The Global Trade Slowdown: A Dynamic Approach

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Abstract

Since 2012, global trade growth has slowed significantly relative to both its historical trend and output growth. There is some debate around whether this slowdown is due to cyclical or structural factors. The answer to this question has important implications for future trade growth. We develop a dynamic quantitative two-country model in which trade responds gradually to changes in trade costs. We capture cyclical and structural factors with movements in productivity and trade costs. We use Bayesian estimation to match the model with time series from the data. We then compute the contributions of cyclical and structural factors on the slowdown. Our model also offers insights on how changes in productivity and trade costs affect trade and output in different ways.

1 Introduction

In the aftermath of the trade collapse, global trade growth has slowed significantly. From 1990Q1-2007Q4, the average trade growth of weighted real imports among OECD countries was 6.8%. Growth of trade plummeted during the subsequent trade collapse. Following a strong recovery, trade growth has been slow both relative to its precrisis growth levels and real output growth. Since 2012, average annual growth of trade has been at 3.2%. The slowdown in average global output has been much less severe, from 2.7% to 1.8%.

How much of this slowdown in trade growth is coming from structural or cyclical factors? The answer to this question is important for our expectations of future trade growth and which policies can be implemented to realize higher trade growth. If the slowdown is just a side effect of weak overall demand that persists in the wake of the Great Recession, then we can expect trade growth to increase in the near future and policies should be aimed toward increasing economic demand in general. On the other hand, if the slowdown is coming from structural factors such as slowing rate of globalization, then low trade growth may be the new normal. In this case, policies aimed at continued globalization will be most effective in raising trade growth.

In this paper, we develop a two-country model with cyclical and structural components that affect trade growth. The model is similar to Alessandria and Choi (2007) but allows for transitory and trend shocks to both productivity and trade costs. In addition to these components, we add habit formation, a trade structure that ensures trade is intensive in durables, and an adjustment cost on the aggregate import share faced by importers. Habit formation smooths out the consumption rate on the economy. Engel and Wang (2011) show that U.S. trade is intensive in durables. Capturing this in the model allows for investment and consumption to respond in different ways to changes in trade costs. The adjustment cost on the import share aids the model in matching the empirical observation that trade is more responsive to changes in trade costs in the long-run than in the short-run. This effect is imperative for the model. Baier and Bergstrand (2007) argue that free trade agreements can take a long time to make an impact on bilateral trade. If this is the case, then the slowdown could be coming from past free trade agreements or other measures of globalization wearing off.

We use the model to answer two questions. First, what is the impact of globalization or productivity movements on trade and output? In section 2, we show that the slowdown is more severe in trade than in output. The model can tell us what movements can account for this. In particular, we find that movements in productivity have a similar impact on trade and output so that the trade to output ratio moves very little. Trade cost movements, on the other hand, generate far more movement in trade, which causes dramatic changes in the trade to output ratio.

Second, we want to quantify the contribution of structural and cyclical factors on the slowdown. To this effect, we use Bayesian estimation to estimate the model to match several series from the data. We then perform an accounting exercise by examining counterfactuals in which structural or cyclical factors are absent. The resulting series for output and trade can give us an idea of how important structural and cyclical factors are in the slowdown.

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 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, this is the first paper that uses 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.

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 years to be realized. Besedeš et al. (2015) argue that some of this is coming from gradual phase out of tariffs. 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.[1] 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.

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 precrisi 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, I 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) 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%. The growth dropped by more than half! Real exports experiences a similar slowdown, going from 6.8% to 3.7%. The fall in growth of nominal values for both imports and exports is even bigger, which comes from falling oil prices in recent years. 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

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

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 5.3% in the precrisis period to 1.7% after 2012. In comparision, the slowdown in real GDP was quite small, going from 1.7% to 1.4%. 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.

3 Globalization Patterns

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 have been 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.[2] We create a concordance between HS8 products and NAICS 6-digit codes.[3] We take simple 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.[4] 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 this type of behavior in globalization by specifying a stochastic process where shocks can have a gradual effect on trade costs.

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

[3] See appendix for details.

[4] Many authors in the literature use the import value weighted tariffs. We reject this method as the tariffs are endogenous to the import decision.

4 Model

We develop a two-country model with heterogeneous firms to study the short- and long-run effects of trade cost and productivity shocks on trade and output. We use the model of Alessandria and Choi (2007) and add adjustment costs on the import share, trade intensity in durable goods, habit formation in consumption, and labor augmenting balanced growth. There are two countries, Home and Foreign, each populated by a continuum of identical and infinitely lived consumers. 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. Given an initial event s_0, 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. We define a firm as the unique producer of a variety of a good. The firms are indexed by $i \in [0, 1]$. Intermediate goods producers use capital and labor to produce their variety. Firm productivity has an aggregate component and an idiosyncratic component. The aggregate component Γ features balanced growth a la 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). 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 or foreign 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 allows the model to reproduce a low short-run and high long-run trade elasticity as observed in the data.

In this economy, there is a complete set of one-period state-contingent nominal bonds denoted in the home currency.

4.1 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 bonds 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 consumption of the previous period, $C(s^t)$ is today's consumption, and β is the discount factor. The budget constraint is

$$P_C(s^t)C(s^t) + \sum_{s^{t+1}|s^t} Q(s^{t+1}|s^t)B(s^{t+1}|s^t) \leq P_C(s^t)W(s^t)L(s^t) + B(s^t) + \Pi(s^t)$$

where $P(s^t)$ is the price of consumption goods relative to the home currency, $W(s^t)$ is the real wage, $Q(s^{t+1}|s^t)$ is the price of a bond $B(s^{t+1}|s^t)$ that pays one unit of the home currency in the next period if s_{t+1} occurs and 0 otherwise, and $\Pi(s^t)$ denotes profits from home intermediate goods producers. Notice that the budget constraint is written in terms of the home currency. Similarly, the foreign budget constraint is

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

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

The first order conditions from the Home consumer's problem are:

$$-\frac{U_L(s^t)}{U_C(s^t)} = W(s^t) \tag{1}$$

$$Q(s^{t+1}|s^t) = \beta \pi(s^{t+1}|s^t) \frac{U_C(s^{t+1})}{U_C(s^t)} \frac{P(s^t)}{P(s^{t+1})} \tag{2}$$

where U_I denotes the marginal utility with respect to $I \in (C, L)$. The Foreign Euler equation for bonds expresses the bond price as

$$Q(s^{t+1}|s^t) = \beta\pi(s^{t+1}|s^t)\frac{U_C^*(s^{t+1})}{U_C^*(s^t)}\frac{P^*(s^t)}{P^*(s^{t+1})}\frac{e(s^t)}{e(s^{t+1})}. \tag{3}$$

Using the two Euler equations, we can derive an expression for the real exchange rate $q(s^t)$

$$q(s^t) = \frac{e(s^t)P^*(s^t)}{P(s^t)} = \frac{U_C(s_0)}{U_C^*(s_0)}\frac{e(s_0)P^*(s_0)}{P(s_0)}\frac{U_c^*(s^t)}{U_c(s^t)} \tag{4}$$

which says that the real exchange rate is proportional to the ratio of marginal utilities.

4.2 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[5]

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

$$I^p(s^t) = \left[\int_0^1 y_h^I(i,s^t)^\theta di^{\frac{\rho}{\theta}} + \omega_I^{1-\rho}\left(\phi(TR(s^t),TR(s^{t-1}))\int_0^1 y_f^I(i,s^t)^\theta di^{\frac{1}{\theta}}\right)^\rho\right]^{\frac{1}{\rho}} \tag{6}$$

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 $\omega_I >$

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

ω_C to capture the empirical observation that trade is intensive in durable goods. Define the trade ratio as

$$TR(s^t) = \frac{Y_f(s^t)}{Y_h(s^t)}$$

where

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

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

$$\phi\left(TR(s^t), TR(s^{t-1})\right) = \left[1 - \frac{\iota}{2}\left(\frac{TR(s^t)}{TR(s^{t-1})} - 1\right)^2\right]. \tag{7}$$

This adjustment cost 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

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

$$\sum_{t=0}^{\infty} \sum_{s^t} Q(s^t|s^{t-1})P_I(s^t)I(s^t) - \int_0^1 p_h(i, s^t)y_h^I(i, s^t)di - \int_0^1 p_f(i, s^t)y_f^I(i, s^t)di \tag{9}$$

with (8) subject to equations 5 and 7; (9) subject to equations 6 and 7. 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

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

$$P_f(s^t) = \frac{\partial X(s^t)}{\partial Y_f^X(s^t)} + \frac{\partial X(s^{t+1})}{\partial Y_f^X(s^t)} \tag{11}$$

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

$$y_h^{X,d}(i,s^t) = \left(\frac{p_h(i,s^t)}{P_h} \right)^{\frac{1}{\theta-1}} Y_h^X \tag{12}$$

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

$$y_f^{X,d}(i,s^t) = \left(\frac{p_f(i,s^t)}{P_f} \right)^{\frac{1}{\theta-1}} Y_f^X \tag{13}$$

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.

4.3 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

$$\sum_{X\in\{C,I\}} y_h^X(i,s^t) + \xi^*(s^t) y_h^{*X}(i,s^t) = k(i,s^{t-1})^\alpha \left(A(i,s^t) l(i,s^t)\right)^{1-\alpha} \tag{14}$$

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 $A(i,s^t)$ represent firm specific capital stock, labor, and productivity, respectively, and ξ^* represents a stochastic iceberg cost of exporting to the Foreign market. Firm productivity $A(i,s^t)$ has an aggregate and idiosyncratic component. In particular,

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

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

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

$$k(i,s^t) = (1-\delta)k(i,s^{t-1}) + x(i,s^t). \tag{15}$$

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 $p_h(i,s^t)$ and

$p_h^*(i, s^t)$ to maximize the present discount value of profits. The problem for an individual firm i can be expressed recursively as[6]

$$V(\eta, k, m, s^t) = \max_{x,l,m',p_h,p_h^*} \pi(i) + m'\pi^*(i) \tag{16}$$
$$+ \sum_{s_{t+1}|s^t} \int Q(s^{t+1}|s^t) V(\eta', k', m', s^{t+1}) dF(\eta')$$

where

$$\pi(i) = \sum_{X \in \{C,I\}} p_h y_h^X(i) - P_C W l - P_I x \tag{17}$$

$$\pi^*(i) = e \left[\sum_{X \in \{C,I\}} p_h^* y_h^{*X}(i) - P_C W(m\tau_1 + (1-m)\tau_0) \right] \tag{18}$$

subject to the production technology (14), the law of motion for capital (15), and the downward sloping demand curves (12 and the Foreign analogue of 13). $F(\eta)$ is the cumulative distribution function of the normal distribution with variance σ_η^2.

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

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

for firms that did export. Then η_0 and η_1 satisfy

$$V_1(\eta_0, k, 0, s^t) = V_0(\eta_0, k, 0, s^t) \tag{19}$$
$$V_1(\eta_1, k, 1, s^t) = V_0(\eta_1, k, 1, s^t). \tag{20}$$

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.

Because the idiosyncratic productivity shocks are iid over time, we know that 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

$$N(s^t) = (1 - N(s^{t-1}))[1 - F(\eta_0(s^t))] + N(s^{t-1})[1 - F(\eta_1(s^t))]. \tag{21}$$

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

$$L_{fc}(s^t) = \int_{i \in \Phi(s^t)} \tau_1 m(i, s^{t-1}) + \tau_0(1 - m(i, s^{t-1}))di. \tag{22}$$

4.4 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 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, 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

$$\begin{aligned}
\xi_d(s^t) &= \rho_{\xi_d}\xi_d(s^{t-1}) + \varepsilon_\xi^d \\
\xi_c(s^t) &= (1-\rho_{\xi_c})\bar{\xi} + \rho_{\xi_c}\xi_c(s^{t-1}) + \Delta + \varepsilon_\xi^c \\
\xi_c^*(s^t) &= (1-\rho_{\xi_c})\bar{\xi} + \rho_{\xi_c}\xi_c^*(s^{t-1}) + \Delta^* + \varepsilon_\xi^c \\
\Delta(s^t) &= \rho_\Delta\Delta(s^{t-1}) + \varepsilon_\Delta^c + \frac{1}{2}\varepsilon_\Delta^d \\
\Delta^*(s^t) &= \rho_\Delta\Delta^*(s^{t-1}) + \varepsilon_\Delta^c + \frac{1}{2}\varepsilon_\Delta^d
\end{aligned}$$

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.

4.5 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 stationary equilibrium so that all allocations and prices are functions of the state s^t. In this model, the state can be summarized by the distribution of (η, k, m) and (η^*, k^*, m^*), aggregate productivity Γ and Γ^*, and variable trade costs ξ and ξ^*. The assumption that idiosyncratic firm productivity is iid over time makes tracking the distribution of individual firm variables much simpler. All firms have the same expectations over their idiosyncratic productivity tomorrow. Thus, export status in the previous period is the only determinant of a firm's capital stock. Firms that did not export in the last period will have a lower capital stock than firms that did. Let $K_0^{(*)}$ be the stock of capital carried by Home (Foreign) firms that did not export in the previous period and $K_1^{(*)}$ the stock of the firms that did. Then the state of the economy can be characterized by K_0, K_0^*, K_1, K_1^*, N, Γ, Γ^*, ξ, and ξ^*.

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

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

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

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%. Our intial guess for ζ is 0.2. We will estimate this parameter later. We choose γ=0.18 so that labor is equal to 1/7 in steady state. This gives a Frisch elasticity of about 1.9, which is close to values in the literature. The intertemporal elasticity of substitution σ is set to 6. 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). We want trade intensive in durables so we set $\omega_I = 2\omega_C$ and set $\omega_C = 0.345$ to get an import share of 15%. The parameter on the adjustment cost of the trade share ι is set to 100 and later estimated. 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.

Our calibration for the production process comes from Rabanal et al. (2011). We set κ, which determines how quickly country productivities converge after a shock, to 0.007. We let $c = c^*$ since we are considering a symmetric case. A steady state growth rate of 0.0035 from Rabanal et al. (2011) implies c=0.0025. We add persistence in the productivity process and set ρ_g=0.3, which is close to estimates in Aguiar and Gopinath (2007) for developed economies. We set $\sigma_\eta = 0.01$.

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 $\rho_\xi^c = \rho_\xi^d = 0.95$. The estimation will reveal that these parameters are actually much closer to 1. We set ρ_Δ=0.93 so that the half-life of a trend shock to trade costs is about 10 quarters. This implies that after 10 years, the shock is worn off and, if trade cost movements were permanent, the economy would be almost to the new steady state. This matches our empirical observations about free trade agreements. The fixed costs of exporting ensure that 3% of exporters stop exporting every period and 20% of all firms export.

The standard deviation for all shocks apart from ε_η is set to 0.01. We use Bayesian estimation to determine these parameters and set the standard deviation of our prior to infinity.

The estimation results as well as the prior distributions are listed in Table 3. At this point, we show the estimation for only a few parameters, but in the future we will estimate many more of the parameters. As a result of previous estimations, we will set $\rho_\xi^c = 0.998$ and $\rho_\xi^d = 0.957$. We also use an ω_C and ω_I from preliminary estimations that are very close to the values in the calibration. Using these values and the parameter values from the calibration, we estimate the standard deviation of all shocks, ζ, ι, and κ. We estimate the model to match six series from the data: U.S. real GDP growth, nominal investment share, nominal trade share, nominal exports over imports, a terms of trade and real exchange rate composite, and a measure of rest of world real GDP growth. 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 1980Q1 to 2016Q2. We define investment in the model to be gross private domestic investment plus the consumption of durables. With this data, we have real GDP growth, the nominal investment share, and the two trade series that we consider. The terms of trade comes from the BEA and the real exchange rate comes from the Bank for International Settlements. We match the sum of the terms of trade and the real exchange rate. Since our model lacks pricing to market, we cannot match both series. By matching the sum, we hope to eliminate problems arising from only matching one of them. The measure for the rest of world real GDP comes from the Federal Reserve Bank of Dallas' Database of Global Economic Indicators. Our final set of six series contains data from 1980Q2 to 2016Q2.

At this point, we are still unsatisfied with the estimation and so will refrain from discussing the implications on contributions of cyclical and structural factors until the fit of the model is better. Below, we present some impulse response functions and some intuition on how different components of the model are important for the results.

6 Results

Figures 5 through 10 show impulse response functions of key variables to the various shocks. We want to examine how the responses of trade and output differ across productivity shocks and trade cost shocks. In particular, we want to see what shocks can help to explain trade and output dynamics in the precrisis and slowdown periods. To that effect, Figure 11 shows the nominal trade to output ratio from 1990Q1 to 2016Q2. The trade to output ratio in the precrisis period is characterized by strong growth of about 45.7% overall, which implies an average growth of about 2.5% annually. Growth for this period is particularly high following the early 2000s recession. From 2002Q1 to 2007Q4, trade to output growth was 34.4% or an average annual growth of 4.9%. The shocks driving growth in trade and output for this period must be able to account for this. During the slowdown period, we actually see a steep decline in the trade to output ratio with overall growth of -14.2% or average annual growth of -3.1%. In addition to the trade to output ratio, the shocks must also account for the growth levels of trade and output for the U.S. economy as described in Section 2.

Now we turn our attention to the impulse response functions. Figures

5 and 6 show the responses to a 1% shock to ε_g^c and ε_g^d, respectively. The figures show that in this model, productivity growth shocks have roughly the same effect on trade and output. A positive shock common to both countries increases productivity of both exporting and non-exporting intermediate goods producers. A differential productivity shock allows Home producers to charge lower prices in the Foreign market, increasing exports. However, prices in the Home market charged by Foreign producers increase, and imports fall. All in all, trade and increase move by almost the same amount and the change in the trade to output ratio is small.

Shocks to trade costs, on the other hand, can generate large movements in the trade to output ratio. Consider Figure 7. The effect of an almost permanent trade cost shock is very large for trade but rather small for output. The response of output comes from factors of production being reallocated towards less efficient firms. When trade costs increase permanently, the price of capital increases. Because of this, all firms will decrease their capital stock. However, exporters decrease their capital stock even more since their prices in the foreign market have gone up and they are facing lower demand. The wealth effect makes labor supply go up but workers go disproportionately towards nonexporters to equate marginal product of labor across firms. In addition, exporting has become less attractive and many firms leave the foreign market. So a larger share of the economy's total capital and labor are being held by less productive nonexporters and there are fewer exporters which produce output for both markets. The result is that output decreases. However, trade decreases by even more as it is directly affected by the decrease in number of exporters and lower demand in the foreign market. This differential impact on trade and output causes the trade to output ratio to decrease by 0.5% in the long run. The increase in nominal TRY on impact arises because of the adjustment cost on the import share. Prices of imports increase on impact and final goods producers would like to stop importing and use more domestic goods but substituting towards domestic goods too quickly is costly. Figure 14 shows the same impulse response function but with $\iota = 0$. That is, with no adjustment cost on the import share. Here, the trade to output ratio responds in the expected direction immediately. For all of the trade cost shocks except the differential permanent shock, we see that large movements in the trade to output ratio can be achieved. For common trend shocks, we see that there is a wealth effect on impact. The agents expect that they will only get poorer with time. This causes them to invest today and so we get an increase in output and trade today followed by large decreases in the future.

Figures 12 through 17 show impulse response functions with no adjustment costs. The same results are true here except that trade is free to adjust more quickly so that there is no "convergence" to a new steady state. Without adjustment costs, the response to a permanent shock to trade costs approximates a static model.

7 Conclusion

Global trade growth has slowed dramatically since 2012 relative both to its historical trend and output growth. Many papers have attempted to decompose the contributions of structural and cyclical factors on the slowdown. Of these papers, none have approached the question with a dynamic quantitative framework. Considering dynamic responses to structural factors such as trade costs could be important for the slowdown. A large literature has showed that trade responds more in the long run to changes in prices than in the short run. Also, trade liberalizations tend to be gradually phased in. These two facts suggest that the high precrisis growth may have been from globalization in the 1990s and early 2000s. If this is true, then lower growth is expected as the economy settles into a new steady state.

We develop a dynamic quantitative two-country general equilibrium model. The model captures cyclical and structural factors through movements in productivity and trade costs. Changes in trade costs can be gradual as is expected with a free trade agreement. We also have adjustment costs on the trade share that cause trade to respond gradually to changes in trade costs. We estimate the model to match data and compute the contributions of cyclical and structural factors on the slowdown.

The model also sheds light on how movements in trade costs and productivity affect trade and output in different ways. We find that shocks to productivity affect output and trade similarly, resulting in no change in the trade to output ratio. On the other hand, changes in trade costs result in dramatic changes in the trade to output ratio as the effect on trade is much greater than the effect on output.

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A Tables

Data	Precrisis	Slowdown
Real Imports	6.8%	3.2%
Real Exports	6.8%	3.7%
Real GDP	2.7%	1.8%

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

Preferences	β=0.99, ζ=0.2, γ=0.18, σ=6
Production	θ=2/3, ρ=1/3, ι=100, ω_C=0.345, ω_I=0.69, δ=0.05, α=0.36
	c=c*=0.0025, κ=0.007, $\rho_g = 0.3$, $\sigma_\eta = 0.15$, σ_g^d=σ_g^c=0.01
Trade Costs	$\bar{\xi}$=1, ρ_ξ^c=ρ_ξ^d=0.95, ρ_Δ=0.93, τ_1=0.0744, τ_0=0.0914,
	$\sigma_\xi^c = \sigma_\xi^d = \sigma_\Delta^c = \sigma_\Delta^d$=0.01

Table 2: Initial calibration for model parameters. Several parameters will later be estimated.

Parameter	Distribution	Prior	Prior Std Dev	Posterior Mean
ζ	Normal	0.2	0.2	0.22
ι	Normal	100	100	32.2
κ	Normal	0.007	0.004	0.001
σ_g^c	Inverse Gamma	0.01	∞	0.0078
σ_g^d	Inverse Gamma	0.01	∞	0.0069
σ_ξ^c	Inverse Gamma	0.01	∞	0.0636
σ_ξ^d	Inverse Gamma	0.01	∞	0.0282
σ_Δ^c	Inverse Gamma	0.01	∞	0.0043
σ_Δ^d	Inverse Gamma	0.01	∞	0.0243

Table 3: Prior distributions and posterior means.

B Figures

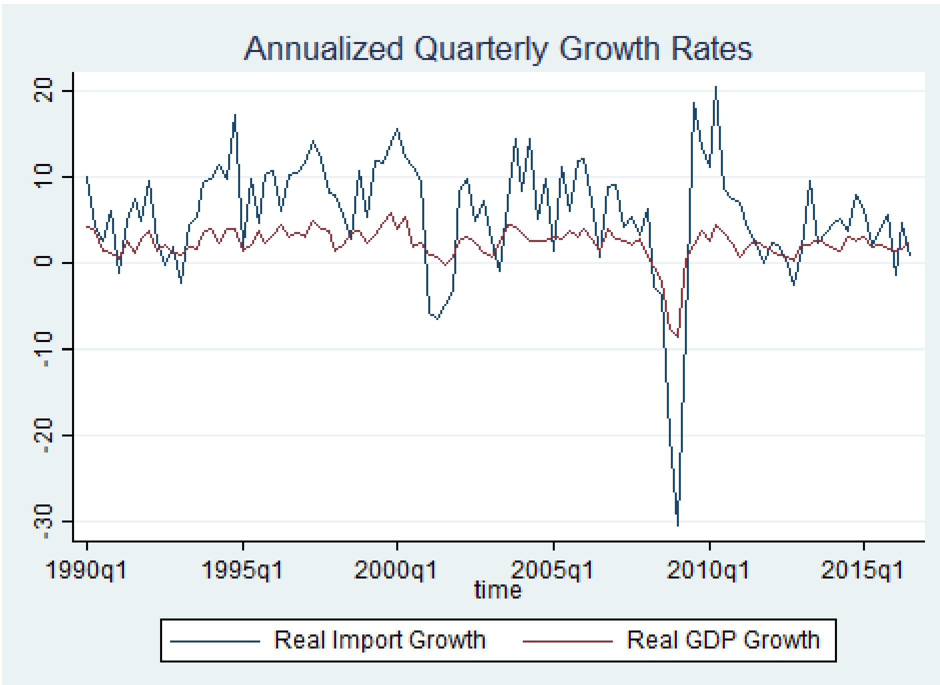

Figure 1: Weighted growth for OECD aggregate.

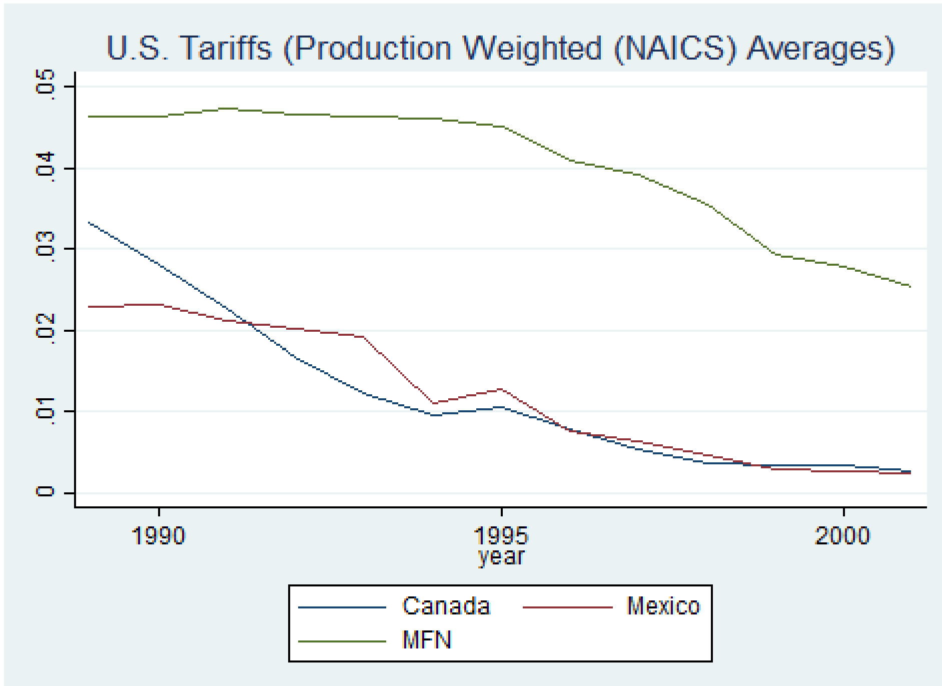

Figure 2: Production weighted average tariffs imposed by the U.S. against Canada and Mexico. Also, the production weighted average most favored nation tariff.

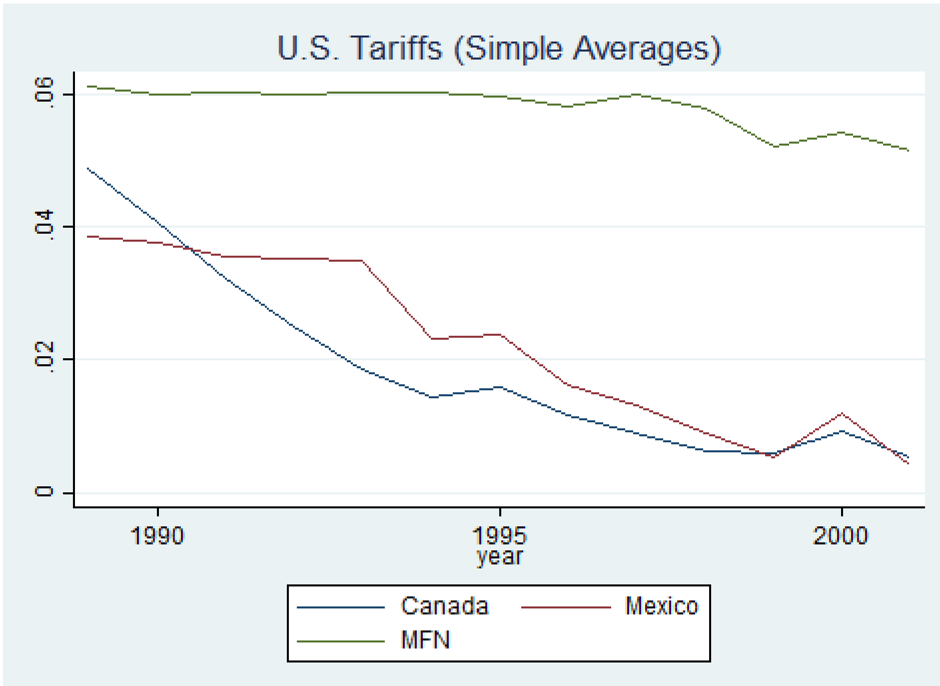

Figure 3: Simple average tariffs across all products at the HS8 level.

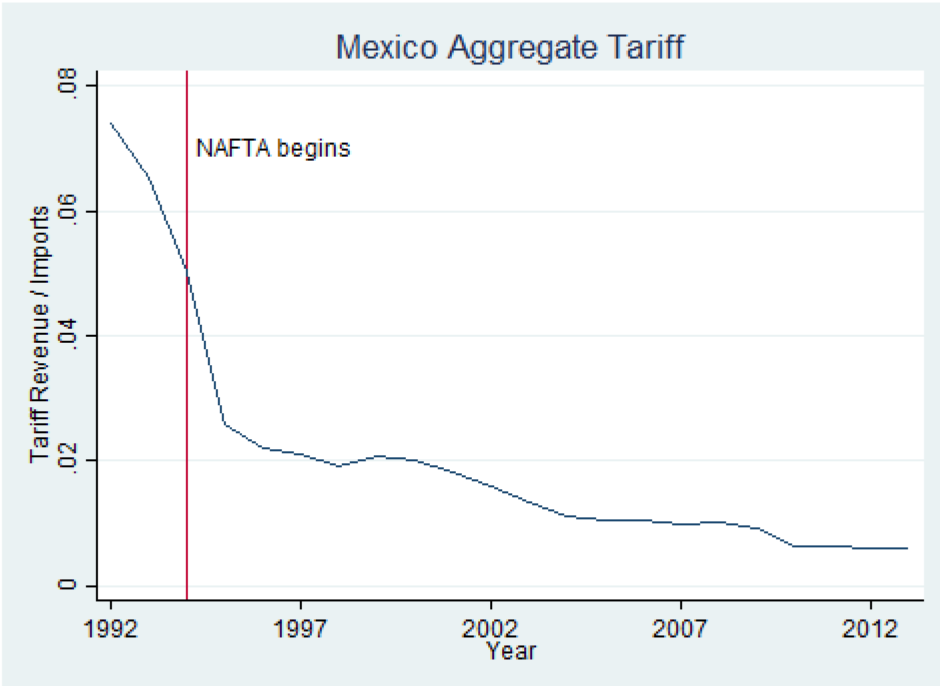

Figure 4: Mexico's aggregate ad valorem equivalent tariff.

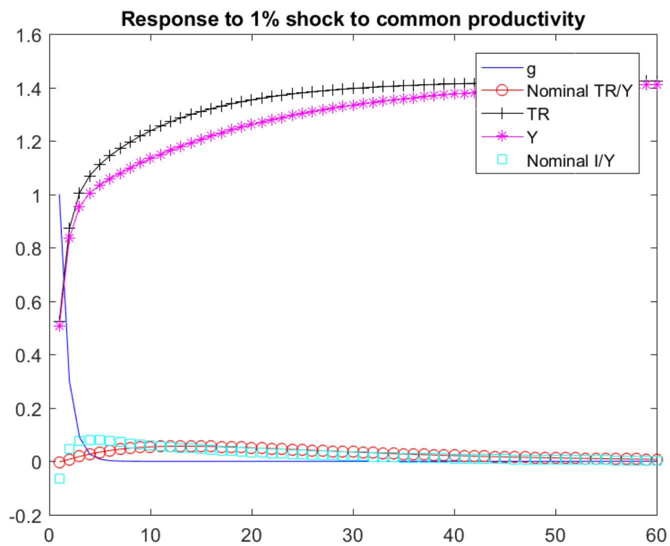

Figure 5: Impulse responses to a 1% shock to ε_g^c.

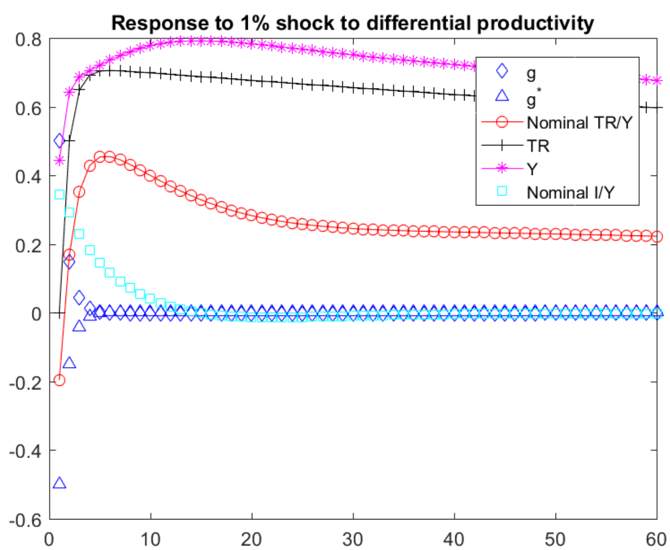

Figure 6: Impulse responses to a 1% shock to ε_g^d.

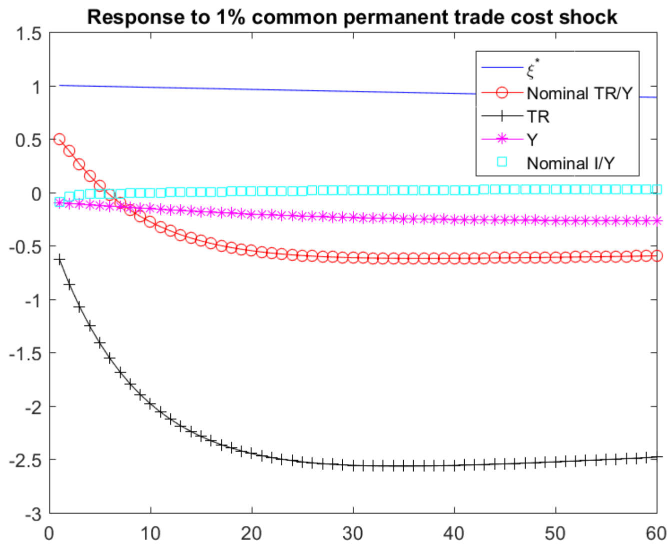

Figure 7: Impulse responses to a 1% shock to ε_{ξ}^{c}.

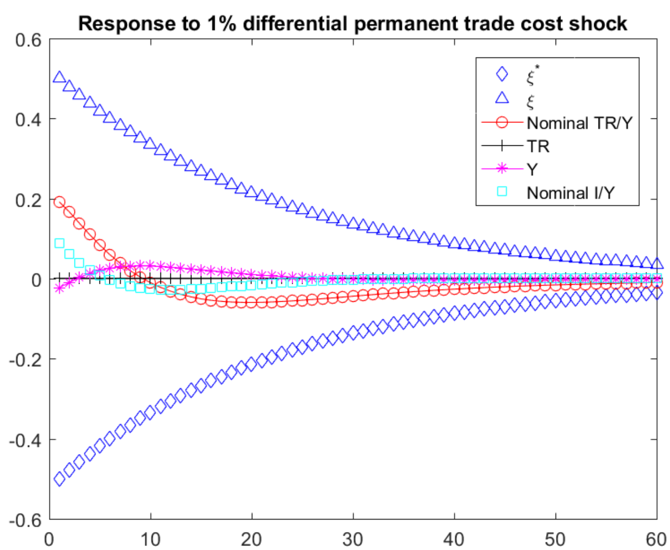

Figure 8: Impulse responses to a 1% shock to ε_{ξ}^{d}.

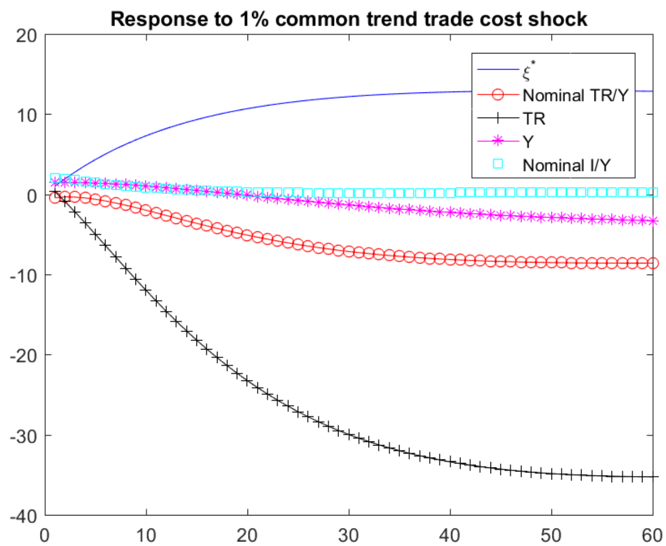

Figure 9: Impulse responses to a 1% shock to ε^c_Δ.

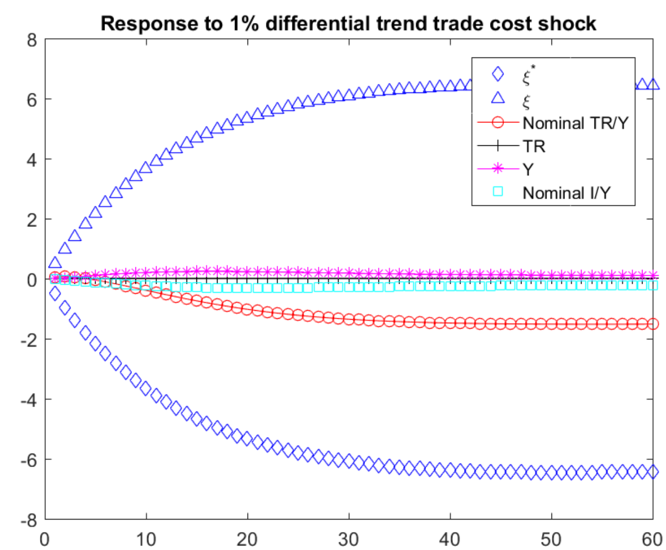

Figure 10: Impulse responses to a 1% shock to ε^d_Δ.

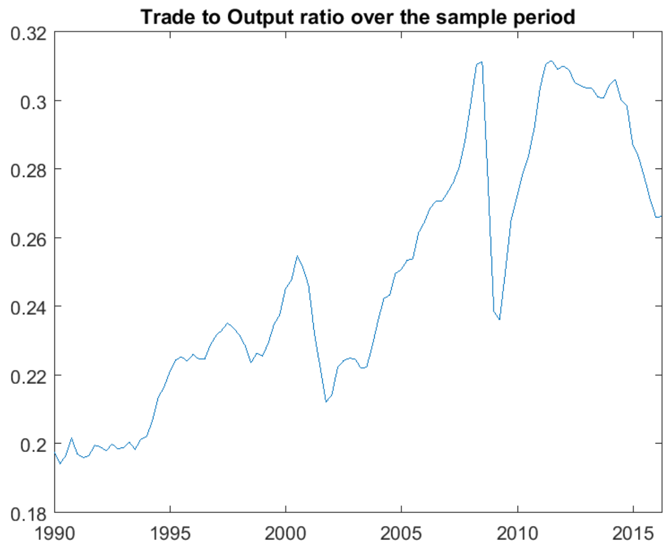

Figure 11: This figure shows the nominal trade to output ratio from 1990Q1 to 2016Q2.

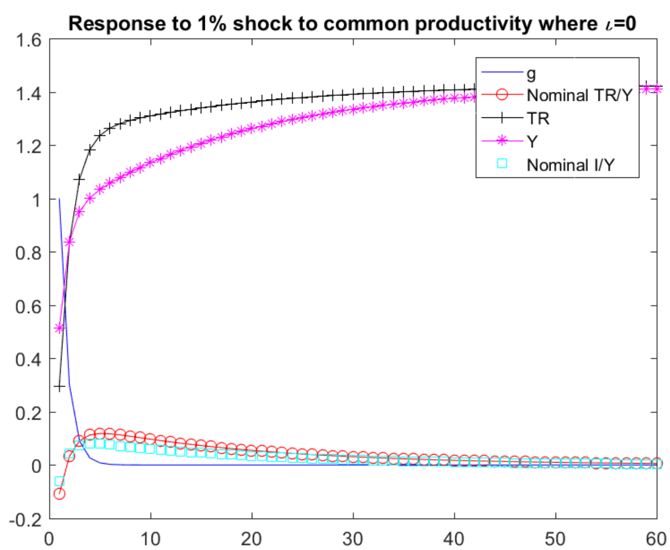

Figure 12: Impulse responses to a 1% shock to ε_g^c with no adjustment cost on the import share.

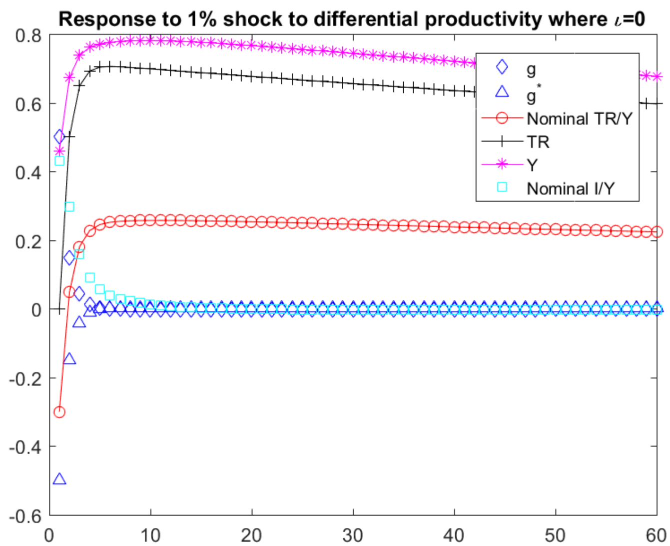

Figure 13: Impulse responses to a 1% shock to ε_g^d with no adjustment cost on the import share.

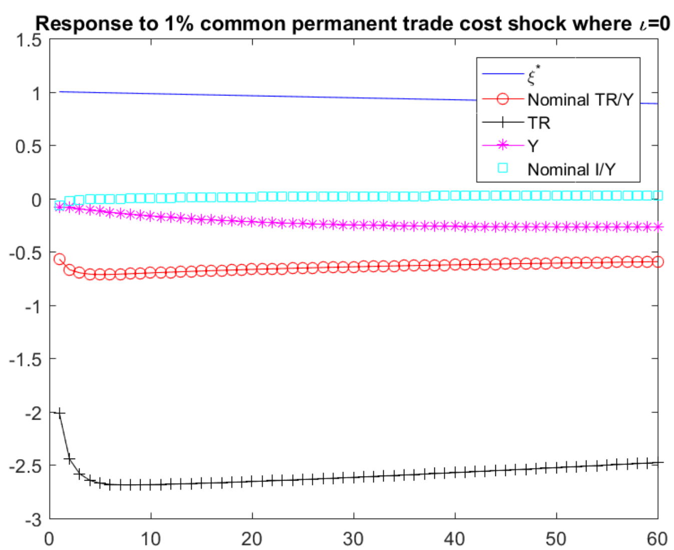

Figure 14: Impulse responses to a 1% shock to ε_ξ^c with no adjustment cost on the import share.

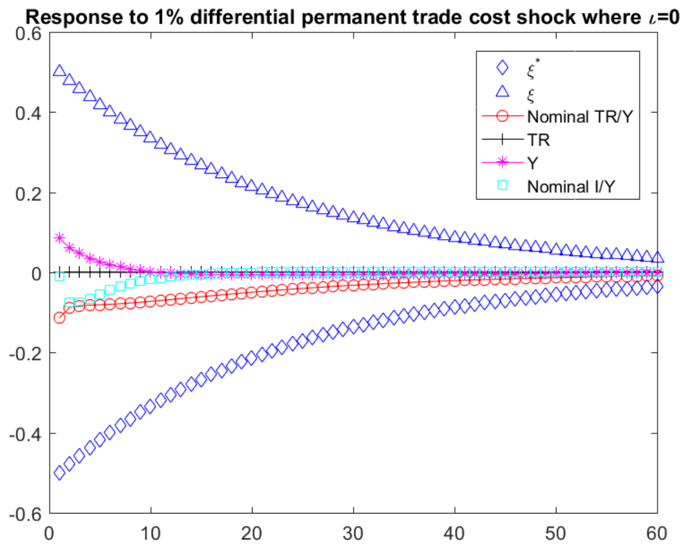

Figure 15: Impulse responses to a 1% shock to ε_{ξ}^{d} with no adjustment cost on the import share.

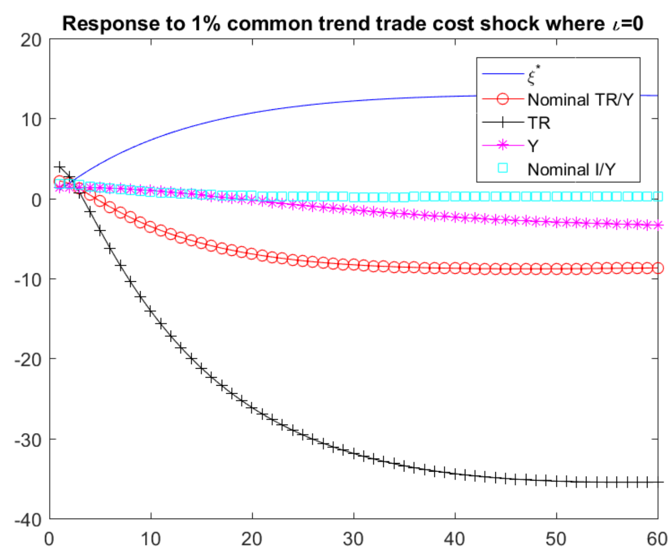

Figure 16: Impulse responses to a 1% shock to ε_{Δ}^{c} with no adjustment cost on the import share.

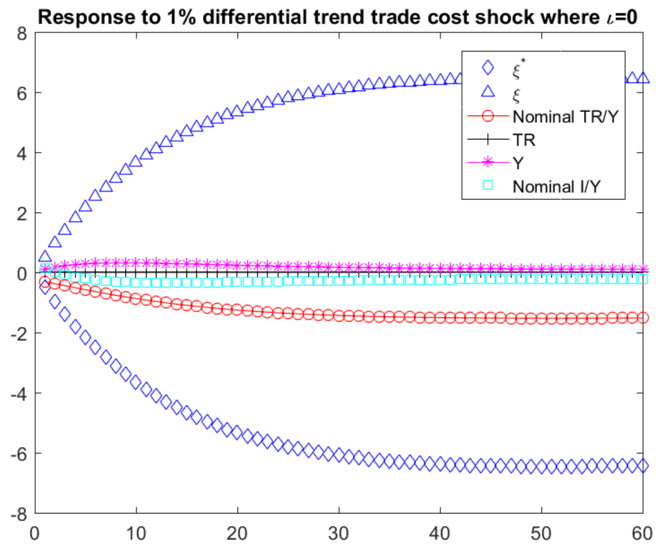

Figure 17: Impulse responses to a 1% shock to ε^d_Δ with no adjustment cost on the import share.