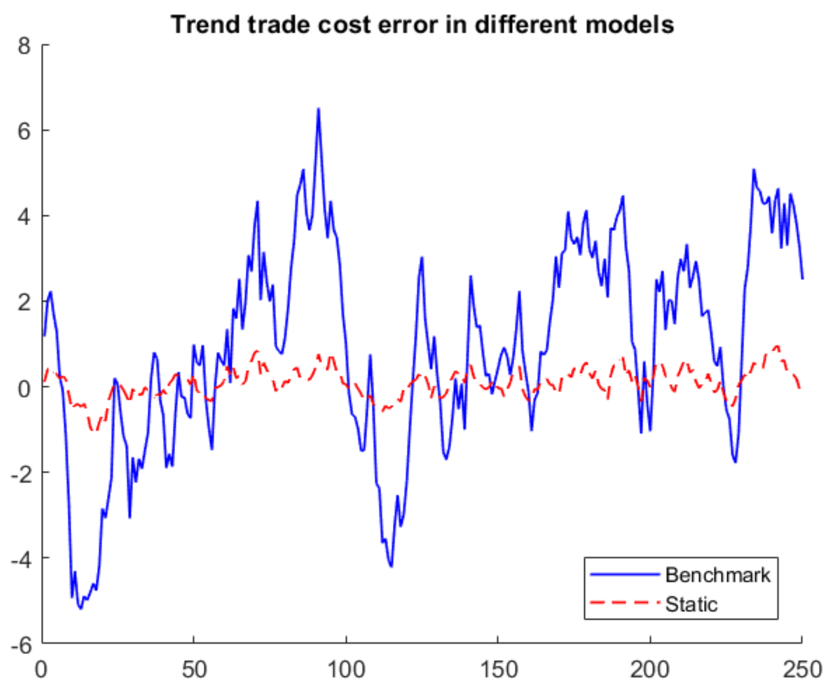


Figure 21: Trend Trade Cost Error in Standard Deviations - Different Models