Trade Policy is Real News: A quantitative analysis of past, current, and future changes in U.S. trade barriers.*

November 2018
First Draft: February 2017

Preliminary

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Abstract
We evaluate the aggregate effects of changes in trade barriers in a model in which trade responds gradually to changes in trade policy and trade policy changes are gradual. Our model offers insights into how changing trade barriers affects the economy and how business cycle shocks can affect trade. We find that a fall in current trade barriers has an expansionary effect while a decline in future trade costs can be recessionary on impact. We find that cancelling agreed upon declines in barriers to be expansionary in the short-run but substantially lowers growth over the medium run. We also find that even controlling for composition, trade tends to lag the recovery in demand for tradables. We capture the growth and trade factors driving the economy with movements in productivity, investment efficiency, the labor wedge, and trade costs. We estimate the model to match the key time series on trade integration and business cycles since 1970. Our estimation yields a path for current and expected future trade barriers and allows us to decompose the source of aggregate fluctuations and integration. We find that trade barriers have been expected to decline but that these declines have been repeatedly delayed. We find that aside from these delays that the outlook on future trade barriers did not change much between 2012 and 2016, but deteriorated substantially since. We also decompose the sources of the trade and growth slowdowns since the Great Recession. We show that data on export participation is helpful to identify future trade costs when exporting is a dynamic decision. We use our model to consider the impact of alternative unilateral and bilateral changes in trade barriers being contemplated.

JEL classifications: E31, F12.
Keywords: Trade Growth, International Business Cycles.

* George.Alessandria@Rochester.edu; cmix@ur.rochester.edu. We thank Ricardo Reyes-Heroles, Davide Melcangi, and audiences at the Banco de Mexico, SED Edinburgh, 2017 CEBRA IFM, NBER Fall 2018 IFM, LAEF conference on "Trade and Macroeconomic Dynamics," and Philadelphia Federal Reserve Bank for helpful comments. A previous version circulated as "The Global Trade Slowdown: Trade and Growth, Cause and Effect."

1. Introduction

The aim of this paper is to quantify the impact of changes in current and future trade policy on the US and global economy. Our analysis departs from previous work in explicitly considering how future changes in trade policy affect the current economy as well as the lagged effect of past trade reforms. We do so in a prototypical international business cycle model. Our focus on the dynamic effects of trade policy are motivated by the large but gradual changes in trade integration and the tendency for trade agreements to contain substantial, predictable declines in trade barriers, or phase-outs, over time.

Our interest in understanding the interplay between business cycles and trade integration is motivated by the the trade and growth slowdowns since the Great Recession and following the Great Trade Liberalization as well as the current contemplation of changes in trade agreements. Trade has increased dramatically but this growth has slowed substantially since the Great Recession. For instance, the US real trade to GDP ratio has roughly held steady from 2012 to 2017 at 29 percent. In stark contrast, in the twenty years leading to the Great Recession, the trade to GDP ratio doubled from 13.5 to 27 percent. The slowdown in trade growth is even more severe as output growth has also fallen across these periods from about 3.0 percent per year to 1.7 percent. These dual slowdowns are common across many countries. In this paper, we use a two country dynamic stochastic general equilibrium model to identify the sources of these dual slowdowns.

Three main explanations for the seeming end of growing trade integration stand out. First, the transition from past trade reforms may be complete. That is, the run up to the Great Recession was characterized by many major trade deals such as CUSFTA, NAFTA, and China's WTO accession that took time to fully increase trade. Second, current and future trade barriers may have risen. This is another important possibility given the tendency for protectionist policies to be countercyclical, the rise in nationalistic politicians globally, the death spiral of prospective major trade agreements such as T-TIP and TPP, and the backlash against NAFTA and the EU from Brexit. Indeed, the 2015 US Transportation Act lowered the allowable import content on federally funded investments by one-third over the next 5 years.[1] And third, the weakness in economic growth may discourage trade. This may operate through an effect of output growth on firm trade participation or through the well-known composition channel that trade is intensive in cyclically sensitive goods such as consumer durables or capital goods.

Quantifying the relative importance of these three sources of trade growth requires a dynamic general equilibrium model of trade integration and the business cycle with three features; 1) exogenous changes in current and future trade policy; 2) an endogenous gradual response of trade to aggregate shocks; and 3) shocks that generate business cycles and changes in trend growth that are consistent with the cyclicality of trade. A dynamic general equilibrium model also allows us to examine the effect of changing trade policy on the slowdown in growth.

Trade barriers are modelled as following a very general stochastic process with asymmetries and trends. Specifically, inward and outward barriers are allowed to move together and apart to capture the unilateral and bilateral changes in trade barriers. Country-specific barriers fluctuate in response to persistent shocks to either the level or the change in trade barriers, what we call trend trade costs. Persistent shocks to the level follow an AR1 process and capture transitory and permanent changes in trade barriers and trade policies. The trend shocks capture the tendency for many trade agreements to include phase-in periods.[2] This general structure of trade barriers imposes some discipline on expectations of future trade policy. It also allows us to compare actual trade barriers against expected trade barriers at different points in times, including the end of our sample.

[1] The Fixing America's Surface Transportation (FAST) was passed in December of 2015. and phased-in an increase in domestic content requirements for transit rolling stock procurements from 60 percent to more than 70 percent by the year 2020.

[2] Baier and Bergstrand (2007) argue that the full impact of free trade agreements (FTA) can take up to fifteen years to be realized.

To capture the endogenous transition to a change in trade policy we build on the dynamic exporting model of Alessandria and Choi (2007). This model extends the international business cycle model of Backus, Kehoe, and Kydland (1994) to include heterogenous firms with a dynamic exporting decision from a large up-front sunk cost of exporting (Das, Roberts, and Tybout, 2009). It is consistent with the micro evidence on exporter characteristics and the dynamics of export participation in response to trade policy changes and aggregate fluctuations. To allow for even more gradual response to shocks we augment this model with input adjustment frictions.

Business cycles are assumed to arise from shocks to productivity and investment efficiency. To capture the growth slowdown, we allow for transitory and trend productivity shocks as well as shock to labor supply and investment efficiency. To capture the cyclicality of trade, trade is modelled as being intensive in durable goods. Engel and Wang (2011) argue that about 70% of trade is in durable goods, and 40% is in capital goods. With this in mind, a change in the composition of demand can have different impacts on trade and output. Indeed, Eaton et al. (2016) show composition accounts for about two-thirds of the decline in trade in the Great Recession.

While our main focus is on the trade slowdown, our model includes a number of channels for trade to affect growth. First, there are the usual efficiency gains from lowering trade barriers operating through the lower costs of trade and shifting production to more efficient producers. Second, as trade is intensive in capital goods, a decline in trade barriers will lower the price of investment and lead to capital deepening. Third, the dynamics of trade barrier will affect the desire to invest and work. For instance, a decrease in future trade barriers is shown to be recessionary. owing to the wealth effect as well as the expected future decline in the price of investment goods. Moreover, a temporary increase in trade barriers will also act much like a negative productivity shock and lead to a decline in output. These effects of trade barriers on investment and growth suggests that partial equilibrium analyses that attribute changes in the composition of final expenditures to growth factors will understate the importance of changes in trade barriers in the trade slowdown.

The model is estimated to match key features of the US and world economy from 1970 to 2017. In particular, the model is estimated to match US and ROW growth, employment and investment rates, relative prices, trade integration, and net exports. Our estimation yields shocks and processes for these shocks. We then use our model decomposition to determine the source of fluctuations in the US trade to output ratio and US growth. We also use the model to provide a forecast of trade and output growth going forward.

Our theory of trade dynamics yields a path of current and future trade barriers that does not just echo the observed path of trade. We find that trade barriers followed expectations downward through 1995. Since then, trade barriers have been rising even as the expected path has forecasted substantial declines. It appears that trade reform has been delayed over and over but there remains much optimism going forward, with only a minimal retrenchment since the start of the Great Recession. These expected future reforms are expected to stimulate the economy in the near term.

There are several papers that examine the relative contributions of cyclical and structural factors on the trade slowdown. Constantinescu et al. (2015) argue that both cyclical and structural factors are important, and that the slowdown may represent convergence to a new trend for trade growth. They find that among the important structural factors are slowing of global value chains and lower investment in the composition of GDP. Empirical work by Boz et al. (2015) suggests that slightly over 50% of the slowdown is coming from cyclical factors. This number comes from estimating the import equation using a measure for demand that is adjusted for import intensity in each component. The predicted trade growth in the slowdown from this model is then interpreted as being the part of the slowdown from cyclical factors. It is likely that structural factors can also affect what is measured as demand in the data, so we take this number to be an upper bound. Freund (2009) argues that historically, the effects of a crisis on trade can last in the medium-run. Ollivaud and Schwellnus (2015) also claim that most of the slowdown is coming from cyclical factors. The results of these papers are all based on empirical work. Very little has been done quantitatively. The second chapter of the October 2016 IMF World Economic Outlook was devoted to this question. The authors use a static version of the quantitative framework of Eaton et al. (2016) to claim that 60% of the slowdown in world trade growth relative to output growth is coming from changes in demand composition. To our knowledge, our paper is the first to use a dynamic quantitative model to assess the slowdown. Capturing dynamic responses to changes in structural variables is vital as these responses tend to be long lasting.

We contribute to a nascent 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, Lewis, and Tesar, 2010, Alessandria, Kaboski and Midrigan, 2010, 2011, 2013, Eaton, Kortum, Neiman and Romalis, 2014). 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 (2017) also propose a dynamic framework to decompose the US trade balance into trade and business cycle shocks, but abstract from capital accumulation. Eaton, Kortum, Neiman and Romalis (2016), Eaton, Kortum, and Neiman (2016) and Reyes-Heroles (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.

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, Bergstrand, and Feng (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.[3] 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, with much debate about how to identify future changes in these variables. There is little doubt that trade agreements (and disagreements) contain important predictable components, although we currently use very little information about those changes in our analysis instead we use the model to infer these changes.

In Section 2, we provide evidence of the slowdown both globally and in the United States. In Section 3, we discuss patterns of globalization in the precrisis period. In Section 4, we describe the model in detail. In Section 5, we describe our calibration of parameters as well as the estimation process and results. In Section 6, we discuss implications of the estimation about trade and output growth, and quantify the contributions of cyclical and structural factors to the trade slowdown in the U.S.

2. The Global Trade Slowdown

In this section, we show that post-recovery growth of global imports has been slow relative to both its historical growth and concurrent income growth. For the sake of completeness of the data, we will use only OECD countries although other authors have shown that the slowdown does in fact occur on a global scale. Constantinescu et al. (2015) show that the

[3]See, for example, Alessandria et al. (2015), Ruhl et al. (2008), and Rabanal and Rubio-Ramirez (2015).

slowdown is more severe for advanced economies.

Using data for all OECD countries from the Quarterly National Accounts, we construct an OECD aggregate for import, export, and GDP growth. We weight a country's import growth by that countries share of total OECD import value. Export growth and GDP growth are similarly weighted. We define the precrisis period to be from 1990q1 to 2007q4 and the slowdown period to be from 2012q1 to 2016q3. We report the average annualized quarterly growth rates in Table 1. Figure 1 shows the growth rates of real imports and GDP since 1980.

The slowdown in trade is severe. Average annualized quarterly growth rates of real imports for the precrisis period is about 6.8%. For the slowdown period, average growth is about 3.2%.[4] Real GDP growth has also slowed relative to the precrisis period, although the drop is not as pronounced. Real GDP went from an average growth rate of 2.7% in the precrisis period to 1.8% in the slowdown period. From 1990Q1 to 2007Q4, trade grew about 2.5 times as fast as output. Now it is growing less than twice as fast. This indicates that growth of trade is slower now both relative to its own growth in the precrisis period and concurrent output growth. These results are consistent with calculations done using different groups of countries performed by Constantinescu et al. (2015), Boz et al. (2015), ...

In this paper, we focus on pre- and post-crisis patterns for the United States. In the U.S., real total trade (exports plus imports) went from an average annual growth rate of 6.5% in the precrisis period to 2.5% after 2012. In comparison, the slowdown in real GDP was quite small, going from 3.0% to 2.1%. Similarly, the decline in the production of tradeable goods proxied by industrial production is about the same. In nominal terms, trade is actually growing slower than output and the trade to output ratio is declining rapidly starting in late 2014. This is likely coming from severe declines in the import price of oil.

[4] The fall in growth of nominal values for both imports and exports is even bigger, which comes from falling oil prices in recent years.

3. Globalization Patterns

We now briefly discuss some aspects of changes in trade policy. We emphasize a decline in barriers with a substantial forward-looking component.

In the 1990s, the developed world saw substantial increases in globalization. The World Trade Organization (WTO) reports over 50 regional trade agreements that went into force between 1990 and 2000. To give some perspective, the 1970s and 1980s each witnessed about ten regional trade agreements reported by the WTO. The 1990s and 2000s also saw an increase in the number of multinational firms and supply chain integration. Lower import tariffs allowed firms to take advantage of lower production costs in foreign countries.

When free trade agreements enter into force, the tariff phase outs tend to be gradual. Kowalczyk and Davis (1998) explain that phase-out periods for tariffs were an area of some debate in early rounds of the General Agreement on Tariffs and Trade. Eventually, it was decided that preferential trade agreement tariff phase-outs for most goods would not exceed 10 years. 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. Trefler (2004) plots average tariffs for Canada and the U.S. against each other and average tariffs against the world in the wake of the Canada-U.S. Free Trade Agreement. The bilateral tariffs show a clear gradual decrease.

Using HS8 tariff data from Feenstra et al. (2002), we construct a production weighted average tariff of the United States against Mexico, Canada, and the Most Favored Nation.[5] We create a concordance between HS8 products and NAICS 6-digit codes.[6] We take simple

[5]The most favored nation tariff is an upper bound on tariffs against all WTO members at the product level imposed by the WTO.

[6]See appendix for details.

averages for HS8 products in a NAICS code to come up with an average tariff for the product. We then use production data from the NBER-CES Manufacturing Industry Database to weight each average tariff by its production relative to the production of the entire manufacturing sector.[7] The weighted tariffs are plotted in Figure 2. Unfortunately, we only have tariff data back to 1989 and are therefore unable to see the change in tariffs imposed against Canada on impact from the Canada-U.S. Free Trade Agreement. However, we see that tariffs imposed against Canada drop quickly at first but then decrease more gradually as time goes on. A similar pattern emerges for Mexico. When NAFTA begins in 1994, we see a large decrease in tariffs against Mexico. After 1995, we see a more gradual decrease in the average tariff.

Figure 3 plots the simple averages of HS8 tariffs against the same three groups. The same patterns are clear for the simple average as well.

Now we turn to analyze Mexico's tariffs imposed against the U.S. In each year between 1991 and 2000, over 70% of Mexico's imports came from the U.S. and about 80% of its exports went to the U.S. Because of this, we can get a good idea of how tariffs against the U.S. moved with the commencement of NAFTA by simply looking at Mexico's aggregate tariff. We get tariff revenue and import value data from the OECD and compute an ad valorem tariff equivalent by dividing tariff revenue by the import value. Figure 4 plots the resulting aggregate tariff. In addition to NAFTA, Mexico underwent a huge trade policy shift from 1992 to 1997, unilaterally cutting tariffs on thousands of products. Because of this, we see tariffs decreasing even before NAFTA began in 1994. However, after a couple years, we still see the same pattern. Namely, that the decrease in tariffs becomes more gradual.

In our model, we will allow for gradual changes in trade policy by specifying a stochastic

[7] Many authors in the literature use the import value weighted tariffs. We do not use this method as the tariffs are endogenous to the import decision. In particularly, the researcher cannot know if imports for a given product are low because the demand for that product is low or if tariffs dissuade people from buying that product from abroad.

process where shocks can have a gradual effect on trade costs. As trade policy takes many forms we follow the gravity literature and use the model to identify the changes in current and future trade barriers.

4. 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, neutral and investment-specific technology, and labor wedges on trade and output. We extend the RBC model with heterogeneous firms with a sunk cost of exporting of Alessandria and Choi (2007) to include trade intensive in durable/capital goods, an adjustment cost on the import share, habit formation in consumption, and a broader set of shocks. This extended model allows us to capture fully the key moments of the US and ROW as related to 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. 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 of a good. The firms are indexed by $i \in [0, 1]$. Intermediate goods producers use capital and labor to produce. Firm productivity has an aggregate component and an idiosyncratic component. The aggregate component Γ features 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). There are also transitory shocks to technology.

All firms produce their variety for the domestic market, but only some produce for the foreign market. In addition to an iceberg cost, firms that export must also pay a fixed cost which depends on their export status in the last period. New exporters must 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 Engel and Wang (2011) 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 for the model to capture the slow adjustment of trade to aggregate shocks observed in the data than through the dynamics of exporting.

A. 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

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

where $\bar{C}(s^{t-1})$ denotes aggregate average consumption of the previous period, $C(s^t)$ is today's consumption, and β is the discount factor. 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

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

where asterisks denote prices and allocations in Foreign and $e(s^t)$ represents the nominal exchange rate. We assume that Foreign consumers are not subject to any labor wedge.

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_I denotes the marginal utility with respect to $I \in (C, L)$. 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 concurrent shocks $\varepsilon_{risk} \sim \mathcal{N}(0, \sigma_{risk}^2)$.

Imposing 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 denotes the real exchange rate.

B. Final Goods Producers

In each country, there are many final goods producers that engage in perfect competition. Home final goods producers use both Home- and Foreign-produced intermediate goods as inputs to create consumption and investment goods according to the following CES production technologies[8]

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

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

where $y_n^X(i,s^t)$ 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 Foreign-produced goods. ω_C and ω_I capture home bias in production of consumption and investment, respectfully. 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

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

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

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

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

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

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

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

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

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

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.

C. Intermediate Goods Producers

Each country has a continuum of intermediate goods producers of measure unity. These firms each produce a unique variety of a good and engage in monopolistic competition. Intermediate goods producers use capital and labor to produce their good. Firm productivity has an aggregate component that is the same for everyone, and an idiosyncratic component.

The production technology of the firm is

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

where $y_h^X(i,s^t)$ and $y_h^{*X}(i,s^t)$ represent domestic and foreign 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

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

where $\varepsilon_g^c \sim N(0,\sigma_g^{c2})$ and $\varepsilon_g^d \sim N(0,\sigma_g^{d2})$. Notice that 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

$$z_t = \rho_z z_{t-1} + \varepsilon_z^c + \frac{1}{2}\varepsilon_z^d$$
$$z_t^* = \rho_z z_{t-1}^* + \varepsilon_z^c - \frac{1}{2}\varepsilon_z^d$$

The idiosyncratic component of firm productivity, $\eta(i, s^t)$ is iid both across firms and across time with $\eta(i, s^t) \sim N(0, \sigma_\eta^2)$.

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.[9] Boileau (2002) includes IST shocks in a BKK framework as modeled here. We let IST in each country follow an AR(1) process:

$$\ln \psi_t = \rho_\psi \psi_{t-1} + \varepsilon_\psi^c + \frac{1}{2}\varepsilon_\psi^d$$
$$\ln \psi_t^* = \rho_\psi \psi_{t-1}^* + \varepsilon_\psi^c - \frac{1}{2}\varepsilon_\psi^d$$

where $\varepsilon_\psi^c \sim N(0, \sigma_\psi^c)$ and $\varepsilon_\psi^d \sim N(0, \sigma_\psi^d)$.

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

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

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

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

value of profits. The problem for an individual firm i can be expressed recursively as[10]

$$
\begin{aligned}
(15)\quad V(\eta, k, m, s^t) = & \max_{x,l,m',p_h^C,p_h^I,p_h^{*C},p_h^{*I}} \pi(i) + m'^{*}(i) \\
& + \sum_{s_{t+1}|s^t} \int Q(s^{t+1}|s^t) V(\eta', k', m'^{t+1}) dF(\eta')
\end{aligned}
$$

where

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

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

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.

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

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

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

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

D. 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 meant to capture bilateral globalization between countries, which is expected to decrease trade costs both on impact and in the future. 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.

E. 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 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 average consumption, lagged final good trade shares, $\mathrm{TR}^i\left(s^t\right)$, and distribution of (η, k, m) across intermediate firms. With idiosyncratic firm productivity that is iid over time the distribution can be summarized by the mass of exporters and the capital stock of exporters and non-exporters (N, K_0, K_1).

5. Calibration and Estimation

In this section we describe the functional forms chosen and parameters calibrated in the model. For many parameters, we begin by calibrating reasonable values and then use Bayesian estimation to choose parameters that can match time series from the data.

The per period utility function is given by

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

The intertemporal elasticity of substitution is $1/\sigma$ and γ gives the share of net consumption in the composite good.

For the portfolio adjustment cost, we choose a functional form that is consistent with a balanced growth path. In this case, the adjustment cost is a function of the ratio of expenditures on new debt to nominal output. In particular, portfolio adjustment costs are convex such that

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

We set ω_b small enough that it induces stationarity but does not affect any equilibrium dynamics of the model.

Table 2 shows the initial calibration for all parameters. A period is one quarter. We set β=0.99 to match a steady state real interest rate of 4%. The parameter ζ which determines habit persistence for consumers, is set to 0.3, within the bounds of the literature. We choose the share of net consumption γ in the utility function to match a Frisch elasticity of about 2, which is close to values in the literature. The intertemporal elasticity of substitution σ is set to 1/6. We set α=0.36 as is common in the literature to match the share of revenue that goes to labor. We set δ=0.05 to increase the investment share to 0.2 in steady state. The elasticity of substitution between varieties within a country is determined by θ. It also determines markups of intermediate firms. Here we set θ=2/3 which implies a markup of 50%. 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 1.5 (ρ=1/3) as in Backus et al. (1994). The parameter on the adjustment cost of the trade share ι is set to 60.

We set κ, which determines how quickly country productivities converge after a shock, to 0.002. This is below the value of 0.007 in Rabanal et al. (2011). Since we are considering an economy with symmetric countries, we are allowing productivities across countries to converge at a slower pace. In this paper, we allow for persistence in the growth rates of productivity and assume countries are symmetric so that $c = c^*$. We $\rho_g = 0.3$, which is close to estimates in Aguiar and Gopinath (2007) for developed economies. To match the steady state growth rate of .0035 from Rabanal et al. (2011) implies $c = .0025$. For Hicks-neutral productivity shocks, we choose a persistence ρ_z of 0.9.

We set the steady state iceberg cost $\bar{\xi} = 1$. We want trade costs to be stationary but very persistent. We need stationarity because we are using a linearization to solve the model. We want high persistence because changes in trade costs are often permanent in nature. We set $\rho_\xi^d = 0.95$ and $\rho_\xi^c = 0.998$. We set ρ_Δ=0.9 so that the model generates the same average trade barrier over the next 10 years as with a 10 year linear phase-in.[11] This matches our empirical observations about free trade agreements. We set $\omega_{ac} = 5$ and will estimate the parameter later on.

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 these parameters to match the following five features from the data in steady state:

1. An aggregate import share of 13.3%
2. 65% of trade is in investment/durable goods
3. 20% of all firms export
4. 3% of exporters stop exporting every period
5. Exporters are 16% more productive than nonexporters on average as in Bernard and Jensen (1999).

The standard deviation for all shocks apart from ε_η are set to 0.01.

For several parameters, these calibrated values serve as prior means in a Bayesian estimation of the linearized model. The estimation results as well as the prior distributions are listed in Table 3. We estimate all shock volatilities, the persistence parameters in each stochastic process, and several other parameters from the model. We estimate the model to match thirteen series from the data: U.S. real GDP growth, real and nominal trade share, real and nominal export-import ratio, detrended hours, real and nominal investment share,

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

the capital goods terms of trade, the fraction of exporting firms in manufacturing industries, and rest of world real GDP growth, nominal investment, and detrended labor. share. As we target the real and nominal shares of investment, trade, and export-import ratio, our model is consistent with the dynamics of real and nominal net exports, the relative price of investment to consumption, the terms of trade, and the relative price of imports to final goods. The estimation also includes estimates of measurement error in nominal trade variables and investment rates, as well as the fraction of firms that export.

U.S. data on nominal and real GDP, investment, consumption, exports, and imports were obtained from the BEA's National Income and Product Accounts tables for the period from 1970Q1 to 2017Q3. We define investment in the model to be gross private domestic investment plus the consumption of durables. The capital goods terms of trade is from the BEA. The measure for the rest of world real GDP comes from the Federal Reserve Bank of Dallas' Database of Global Economic Indicators and the ROW investment share and labor has been constructed from US trading partners from the OECD. To get the fraction of firms that export, we use Compustat and define a firm to be an exporter if it pays foreign taxes in period t. Before 1998, firms were required to report export sales so that exporters were more easily identified. Our series is highly correlated with this series in the overlapping periods. The model matches all thirteen series almost exactly, as shown in Figure 5.

Table 3 gives the posterior means for all estimated parameters. The estimation gives a low value for the mean growth rate c of 0.0007 but a high value for ρ_g of 0.95. These two values imply a steady state quarterly growth rate of $c/(1-\rho_g) = 0.15\%$. As previously mentioned, the average quarterly growth rate of output from the data is about 0.35%. Our estimation tells us that less than half of this growth is coming from growth in aggregate productivity so that trade costs and IST shocks are potentially big drivers of growth. The estimated elasticity of substitution between home and foreign goods is $1/(1-\rho) \approx 5$. This is within the bounds of the literature for a long run trade elasticity. The input adjustment costs will constrain the short run elasticity. The elasticity of substitution between varieties, determined by θ, is about 10, implying a markup of 11.1%.

Other than for productivity growth shocks, the persistence of the shocks are consistent with the literature. Shocks to IST are almost permanent as the relative price of investment has declined steadily over the period. Since IST is the main driver of this relative price, these persistent declines necessitate an almost permanent AR(1) component for IST.

6. Results

In this section, we examine the source of fluctuations in growth- and trade-related variables. To highlight the model's identification we first consider the response of key variables to innovations to productivity, investment costs, and trade costs. We then discuss the dynamics of trade and growth factors and their contribution to trade and output fluctuations. We then examine the model's forecasts for trade and growth. To close, we contrast the results in our dynamic trade model with those from a static trade model with no forward looking trade decisions or variables.

A. Impulse Responses

As our model has a number of novel features we discuss each shock in detail. We focus on global shocks only given that we have many shocks, that country-specific shocks are often discussed in the literature, as well as the global nature of the slowdowns. We first consider the effect of shocks that are emphasized as being the source of business cycles and then consider trade shocks. In each of the following impulse responses, we will look at four key series: trade, output, investment, and a trade to trade-weighted demand ratio which controls for the changing composition of demand over the cycle.

Aggregate Shocks

Figure 14 shows that a shock to the trend in global productivity leads to a gradual decline in global productivity. The effect is largest on impact but productivity continues to fall for the next 10 years owing to the high persistence estimated. On impact, this shock is expansionary as consumers work harder in advance of the impending deteriorating times. Investment also rises to smooth out the shock. After the initial boost in output, real output gradually falls as the country reduces its capital stock.

Given the capital-intensity of trade, the investment increase leads to a relatively sharp temporary increase in the trade-output ratio that decreases as the economy runs down it's capital stock. When we control for the changing composition of demand, we find that trade moves very little relative to demand in the short-run. In the long-run, even controlling for demand we see that trade share falls less than 1 percent over the next 10 years. The short-run effect arises because of the input adjustment cost. When the shock hits, the wage falls which makes exporting cheaper by lowering the fixed costs. This causes an increase in the number of exporting firms. However, as productivity continues to decrease, exporters become less competitive and leave the market. If $\iota = 0$, then trade to trade weighted demand follows this same pattern, increasing on impact and eventually decreasing in the long run. The input adjustment cost keeps agents from consuming more imports on impact since a temporary increase in trade is costly. They adjust gradually to a lower long run trade to demand ratio.

Figure 15 shows that a transitory decrease in productivity lowers output temporarily for the usual reasons. Hours, investment, and the trade share all fall on impact and then mean revert with the shock. Again, controlling for the composition of trade, we find only a small effect on trade relative to demand. Interestingly, trade relative to demand falls gradually over the first three years as exporters slowly leave the export market.

A persistent increase in the efficiency of producing US investment goods boosts output and the investment rate (Figure 16). The higher investment rate increases the scale of trade flows and encourages more exporting so that the trade share has a persistent increase. Controlling for the composition of demand, we see consistent growth in trade for the first 5 years after the shock. This arises because the increasing productivity of investment goods makes exporters more competitive for a given iceberg cost and gradually increases the number of exporting firms.

These three shocks show that trade will respond gradually to aggregate shocks, lagging the real economy. This lagged effect is a result of the slow entry and exit of firms and our input-adjustment costs. It suggests that traditional forces giving rises to recessions will lead to persistent declines in trade above and beyond any composition channels.

Trade Costs Shocks

We next consider the impact of changes in trade costs. Figure 17 plots a decline in the trend of trade costs. This gradually lowers trade costs. Perhaps surprisingly, it also generates a temporary recession on impact. The expected decline in trade costs makes consumers richer and also lowers the future price of investment. Both effects lead to a sharp contraction in hours and investment on impact. At the same time, trade increases on impact. Firms understand that they will pay adjustment costs as they use more imports in production. To take advantage of lower costs in the future, they want to prepare themselves by increasing their use of imports on impact. The adjustment costs they incur on impact are substantial, and contribute to the recession. After the initial period, the falling trade costs generate growth in all variables, and the level of investment and output both recover within five quarters. These trend trade cost shocks generate substantial and lasting growth on trade and on the trade to output ratio, as well as persistent but small growth in macro variables.

Figure 18 plots the impact of a persistent shock to the common trade cost. As this shock is close to a unit root, a decrease in trade costs leads to a small but persistent boom. On impact the investment rate rises and trade share rise. These remain elevated throughout with the trade share gradually growing owing to the accumulation of more exporters and changing input mix. We find the trade elasticity starts at about 0.5 and then very gradually rises to close to about 5 over the next 10 years.

Figure 19 shows the response to a persistent decrease in the common trade costs with almost no adjustment cost. Here, the trade to output ratio rises on impact and then continues to rise over the next eight quarters before mean-reverting with the shock. The eight quarter impact is about 60% more than the impact effect and largely reflects the dynamics of export participation. Thus the response of trade is much faster than with our input adjustment costs. We can also see that the input adjustment costs are a key factor in giving a small short run trade elasticity. Without them, the short-run elasticity is not far from the long-run elasticity.

Notice that future change in trade costs move trade and macro variables in the opposite direction than changes in current trade costs initially. Of course these shocks are quite different in size. To understand their relative importance we consider some examples in which the present value of the shocks are the same. That is, we define the expected present value of trade costs (PVTC) as

$$\xi_{PV,t} \equiv (1-\beta)\mathbb{E}_t \sum_{s=0}^{\infty} \beta^s \xi_{t+s}.$$

The PVTC can be interpreted as the discounted mean value of trade costs if no further nonzero trade cost shocks arrive. Plugging in the stochastic process for ξ_{t+s}, we get

$$\xi_{PV} = (1-\beta)\left[\frac{\xi_c}{1-\beta\rho_{\xi_c}} + \frac{1}{2}\frac{\xi_d}{1-\beta\rho_{\xi_d}} + \frac{\beta\rho_\Delta \Delta}{(1-\beta\rho_{\xi_c})(1-\beta\rho_\Delta}\right].$$

Consider two shocks that have the same PVTC. One is a permanent shock and the other is a trend shock. Figure 20 shows the responses of trade and output to these two different shocks. The response of trade is nearly identical in the two cases. Both shocks generate a slow adjustment of trade coming from the input adjustment cost and the sunk cost of exporting.

The input adjustment cost also causes firms to adjust their mix of inputs more quickly to take advantage of lower trade costs in the future. Thus, the impact of the trend shock on trade is larger than would be expected given the modest decrease in concurrent trade cost. Trade grows slightly faster with trend trade costs as the decreasing trade costs are an additional source of growth. On average, trade grows 20% faster with the trend shock than with the permanent shock over 40 quarters.

Output, on the other hand, responds differently in the two cases. With a permanent shock, output grows significantly on impact because of the lower trade costs boosting production of exports. After that, growth in output is relatively low and comes from the adjustment of trade to the lower trade costs. Foreign firms gradually demand more Home goods, and output grows as the export sector expands. If instead a trend trade cost shock hits the economy, output contracts on impact due to the wealth effect and the expectation of cheaper investment in the future. After that, output grows relatively quickly due to the expansion of the export sector and the direct effect of decreasing trade costs. On average, output grows 60% faster with the trend shock over 40 quarters.

Anticipatory effects of Realized and Unrealized Trade Reforms

We also consider a series of phased in trade liberalizations whose initial implementation occurs at different times to show that anticipated reforms can be quite recessionary. Later reforms are assumed to have sharper declines so that the present value of the decline in trade costs is equal. Each reform is chosen to double the trade to GDP ratio after about 10 years.

Figure 10 plots reforms with 1 quarter, 1 year, and two year delays. In all liberalizations, output falls until the reform starts and then rebounds only surpassing its initial level a few quarters after the start of the reform. The decline in output is initially a result of a decline in employment which then gets amplified owing to a decline in investment. The decline in employment can be quite large on impact as a reform two years in the future lowers employment by almost 1.25 percent. It can also be quite prolonged taking quite a few quarters to surpass its initial levels. In the two year reform case, employment only surpasses its initial levels 4 years after the reform is announced. These strong effects in part reflect a strong desire to cut back on investment as consumers run down their capital stocks and delay investment until the price of capital has fallen. With the implementation of the reform the capital stock gets rebuilt but only gradually as substantially resources go to building up exporter capacity.

We now consider how eliminating expected future trade reforms affects the economy. In particular, figure 11 plots the impact of a reform that is set to start in 8 quarters that either gets canceled entirely or delayed another eight quarters.

Starting with the cancellation case, we see that canceling the reform is expansionary. Employment and GDP jump almost 2 percent on impact. Investment jumps 7 percent to a level above the previous steady state as the economy seeks to rebuild its capital stock. When the reform is just delayed there are much more muted expansionary effects as employment only increases by 1/2 percent and investment by about 2 percent. These are only on impact as these fall in anticipation of the delayed reform in year 4.

B. Trade and Growth Slowdown

Figure 7 shows the estimated series for all business cycle exogenous variables. The top left panel shows estimated aggregate productivity movements for the U.S. and the rest of the world. US productivity fell in the 1980s with the recession but recovered quickly. The ROW is a trade weighted aggregate of US trading partners. Thus, the drop in productivity for the ROW in the 1990s is probably coming from the bad economic situation in Mexico, a large trading partner of the US. The ensuing sharp increase in productivity may be coming from an increasing trade weight on China starting in the early 2000s. We see that in the slowdown period, both US and ROW productivity are quite stagnant and US productivity seems to be in a slow decline. This indicates that movements in productivity are also important for explaining the slowdown.

The top right panel of figure 7 shows US and ROW IST. The ratio of ROW to US IST is pinned down by the capital goods terms of trade series that we match in estimation. We see a decrease in foreign IST start in the late 1990s and an increase in IST for the US over the whole period. Our estimation puts much more weight on US variables and yields series for technology and IST that seem consistent with other estimates. For the rest of the world we find much larger swings and we find that an important technology boom starting in 2000 that accompanies substantial technology regress in IST.

The bottom left panel shows the US labor wedge. It accords well with the substantial increase in employment rates from the 80s to the 2001 Recession as well as declining employment rates since then. As expected, the labor wedge drops sharply during the Great recession and seems to have recovered from the most recent recession.

A key advantage of our approach is that it yields an estimate of current and future trade costs. Figure 8 shows the estimated movements in the log of trade costs from the model. For foreign firms exporting to the United States, we see that trade costs increase dramatically starting in 1996. Exporters in the U.S. face decreasing trade costs until the mid-2000s when there is a reversal and trade costs increase until becoming somewhat stable in the post-recession period. These trade costs move quite differently than what one would get out of a constant elasticity model in which trade costs are inversely related to trade shares and tend to move quite differently than observed measures like the Baltic Dry Index. Trade flows here depend on current trade costs and the future direction of trade costs. For this reason, we also show the PVTC in Figure 9. The series for PVTC is quite volatile since even small shocks to the trend component of trade costs have large effects. The adjusted PVTC series shows a moving average of the current and past PVTC and serve as a way of demeaning the PVTC. We see here that the PVTC is decreasing throughout almost the entire period for both the US and the ROW. The present value of trade costs imposed by the rest of the world fall especially quickly after the accession of China into the WTO in 2001. In the slowdown period, the PVTC has remained stagnant in both regions.

Figure 12 plots the estimated path of common trade costs along with expectations of the path in trade costs for the subsequent 10 years at various points. The actual paths of trade barriers can be quite different than expectations. For instance, large decreases in trade costs were expected in 2001 but were not realized and trade costs rose instead. Large decreases were also expected prior to the most recent recession. While trade costs did decline sharply in 2009, they quickly rose again directly preceding the slowdown period. Agents modified expectations and were no longer expecting such large decreases by 2012 (although the expected decrease is still large). Figure 13 shows how the trend trade cost has changed over time and clearly shows that the outlook for trade barriers worsened at the end of 2015.

A key feature of the dynamics of trade costs is that trade costs have been expected to fall more or less since NAFTA. Expectations of the decline increased with China joining the WTO. Owing to the worsening economic environment leading up to the Great Recession and the persistent trade growth, the estimation infers a further decline in future trade costs. These have perpetually been delayed.

Figure 21 plots the trade to output ratio and counterfactuals with only trade cost shocks (TC), productivity shocks (Productivity) and investment cost shocks (IST). About half of the 80 log point rise in trade from 1980 to 2016 is attributed to a change in trade barriers. This growth starts in 1990, one year after the Canada-U.S. Free Trade Agreement went into force. Trade costs then generate consistent growth in trade until the slowdown period. IST shocks generate large growth initially but then fall off quickly starting in the mid-1990s. This is perhaps not surprising since the investment rate is essentially unchanged compared to 1980. Leading up to the recession, IST shocks were a large drag on trade and have created no trade growth during the slowdown period. Productivity was a drag on trade until the 2000s when it suddenly began to increase the trade to output ratio dramatically. This may come from the increase in ROW productivity which made importing much more attractive. Much of the early growth in the trade to output ratio is coming from "Initial Values." These are 1980 values of endogenous variables as estimated in the model. As these are likely determined by a combination of factors, we do not assign them to any one exogenous shock. Zooming into the period following the Great Trade Collapse we find that the effect of all exogenous variables on trade is practically zero.

C. Policy Experiments

As trade policy has been often discussed by the current US administration, we now consider some possible changes in trade policy. We specifically consider two changes in trade policy that lowers trade costs of US exports while raising the tariffs imposed against foreign exports. In one scenario, the changes in tariffs also causes a trade war. All trade costs become permanently fixed at the new level. This entails a large positive shock to the trend component of trade costs and thus increases the PVTC. In the second scenario, the policy change is followed by no additional unexpected shocks. Trade costs follow agents' expectations and decrease sharply in the ensuing periods. We call this scenario "Negotiation."

Figure 22 shows the effects of several trade and macro variables of these two scenarios. For reference, we either detrend these policy changes by the expected evolution of the economy (Y,C,I, L) or also plot the expected dynamics of the economy. As mentioned, the PVTC increases significantly in the trade war case since agents were expecting large decreases in trade costs that will not be realized. From the wealth effect, this creates a temporary increase in investment, output, and labor and a sharp decline in consumption .Trade decreases significantly as it is very responsive to the PVTC. This decline in trade is driven by the exit of exporters and therefore decreases all macro variables relative to the case with no shocks. Net exports as a share of GDP rapidly goes to surplus and then remains in surplus.

The negotiation scenario is close to the case with no shocks for all variables, although it leads to a slight decline in employment on impact. It also leads to a reversal of the net exports. It shifts the US into surplus a year faster than otherwise. The RER appreciates slightly compared to the no shocks case.

D. Trade and Growth Forecasts

Our dynamic theory can also be used for forecasting. Here we consider the dynamics of the trade-output ratio as well as GDP growth. Recall, trade will evolve in response to past and future trade cost changes as well as the aggregate shocks. Figure 23plots the point forecast for real trade-output with a two standard deviation confidence interval. Our theory predicts that trade will grow robustly. There is considerable uncertainty about this forecast though.

Output growth is expected to pick up (figure 24) quite a bit relative to trend with an increase by about 7.5 percentage points. About half of this growth is attributed to the expected decline in trade costs.

E. Sensitivity

To clarify the effect of modelling trade as arising from a dynamic trade model we consider an alternative model without these features. In particular, we eliminate trend trade cost changes and instead assume all shocks to trade costs are nearly permanent. We also eliminate the sunk export cost and the input adjustment frictions. The model is estimated using the same data. Table 4 summarizes the estimated parameters.

A key finding is that the static model's fit is considerably worse with a marginal likelihood of compared to 2520 to 2200. Additionally, the model generates a very stable forecast for the trade share and real output going forward.

7. Conclusion

This paper is a first attempt to study US trade integration, business cycles, and balanced growth in a unified framework. Our model allows for a range of aggregate shocks to influence trade flows and for shocks to trade costs to affect business cycles. Importantly, we allow trade to respond gradually to aggregate shocks through firms' durable investment in market access and explicitly model the changing trends in trade and growth with trend and level shocks. We show that these changing trends and their lagged effects on trade are important to capture the growth and trade slowdowns following the Great Recession.

A couple of key finding stand out from our dynamic trade theory. First, we find that the usual shocks leading to recessions will depress trade even as output begins to recover as firm's gradually exit and re-enter the export market. Second, we find that while current trade liberalizations are expansionary, future trade liberalizations are contractionary. The contractionary effect of future liberalizations arise from the wealth effect on labor supply along with a substitution effect from future investment and production costs being lower. We find these effects can be quite large. Because of these anticipatory effects, eliminating or delaying future changes in trade barriers can have expansionary short-term effects at the expense of medium term growth.

Our focus on realized and unrealized future trade reforms is of particular relevance as the U.S. has recently signed and withdrawn from a number of current and future trade agreements such as the Transatlantic Trade and Investment Partnership (T-TIP), Trans-Pacific Partnership (TPP), NAFTA and the Korean-US FTA.[12] Moreoever, since the 2016 US Presidential election, the spectre of rising trade barriers has been a very real concern even if changes in trade policy or really were put in effect in 2018. Our analysis suggests the anticipated scaling back of trade agreements may have had a positive effect on economic

[12]T-TIP is an agreement between the US and EU and was signed in 2013, the TPP is an agreement among many Asian nations that the US signed in 2016 and wthdrew from in 2017.

activity since 2016.

A key advantage of our dynamic theory is that it disciplines expectations on future growth and trade barriers. As many changes in trade policy can be anticipated, and are currently being discussed, this is a necessary feature of any quantitative analysis. This is particularly important as with trade intensive in durables and capital goods, trend shocks to productivity and trade barriers are shown to lead to substantial fluctuations in the investment rate and trade share. We find that trade barriers have been rising while expectations for future trade barriers have been falling and that these future declines have been essential in expanding trade since the early 2000s. We also find that these expected declines have been delayed over and over again since the Great Recession and that since 2015 the future path has moderated a bit.

We also use our model to consider a number of counterfactual trade policies aimed at closing the US trade balance. We find that trade policy can be used to bring the trade balance quickly into surplus. If the adjustment is coordinated then this may have a slight recessionary impact on the US while if it results in a trade war this would stimulate the economy in the near term but substantially lower output and growth in the next three to five years.

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Data	Precrisis	Slowdown	Percent change
OECD Real Imports	6.8%	3.2%	-53%
OECD Real Exports	6.8%	3.7%	-46%
US Real Trade	6.5%	2.6%	-60%
OECD Real GDP	2.7%	1.8%	-33%
US Real GDP	3.0%	2.0%	-33%
ROW Real IP	3.3%	2.5%	-25%
US Real IP	2.8%	1.0%	-64%

Table 1: Precrisis and slowdown average annualized quarterly growth rates.

Preferences	β=0.99, ζ=0.3, γ=0.18, σ=6
Production	θ=2/3, ρ=1/3, ι=400, ω_C=0.076, ω_I=0.895, δ=0.05, α=0.36
	c=c*=0.0025, κ=0.002, $\rho_g = 0.3$, $\sigma_\eta = 0.3$, σ_g^d=σ_g^c=0.01
Trade Costs	$\bar{\xi}$=1, ρ_ξ^c=0.998, ρ_ξ^d=0.95, ρ_Δ=0.9, τ_1=0.039, τ_0=0.077,
	$\sigma_\xi^c = \sigma_\xi^d = \sigma_\Delta^c = \sigma_\Delta^d$=0.01

Table 2: Initial calibration for model parameters. Estimated parameters include persistence and volatility of all shocks. We also estimate c, ω_C, ω_I, ρ, θ, and $\bar{\psi}$.

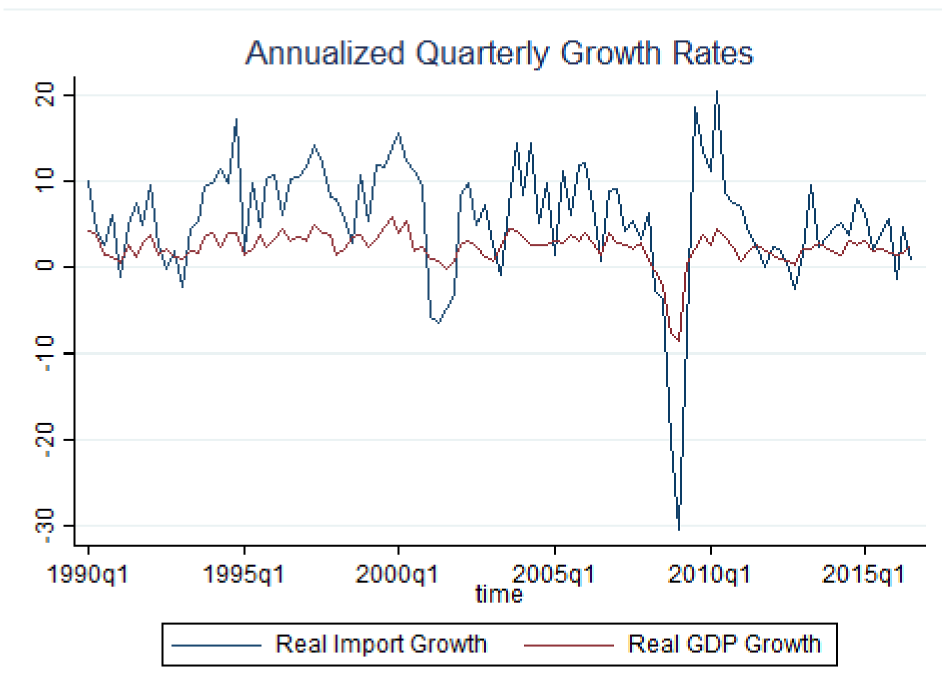

Figure 1: Weighted growth for OECD aggregate.

Param	Prior Dist	Pr Mean	Pr Std Dev	Lower Bd	Upper Bd	Post Mean
c	Normal	0.0025	0.002			0.0001
ρ	Beta	0.33	0.15	0	0.99	0.81
$\theta - \rho$	Inverse Gamma	0.34	0.15			0.09
$\bar{\psi}$	Normal	0	0.01			0.07
ω_{ac}	Uniform			0	10	3.42
ρ_ξ^d	Beta	0.95	0.05	-1	0.999	0.98
ρ_Δ	Beta	0.9	0.03	0.92		
ρ_g	Beta	0.3	0.2	0	1	0.95
ρ_z	Beta	0.9	0.05	-1	1	0.93
ρ_ψ	Beta	0.9	0.05	-1	1	0.9995
ρ_l	Beta	0.9	0.05	-1	1	0.97
ρ_{risk}	Beta	0.18	0.05	-1	1	0.20
σ_ψ^c	Inverse Gamma	0.01	∞			0.019
σ_ψ^d	Inverse Gamma	0.01	∞			0.041
σ_z^c	Inverse Gamma	0.01	∞			0.008
σ_z^d	Inverse Gamma	0.01	∞			0.019
σ_g^c	Inverse Gamma	0.01	∞			0.002
σ_g^d	Inverse Gamma	0.01	∞			0.004
σ_ξ^c	Uniform			0	0.12	0.088
σ_ξ^d	Inverse Gamma	0.01	∞			0.023
σ_Δ^c	Inverse Gamma	0.01	∞			0.028
σ_l	Inverse Gamma	0.01	∞			0.007
σ_{risk}	Inverse Gamma	0.01	∞			0.052
$\mathrm{corr}(\varepsilon_\xi^c, \varepsilon_\Delta)$	Normal	0	0.2			0.52

Table 3: Prior distributions and posterior means.

Param	Prior Dist	Pr Mean	Pr Std Dev	Lower Bd	Upper Bd	Post Mean
c	Normal	0.0025	0.002			0.002
ω_C	Beta	0.078	0.05	0	1	0.0004
ω_I	Beta	0.895	0.05	0	1	0.876
ρ	Beta	0.33	0.15	0	0.99	0.212
$\theta - \rho$	Inverse Gamma	0.34	0.15			0.6
$\bar{\psi}$	Normal	0	0.01			-0.07
ρ_g	Beta	0.3	0.2	0	1	0.54
ρ_z	Beta	0.9	0.05	-1	1	0.93
ρ_ψ	Beta	0.9	0.05	-1	1	0.997
σ_ψ^c	Inverse Gamma	0.01	∞			0.105
σ_ψ^d	Inverse Gamma	0.01	∞			0.206
σ_z^c	Inverse Gamma	0.01	∞			0.014
σ_z^d	Inverse Gamma	0.01	∞			0.017
σ_g^c	Inverse Gamma	0.01	∞			0.009
σ_g^d	Inverse Gamma	0.01	∞			0.015
σ_ξ^c	Inverse Gamma	0.01	∞			0.04
σ_ξ^d	Inverse Gamma	0.01	∞			0.064

Table 4: Estimation priors and results for a static model with no input adjustment costs (ι=0), no sunk cost of exporting ($\tau_0 = \tau_1$), and no gradual phase-ins ($\sigma_\Delta = 0$).

Variable	Growth	Trade	ε_g^c	ε_g^d	ε_ψ^c	ε_ψ^d	ε_z^c	ε_z^d	ε_Δ^c	ε_ξ^c	ε_ξ^d
RER	94.11	5.89	0.00	32.04	0.00	59.68	0.00	2.40	0.02	0.01	5.86
Real Trade	19.82	80.18	0.74	0.10	18.56	0.00	0.42	0.00	56.19	23.99	0.00
Real Output	89.90	10.10	0.16	31.69	1.91	55.14	0.15	0.85	3.85	0.77	5.48
Trade/Output	34.01	65.99	0.98	6.18	14.67	11.79	0.21	0.18	44.90	19.91	1.17
Inv/Output	92.44	7.56	0.07	34.15	0.94	57.05	0.01	0.22	1.85	0.19	5.52
Labor	35.55	64.45	2.04	3.80	22.06	6.45	0.27	0.93	59.81	3.06	1.57

Table 5: Variance decomposition of HP-filtered variables. The first column is the percent of variance coming from growth, productivity, and investment specific technology shocks. The second column is the percent of variance from shocks to trade costs. Columns 3-11 show the contribution to the variance for each type of shock separately.

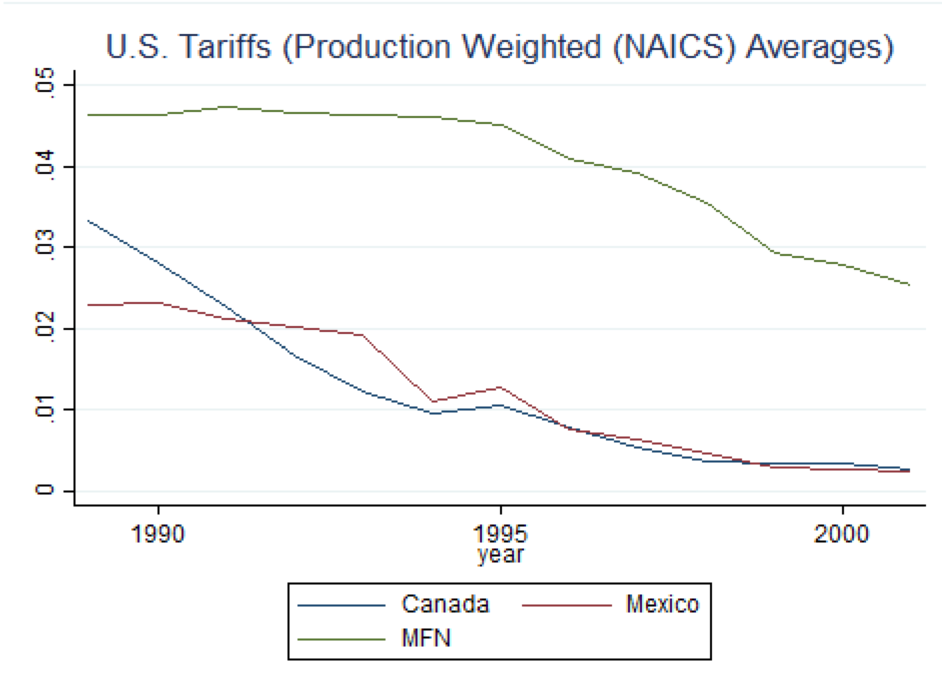

Figure 2: Production weighted average tariffs imposed by the U.S. against Canada and Mexico. Also, the production weighted average most favored nation tariff.

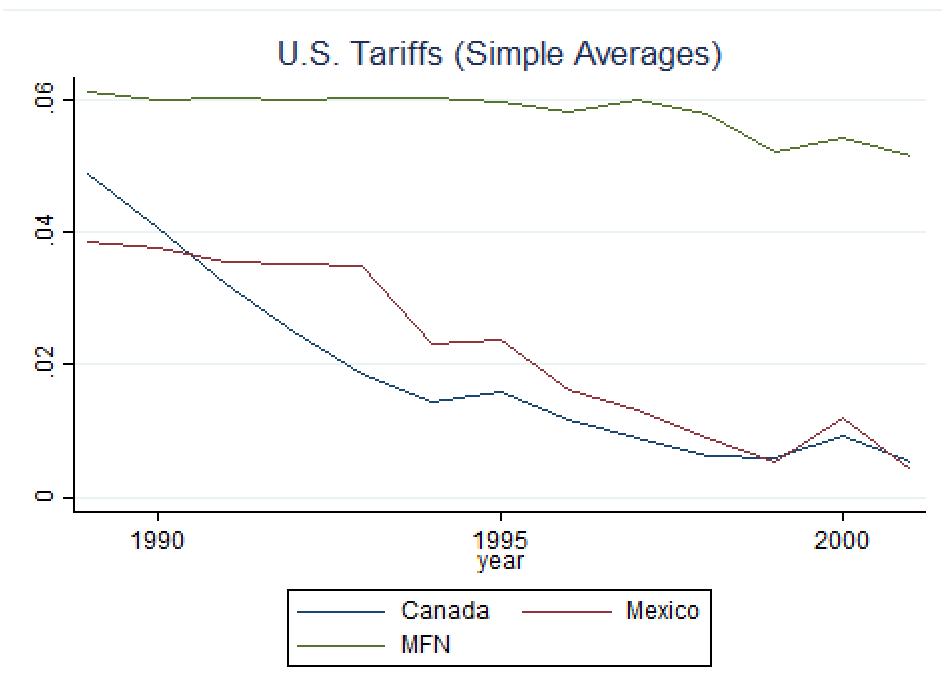

Figure 3: Simple average tariffs across all products at the HS8 level.

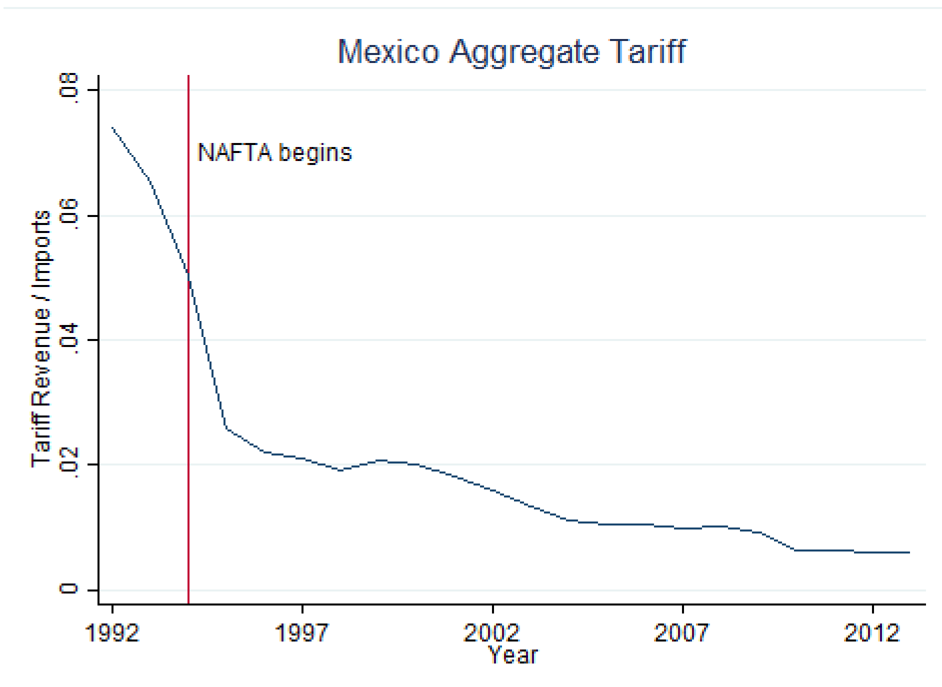

Figure 4: Mexico's aggregate ad valorem equivalent tariff.

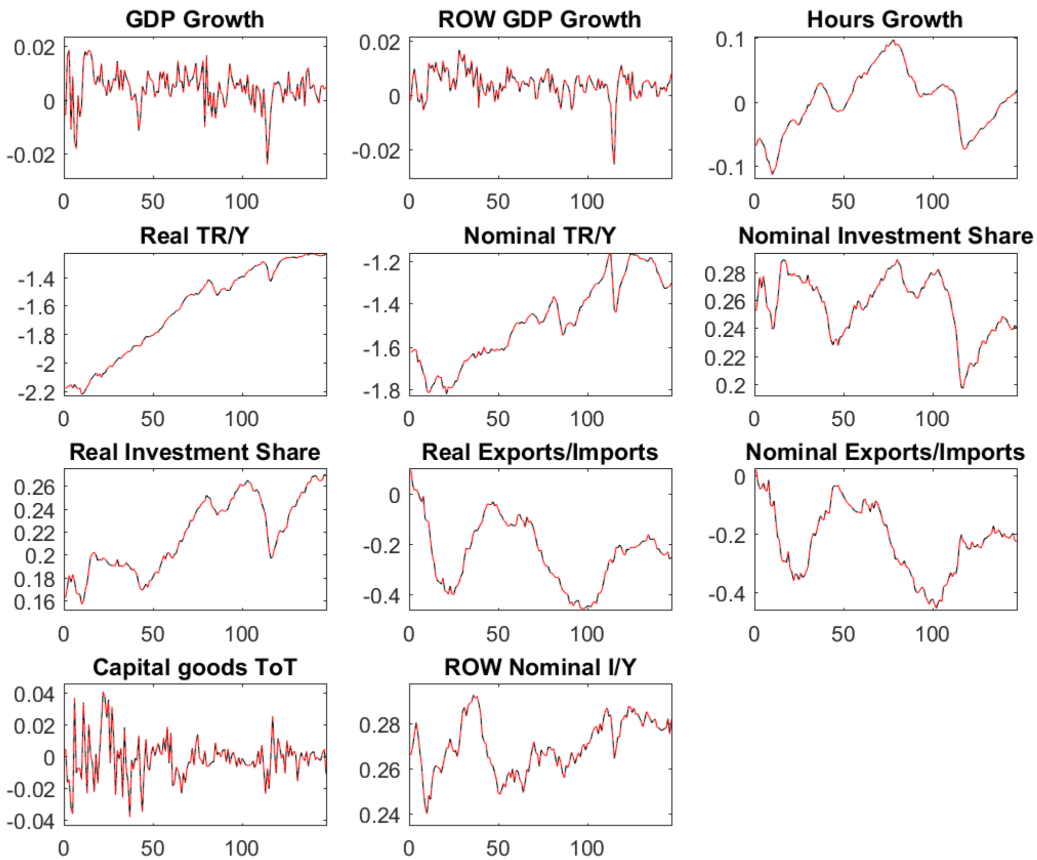

Figure 5: This figure shows the historical data (black) and the estimated series (red).

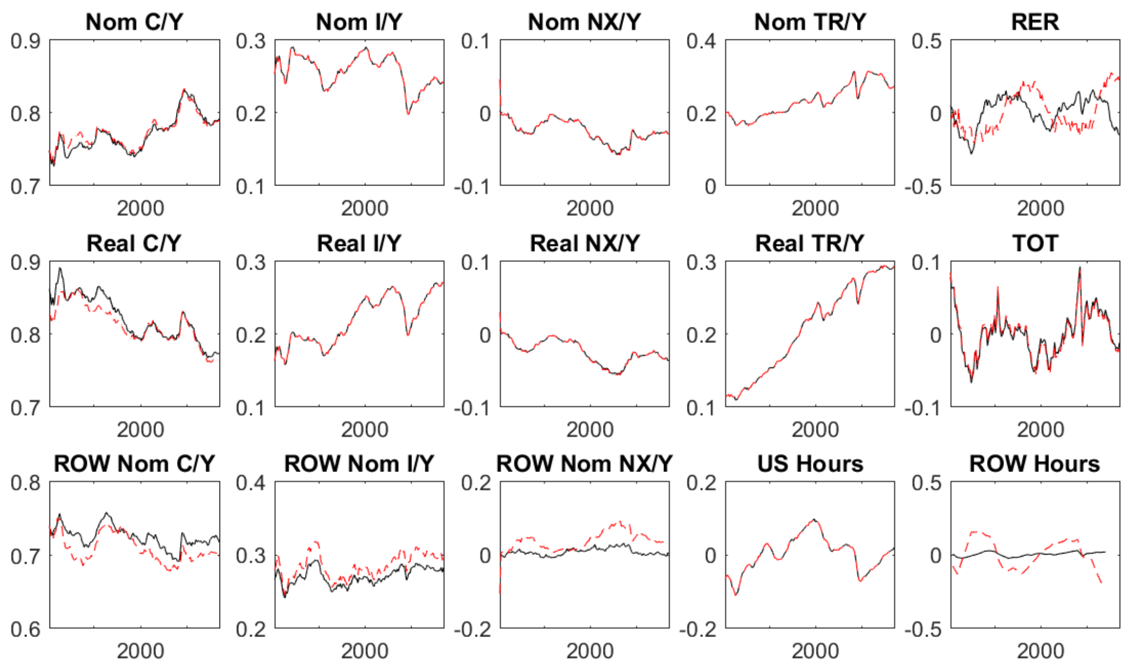

Figure 6: Historical data (black) vs model predictions (red) for several important series, many of which are matched explicitly in estimation.

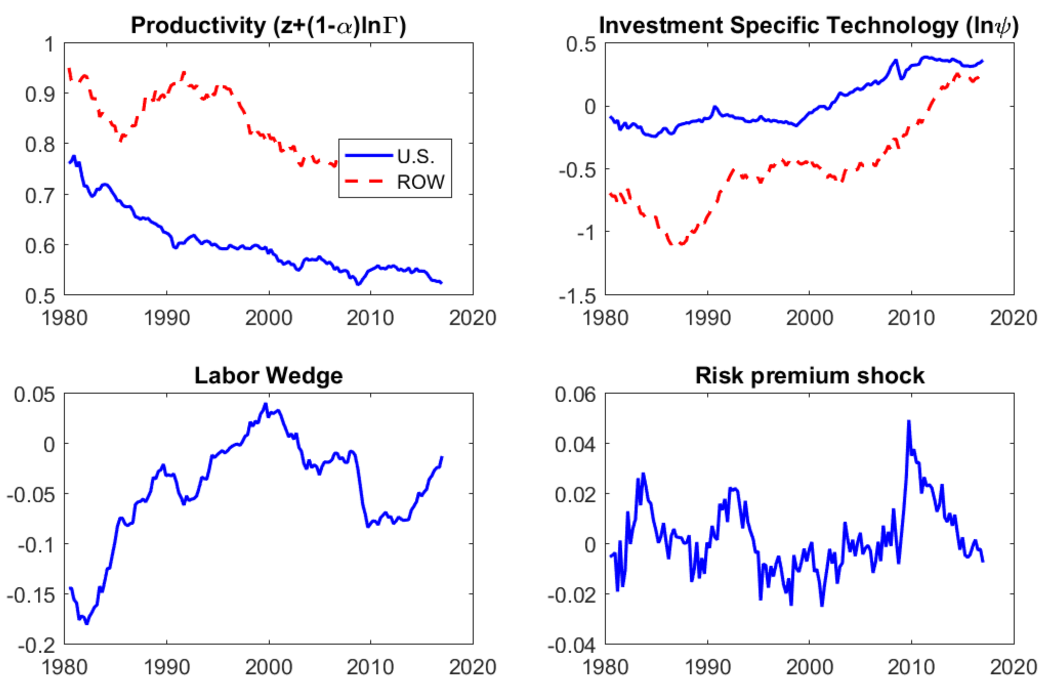

Figure 7: Historical data (black) vs model predictions (red) for several important series, many of which are matched explicitly in estimation.

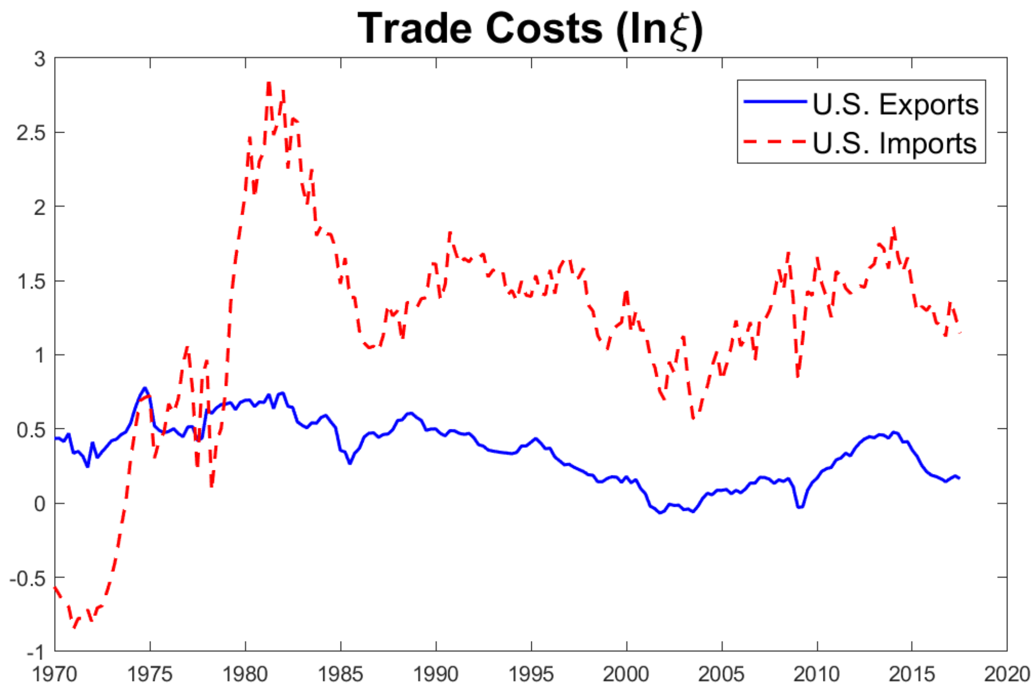

Figure 8: Estimated trade costs from 1980 to 2016.

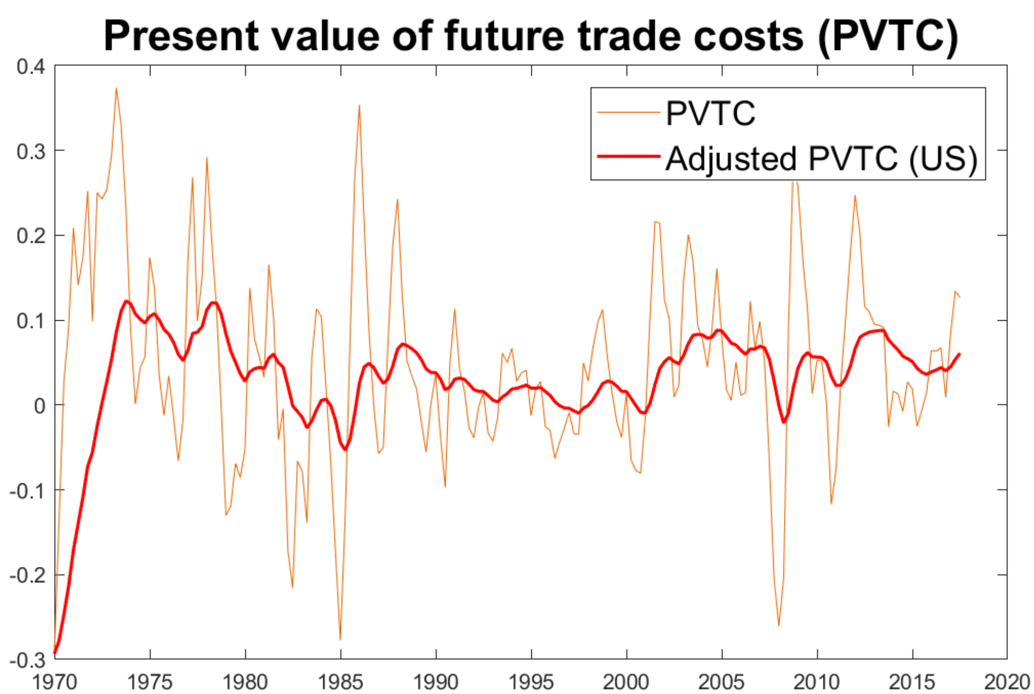

Figure 9: Estimated expected present value of trade costs.

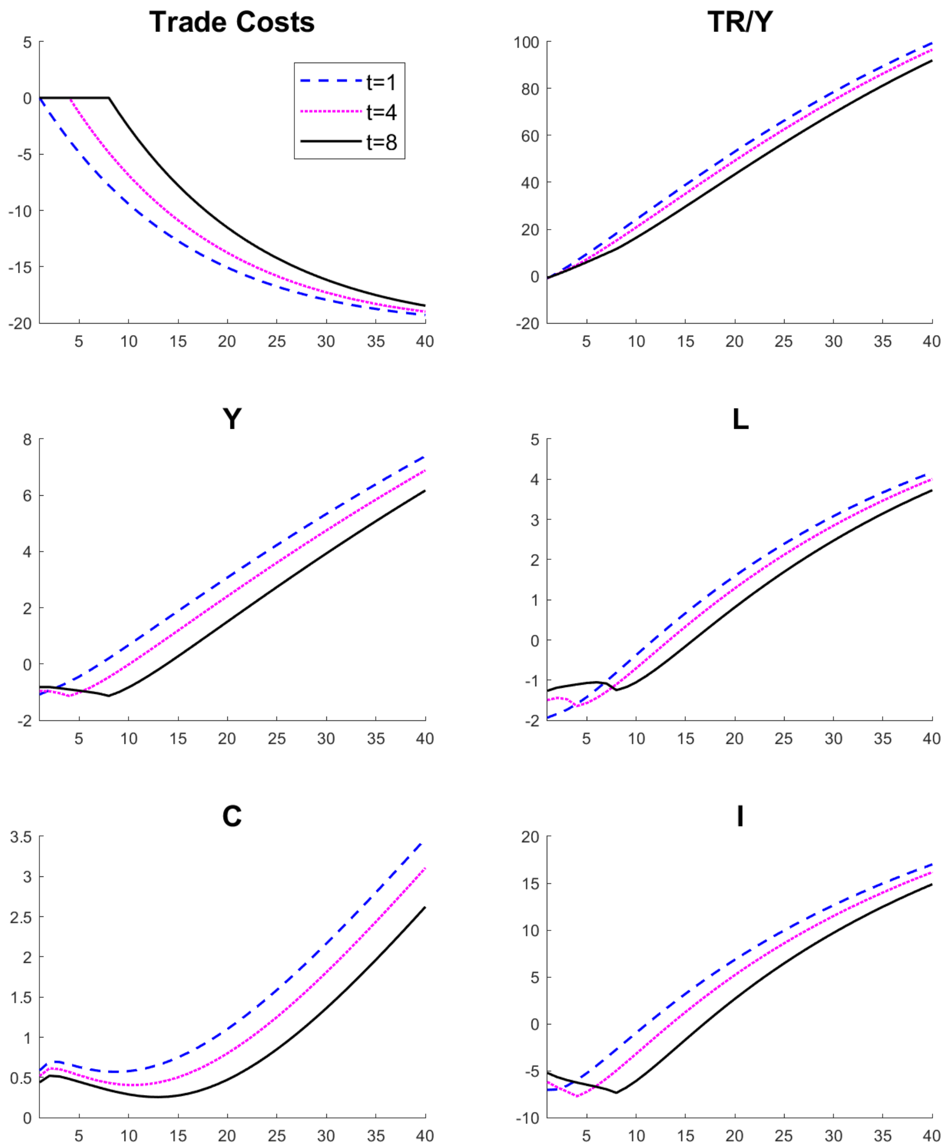

Figure 10: Macroeconomic responses to the announcement of a global trade liberalization one quarter, one year, and two years in advance.

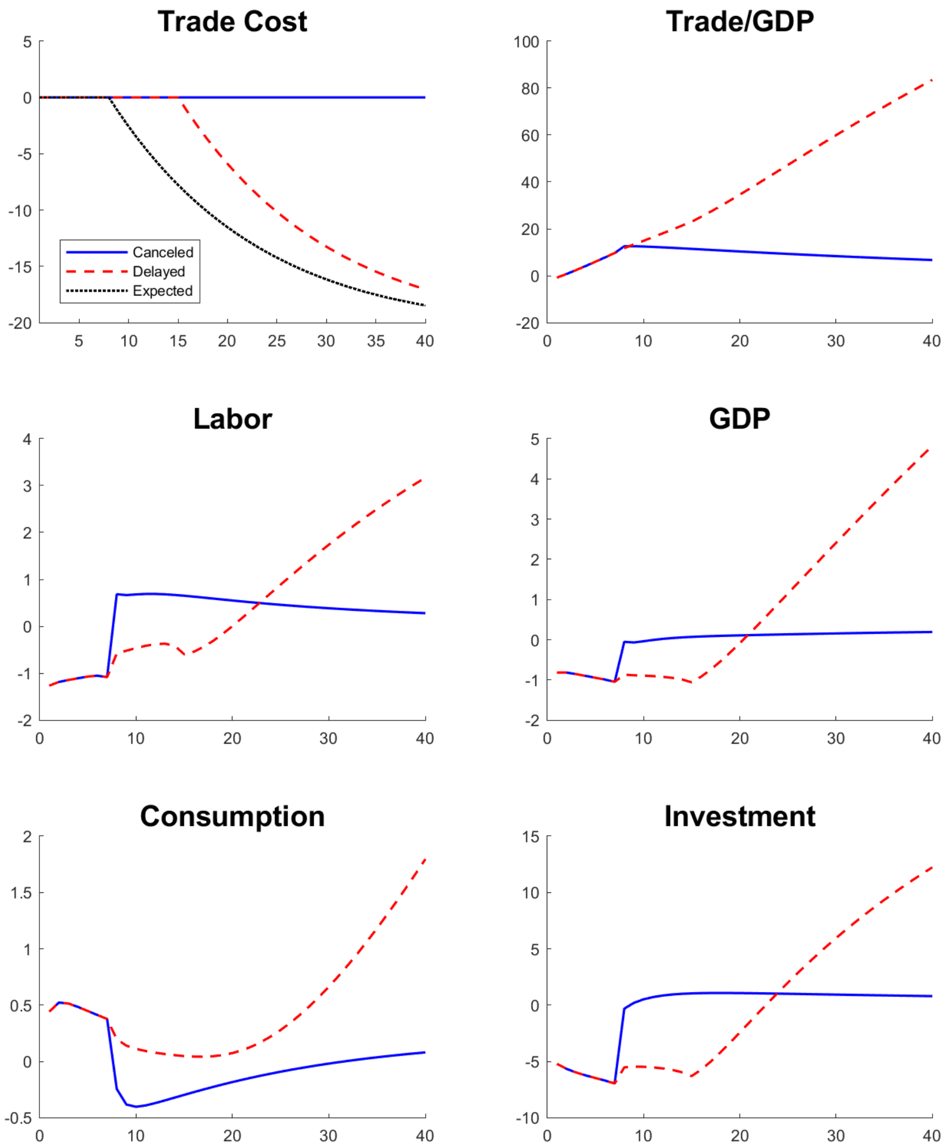

Figure 11: Macroeconomic responses to the cancellation or delay of a liberalization that was announced two years in advance. Announcement of cancellation or delay is made one quarter before the expected liberalization.

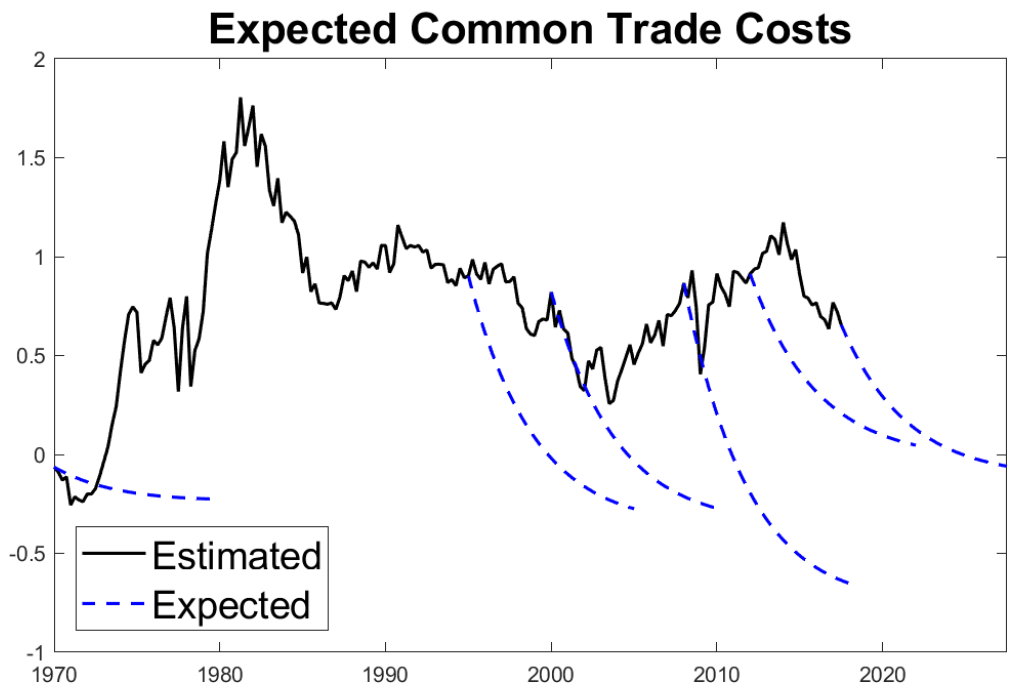

Figure 12: Common trade cost faced by exporters. Blue lines show agents predictions for future trade costs at different horizons.

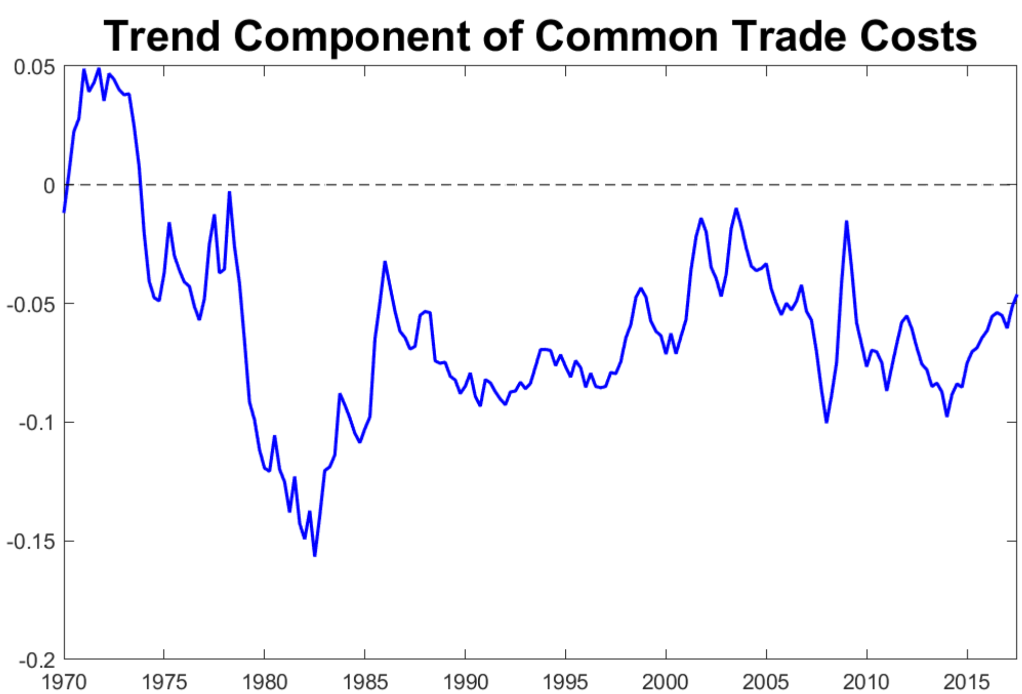

Figure 13: Trend component of common trade costs.

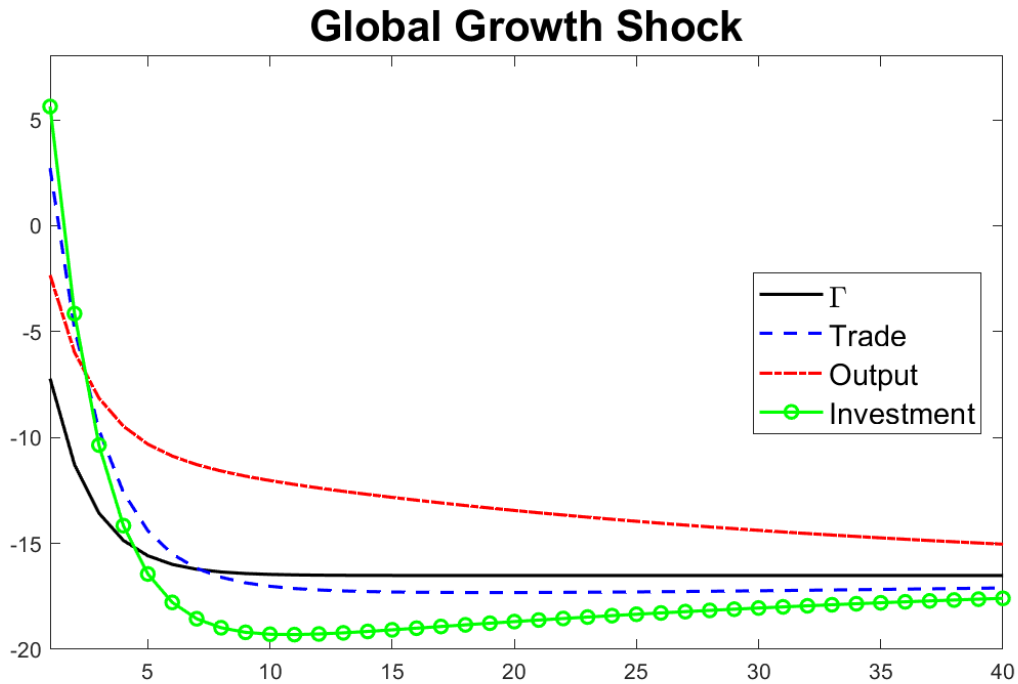

Figure 14: Impulse responses to a one standard deviation shock to ε_g^c.

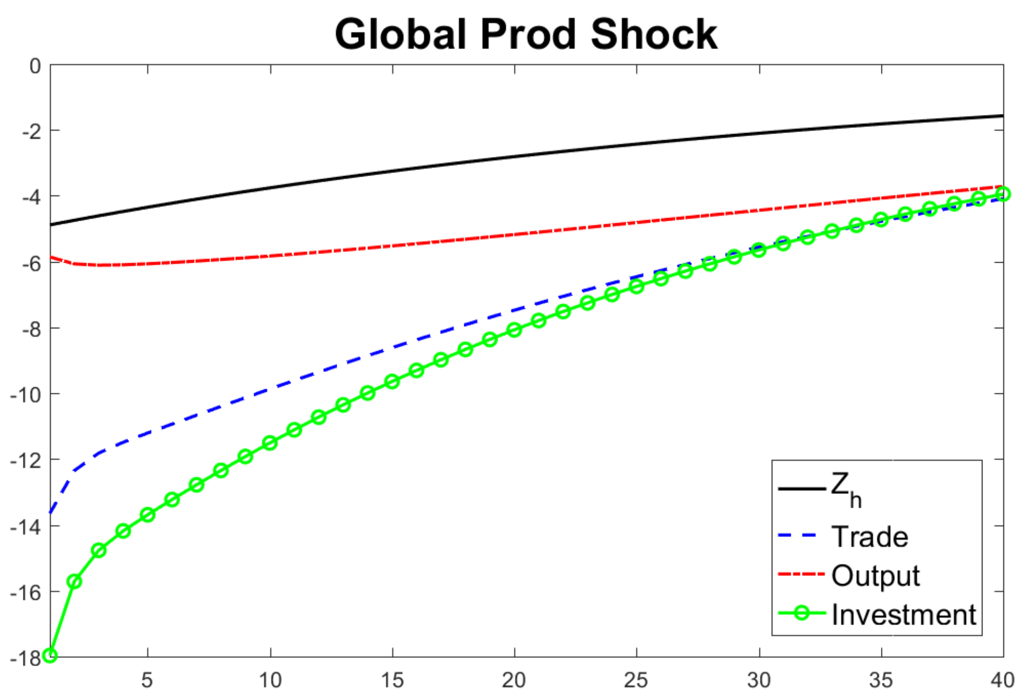

Figure 15: Impulse responses to a one standard deviation shock to ε_z^c.

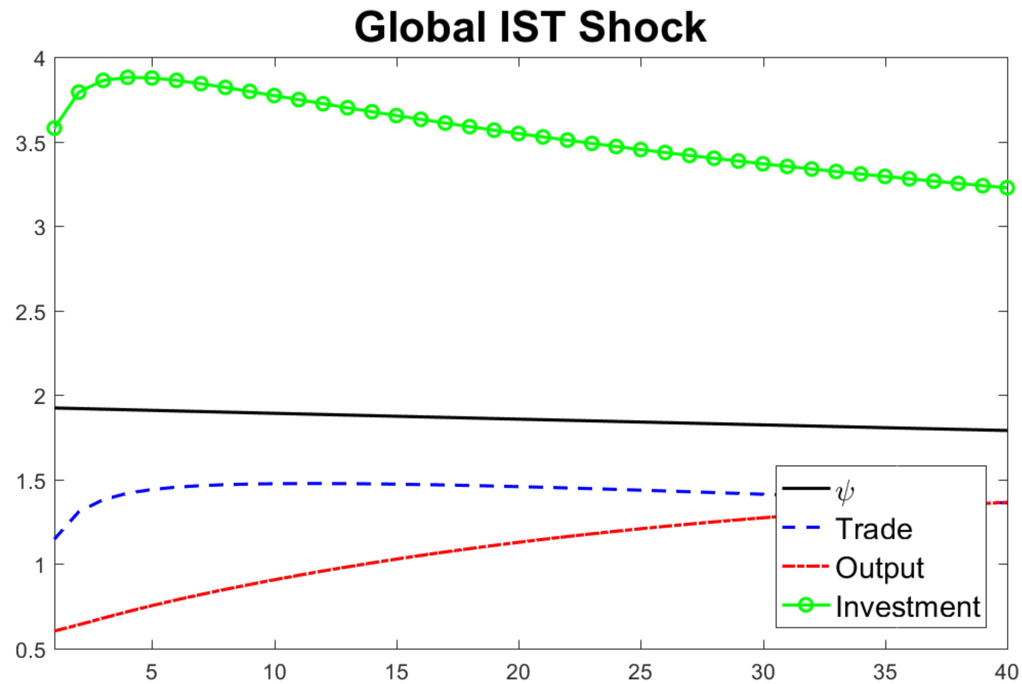

Figure 16: Impulse responses to a one standard deviation shock to ε_{ψ}^{c}.

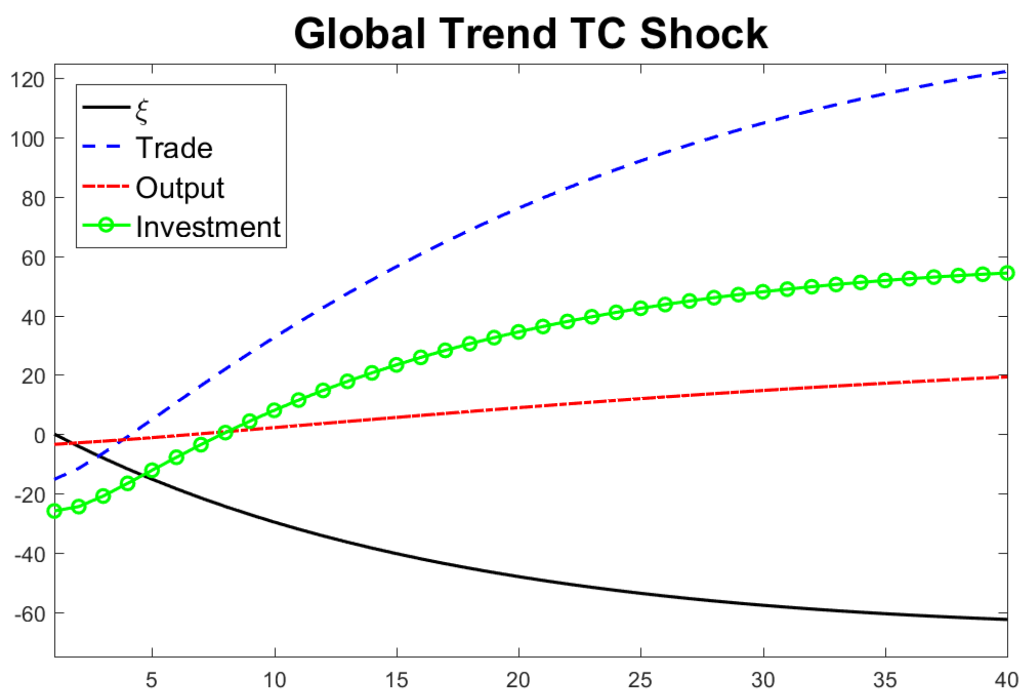

Figure 17: Impulse responses to a one standard deviation shock to ε_{Δ}^{c}.

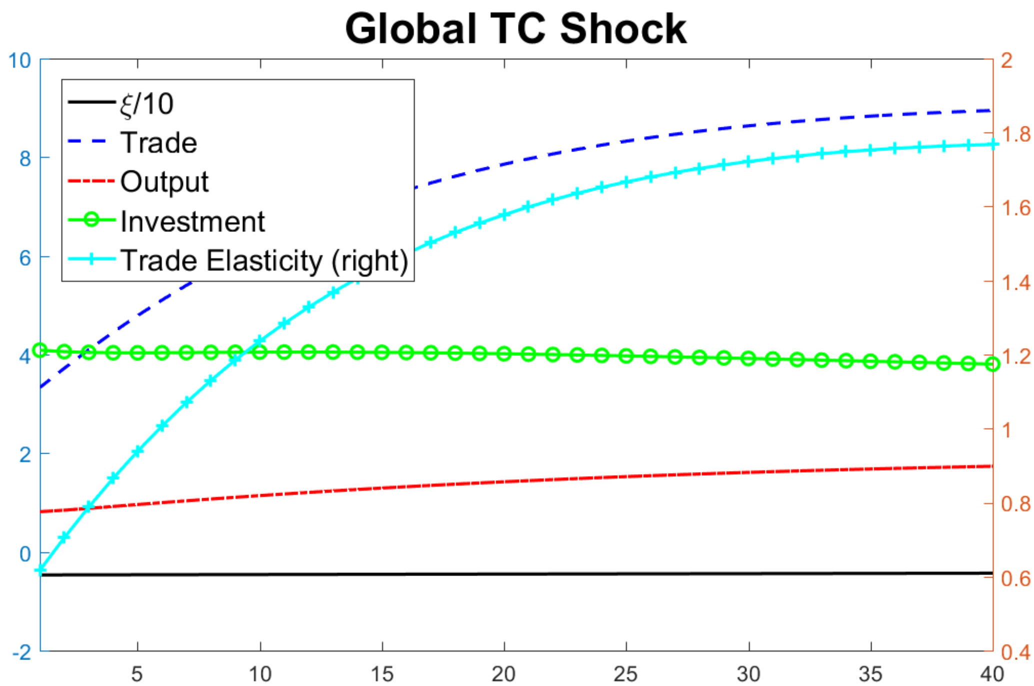

Figure 18: Impulse responses to a one standard deviation shock to ε_{ξ}^{c}.

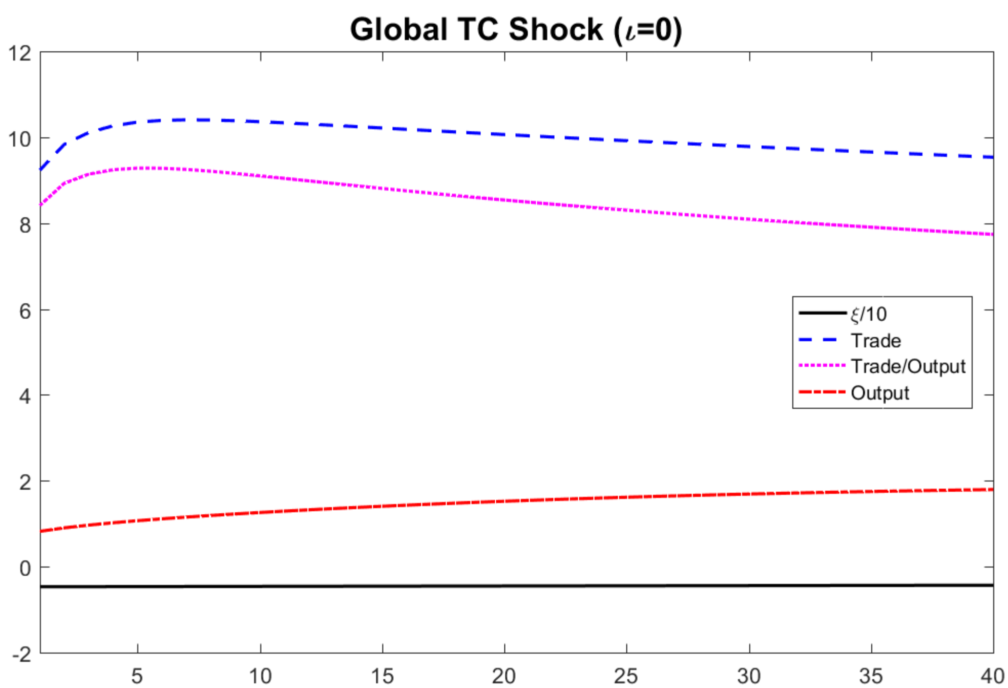

Figure 19: Impulse responses to a 1% shock to ε_{ξ}^{c} with no adjustment cost on the import share.

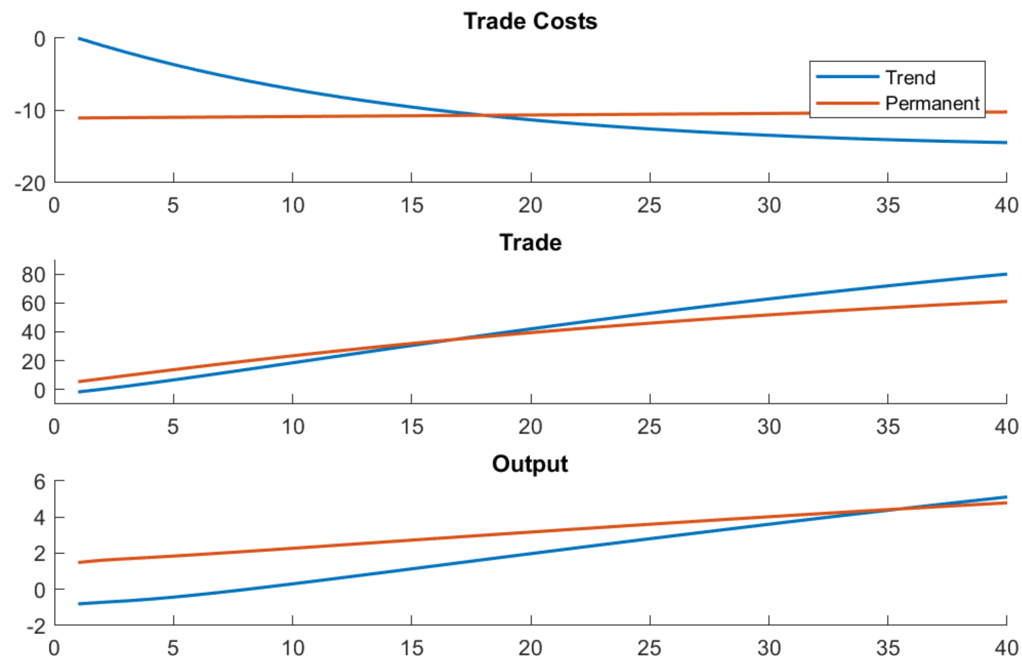

Figure 20: Response of trade and output to permanent and trend trade cost shocks with the same PVTC.

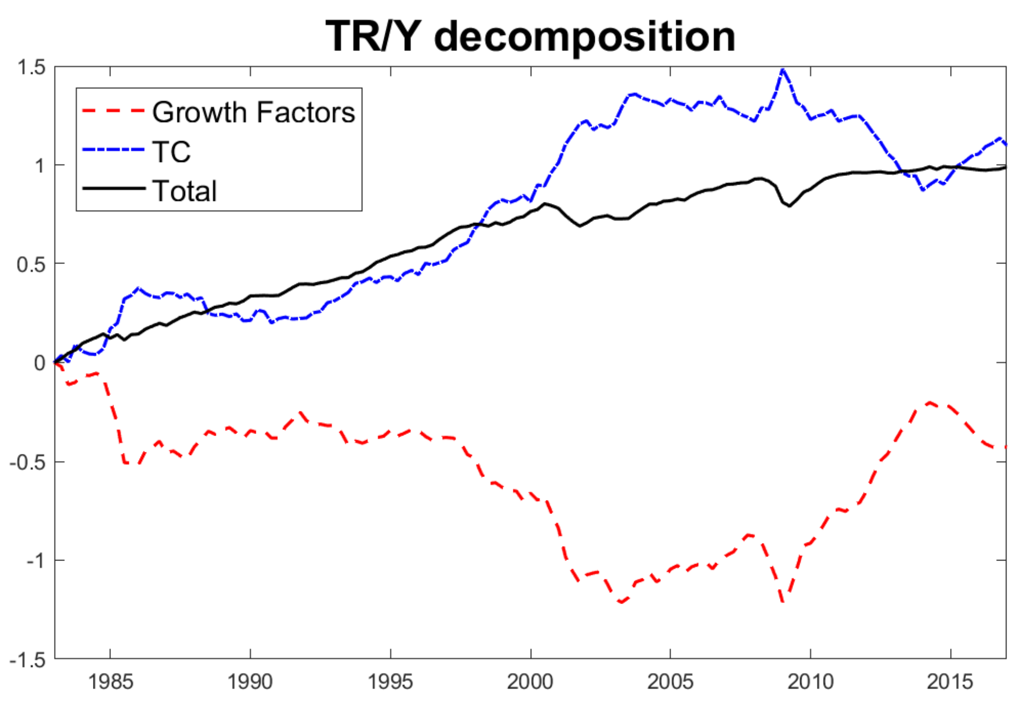

Figure 21: Trade to output ratio counterfactuals where growth shocks or trade cost shocks are eliminated.

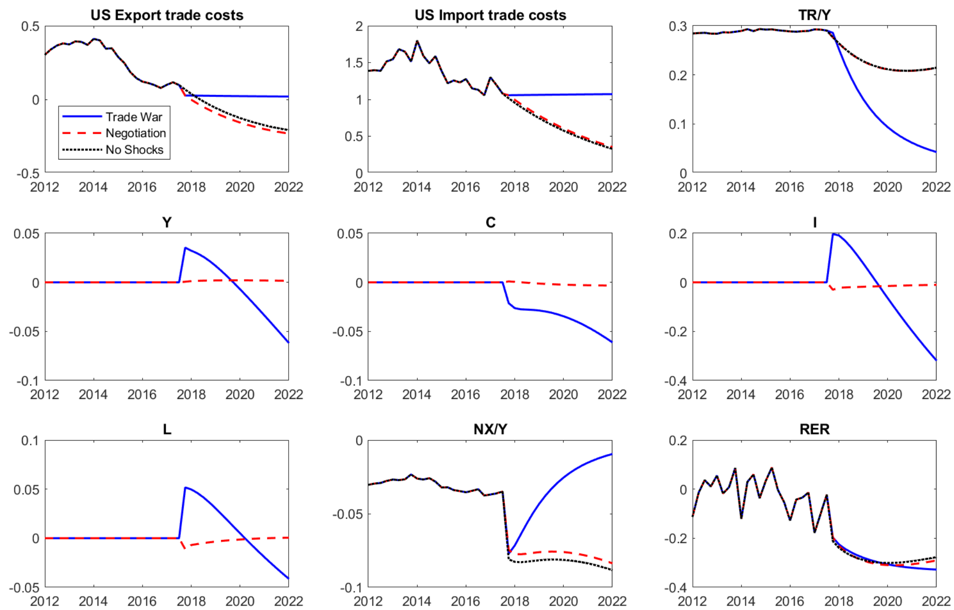

Figure 22: The effect of two alternate responses to a trade policy change. The graphs for output, consumption, investment, and labor show the effect of each policy relative to the case with no policy shock.

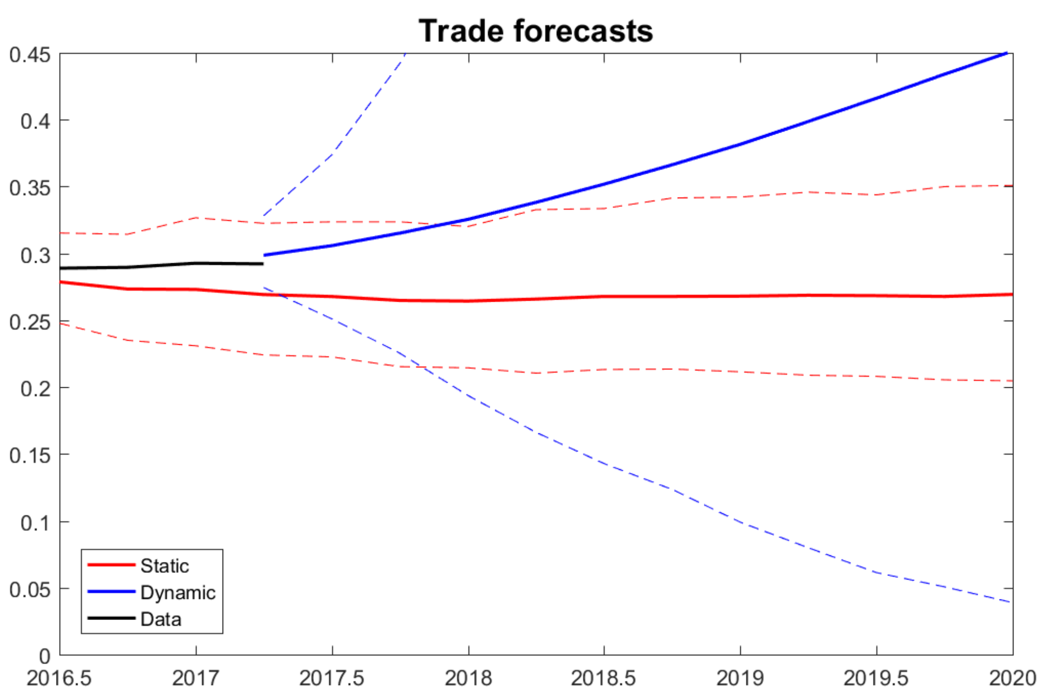

Figure 23: Forecasts of the trade to output ratio in the benchmark vs a static model.

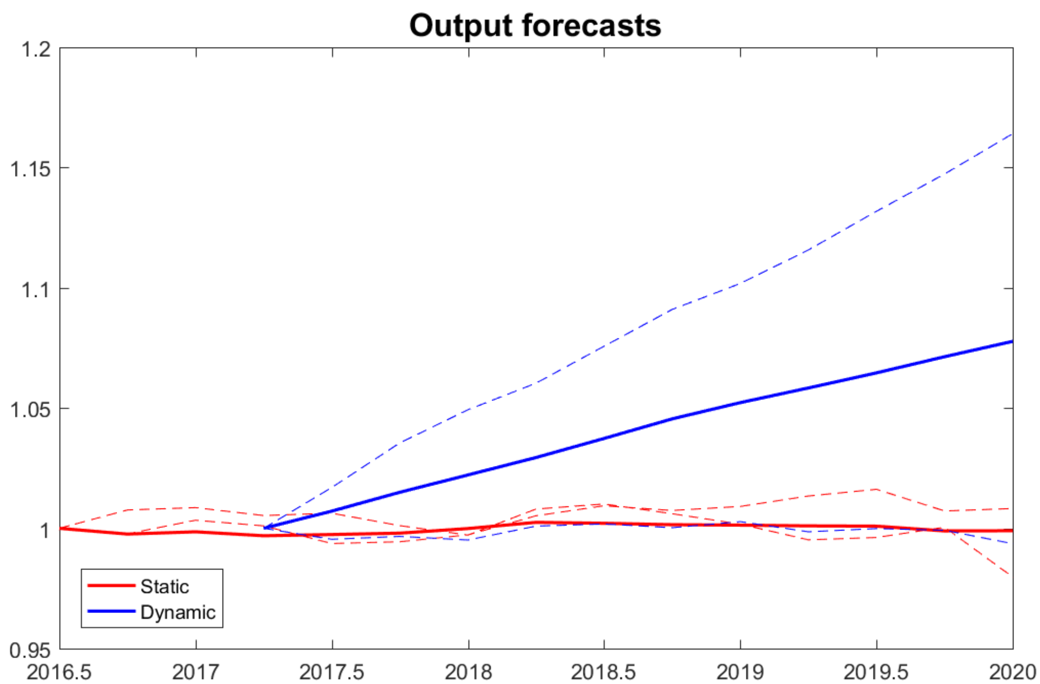

Figure 24: Forecasts of output in the benchmark vs a static model.