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ABSTRACT

We study how changes in trade barriers contributed to the dynamics of the US trade balance and real exchange rate since 1980 - a period when trade tripled. Using two dynamic trade models, we decompose fluctuations in the trade balance into terms related to trade integration (global and unilateral) and business cycle asymmetries. We find three main results. First, the relatively large US trade deficits as a share of GDP in the 2000s compared to the 1980s mostly reflect a rise in the trade share of GDP. Second, controlling for trade, only about 60 percent of net trade flows are due to business cycle asymmetries. And third, about two-thirds of the contribution of business-cycle asymmetries are a lagged response. For instance, the short-run Armington elasticity is about 0.2 while the long-run is closer to 1.12 with only 6.9 percent of the gap closed per quarter. We show that a two-country IRBC model with a dynamic exporting decision, pricing-to-market, and trade cost shocks can account for the dynamics of the US trade balance, real exchange rate, and trade integration. The model clarifies how permanent and transitory changes in trade barriers affect the trade balance and how to identify changes in trade barriers. We also show the effect of temporary trade policies on the trade balance depends on whether they induce a trade war.

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1. Introduction

What leads a country to run a trade deficit or surplus? This question rose to prominence with the large US trade deficits in the mid to late 2000s and concurrent large surpluses by China and some other Asian economies.[1] The traditional view is that the trade balance reflects cross-country differences in the business cycle from country-specific productivity, monetary, and fiscal shocks, or longer-term structural asymmetries related to demographics, social insurance, or wealth. A contrasting view, commonly advanced by politicians, is that cross country differences in trade barriers or trade policy are important drivers of the trade balance. This alternative view has much support in the US administration and is perceived to be shaping US trade policy. The aim of this paper is to evaluate the relative importance of these diverse views for the dynamics of the US's trade balance. Contrary to the traditional view, we find trade policy is an important driver of the US trade balance, although through a different mechanism than those favored by politicians.

To set ideas, Figure 1 plots two salient features of the US economy's connection with the rest of the world (ROW): rising trade deficits and rising trade. First, since 1980 the US trade balance shows two cycles of increasing amplitude. In the 1980's cycle, the US trade deficit as a share of GDP peaked in the third quarter of 1986 at 2.6 percent. Twenty years on, it peaked again but now at 5.6 percent of GDP. In both cases, the maximum trade deficit lagged the peak real exchange rate by about 6 quarters and the peak real exchange rates change was smaller in the 2000s , suggesting an increased sensitivity of the trade balance to the real exchange rate. Second, the near doubling of the US trade deficit occurred as trade, measured as the sum of exports and imports, doubled from 12.9 percent of GDP to 26.1 percent,[2] as policy and non-policy trade barriers were reduced.

We emphasize two channels through which changes in trade barriers influence the trade balance. First, there is a *scale* effect of trade on the trade balance. As a country becomes more open, perhaps by entering into symmetric bilateral trade agreements that lower trade barriers in both directions, the usual factors - country-specific shocks that generate asymmetries in the business cycle - can generate larger swings in the trade balance. Quite simply, a

[1] This was also a key question at times in the 70's and 80's.

[2] From 1980 to 2015 the real trade share of GDP rose from 11.5 percent to 29.0 percent.

closed economy cannot run a trade deficit or surplus but an open economy can. This explanation would be consistent with real exchange rate fluctuations being associated with larger fluctuations in the trade balance over time.

Second, there is a *sequencing* effect from a temporary unilateral change in a trade barrier. That is, persistent differences in the pace that countries open up to each other can generate intertemporal trade. An example of this might be a US trade policy of lowering import barriers in return for future reductions on barriers on US exports. Similarly, temporary unilateral trade barriers such as anti-dumping duties, safeguards, quotas, or voluntary export restraints, perhaps in response to surges from the first mechanism or the business cycle, generate a temporary gap in inward and outward trade barriers. Indeed, Bown and Crowley (2013) find that temporary trade barriers in the US and its main trading partners appear to rise in recessions, following import surges, and following an appreciation. If this gap in trade policy is expected to be persistent, but not permanent[3] then when the cost of importing is relatively low compared to the cost of exporting there is a strong motive for consumption to be relatively high in the US relative to the ROW, leading to sustained trade deficits.

To quantify the relative importance of changes in trade barriers versus other business cycle asymmetries for the US trade balance requires identifying the changes in inward and outward trade barriers. We follow the Gravity literature and use theory to identify these changes. We measure trade costs in both partial and general equilibrium models that allow for trade to respond gradually to aggregate shocks. Both models attribute about two-thirds of the fluctuations in the US trade balance to changes in trade barriers and yield series for trade barriers that appear consistent with the conventional narrative on the timing of US trade policy. We start with a partial equilibrium model since this requires no assumptions about the source of relative price fluctuations or the asset side of the economy, two important, but far from settled, issues in international macroeconomics. Our partial equilibrium approach offers a convenient characterization of the cyclicality of the trade balance and its comovement with the real exchange rate. We move to a general equilibrium model to show how assumptions about the nature and persistence of trade shocks and modelling assumptions identify trade

[3] We don't consider the role of permanent unilateral changes in trade barriers but in models with a dynamic export decision these can lead to intertemporal trade (see Alessandria, Choi and Ruhl, 2014).

policy shocks and expectations on future trade policy.

To bring our main ideas on the scale and sequencing effects into focus it helps to split the trade balance as a share of GDP into a term related to the level of trade to GDP (TRY) and another term that is the trade balance as a share of trade (TBTR),

$$(1) \quad TBY = \frac{X+M}{Y}\frac{X-M}{X+M} = TRY \cdot TBTR,$$

where X is the exports to the ROW M is the imports at home, and Y is the GDP at home. As is well-known, most of the increase in trade integration, measured by TRY, is attributed to cuts in average trade barriers, and thus captures the scale effect. Figure 2 plots the US trade balance to GDP ratio and a counterfactual US trade balance holding the trade share constant at its level in 1986, prior to entering into either the Canadian-US or North-American free trade agreements.[4] The counterfactual peak trade deficit in 2006 of only 2.7 percent is almost the same as in 1986, suggesting that the historically large deficits of the 2000's were primarily related to the historically large trade share.[5] This may also explain why the swings in the real exchange rate were of similar magnitude to the 1980s.

We next show how the sequencing effect can be identified from the fluctuations in the trade balance to trade ratio (TBTR). We do this in partial and general equilibrium models. Both approaches leverage the benchmark Armington trade model, the core trade block in nearly all sticky and flexible price models with all asset market structures.[6] In the Armington model the trade balance to trade ratio is determined by cross-country differences in expenditures, international relative prices, trade barriers, and the elasticity of substitution between imported and domestic goods - the Armington elasticity.

Our partial equilibrium decomposition takes a very conservative approach to identifying

[4] Negotiations on the CUSFTA begin in 1986 and it went into effect January 1, 1989. NAFTA went into effect January 1, 1994. Both agreements contained phase-outs of tariffs and other trade barriers.

[5] This decomposition also clarifies the need to study the trade balance in a multi-good model rather than single-good models as is common in a branch of the literature (see for example Caballero, Farhi, and Gourinchas, 2008, Mendoza, Quadrini, and Rios-Rull, 2009, McGrattan and Prescott, 2010). Beyond the counterfactual predictions on relative prices, in a one-good model there is only net trade so that the trade to GDP ratio equals the absolute value of the trade balance to GDP (TRY=$|TBY|$) and the trade balance to trade ratio fluctuates between minus one and one, which are clearly inconsistent with Figures 1 and 2.

[6] Heathcote and Perri (2014) discuss various asset structures. In international macro models the asset structure relates the movements in relative prices to relative spending and the Armington trade models relates these to the trade balance. Our partial equilibrium approach imposes no asset structure and instead uses the data on relative spending and relative prices.

the sequencing effect. To begin with, we assume all fluctuations in business cycle variables - relative prices or relative spending - are unrelated to changes in trade barriers. The gap between trade flows in theory and data is then captured by the differences in inward and outward trade barriers or the gap in the trade wedge[7]. To minimize the role of this gap further we explicitly account for the well-known idea that the trade balance takes time to respond to movements in the real exchange rate and terms of trade. These lagged effects are captured by allowing for a short-run and long-run Armington elasticity and a speed of adjustment between these two horizons. By estimating these elasticities we again are being quite conservative as any changes in trade barriers that are correlated with the business cycle will bias our elasticity estimates and reduce our inferred gap in trade policy. Of course, abstracting from the slow adjustment of trade to business cycle asymmetries magnifies the importance of changes in trade barriers for the trade balance.

Our partial equilibrium decomposition of the trade balance to GDP yields three main results. First, the relatively large trade deficits as a share of GDP of the US in the 2000s compared to the 1980s mostly reflects a rise in the trade share of GDP. Second, about 40 percent of the fluctuations in the ratio of the trade balance to trade reflect an uneven pace of trade liberalization. Third, while asymmetries in the business cycle, as reflected in movements of relative production and expenditures and relative prices, account for the remaining 60 percent of fluctuations in the trade balance over trade, almost 2/3 of the business cycle induced movements in net trade flows are a lagged response to asymmetries in the business cycle. A simple way of seeing this is that the short-run Armington elasticity is estimated to be about 0.20 while the long-run is closer to 1.12 with only 6.9 percent of the gap closing each quarter. Ignoring the gradual response of net trade flows to the business cycle substantially increases the importance of uneven changes in trade barriers.

Our partial equilibrium decomposition also provides an accounting of the timing of trade integration split between common, bilateral changes in trade barriers and uneven changes in trade barriers. The dynamics of our inferred trade barriers are consistent with a typical narrative on US trade policy. There was substantial reduction in global barriers from the

[7] Our decomposition extends the trade wedge accounting approach of Levchenko, Lewis and Tesar (2010) and Alessandria, Kaboski, and Midrigan (2011, 2013).

1980s through the early 2000s. Starting in the mid 2000s trade barriers have held steady and since the Great Recession they have increased. We also find substantial differences in inward and outward barriers. Namely, the ROW appears to open up relative to the US starting in the early 80s with the rise in protectionist policies under Reagan, followed by the Canadian and North American free trade agreements. This continues until the late 90s at which point the US starts opening faster to the ROW around the time that it grants permanent normal trade relations to China and China joins the WTO. And finally, we see that the US has opened up substantially relative to the ROW since the Great Recession.

To relate the trade balance to the shocks generating business cycles we next develop a symmetric two-country DSGE model of trade integration and business cycles in section 4. Our model allows for changes in trade barriers to affect relative prices and relative spending. It also allows for past and future changes to trade barriers to affect a country's wealth and desire to borrow and lend. Our model extends the general equilibrium heterogeneous producer model of Alessandria and Choi (2007). This is a variation of the Backus, Kehoe, and Kydland (1994) international real business cycle model with heterogenous producers subject to idiosyncratic productivity shocks and a sunk and fixed cost of exporting as in Dixit (1989), Baldwin and Krugman (1989), and Das, Roberts and Tybout (2007). These forms of heterogeneity and fixed trade costs are consistent with both producer export dynamics and the slow rise in trade following a trade reform, particularly for the US.

We extend the model along two dimensions. First, we introduce a reason for producers to set different prices across countries (pricing-to-market) by allowing an exporter's elasticity of demand and markup to vary with the real exchange rate. Pricing-to-market is crucial to explain the persistent deviations from the law of one price across countries and to get the real exchange rate to fluctuate more than the terms of trade as in data (see Engel, 1999). Second, we introduce shocks to the costs of trade in each country and financial shocks that affect country-specific discount factors. We model changes in trade barriers as global and unilateral shocks. Global shocks change the cost of imports and exports equally, while unilateral shocks move the costs of imports and exports in opposite directions. Financial shocks are a parsimonious way to capture explanations based on foreigners having a relatively high savings rate relative to the US.

In our two country symmetric economy,[8] global shocks to trade barriers affect gross trade flows but do not affect net trade flows. Unilateral shocks affect net trade flows when they are not expected to be permanent. More importantly, for identification purposes, these unilateral shocks lead to large changes in the real exchange rate and small changes in the terms of trade as in the data. On the other hand, financial shocks, tend to have large effects on net trade flows and small effects on the real exchange rate.

The model is estimated on US net and gross trade flows, relative prices, and production using Bayesian methods and allows us to quantify the general equilibrium effect of changes in trade barriers on international relative prices and relative expenditures. We find that about one quarter of the movements from our empirical decomposition that were attributed to business cycles can be attributed to changes in international trade barriers as these unilateral changes have a small effect on the gap in spending across countries but a big effect on international relative prices. We also find that about 15 percent of the growth in US trade that we attributed to changes in trade barriers can be attributed to the growth in productivity in the ROW. Putting these together we find that changes in trade barriers once again account for about two-thirds of the fluctuations in the trade balance as a share of GDP since 1991. Moreover, our model predicts that holding trade barriers fixed would have lead to a smaller trade deficit since the Great Recession.

Our GE model also yields an estimate of the elasticity of substitution between imported and domestic goods that differs substantially from the partial equilibrium model.[9] In the partial equilibrium model we estimate a short-run elasticity of 0.20 and a long-run elasticity of 1.12 while in the GE model we estimate an elasticity of 2.76. Moreover, in response to a permanent decline in trade barriers, the model yields a trade elasticity of about 4.5. Thus our GE model is consistent with what Ruhl (2004) calls the trade elasticity puzzle - the

[8] Building on this paper, Alessandria, Choi and Lu (2016) consider an asymmetric variation of the current model in the context of China's trade integration and growth. With asymmetric countries, transitory common trade cost shocks also affect intertemporal trade since they have larger effects on the wealth of the smaller, more open economy. Ravikumar, Santacreu, and Sposi (2017) show global trade reforms can generate intertemporal trade in a model with capital accumulation and asymmetric countries.

[9] A large literature estimates the trade elasticity. Similar to Hooper, Marquez, and Johnson (2000), we estimate an error correction model of trade flows, but unlike that paper we focus on net trade flows. Gallaway, McDaniel and Rivera (2003) estimate these at the industry level, and find that long-run elasticities are generally two to three times short-run trade elasticities.

tendency for the trade response to fluctuations in the real exchange rate to be quite low over the business cycle, while responses to changes in tariffs and trade barriers are quite high. In our case, the low short-run elasticity can be attributed to ignoring how trade barriers influence relative prices and relative expenditures and the shocks to differential trade costs. Our estimated model also generates a path of increased export participation by US producers that closely matches the data.

We then use our estimated model to consider the effect on the trade balance of some different scenarios in which US barriers on imports rise more than exports in the future but only temporarily. As these policies are expected in the future, they generate a trade deficit today and in the long-run even after the policy has been eliminated. While the policy is in place, the US will run a trade surplus and the size of the surplus will depend on the nature of the US's trading partners response. A trade war will reduce the surplus more with time as trade declines. We show these policies have a much smaller impact in models without a dynamic exporting decision or pricing-to-market.

2. Related Literature

We conduct a dynamic analysis of US business cycles and trade integration. On the business cycle side, it builds on the international business cycle model of Backus, Kehoe and Kydland (1994), hereafter BKK.[10] Several papers extend this model to allow for a low short-run and high long-run trade response but abstract from changes in trade costs over time.[11] Unlike these papers, which focus on the model's ability to match first and second moments of filtered variables and highlight certain inconsistencies, our model is estimated to match the data and thus can decompose the source of fluctuations in key cross-country variables.[12] Indeed, while not our focus, we are able to decompose the source of the key puzzles emphasized in the literature. Additionally, since our model nests the standard models in the literature, it clarifies the necessary assumptions to capture aggregate fluctuations.

[10] See Chari, Kehoe and McGrattan (2002), Corsetti, Dedola and Leduc (2008), Heathcote and Perri (2002, 2014), and Croce, Colacito, Ho, and Howard (2018).

[11] See Alessandria and Choi (2007), Drozd and Nosal (2011), Engel and Wang (2012), and Imura (2013).

[12] Our model analysis matches relative prices, relative quantities, and trade and thus can speak to a broader range of issues related to comovement, risk sharing, and exchange rate volatility as well as the contribution of trade integration to consumption growth and employment changes.

We also contribute to the recent literature on global imbalances[13] that propose alternative mechanisms to explain the widening US trade deficit depicted in Figure 1. These papers consider one-good models that abstract from real exchange rate fluctuations or trade integration. Obstfeld and Rogoff (2005) and Dekle, Eaton, and Kortum (2008) consider multi-good models of trade balance adjustment and focus on the impact on the real exchange rate of exogenous adjustments in the trade balance. They emphasize the real exchange rate adjustment strongly depends on the elasticity of substitution and argue for different values depending the horizon considered. Kehoe, Ruhl and Steinberg (2017) also study the dynamics of the US trade balance but are focused on its contribution to the decline in manufacturing employment. They do not consider the role of changes in trade barriers. A key conclusion of our analysis is that the when trade barriers are allowed to change, the same theory can explain the 1980's and 2000's US trade balance dynamics.

Similar to Obstfeld and Rogoff (2000), we consider the role of trade costs in aggregate fluctuations. Unlike that paper, we are interested in how changes in bilateral trade costs may contribute to aggregate fluctuations. A few papers consider the aggregate effects of asymmetric trade barriers. Kose and Yi (2006) show that the cross-country correlation of output increases with bilateral trade. Fitzgerald (2012) shows that heterogeneity in trade costs is important for understanding the extent of observed risk-sharing. Barattieri (2014) also considers the effect of uneven changes in trade integration for trade imbalances that arise from symmetric changes in trade barriers across sectors but with countries differing in sectoral comparative advantage. Complementary to our analysis are Eaton, Kortum, and Neiman (2016b) and Reyes-Heroles (2016) who use multi-country multi-industry static trade models to study the role of perfectly anticipated changes in common trade barriers and other aggregates in the distribution of trade imbalances and aggregate fluctuations.[14] Our estimation of a stochastic model allows us to differentiate between anticipated and unanticipated shocks. We find that most movements in trade costs (and productivity) have been asymmetric and unanticipated and that a model with a dynamic trade decision best fits the data. Abstracting

[13] See Caballero, Farhi, and Gourinchas, 2008, Mendoza, Quadrini, and Rios-Rull, 2009, McGrattan and Prescott, 2010.

[14] These models allow for dynamic interactions in perfect foresight economies but trade is a static decision.

from these exporter dynamics leads to a much larger role for asymmetric trade barriers in the fluctuations in the trade balance. We also make clear that the persistence of a change in trade barriers crucially determines international borrowing and lending.

A recent group of papers motivated by the Great Trade Collapse also identify and measure the change in trade costs to understand their aggregate implications.[15] Unlike these papers, we allow trade to respond gradually to aggregate shocks and show that these lags strongly influence estimates of changes in trade barriers. A key finding in our paper is that abstracting from these dynamic considerations overstates the importance of trade barriers for the dynamics of the trade balance.

3. Theory and Evidence

We begin by describing the key cyclical features of US net trade flows and constructing measures of inward and outward trade barriers using the Armington demand system common to trade models. This demand system relates net trade flows to substitution effects from movements in relative prices and income effects from differences in spending. It is useful to make five points. First, consistent with the literature on the J-curve, net trade moves[16] slowly following business cycle asymmetries such as cross-country differences in spending or international relative prices. Second, with respect to the relative prices, this slow adjustment does not reflect differences in the composition of spending as emphasized by BKK. Instead, the slow adjustment of net trade flows primarily reflects differences in short- and long-run responses to movements in relative prices or relative income. Third, the theory misses out on substantial movements in net trade flows so large cyclical fluctuations in unilateral trade barriers are necessary to account for the gap between theory and data. Fourth, ignoring the slow adjustment of net trade flows would lead one to infer much larger fluctuations in trade barriers over time. Finally, we show that increases in trade, or the scale effect, has been the main driver of widening US trade deficits.

[15] See Levchenko, Lewis, and Tesar (2010) Alessandria, Kaboski and Midrigan (2010, 2011, 2013) and Eaton, Kortum, Neiman and Romalis (2016a).

[16] Some may take issue with our terminology as we are considering the comovement between a number of endogeneous variables. Our analysis should be interpretted as calculating/estimating the necessary frictions to explain the comovement between relative prices and relative quantities. In our structual model in the next section we will take a strong stand on the underlying shocks moving relative prices and quantities.

There are two key reasons to describe the determinants of net trade flows through the lens of the partial equilibrium Armington trade model. First, as nearly all models share this structure, we can go straight to the data without taking a stand on what causes international movements in the terms of trade and real exchange rate or what asset market frictions determine the relationship between relative spending and relative prices. In our general equilibrium model, we will see how assumptions along both dimensions influence our interpretation of the source of net trade fluctuations. Second, it permits us to organize the data in a way that is closely related to both the gravity literature on gross trade flows that infers trade costs from trade flows as well as the empirical literature that describes the comovement between trade flows, relative prices, and spending in terms of income and price elasticities (see Marquez, 2002, and Leibovici and Waugh, 2014).

A. Theory

We now show that the simple decomposition of the trade balance in equation 1 is closely related to the Armington trade model common to almost all multi-country trade models of integration and business cycles. In the Armington trade model, home and foreign goods are imperfect substitutes with a constant elasticity of substitution (CES). This yields a CES import demand for imports at home and exports to the ROW such that the log ratio of exports to imports is described by the following equation

$$(2) \quad \ln(X/M) = \ln(\omega^*/\omega) - \rho\left[\ln(P_x\xi^*/P^*) - \ln(P_m\xi/P)\right] + \ln(D^*/D),$$

where ρ is the elasticity of substitution between home and foreign goods, ω, ω^* are preferences for imported goods, $\xi, \xi^* > 1$ are iceberg trade costs or tariffs on exports and imports that create a gap between the factory and consumer price, P_x and P_m are the factory export and import prices[17], P, P^* are the home and foreign price levels that depend on the imported prices inclusive of trade barriers, and D, D^* denote home and foreign domestic spending on tradables.[18]

[17] According to the BLS, U.S. import and export prices generally exclude freight charges and tariffs. To the extent that these international trade costs are included in import and export prices our empirical approach will understate their importance.

[18] This equation also holds in the Eaton-Kortum and Melitz-Chaney trade models.

The trade balance to trade ratio is approximated[19] by the log export-import ratio

$$(3) \quad TBTR = \frac{X-M}{X+M} \approx 0.5 \ln\left(X/M\right),$$

so that we can then decompose the trade balance to GDP into a term that depends on the export-import ratio and another term that depends on the trade share of GDP,

$$(4) \quad TBY \approx 0.5 \ln\left(X/M\right) \cdot TRY.$$

It is useful to combine the changes in trade costs and tastes into a single term that is the trade wedge, $T = \omega\xi^{-\rho}$, $T^* = \omega^*\xi^{*-\rho}$. Defining the terms of trade and real exchange rate as

$$(5) \quad TOT = P_m/P_x \text{ and } RER = P^*/P,$$

the main equation becomes

$$(6) \quad \ln\left(X/M\right) = \ln\left(T^*/T\right) + \rho\left(\ln TOT + \ln RER\right) + \ln\left(D^*/D\right).$$

This decomposes the real export-import ratio into changes in the difference in trade wedges, substitution from relative prices, and relative expenditures. The effect of relative prices depends on the sum of the terms of trade of the real exchange rate. When considering the nominal export-import ratio this split matters as this equals

$$(7) \quad \ln\left(\frac{\xi^* P_x X}{\xi P_m M}\right) = (\rho - 1)\left(\ln TOT + \ln RER\right) + \ln\left(RER \cdot D^*/D\right) + \ln\left(\frac{\xi T^*}{\xi^* T}\right).$$

Additionally, our assumption about the source of the trade wedge will also matter as trade shocks[20] will drive a wedge between the nominal export import ratio and real export-import ratio while taste shocks will not.

The log export-import ratio does not require any assumptions about either the asset side of the model that relate relative spending to relative prices or the price frictions that relate the terms of trade to the real exchange rate. For instance, with complete markets, no capital goods and CRRA separable preferences, Backus and Smith (1993) show that the ratio of cross

[19] This approximation is quite precise. The maximum gap between the log export-import ratio and the trade balance to trade ratio is less than 0.4 percentage points (22.7 percent vs 23.1 percent).

[20] The size of this wedge will depend on how much of the trade cost is incurred to the border versus to the consumer.

country spending moves in proportion to the real exchange rate with the proportion linear in the intertemporal elasticity of substitution and that this risk-sharing condition is clearly violated in the data. Likewise, in two good models and perfect competition BKK show the terms of trade is more volatile than the real exchange rate by a factor increasing in trade openness, which is again is violated strongly in the data.

This equation also sheds light on BKK's famous "S-curve" result that echoes an earlier literature's emphasis on the J-curve. They show that the trade balance as a share of GDP is more correlated with past movements in the real exchange rate than current movements[21] and that this feature is well-described by a two country DSGE model with productivity shocks and capital accumulation.[22] In that model a positive transitory productivity shock at home leads both to a real exchange rate depreciation and a trade deficit. The cross country productivity gap lowers the price of the home good yielding a depreciation while creating a large temporary gap in investment between home and foreign leading to a trade deficit. As the gap in investment is relatively short-lived, the trade deficit is also quite short-lived while the depreciation is quite persistent yielding the cross-correlation in the data.

The apparent success of the two country RBC model in explaining the comovement between the trade balance and the real exchange rate is rooted in its two well-known failures: the quantity and price puzzles. The quantity puzzle is the inability of the model to generate business cycles that are synchronized across countries. The price puzzle is the inability of the model to generate large enough relative price movements. Whenever the real exchange rate depreciates, say from an increase in productivity, substitution makes the ratio of exports to imports increase. To generate a trade deficit with a depreciation then requires the second term, the difference in foreign and domestic expenditures, to respond strongly to offset the substitution effect. Taken together the quantity and price puzzles make the expenditure effect quite strong and the substitution effect weak. With a strong but temporary gap in cross country expenditures the ratio of expenditures will move from deficit to surplus over time

[21] BKK focus on the dynamics between the trade balance and the terms of trade. However, in their model (and the data) the terms of trade and real exchange rate are perfectly (highly) correlated.

[22] BKK focus on the nominal trade balance which is highly correlated with the real trade balance. Raffo (2008) points out that in the BKK model that real and nominal trade balances are negatively correlated when investment is constrained to match the observed pattern in the data while in the data they are quite positively correlated. Given our focus on matching trade flows and relative prices these are less of a concern.

explaining the gradual response of the trade balance following the depreciation.

Controlling for relative expenditures, the trade-expenditure ratio,

$$\text{(8)} \quad \ln(X/M) - \ln(D^*/D) = \rho\,[\ln TOT + \ln RER] + \ln(T^*/T)\,,$$

isolates the substitution effect. A depreciation will always be associated with a surplus in this alternative measure of net trade flows in all constant elasticity models. Moreover, correlations of the left hand side with lags of the real exchange rate will equal the autocorrelation of the trade-expenditure ratio.

Of the series in this equation, the only one that requires some discussion is the measure of expenditures. US expenditures are proxied with an equally weighted average of spending on consumer goods and investment goods since this accounts for trade being intensive in durables. We lack a direct measure of foreign spending and thus use a measure of trade-weighted foreign industrial production. Obviously, foreign industrial production will overstate (understate) foreign expenditures when the US is running a deficit (surplus); however, given the level of openness this tends to be a relatively small bias.[23]

Figure 3 plots the cross-correlation between the real exchange rate and two measures of the export-import ratio in the data and the BKK model. Panel A shows that the contemporaneous correlation of the export-import ratio with the real exchange rate is positive[24] in the data but that the export-import ratio is more strongly correlated with lagged real exchange rate movements with a peak correlation at about 6 quarters. Panel B shows that the cross-correlation is quite similar between the real exchange rate and trade-expenditure ratio. Indeed, there is a stronger lagged relationship. Thus, differences in the timing of expenditures do not drive the asymmetry in the data.

We next examine the cross-correlation of these variables in the BKK model from productivity shocks. The theory generates an asymmetric cross correlation function although it overpredicts the cross-correlation at all horizons. Moreover the gap between the correlation

[23]We explore some of the biases from the weighting on expenditures as well as using ROW production rather than expenditures in Appendix 2. We find these biases tend to be relatively small when we account for them both in our measure of expenditures and in our GE model.

[24]BKK actually emphasize a negative contemporaneous correlation. This negative correlation is only present when the model and data are HP filtered.

of the export-import ratio at lags and leads is much smaller than the data. More importantly, panel B demonstrates that controlling for expenditures eliminates the asymmetry in the cross-correlation function.[25] This clearly suggests a need for a time-varying Armington elasticity and/or shocks to the gap in the trade wedge to capture the dynamic relationship between relative prices and relative quantities.

B. Evidence

To evaluate the determinants of the fluctuations in the export-import ratio we follow the trade wedge literature by measuring the gap between observed net trade flows and predicted trade flows using the observed relative prices and relative spending. Doing so requires a measure of the Armington elasticity. There is much disagreement about this parameter. For instance, Eaton, Kortum, Neiman and Romalis (2016a) set it to 3 in their study of trade in the Great Recession while Heathcote and Perri (2014) advocate for an elasticity closer to 0.4. Given this disagreement, and our desire to minimize the importance of the gap in trade barriers on net trade flows, we estimate equation 8, where now $\ln(T^*/T)$ can be interpreted as a combination of trade integration shocks plus a residual. Of course, we are cautious about a structural interpretation of this parameter. Our estimation minimizes the importance of these trade wedges as a source of net trade flows and provides a simple summary of the comovement between net trade, relatives prices, and relative spending.

Table 1 reports the results of three types of regressions, in levels, first differences, and first differences with an error correction term.[26] The error correction regression permits us to distinguish between short-run and long-run relationships and are common in studies of trade dynamics (Hooper, et al., 2000, Marquez, 2002). For the level regression the term on relative expenditures is constrained to be unitary as theory suggests. All coefficients are significant.

We consider two regressions in levels. The first follows the trade literature and constrains the Armington elasticity to 3. It implies we are only estimating the mean in the data. It is

[25] For the US measure of expenditures we use a weighted average of consumption and investment while we proxy foreign expenditures on tradables with foreign industrial production from the Dallas Fed. Using this empirical measure in the BKK model delivers an almost identical result in Figure 3B. See the Data appendix for more details.

[26] The error correction model is $\Delta y_t = \beta + \gamma_{SR}\Delta p_t + \Delta d - \alpha\left(y_{t-1} - \gamma_{LR}p_{t-1} - d_{t-1}\right) + \varepsilon_t$ were y is the dependent variable, p is the relative price term, and d is the relative spending term.

equivalent to measuring the trade wedge as a residual but leads to a very poor fit, supporting our approach to estimate the elasticity of substitution. When we estimate the elasticity separately (column Level 2) we find an elasticity of substitution closer to 0.28 which is closer to the value used in the international macro literature, although this elasticity mixes the short-run and long-run effects of relative prices on the export-import ratio.

Our regressions in differences separate the short-run and long-run source of movements in net trade flows. Now the Armington elasticity is quite low in the short run. The error correction model yields a short run elasticity of 0.119 and a long-run elasticity of 1.026 with 6.6 percent of the gap between the current and long-run gap in the export-import ratio closed each quarter. If the short-run effect of differences in expenditures is allowed to differ[27] from 1, generalizing the slow adjustment, we estimate a coefficient on expenditures of 0.608, a short-run price elasticity of 0.18 and a long-run Armington elasticity of 1.09 with only 6.7 percent of the gap closed per quarter. If we follow Alessandria, Kaboski, and Midrigan, (2011, 2013) by accounting for the change in net inventory investment,[28,29] we find a slightly higher short-run and long-run elasticity of 0.204 and 1.124 and slightly faster adjustments (6.9 percent), although now the impact response of differences in expenditures is lower (0.58).

The fit, measured by adjusted R^2, of the empirical model rises from 26.2 percent in differences to 43.7 percent in our short-run/long-run model. The fit of the empirical models suggests there are substantial movements in the export-import ratio that are related to trade integration. These shocks could reflect a different pace of liberalization (contemporaneous and lagged effects) or perhaps inventory type considerations that we haven't fully accounted for. The improved fit of the error correction model, plus the relatively low short-run price and expenditure coefficients, suggest that a substantial fraction of the effects of relative spending and relative prices occur gradually. In what follows the best fit is our benchmark dynamic model.

[27] This case also helps to capture any differences related to the composition of trade being different than our measure of expenditures. A sign that this is not overly important is that when we estimate a coefficient on the long-run expenditure term it is not significantly different than 1.

[28] Alessandria, Kaboski, and Midrigan, (2011 and 2013) show that international trade frictions lead to higher inventory holdings on imported than domestic goods and that periods of rapid trade adjustment are strongly related to inventory adjustments.

[29] In this regression we only use a measure of the change in net inventory investment in the US as we lack a similar measure in US trading partners. The gain in explanatory power is thus perhaps understated.

The estimated coefficients from the regressions can be used to construct a predicted path of the export-import ratio. We decompose the export-import ratio into two components, $\ln(X_t/M_t) = \ln(X_t/M_t)^{BC} + \ln(X_t/M_t)^{TW}$, where $\ln(X_t/M_t)^{BC}$ is the business cycle component that can be explained by variation in the current and past relative prices and relative expenditure, and $\ln(X_t/M_t)^{TW}$ is the gap in the trade wedge that is composed of the current and past residuals. Figure 4A plots the predicted export-import ratio, $\ln(X_t/M_t)^{BC}$, for the static and dynamic statistical models and Figure 4B plots the gap in the trade wedge, $\ln(X_t/M_t)^{TW}$, for static and dynamic model. The dynamic model clearly captures the gradual movements in the export-import ratio to movements in the real exchange rate and relative spending. In particular, the delayed response of the trade-expenditure ratio to the Plaza and Louvre Accords and the depreciation of the dollar in the early 2000's are quite evident.

The first four columns of Table 2 report the source of fluctuations in the export-import ratio from each of our statistical models over the whole sample and in the post 1991 period. The contribution of trade liberalization and business cycle shocks is measured by their share of the variance. With a single Armington elasticity, the business cycle components account for about 40 to 52 percent of the variance in the export-import ratio. If we allow for a short-run and long-run elasticity then it increases to almost 77 percent. There is substantial positive comovement between the trade wedge and business cycle components in the single elasticity movements. If we include the comovement component to the contribution, the single elasticity models account for about 69 percent of the variance while the error correction model accounts for 83 percent of the variance.[30] A conservative reading of the data is that about 2/3 of the fluctuations can be explained by the model. We also split the error-correction model into the predicted movements coming from the short-run part of the model in the column SR*. Using this decomposition we estimate that about 1/3 of the fluctuations in the export-import ratio are the delayed response to the business cycle. We attribute the movements of the export-import ratio that are not explained by the movements in relative prices or relative expenditures as arising from unilateral trade integration shocks. Thus depending on our empirical model, uneven trade liberalization explains between 23 and 56 percent of the

[30] With the restriction of the coefficient of the relative expenditure being 1, $\ln(X_t/M_t)^{BC}$ and $\ln(X_t/M_t)^{TW}$ are correlated.

fluctuations in the export-import ratio.

Using the decomposition of the export-import ratio, we next decompose the trade balance to GDP ratio into the business cycle, the trade wedge, and the scale effect components[31],

$$TBY_t = \underbrace{0.5 \cdot TRY^* \cdot \ln\left(X_t/M_t\right)^{BC}}_{TBY_t^{BC}} + \underbrace{0.5 \cdot \left[\overline{TRY} \cdot \ln\left(X_t/M_t\right)^{TW} + \left(TRY_t - \overline{TRY}\right)\ln\left(X_t/M_t\right)\right]}_{TBY_t^{TW}}.$$

The first and second terms hold the trade share of GDP constant, $\overline{TRY}$, and the third term accounts for the changes in the trade share. Since the scale effect is one of the novel mechanisms that we emphasize, we combine these terms into TBY^{TW}. The last three columns of Table 2 reports a variance decomposition of TBY_t and we now include our decomposition using the initial trade share labelled as *Business Cycle* in Figure 2. When we set the TRY^* to the initial period, the business cycle component explains only 16 percent of the TBY_t variation. Indeed, figure 2 shows that trade wedges account for nearly all of the trade balance since the Great Recession. As we raise the TBY^*, the contribution of the business cycle component increases (16 to 52 percent) due to the scale effect. The contribution of the trade barriers (common and differential) is quite substantial. Including the comovement effects they explain about 48 to 83 percent of the TBY_t variations. The importance of business cycle versus trade shocks varies over time. Looking narrowly at the post 1991 swing we find that the contribution of the business cycle component rises 8 to 24 percentage points.

We now show that increased trade integration also accounts for a substantial share of the increased dispersion in the trade balance as a share of GDP across countries over time. Using Penn World Tables 9.0 data, in Figure 5 we plot the cross-sectional dispersion in the nominal trade balance to GDP and the nominal export-import ratio, measured as the standard deviation, against the median trade share of GDP from 1970 to 2014. There is a very strong positive correlation between the annual cross-sectional dispersion in the trade balance as a share of GDP and the median trade share of GDP but a very weak correlation between the export-import ratio and trade.[32]

[31] This is a decomposition of the source of fluctuations in the trade-balance to GDP coming from an accounting identity. It is in no way attributing the fluctuations in the trade balance to particular shocks. We will use the model to decompose the shocks leading to these fluctuations.

[32] We explored controlling for other factors such as dispersion in output growth and found this had almost no explanatory power particularly once we controlled for aggregate trade flows.

C. Changes in trade barriers

We next consider the inferred changes in policy and non-policy trade barriers from our empirical models. So far, our empirical work yields the gap in the ROW and US trade wedge. Each country's trade wedge is constructed as a residual using the estimated coefficients. Figure 4B plots the export-import ratio and the gap in trade wedges from the static and dynamic empirical models. The gap in the wedge from the static model is highly correlated with the data while the gap in the wedge from the dynamic model is much less correlated.

Focusing on the gap in the wedge from the dynamic model, there is a substantial swing in trade policy from 1979 to 1983[33] followed by more gradual change beginning in 1983 with the ROW becoming relatively more open to the US. This year certainly marks a turning point in US trade policy as Voluntary Export Restraints (VERs) on Japanese cars begin to bind[34], Steel Quotas are imposed, Congress passes the Buy America Act, and the Reagan administration steps up its push for reciprocity in trade relations. The pace of integration accelerates in the late 1980s at about the time of the Canadian-US Free Trade Agreement and again with NAFTA. Both agreements lowered barriers on US exports much more than barriers on US imports which were already quite low (see Trefler 2004).

The gradual opening of the ROW relative to the US continues until about 1989 at which point the US begins to become relatively more open to foreign goods. Our dynamic model suggests this is an inflection point in relative trade policy while the static model points to quite a large reversal in the direction of opening. Since the Great Recession the US has become substantially more open to the ROW. This may reflect the strong home bias inherent in fiscal expansions in a number of countries such as China. Absent this change in the gap in trade policy, US net trade flows would have been expected to move strongly to balance as a result of the persistently weak dollar and strong expansion in foreign output.

Figure 6 plots the common trade wedge that comes from the empirical dynamic trade model along with the HP trend with a smoothing factor of 1600.[35] A few interesting points

[33] These movements coincide with the second oil shock and may reflect changes in OPEC's market power.

[34] In May 1981 Japanese automakers agreed to limit exports of passenger cars for three years. This VER was initially not very binding given the weakness in auto sales in 1981 and 1982, but became quite binding as the economy took off in 1983. The policy was extended and remained in place through 1994. Berry, Levinsohn, and Pakes, 1999, provide a structural analysis of these policies.

[35] Here, we use the empirical model to obtain the home and foreign trade wedges, ω_H and ω_F. Then,

are evident. First, trade integration was fairly steady until the early 2000s. Second, since the mid 2000s, a couple of years prior the Great Recession, trade integration has slowed. The timing of the slow-down in the trade wedge is perhaps a bit earlier than one might suspect given the trade data, which was continuing to grow up to the Great Recession and with the Great Trade rebound. However, our empirical model allows for trade barriers and relative prices to only gradually affect trade and so the continued growth in trade reflects the final stages of the transition to changes in trade policy.

4. General Equilibrium Model

We now develop a DSGE two-country model with heterogenous producers entering and exiting the export market so that trade responds gradually to aggregate shocks. We extend the dynamic exporting model of Alessandria and Choi (2007) to include more shocks, variables markups, an endogenous discount factor, and incomplete financial markets. The model nests models with a static export decision or no export decision and is able to capture the observed comovement between the terms of trade, real exchange rate, and relative spending. It also allows for non-trade related aggregate shocks to cause "changes" in inferred trade wedges from mismeasured prices owing to changes in the extensive margin of exporting that introduce gains from variety absent from trade prices (Feenstra, 1994).

The model is useful to evaluate the impact of persistent changes in symmetric and asymmetric changes in trade costs, productivity, and financial shocks on net flows and the aggregate economy. We estimate the model to identify the source of aggregate fluctuations and conduct counterfactual policy experiments. We show how changes in trade barriers can lead to large effects on net trade flows, particularly when the shocks are temporary. We also show that alternative, simpler models that abstract from exporter dynamics yield very different accountings of the source of net trade flows and counterfactuals.

In each country, there is a final non-tradeable good made of a different mix of tradable intermediates. The final good price in each country is normalized to 1, $P_t = P_t^* = 1$, but the real exchange rate, q_t, is defined as the relative price of a basket of home to foreign goods.[36]

we estimated the bilateral wedge, ω_C, with a common factor model: $\omega_{Ht} = \alpha_H + \omega_{Ct} + \nu_{Ht}$ and $\omega_{Ft} = \alpha_F + \omega_{Ct} + \nu_{Ft}$ with AR(1) processes for ω_{Ct}, ν_{Ht},and ν_{Ft}.

[36]This assumes that the price of goods in the US in dollars is 1 and the price of a basket of goods in euros

Consumers: Consumers choose consumption and leisure to maximize welfare

$$W_0 = \max_{\{C_t, L_t\}} E_0 \sum_{t=0}^{\infty} \Theta_t U\left(C_t, L_t\right),$$

subject to a sequence of budget constraints

$$C_t + Q_t B_t + \frac{\zeta_b}{2}\left(\frac{Q_t B_t}{Y_t^N}\right) = W_t L_t + B_{t-1} + \Pi_t, \text{ for all } t,$$

where $U\left(C, L\right) = \left[C^{\gamma}\left(1-L\right)^{1-\gamma}\right]^{1-\sigma} / \left(1-\sigma\right)$. Π_t is the dividend payments from home firms and Q_t is the discount price of a non-contingent bond. To ensure stationarity, there is a small bond holding cost in each country, $\frac{\zeta_b}{2}\left(\frac{Q_t B_t}{Y_t^N}\right)$ with Y_t^N equal to nominal home GDP.

The stochastic cumulative discount factor evolves as

$$\ln\left(\Theta_{t+1}/\Theta_t\right) = \ln \beta_t = \left(1-\rho_b\right)\ln \overline{\beta} + \rho_b \ln \beta_{t-1} - \psi \ln\left(\widetilde{C}_t/\overline{C}\right) + \varepsilon_\beta/2,$$

where $\overline{\beta}$ is the steady state β, $\overline{C}$ is the steady state C, and $\widetilde{C}_t$ is the average (aggregate) consumption in the economy, and ε_β is a shock. The discount factor β_t is external. The foreign discount factor evolves similarly but with the discount factor shock coming in with a negative sign. Since Uzawa (1968), endogenous discount factors are commonly used in international models (Corsetti, et al. 2008).[37] This introduces a channel for aggregate shocks to move the real exchange rate and relative consumption in a way that models with pure time separable preferences lack (Backus and Smith, 1993). The shocks are quite common in international finance papers (Pavlova and Rigobon, 2007, or Maggiori and Gabaix, 2015)

The model abstracts from capital accumulation since this mechanism does not seem to be critical for the dynamic relationship between international relative prices and the trade balance. Empirically, investment is in our measure of spending and so one should view the consumer as having some preference for a flow of consumption and investment but ignores the effect of investment on future output.

Aggregation Technology or Consumption Index: A competitive retail sector combines a continuum of domestic varieties with the available imported varieties to produce the final

is 1 and that q is the exchange rate of dollars per euro.

[37] As in Kehoe, Ruhl, and Steinberg (2017) the discount factor shock captures aspects outside of the model that affect consumption directly but not trade.

good. The aggregators are

$$D_t = \left(Y_{Ht}^{\frac{\rho-1}{\rho}} + \omega^{\frac{1}{\rho}} Y_{Ft}^{\frac{\rho-1}{\rho}} \right)^{\frac{\rho}{\rho-1}}, \; Y_{Ht} = \left(\int_0^1 Y_{hit}^{\frac{\theta-1}{\theta}} di \right)^{\frac{\theta}{\theta-1}}, \; Y_{Ft} = \left(\int_{i \in \mathcal{E}_t^*} Y_{fit}^{\frac{\theta_t-1}{\theta_t}} di \right)^{\frac{\theta_t}{\theta_t-1}}.$$

where Y_H, Y_F are the composite domestic and imported goods, ω denotes the weight on imported goods and ρ is the Armington elasticity. The elasticity of substitution across imported varieties is allowed to be time varying, $\theta_t = \theta q_t^{\zeta}$ with q_t being the real exchange rate (a rise in q means real depreciation of home). We treat exported varieties symmetrically so that $Y_{Ht}^* = \left(\int_{i \in \mathcal{E}_t} \left(Y_{hit}^* \right)^{\frac{\theta_t^*-1}{\theta_t^*}} di \right)^{\frac{\theta_t^*}{\theta_t^*-1}}$ with $\theta_t^* = \theta q_t^{-\zeta}$. This is a parsimonious way of introducing pricing-to-market and can be microfounded with search frictions.[38] A key advantage of this form of pricing-to-market, rather than nominal rigidities, is that it generates quite persistent deviations from the law of one price. The ideal price indices for the aggregates are

$$P_{Ht} = \left(\int P_{hit}^{1-\theta} di \right)^{\frac{1}{1-\theta}}, \; P_{Ft} = \left(\int_{i \in \mathcal{E}_t^*} P_{fit}^{1-\theta_t} di \right)^{\frac{1}{1-\theta_t}}, \; P_t = \left(P_{Ht}^{1-\rho} + \omega P_{Ft}^{1-\rho} \right)^{\frac{1}{1-\rho}} = 1.$$

In equilibrium $D_t = C_t$.

Firms: The firm's production function is $Y_{it} = e^{z_t + \eta_{it}} L_{it}$, where z_t is the country-wide productivity, η_{it} is a firm-specific productivity shock with $\eta_{it} \overset{iid}{\sim} N\left(0, \sigma_\eta^2\right)$. Country-specific productivity follows an AR(1) process.

To capture the dynamics of export participation, fixed export costs are $W_t f_0$ for starters and $W_t f_1$ for continuing exporters. The (gross) marginal trade cost is given by ξ_t^* for home exporters, and ξ_t for foreign exporters. The resource constraint for each good equals

$$Y_{it} = Y_{hit} + m_{it} \xi_t^* Y_{hit}^*,$$

where $m_{it} = \{0, 1\}$ is the current export status of firm i. The marginal trade cost is stochastic and also follows and AR(1) process. We abstract from changes in the two types of fixed export costs although these do move around over the cycle as the firm must hire workers to pay these costs and the real wage does fluctuate.

[38] See Alessandria (2009), Alessandria and Kaboski (2011), or Drozd and Nosal (2012).

The dynamic program of a firm is then

$$V_t(\eta, m) = \max_{m', p, p^*, l} p y_t(p) + m' q p^* y_t^*(\xi^* p^*) - Wl - m' W f_m + Q_t E V_{t+1}(\eta', m')$$

where m summarizes past export status and determines the current fixed export cost, and q is the real exchange rate. The aggregate state which includes the exogenous trade costs, productivity, and discount factor and endogenous assets and distribution of exporters and nonexporters is subsumed in the time subscript of the value function.

As firms face market-specific demand elasticities they set a destination-specific price,

$$p_h(\eta, m) = \frac{\theta}{\theta - 1} \frac{w}{e^{z+\eta}}, \text{ and } p_h^*(\eta, m) = \frac{\theta q^{-\zeta}}{\theta q^{-\zeta} - 1} \frac{w}{q e^{z+\eta}},$$

and deviations from the law of one price will be proportional to the real exchange rate, q,

$$\frac{\ln(q p_h^* / p_h)}{\ln q} \approx \frac{\zeta}{\theta - 1},$$

If $\theta = 4$ and $\zeta = 0.75$, then a 10 percent appreciation will reduce the foreign price by 2.5 percent compared to the home price. In terms of the literature on exchange rate pass-through this implies a pass-through of 75 percent.

When the cost of starting to export exceeds the cost of continuing to export, $W_t f_0 > W_t f_1$, the decision to export is dynamic. There is a threshold technology for exporters to continue exporting, η_{1t}, and a second threshold technology for non-exporters to start exporting, $\eta_{0t} > \eta_{1t}$. Firms will move in and out of the export market in response to shocks to idiosyncratic and aggregate shocks. These thresholds satisfy the following equations

$$W_t f_m - \pi_t(\eta_{mt}) = Q_t E_t \left(V_{t+1}(\eta_{t+1}, 1) - V_t(\eta_{t+1}, 0) \right), \ m \in \{0, 1\}.$$

The mass of firms over productivity and exporting in each country is a state variable. When idiosyncratic shocks are iid, this reduces to only one additional state variable per country, the stock of past exporters, which evolves as

$$N_t^j = N_{t-1}^j \Pr\left(\eta \geq \eta_{1t}^j\right) + \left(1 - N_{t-1}^j\right) \Pr\left(\eta \geq \eta_{0t}^j\right), \ j = \{\quad ,*\}$$

Given the iid nature of idiosyncratic costs, the export decision introduces a way to lower the cost of trade by increasing the mass of low fixed-cost exporters.[39]

Aggregate Variables: The key moments of interest in the model are listed below.

$$
\begin{aligned}
Y_t^N &= \int \left(P_{hit}Y_{Hit} + q_t P_{hit}^{*} Y_{Hit}^{*}\right) di, \\
Y_t^R &= Y_t^N / P_{Ht}, \\
EX_t^N &= \int q_t P_{hit}^{*} Y_{hit}^{*} di = \omega^{*} q_t P_{Ht}^{*1-\rho} D_t^{*}, \text{ and } IM_t^N = \int P_{fit} Y_{fit} di = \omega P_{Ft}^{1-\rho} D_t, \\
NXY_t &= \frac{EX_t^N - IM_t^N}{Y_t^N}, \\
P_{Xt} &= q_t \left(\frac{1}{N_t}\int_{i\in\mathcal{E}_t} \left(P_{hit}^{*}\right)^{1-\theta_t^{*}} di\right)^{\frac{1}{1-\theta_t^{*}}} e^{\frac{\varepsilon_m}{2}}, \; P_{Mt} = \left(\frac{1}{N_t^{*}}\int_{i\in\mathcal{E}_t^{*}} P_{fit}^{1-\theta_t} di\right)^{\frac{1}{1-\theta_t}} e^{-\frac{\varepsilon_m}{2}}, \\
EX_t^R &= \frac{EX_t^N}{P_{Xt}}, \text{ and } IM_t^R = \frac{IM_t^N}{P_{Mt}}, \\
tot &= \ln\left(P_M / P_X\right), \\
\ln\left(EX^R/M^R\right) &= \ln\frac{EX^N/P_X}{IM^N/P_M} = \left(\tau_t^{*} - \tau_t\right) + \rho\left(tot + rer\right) + d^{*} - d, \\
\tau_t^{*} - \tau_t &= \ln\left(\frac{\omega^{*}}{\omega}\right) + \rho\ln\frac{\xi_t}{\xi_t^{*}} + (\rho - 1)\left(\frac{\ln N_t^{*}}{\theta_t - 1} - \frac{\ln N_t}{\theta_t^{*} - 1} + \varepsilon_m\right),
\end{aligned}
$$

Export and import price indices are factory gate prices, ignore the benefits of increased varieties, and include a measurement error. Real export and imports are nominal trade deflated by trade prices. The trade wedge will vary from changes to the ratio of trade costs and export participation, which varies from business cycle and trade cost shocks.

5. Solution and Estimation

The model is solved by linearizing around the steady state.[40] Several parameters are fixed to conventional values and the rest are estimated using Bayesian techniques (Table 3).

The time period is a quarter ($\beta = 0.99$). The weight on leisure is set so that hours worked equals 1/4. The bond adjustment cost is set to ensure stationarity. The fixed trade costs (f_0, f_1), standard deviation of idiosyncratic productivity shocks (σ_η), and the weight in the

[39]Enriching the model with persistent idiosyncratic shocks or a growth profile for new exporters yields somewhat similar propagation of trade cost and aggregate shocks (see Alessandria, Choi, and Ruhl, 2015).

[40]Even though we consider some large shocks to trade costs, trade remains a relatively small of output and so most of the dynamics look similar when we solve the model using global or local methods.

aggregator ($\omega = \omega^*$) are chosen so that in steady state trade is 10 percent, export participation is 20 percent, the quarterly exporter exit rate is 2.5 percent, and exporters are 50 percent larger than non-exporters, which are consistent with US trade and exporter characteristics in the early 90s (see Alessandria and Choi, 2014b).

There are four preferences parameters to estimate: 1) the Armington elasticity, ρ, 2) the pricing-to-market elasticity, ζ, 3) risk-aversion , σ, and 4) the weight on external habit, ψ.

We rewrite the country-specific shocks to include a common and differential shock,

$$\begin{bmatrix} \ln \xi_t \\ \ln \xi_t^* \end{bmatrix} = \begin{bmatrix} \ln \xi_{ct} + \ln \xi_{dt}/2 \\ \ln \xi_{ct} - \ln \xi_{dt}/2 \end{bmatrix} \text{ and } \begin{bmatrix} \ln z_t \\ \ln z_t^* \end{bmatrix} = \begin{bmatrix} \ln z_{ct} + \ln z_{dt}/2 \\ \ln z_{ct} - \ln z_{dt}/2 \end{bmatrix}.$$

Productivity and trade cost shocks follow an AR(1) process. It is assumed there are no spillovers of shocks and that shocks are uncorrelated. Recall that shocks to the discount factor and export/import prices move them in opposite directions across countries so that we are estimating the persistence and variance of 6 shocks. Finally, because relative prices and relative production are indices their levels must be estimated.

The fifteen parameters are estimated using six time series from the US and the rest of the world: 1) US real trade share of GDP, $((X + M)/Y)$, 2) the terms of trade plus the real exchange rate (totq), 3) the US real export-import ratio ($EXIMR$), 4) US detrended industrial production, (IP), 5) The ratio of foreign to US Industrial Production and 6) the terms of trade. Note that this implies we can match the real exchange rate and nominal export-import ratio. For these parameters we have relatively flat priors. Figure 7 shows the data and model along with the estimated innovations to productivity and trade costs.

A. Estimation Results

The shocks are found to be quite persistent as expected given this is a period of substantial trade integration, persistent trade imbalances, and persistent swings in production. The posterior mean of the common (differential) trade cost shock is close to a unit root, $\rho_{\xi_c} = 0.998$ ($\rho_{\xi_d} = 0.999$). The common trade cost is less volatile with $\sigma_{\xi_c} = 0.006$ vs. $\sigma_{\xi_d} = 0.04$. The common productivity shock is slightly less persistent than the differential productivity shock (0.995 vs. 0.996) and slightly more volatile (0.012 vs. 0.011). The persistence of the beta shock is 0.937 with a standard deviation of 0.0006.

The posterior mean of the Armington elasticity is $\rho = 2.76$, which is quite a bit higher than in our empirical analysis and provides some sense of the biases arising from not accounting for the extensive margin of trade, the endogeneity of prices and quantities, and the trade cost shocks. The risk aversion parameter equals $\sigma = 7.47$, or only slightly larger than that used by Chari et al. (2002) in their study of real exchange rate fluctuations. The pricing-to-market parameter equals 0.56. Finally, we find very little external habit of only 0.2 percent.

Figure 8 plots the path of trade costs, productivity, and discount factors along with their expected path in 1980, measured as deviations from the steady state. The gap in trade costs was quite large initially and was expected to not change much, although there were sizeable fluctuations over time. The common trade cost was quite large initially, and expected to fall slightly. The actual path of trade cost involved a much larger drop than expected (25 percent vs.. 3 percent). For productivity, the US was 15 percent below[41] the ROW in 1980 but the gap has widened instead of closing as predicted. Average productivity starts 12 percentage points above steady state and has grown. Initially, US agents are more patient but there are two large swings with US agents less patient in the 1980s and 2000's.

B. Evidence on Exporting Margin

We now show that the model generates realistic movements in export participation. A key feature of our model is the inclusion of a dynamic exporting decision. Models of this sort have been shown to explain the entry and exit decision of firms in response to changes in trade barriers (Das, Roberts, and Tybout, 2003, Alessandria and Choi, 2014b). The bottom two panels of Figure 8 plot the estimated share of US and ROW firms exporting along with a series for US exporters[42] Despite not being targeted, and the minimal heterogeneity in the model, it captures most of the growth and cyclical fluctuations in export participation.

C. Identification

In our model only asymmetric shocks affect relative quantities and relative prices. In the data there are relatively large movements in relative prices compared to relative quantities

[41] Our model does not seperate out productivity from population, employment, or capital and thus productivity primarily reflects country size.

[42] The data is described in the data appendix

hence the low Armington elasticity estimated in our empirical model. We now show that this aspect of the data suggests relatively large shocks to asymmetric trade barriers. Figure 9A plots the impulse response of key macroeconomic variables to the three asymmetric shocks.

First, consider a persistent shock to the discount factor, β, that makes the home country's agents relatively impatient. Home would like to borrow and run a real and nominal trade deficit. Because of the home bias in consumption, this increases world demand for home goods relative to foreign goods and leads to an appreciation of the home real exchange rate. This appreciation is modest compared to the movements in net trade flows. There are small increases in foreign output relative to home output and the real trade share.

Second, consider a shock that increase the ratio of home to foreign productivity, z_d. This shock decreases the ratio of foreign to home output. With an endogenous discount factor, it generates a large and persistent trade deficit. The increased borrowing combines with the change in the relative costs to generate a modest real exchange rate depreciation. Again, net trade flows move substantially more than international relative prices.

Third, consider a trade cost shock, ξ_d, lowering the cost of home imports and raising the cost of home exports. This lowers home's retail price of imports and raises the retail price of exported goods in foreign; shifting world demand towards foreign goods causing a large depreciation and a small nominal and real trade deficit. The nominal trade deficit is larger than the real trade deficit as it includes the direct effect of the change in trade costs. The effects on net trade flows are small as the shock is very close to permanent.

Figure 9B plots the dynamics of output, consumption, trade and export participation in response to shocks to common productivity. Shocks to productivity, z_c, primarily affect output and consumption while trade costs, ξ_c, affect trade and exporting. Owing to the gradual expansion of exporters from the sunk cost, exports grow gradually.

Finally, we consider each shock's contribution to the dynamic correlations observed in our partial equilibrium analysis. Table 5 reports the results of similar regressions on model generated data of 100,000 observations. The top row shows that the level regressions yield a higher Armington elasticity than in differences and that the long-run coefficient is larger than the coefficient from the level regression. In the bottom three rows we run the same regression, but now eliminating one shock from the model. Without productivity or discount factor shocks we still have a very low Armington elasticity. Without trade shocks, we recover a very high Armington elasticity with a short-run elasticity of 2.3, an average elasticity of 4.2, and a long-run elasticity of 6.1. Thus, asymmetric trade shocks bias down estimates of the Armington elasticity. These estimates along with our finding of higher elasticity from a common trade costs is consistent with Ruhl's (2004) trade elasticity puzzle.

D. Temporary Trade Protection

To highlight the influence of trade policy on the trade balance we consider a temporary trade policy such as an anti-dumping penalty, safeguard measure,[43] or voluntary export restraint.[44] This is modelled as a shock that raises the gap between import and export costs by 10 percentage points. As these policies are rarely a surprise the policy is announced to start in two quarters and last for three years. The timing of this policy (pre-announced with a 3 year duration) mimics the 1981 US policy on Japanese autos. The present value of the shock is equivalent to an AR(1) shock with a persistence of 0.92.

Four scenarios are considered. First, we consider a Negotiated adjustment with an increase in import costs and reduction in export costs. Second, we consider an immediate Trade War such that common trade costs rise with the gap. Third, we consider a Trade War that escalates gradually and de-escalates gradually. And finally, we consider a Trade War that gradually escalates and remains in place, much like in the Great Depression.

The Negotiated adjustment isolates the sequencing effect while in the Trade War cases the scale effect also matters. Each case starts from a steady state trade share of GDP of 30 percent. Agent's know which case they are in and fully anticipate how changes in trade barriers will affect trade flows.

Figure 10 depicts the dynamics of trade barriers, trade, and net trade flows under all policies. In all four cases, as agents know that barriers will be relatively high for trade into the home country in two quarters there is an incentive for the home country to consume in advance (and foreign to delay) and so the home country will run a small trade deficit initially followed by a surplus for the next 12 quarters. Once the policy is removed the home country

[43] Safeguard measures (Section 201 of 1974 Trade Act) restrict imports temporarily if an industry is injured or threatened with injury.

[44] Given the nature of the shocks we solve the model using global methods.

will run a persistent trade deficit.

Even though the gap in trade barriers is the same in all the policies, the Negotiated policy leads to larger swings in the trade balance than the Trade Wars since these also lower trade.[45] The difference in the trade balance is not monotonic since trade falls gradually with the implementation of the policy and rises gradually in anticipation of the removal, or lack thereof. In total, surpluses are 75 to 85 percent of the negotiated policy and there is a smaller deficit upon removal.

E. Variance Decomposition

We now discuss the source of fluctuations in some key variables that determine the trade balance. We focus on the contribution of different shocks. Figure 11 plots the source of fluctuations in the real trade share, export-import ratio, and real trade balance as a share of output split between the initial conditions and the subsequent shocks.

Growth in the US real trade share is plotted in panel A. About 78 percent of the growth in trade is attributed to changes in trade costs, 17 percent reflects the growth in productivity in the rest of the world, and 5 percent is the waning effects of initial conditions which mostly captures some small mean reversion in trade costs and accumulation of exporters. Discount factor shocks have no effects on the real trade share.

The real export-import ratio is plotted in the panel B. Here we see that the initial conditions, mostly the US net foreign assets could have been expected to generate a deficit over time and that this should have led to a deficit twice as large as the data by 2015. There are sizeable swings from the shocks to the difference in productivity and discount factor shocks but by the end of the sample these two together would predict a surplus. Shocks to the gap in trade costs and measurement error in the terms of trade contributed to a modest surplus in the beginning and end of the sample, but a deficit from the mid 1980s to early 2000's.

The trade balance as a share of output is plotted in the panel C. To construct this from the model we use the following accounting identity

$$TBY_t = TRY_0 \ln\left(EX_t^R/M_t^R\right)/2 + \left(TRY_t - TRY_0\right) \ln\left(EX_t^R/M_t^R\right)/2,$$

[45] The effect of the policy on output, consumption, and employement depend on the response. In the negotiated case, US consumption falls and employment rises during the policy.

which permits us to measure the direct and interacted effects of shocks and initial conditions. With 6 possible determinants of each variable it is impractical to separate out each effect. Instead, we plot a few reasonable counterfactuals. First, we plot the dynamics assuming that there are no shocks to either type of trade cost. This substantially reduces what we called the scale effect since about 85 percent of the growth in trade could be attributed to changes in common trade cost. Now the peak trade deficit in the 80s and 2000s are nearly identical at about 2 percent. Moreover, the US trade balance is roughly in balance from 1990 to 1997 and half as big since the Great Recession. Compared to our crude accounting for trade integration in Figure 2, our GE model suggests changes in trade barriers are an even more important source of the trade deficit over the sample.

We also plot the impact of the asymmetric trade shock plus the common trade cost shock interacted with all the other shocks. This makes it clear that the larger deficits in the 2000s relatively to the 1980s is almost entirely due to trade policy.

6. Sensitivity Analysis

Here we examine the sensitivity of our findings for the benchmark model by varying some key modelling assumptions. A general finding is that the benchmark model is most conservative in measuring the contribution of asymmetric trade policy shocks to net trade flows.[46] We first show that the persistence and variance of the asymmetric trade cost shock is a crucial determinant of net trade flows and relative prices. If we slightly lower its persistence we substantially increase its importance for net trade flows. If we eliminate it, so that there are no unilateral changes in trade barriers, the model fails to match the dynamics of relative prices or the nominal trade balance. If we replace asymmetric trade costs with asymmetric demand shocks to the taste for imports, we find almost identical results to the low persistence calibration. We vary the fixed export cost to make exporting a static decision and find trade cost shocks to be a bigger driver of net trade flows. We also make exporting more persistent by increasing the ratio of the startup to continuation cost and find a larger role for asymmetric trade cost shocks. We eliminate pricing-to-market and find the model attributes much more

[46] We will focus on the export-import ratio rather than the trade balance to gdp ratio since the impact of common trade costs on trade flows is not very sensitive to our modelling assumptions.

of the fluctuations in the nominal trade balance to shocks to asymmetric trade shocks. The results from these calibrations are reported in Table 6.

A. Persistence and variance of asymmetric trade policy shocks

We have shown that asymmetric trade policy shocks generate a motive for intertemporal trade. We have also found that they are important to match the high volatility of relative prices with limited fluctuations in relative trade flows. We now consider an experiment in which we lower their persistence and one in which we eliminate them entirely.

The persistence of shocks determines the incentive to borrow and lend. In our benchmark estimation, the asymmetric trade costs are near a unit root, leading us to find a relatively small role from asymmetric trade cost shocks for the real or nominal export-import ratio. There are a couple of reasons to suspect our estimation overstates the persistence of asymmetric trade shocks. First, many asymmetric trade policies are temporary such as anti-dumping duties, voluntary export restraints, quotas, or even tariffs, with well defined terminal points. Second, these asymmetric shocks identify the real exchange rate, which is well-known to be near unit root. To account for these concerns, we consider a version with a less persistent process.

We re-estimate a version of the model with $\rho_{\xi_d} = 0.975$ and find asymmetric trade cost shocks to be more important in real and nominal net trade flows fluctuations. An interesting feature is that these shocks tended to offset the fluctuations in net trade flows. Absent these shocks, from 2010 to 2015, the nominal export-import ratio would have averaged only -6.4 percent rather than -23.4 percent.

We next eliminate the asymmetric trade shocks $\left(\sigma_{\xi_d} = 0\right)$. This variation provides a much worse fit to the data as we can no longer match the terms of trade and real exchange rate separately. Figure 12 plots the real exchange rate, terms of trade, and nominal export-import ratio for this variation. The US real exchange rate now fluctuates very little and primarily mirrors the difference in productivity growth which implies a sustained appreciation of about 10 percent over the sample. On the other hand, the terms of trade fluctuates much more than the data and is even more volatile than the real exchange rate. However, nearly all of the terms of trade fluctuations are attributed to measurement error. This then implies that the nominal export-import ratio is quite far off from the data with trade deficits that are nearly twice as large as those observed in the data since 2010.

B. Demand shocks

Asymmetric trade policy shocks affect the relative cost of getting products from foreign factories to domestic consumers and tilt world demand towards the relatively low trade cost country which then causes their goods to appreciate. An alternative approach is to shock the relative taste for imported goods as in the international finance literature (Pavlova and Rigobon, 2007, Gabaix and Maggiori, 2014). In our partial equilibrium trade wedge accounting, taste and trade cost shocks work identically for real trade flows but not for nominal trade flows as trade cost shocks create a gap between these different trade flows. In our GE estimation this feature leads us to estimate a less persistent shock process and thus a larger role for them in net trade flows.

From Table 6 we see that treating these asymmetric shocks as taste shocks leads them to generate larger fluctuations in real and nominal net trade flows. Without these taste shocks as the driver of asymmetries, since 2010 the US would have run a nominal trade deficit of about 8 percent versus a deficit of 23 percent. Their importance in net flows is quite similar to the case with less persistent asymmetric trade shocks.

C. Persistence of exporting - altering the short-run and long-run elasticity

Now we consider how the time it takes to expand exports affects our results. Specifically, a key feature of the micro and macro data is that export participation and exports only gradually respond to changes in trade policy or other aggregate shocks. We capture this by using a version of the Baldwin-Dixit-Krugman-Roberts-Tybout sunk cost of exporting model. In this model, a relatively high up-front cost of exporting makes part of the entry decision an investment in lowering future export costs. We can vary the size of this investment by varying the ratio of the startup to continuation costs. We consider two variations. The first is a static model of exporting so that $f_0 = f_1$. The second is a model with an even larger gap between the entry and continuation cost. As we move from the static to benchmark to the higher sunk cost model, we increase the gap between the short-run and long-run trade elasticity. In the static model, there is only one trade elasticity. In our high sunk cost model, trade responds less in the short-run and more in the long-run relative to our benchmark model.

The static model provides a worse fit to the data. We estimate a slightly higher Armington elasticity and slightly large asymmetric trade cost shocks. It also attributes a larger fraction of the fluctuations in real net trade flows to these asymmetric trade shocks than our benchmark model and a smaller share of the fluctuations in the nominal export-import ratio.

The high sunk cost model is a slightly worse fit than our benchmark estimation. It suggests that asymmetric trade costs are more important in the fluctuations in nominal and real net trade flows than our benchmark estimation. It also suggests somewhat different contributions in key moments. For instance, the Plaza Accord in 1985 shows up as sharply reducing the real export-import ratio.

D. Pricing-to-market

Now we consider the role of pricing-to-market in accounting for net trade flows. Specifically, we eliminate pricing-to-market in the static exporting model which yields the conventional model used in both studies of trade integration and international business cycle fluctuations. In this model asymmetric trade shocks are more important drivers of net flows. Figure 13 compares the estimated contribution of asymmetric trade shocks in this model for net trade flows, relative production, and relative spending to those in the benchmark and static export model with pricing-to-market.

Without pricing-to-market we estimate a much lower Armington elasticity of 1.37 and thus require much larger shocks to the asymmetric trade costs. This substantially increases the importance of asymmetric trade costs in accounting for nominal net trade flows (see Table 8). The model now predicts that about half of the nominal export-import ratio since 2010 is accounted for by these shocks. Without pricing-to-market these shocks contribute significantly more to the real export-import ratio and have been a strong force pushing that towards surplus. Indeed, without these shocks the real trade deficit would have been about 10 percentage points larger. The bottom two panels show that these asymmetric trade shocks are now about twice as important for cross country differences in output and about 5 times as important for cross-country differences in real spending. Indeed, the static model with no pricing-to-market suggests US real expenditures relative to the rest of the world have risen by 10 percent since 2000 compared to only 3 percent in the benchmark model.

We conclude by comparing the impact of a temporary change in trade policy in the conventional trade model to our benchmark model in the bottom two panels of Figure 10. For simplicity, we focus just on the case of a gradual trade war and put the same shocks through both models. Here we see that the conventional model predicts negligible fluctuations in the trade balance and a much smaller effect on trade (15% of the decline in the benchmark model). This is largely a result of having a much lower trade elasticity and no reasons for firms to act in advance of changes in trade policy.

7. Summary

There is little doubt that the tripling of US trade from 1980 to 2015 is due to changes in trade barriers and that these barriers have differed on imports and exports over time. There is more doubt about how these trade barriers have influenced the trade balance. To quantify the role of changing trade barriers for the US trade balance, we undertake a dynamic analysis of US business cycles and trade integration. Interpreting the data on business cycles and trade integration through two standard dynamic trade models, we find that changes in trade barriers matter for the trade balance, particularly when measured as a share of GDP.

Our analysis uses observed trade flows and relative prices to examine the sources of trade balance dynamics in a large class of models. The relatively large movements in relative prices compared to net trade flows is key to identifying shocks. We show that the traditional source of movements in the trade balance operating through changes in relative prices or relative expenditure are less important than previously understood, particularly if one focuses solely on their contemporaneous effects. Allowing for gradual trade dynamics is important to not overstate the contribution of trade barriers. Extending standard models to allow for gradual trade dynamics and changing trade barriers appears necessary for understanding the cyclical behavior of the trade balance and the transmission of business cycles. While we focus on gradual trade expansion from the entry and exit decisions of firms, alternative mechanisms for gradualness should be explored, but in a manner that is disciplined by the movements in the terms of trade, real exchange rate, and relative expenditures.

We show that changes in trade policy matter for the US trade balance (and relative prices) in a period when trade grew. Whether changes in trade barriers continue to influence the trade balance depends on future policy and non-policy developments. There appear conflicting prospects though. On the one hand, common trade barrier have been fairly stable since the early to mid-2000s after steadily falling from the 1980s. As these trade barriers likely reflect bilateral changes in trade policy and there are limited prospects for US trade agreements on the horizon trade may be less important for the trade balance going forward. On the other hand, there is strong evidence that US inward and outward barriers have moved apart since the Great Recession. If trade policy is aimed at bringing these back to pre-Great Recession levels, then these may strongly influence the trade balance going forward.

Our paper clarifies how alternate assumptions about price setting and export participation identify the source of aggregate fluctuations. Without pricing-to-market or a dynamic export decision, we infer a much larger role of asymmetric trade policy shocks for borrowing and lending and aggregate fluctuations. These assumptions also imply very different estimates of the Armington elasticity and outcomes for alternative changes in trade policy.

Finally, we have focused quite narrowly on how changes in trade policy and traditional business cycle shocks affect the trade balance as this is a key variable in many models and a political lightning rod. Since our general equilibrium model is estimated to match international relative prices, US and ROW production, net and gross trade flows, there are many other features of international business cycles that are puzzling in standard models that our analysis can account for, such as the tendency of the output to be more correlated than consumption, the high real exchange rate volatility, and the weak correlation between relative consumption and the real exchange rate (the Backus-Smith puzzle). Our framework is also useful for understanding how much changes in trade barriers may have boosted growth along the transition to a more integrated economy as well as the source of the global slowdown in trade and growth since the Great Recession (see Alessandria and Mix, 2017).

Data Appendix

Here we describe the main series. Recall that our main equation is

$$\ln(X/M) = \ln(\omega^*/\omega) - \rho\left[\ln(P_x\xi^*/P^*) - \ln(P_m\xi/P)\right] + \ln(D^*/D),$$

- D - equally weighted avg. of Real PCE: Goods and Real Gross Private Domestic Investment
- D^* - US trade-weighted World Economies Industrial Production (Dallas Fed)
- P/P^* - Real Broad Trade-Weighted Exchange Value of the US$ (Mar-73=100) (FRB)
- X - Real Exports of Goods & Services (SAAR, Bil.Chn.2005$) (BEA)
- M - Real Imports of Goods & Services (SAAR, Bil.Chn.2005$) (BEA)
- P_X - Exports of Goods & Services: Chain Price Index (SA, 2005=100) (BEA)
- P_M - Imports of Goods & Services: Chain Price Index (SA, 2005=100) (BEA)
- NII - Real Net Inventory Investment (SAAR, Bil.Chn.2005$) (BEA)
- P - Consumption deflator (Consumption : Chain Price Index (SA, 2005=100)) (BEA)
- Time period: 1979q1 to 2015q4.
- An Export participation series is calculated using Compustat (1978-1996), the Census' Profile of US Exporters (1996-2015), and number of firms from Business Dynamics Statistics. For 1980 to 1996 we calculate the share of manufacturing and wholesale firms exporting in Compustat. To account for Compustat overweighting large firms we focus on participation among firms with annual sale less than 20 percent of the median firm. For 1996 to 2014, we use a count of exporters from the Census data and divide by the BDS firms in manufacturing, wholesale, transportation and retail sectors. We only use 20 percent of the retail firms in our count of total firms to adjust for the low export participation and size. We adjust participation in 1996 for a poor match rate in the Profile data and then scale the Compustat data using the 1996 ratio of Compustat to Census Profile participation.
- Penn World Tables 9.0 Data: We used the nominal export and import share of GDP.

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Table 1: Estimates of US Export-Import Ratio

	Level1	Level2	Difference	ECM1	ECM2	ECM3
Short-run						
Price	3	0.283*	0.137***	0.119***	0.180***	0.204***
		(2.52)	(4.66)	(5.02)	(6.57)	(7.98)
Spending	1	1	1	1	0.608***	0.576***
					(4.17)	(4.01)
Adjustment				0.0659***	0.0667**	0.0687***
				(3.54)	(3.54)	(3.98)
Long-run						
Price				1.026***	1.091***	1.124***
				(7.75)	(6.36)	(5.78)
N	148	148	148	148	148	148
rmse	0.348	0.075	0.0215	0.0201	0.0192	0.0187
R_a^2	-5.82	0.682	0.262	0.352	0.411	0.437
Inventory	N	N	N	N	N	Y

Period: 1979Q1-2015Q4. T-stats based on Newey-West s.e. in parentheses. ECM stands for error correction model. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 2: Decomposition of Export-Import Ratio and Trade Balance to GDP Ratio (%)

	Real Export-Import Ratio				Trade Balance to GDP Ratio		
	Level	Difference	SR*	SR/LR	Initial Trade	1986 Trade	Avg. Trade
			Whole sample				
Business Cycle	51.5	43.6	40.2	76.8	16.4	21.8	52.0
Trade Wedge	31.6	30.6	26.8	16.8	58.0	54.5	48.1
Comovement	16.9	25.8	33.1	6.5	25.5	23.7	-0.1
			Since 1991				
Business Cycle	66.8	53.6	42.2	93.2	24.0	31.9	76.0
Trade Wedge	28.1	22.8	20.5	13.9	42.7	37.7	28.7
Comovement	5.1	23.6	37.2	-7.0	36.8	33.9	-1.2
TRY^*					11.2	13.0	20.0

Note: SR* uses coefficient on difference terms only.

Table 3: Parameters

Fixed Parameters

β	ζ
0.99	0.0001

Calibrated Parameters

Parameter	Value	Target	
γ	0.301	Labor	25
ω	0.277	Trade share	10
f_0	0.128	Export	20
f_1	0.037	Exporter stopper rate	2.5
σ_η	0.150	Exporter premium	50
θ	4.000	Markup	33

Estimated Parameters

	prior mean	post. mean	90% HPD interval		prior	pstdev
ρ_{z_c}	0.950	0.995	0.990	0.999	unif	0.029
ρ_{z_d}	0.950	0.996	0.993	0.998	unif	0.029
ρ_{ξ_c}	0.950	0.998	0.996	1.000	unif	0.029
ρ_{ξ_d}	0.950	0.999	0.998	1.000	unif	0.029
ρ_b	0.950	0.937	0.913	0.962	unif	0.029
σ_{ξ_c}	0.004	0.006	0.005	0.007	invg	0.200
σ_{ξ_d}	0.004	0.040	0.035	0.044	invg	0.200
σ_{z_c}	0.010	0.012	0.011	0.014	invg	0.200
σ_{z_d}	0.010	0.011	0.010	0.012	invg	0.200
σ_b	0.001	0.001	0.001	0.002	invg	0.200
σ_p	0.010	0.023	0.021	0.025	invg	0.050
ζ	0.500	0.559	0.531	0.587	norm	0.100
ψ	0.010	0.002	0.002	0.003	invg	0.100
ρ	2.495	2.764	2.407	3.106	unif	0.863
σ	4.500	7.469	6.786	8.000	unif	2.021

Table 4: Alternative Models - Parameter Estimates

	Benchmark					Static	
	Full	ρ_{ξ_d}=0.975	σ_{ξ_d}=0	High Sunk	Demand	PTM	No PTM
ρ_{z_c}	0.995	0.984	0.990	0.995	0.990	0.995	0.994
ρ_{z_d}	0.996	0.990	0.991	0.996	0.990	0.995	0.998
ρ_{ξ_c}	0.998	0.998	0.994	0.998	0.992	0.999	0.999
ρ_{ξ_d}	0.999	0.975	-	0.999	0.997	0.999	0.994
ρ_b	0.937	0.977	0.962	0.937	0.972	0.934	0.94
σ_{ξ_c}	0.006	0.010	0.003	0.007	0.027	0.004	0.038
σ_{ξ_d}	0.040	0.047	-	0.029	0.090	0.043	0.104
σ_{z_c}	0.012	0.012	0.012	0.012	0.012	0.012	0.012
σ_{z_d}	0.011	0.011	0.011	0.011	0.012	0.011	0.011
σ_b	0.001	0.001	0.001	0.001	0.001	0.001	0.002
σ_p	0.023	0.024	0.162	0.024	0.024	0.019	0.052
ζ	0.559	0.535	0.524	0.720	0.682	0.597	-
ψ	0.002	0.002	0.002	0.002	0.002	0.002	0.002
ρ	2.764	2.249	3.622	2.724	2.124	3.330	1.385
σ	7.469	7.822	7.434	7.318	7.586	7.644	7.577
Density	2158.3	2134.9	1550.3	2155.3	2144.4	2136.4	2032.0

Table 5: Armington Elasticity Estimates from Simulated Data

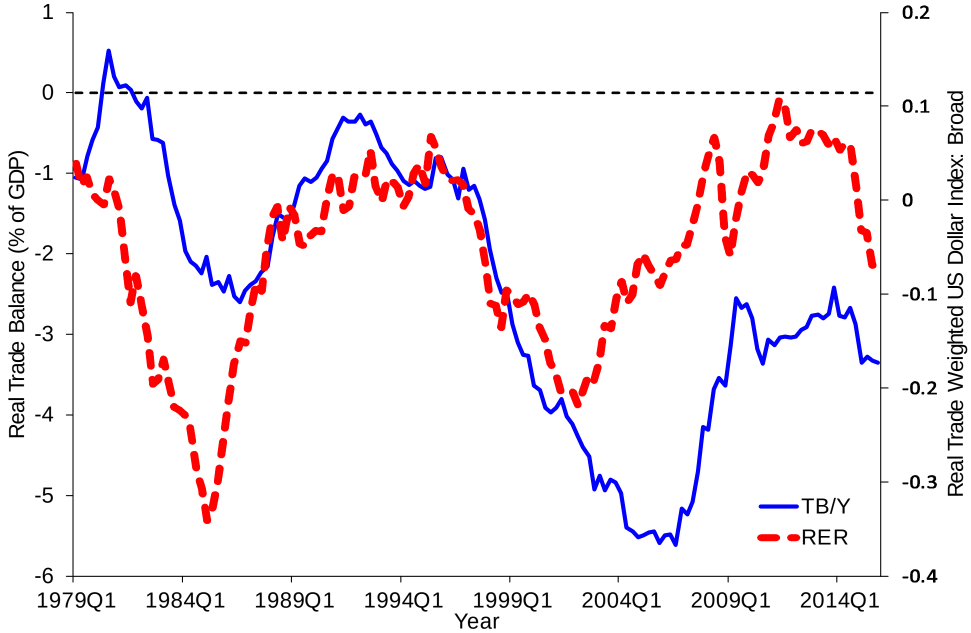
	Level	Diff.	ECM	
			SR	LR
All Shocks	0.511***	0.152***	0.152***	0.714***
	(0.002)	(0.002)	(0.002)	(0.002)
No Prod. Shocks	0.476***	0.159***	0.159***	0.485***
	(0.000)	(0.002)	(0.002)	(0.003)
No Trade Shocks	4.202***	2.358***	2.357***	6.085***
	(0.007)	(0.005)	(0.005)	(0.069)
No Beta Shocks	0.509***	0.014***	0.015***	0.934***
	(0.002)	(0.000)	(0.000)	(0.028)

Table 6 : Contribution of Shocks to Conditional Variance (%)

	Z_c	Z_d	ξ_c	ξ_d	β	ε_p	Initial	Joint	Total
				Real Export-Import Ratio					
Bench-Full	0.0	43.8	0.0	0.5	50.6	2.6	22.2	-	186.3
Bench-ρ_{ξ_d}=0.975	0.0	72.5	0.0	27.4	216.4	2.8	81.6	-	186.3
Bench-σ_{ξ_d}=0	0.0	41.1	0.0	0.0	223.8	132.4	36.5	-	186.3
Bench-High Sunk	0.0	52.7	0.0	1.1	50.7	2.7	26.6	-	186.3
Bench-Demand	0.0	75.5	0.0	13.7	123.1	2.6	49.3	-	186.3
Static-PTM	0.0	28.6	0.0	1.7	44.1	2.6	17.3	-	186.3
Static-No PTM	0.0	38.4	0.0	11.6	91.5	12.3	29.6	-	186.3
				Real Trade Share					
Bench-Full	0.0	1.9	94.7	0.0	0.0	0.0	1.5	-	39.8
Bench-ρ_{ξ_d}=0.975	0.0	0.9	100.3	0.0	0.1	0.0	1.5	-	39.8
Bench-σ_{ξ_d}=0	0.0	1.4	69.4	0.0	0.2	0.0	0.5	-	39.8
Bench-High Sunk	0.0	1.9	90.0	0.0	0.0	0.0	1.0	-	39.8
Bench-Demand	0.0	2.0	56.1	0.0	0.1	0.0	1.5	-	39.8
Static-PTM	0.0	2.0	108.5	0.0	0.0	0.0	3.8	-	39.8
Static-No PTM	0.0	1.5	110.3	0.0	0.0	0.0	3.5	-	39.8
				Real TB to GDP Ratio					
Bench-Full	0.00	39.5	0.00	0.3	37.3	1.9	1.8	49.0	2.6
Bench-ρ_{ξ_d}=0.975	0.0	61.7	0.0	20.4	160.0	2.1	13.9	21.9	2.6
Bench-σ_{ξ_d}=0	0.0	34.9	0.0	0.0	169.9	97.8	6.2	16.4	2.6
Bench-High Sunk	0.0	47.5	0.0	0.8	37.5	2.0	2.7	49.8	2.6
Bench-Demand	0.0	68.7	0.0	10.2	91.3	1.9	10.2	19.6	2.6
Static-PTM	0.0	25.7	0.0	1.2	32.6	1.9	0.7	50.8	2.6
Static-No PTM	0.0	32.4	0.0	8.7	67.7	9.1	1.6	58.2	2.6
				Nominal Export-Import Ratio					
Bench-Full	0.0	66.3	0.0	6.1	56.6	0.0	27.5	-	147.5
Bench-ρ_{ξ_d}=0.975	0.0	99.8	0.0	68.3	227.9	0.0	89.9	-	147.6
Bench-σ_{ξ_d}=0	0.0	41.9	0.0	0.0	194.1	0.0	32.2	-	208.5
Bench-High Sunk	0.0	74.9	0.0	8.7	53.5	0.0	30.8	-	147.6
Bench-Demand	0.0	101.1	0.0	45.3	131.4	0.0	52.6	-	147.6
Static-PTM	0.0	54.5	0.0	4.7	57.2	0.0	25.1	-	147.6
Static-No PTM	0.0	51.7	0.0	20.4	60.4	0.0	12.4	-	147.6
				Nominal Trade Share					
Bench-Full	0.0	0.7	58.2	3.1	0.0	0.0	0.2	-	50.3
Bench-ρ_{ξ_d}=0.975	0.0	0.5	61.4	3.3	0.0	0.0	0.1	-	49.6
Bench-σ_{ξ_d}=0	0.0	0.6	49.2	0.0	0.1	0.0	4.8	-	40.6
Bench-High Sunk	0.0	0.6	54.9	3.3	0.0	0.0	0.4	-	48.7
Bench-Demand	0.0	0.6	33.0	3.2	0.0	0.0	5.2	-	54.2
Static-PTM	0.0	0.9	64.2	2.8	0.0	0.0	0.0	-	54.9
Static-No PTM	0.0	0.8	70.4	2.2	0.2	0.0	0.1	-	50.2
				Nominal TB to GDP Ratio					
Bench-Full	0.0	45.5	0.0	3.6	32.7	0.0	4.3	49.1	2.5
Bench-ρ_{ξ_d}=0.975	0.0	68.2	0.0	44.7	135.5	0.0	8.3	22.6	2.5
Bench-σ_{ξ_d}=0	0.0	25.7	0.0	0.0	109.7	0.0	4.2	4.1	3.8
Bench-High Sunk	0.0	50.0	0.0	5.1	30.5	0.0	5.9	45.1	2.6
Bench-Demand	0.0	70.1	0.0	30.0	77.0	0.0	7.3	19.9	2.5
Static-PTM	0.0	47.3	0.0	3.3	40.9	0.0	0.9	78.2	2.1
Static-No PTM	0.0	48.8	0.0	17.5	46.7	0.0	0.1	67.7	1.3

Figure 1: US Trade Balance, Trade Share, and Real Exchange Rate

A. Trade Balance and Real Exchange Rate



B. Trade Balance and Trade Share

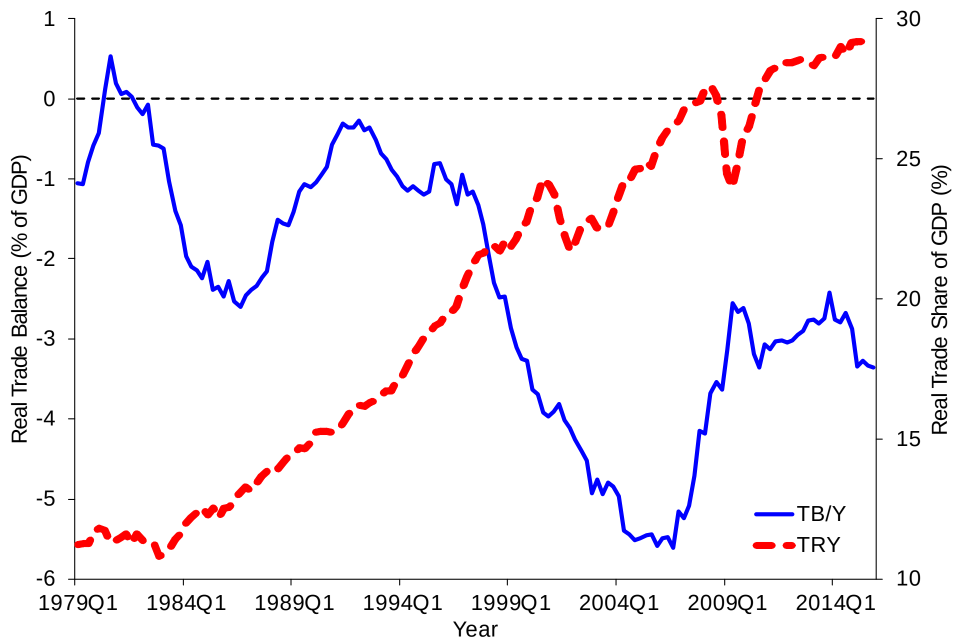


Figure 2: Contribution of Trade Growth to Trade Balance

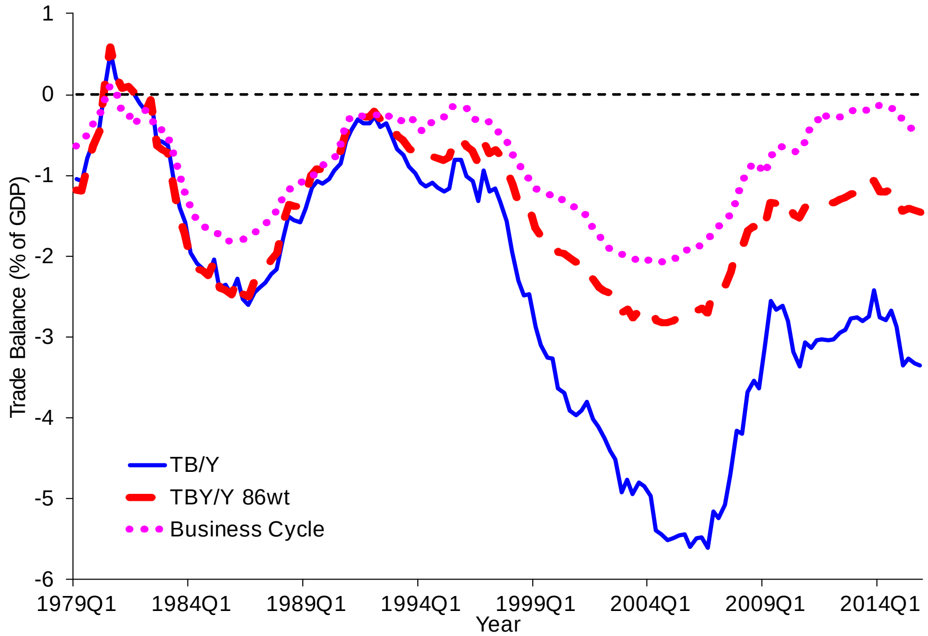


Figure 3: Comovement of RER

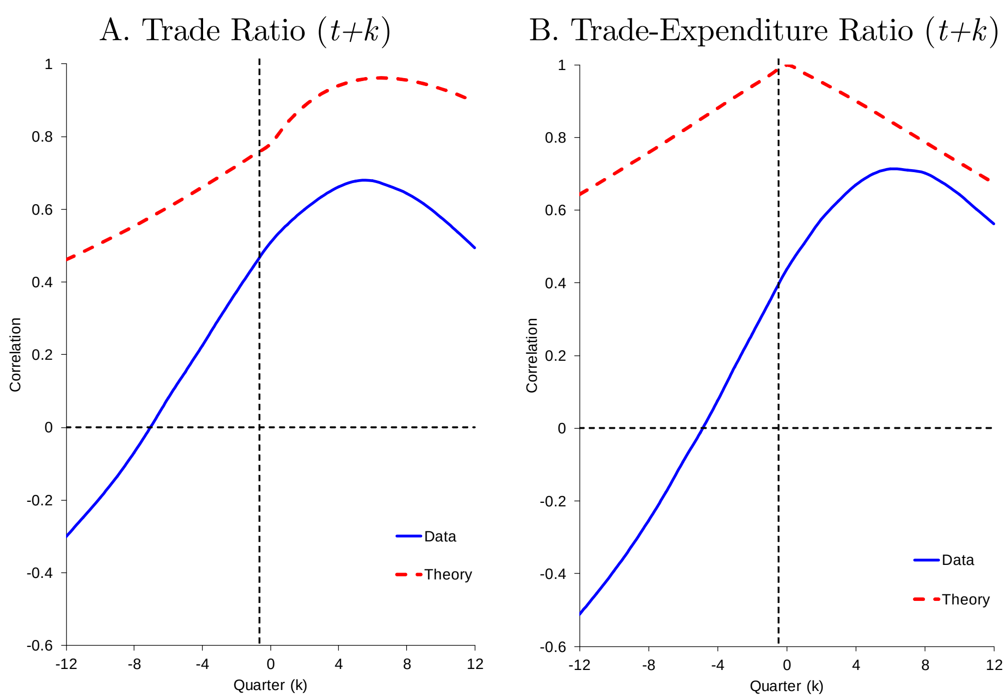
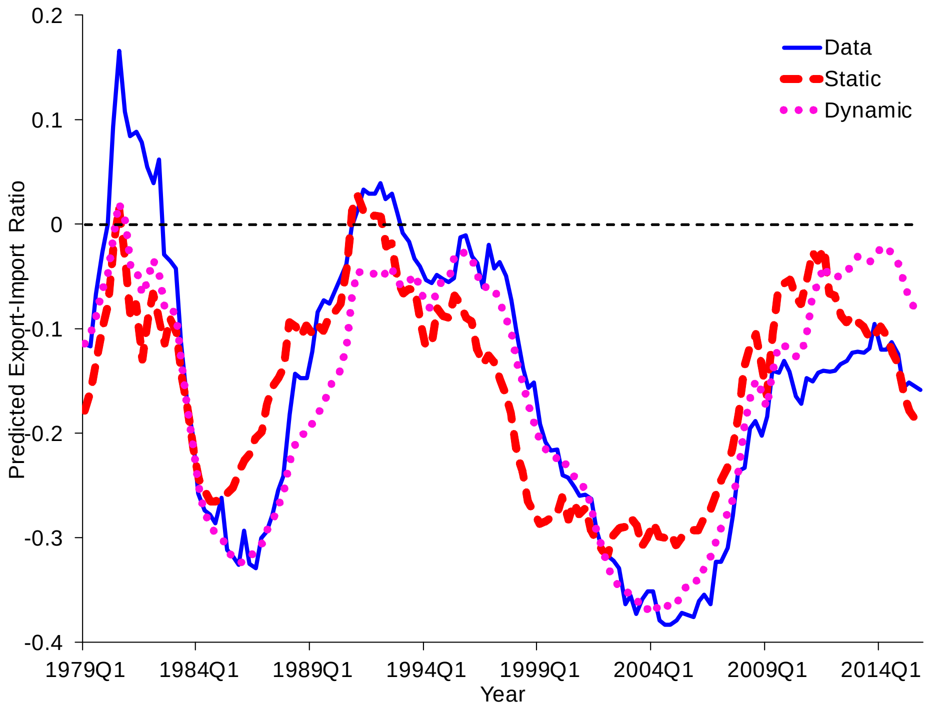


Figure 4: Net Trade Flows and Wedges

A. Export-Import Ratio



B. Export-Import Ratio and Trade Wedges

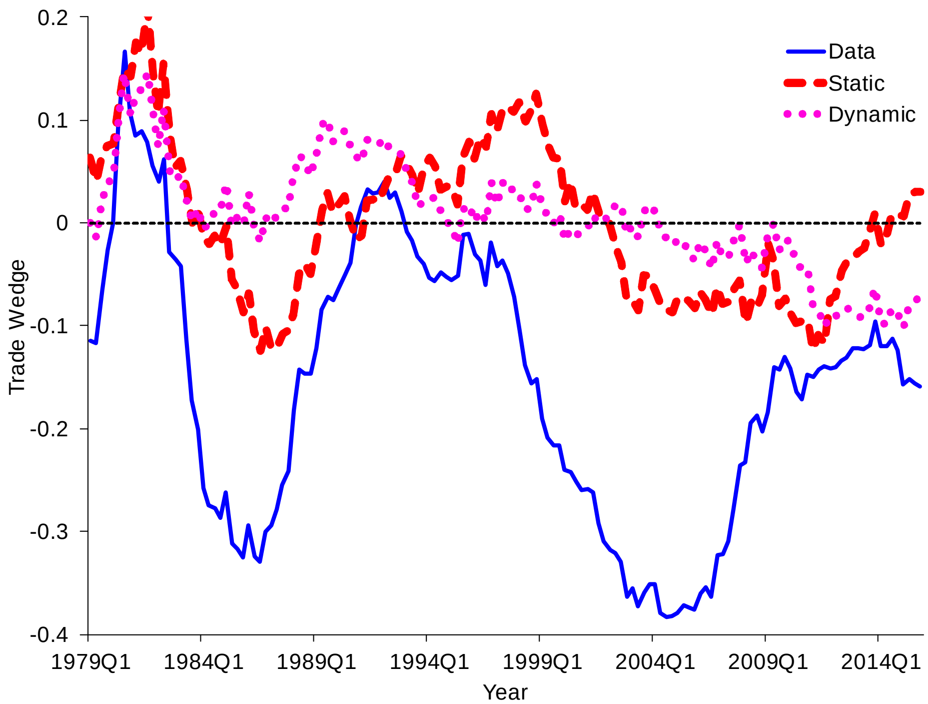


Figure 5: Dispersion in Net Trade Flows and Trade Share of GDP

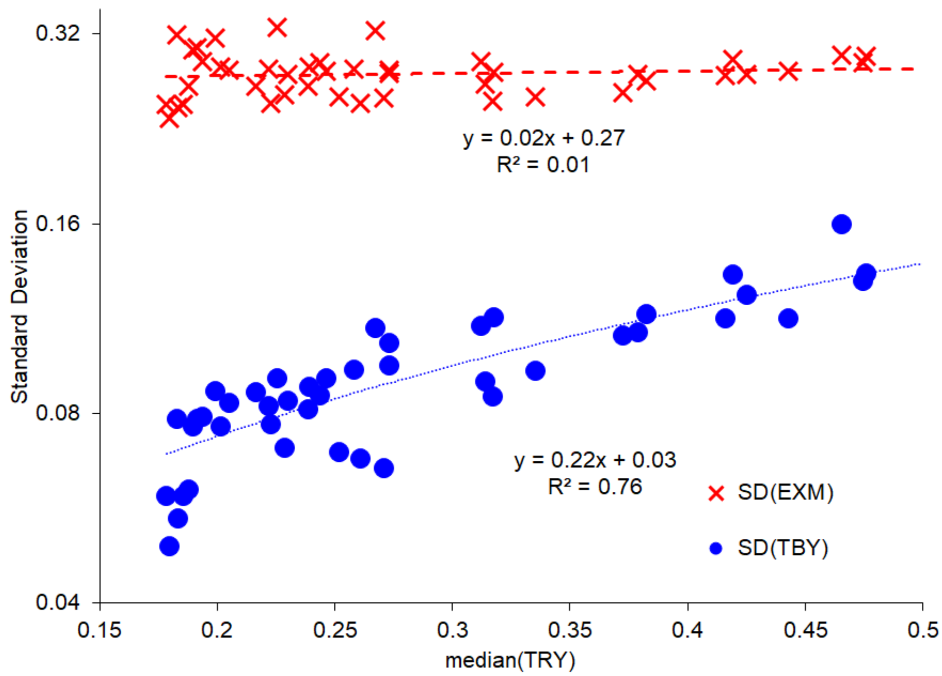


Figure 6: Common Trade Wedge

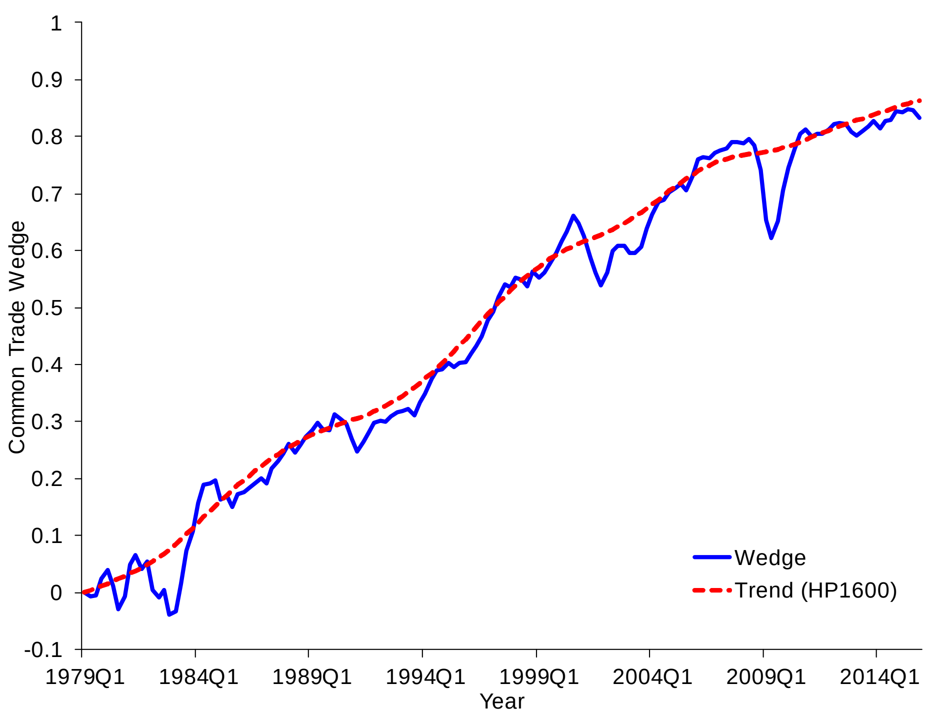
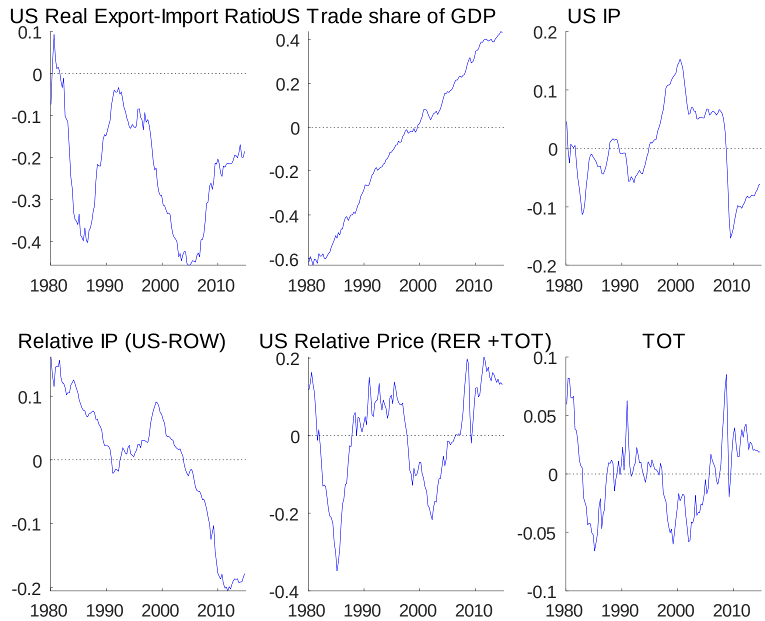


Figure 7: Smoothed Series and Shocks

A. Smoothed Series (Data and Model)



B. Estimated Shocks

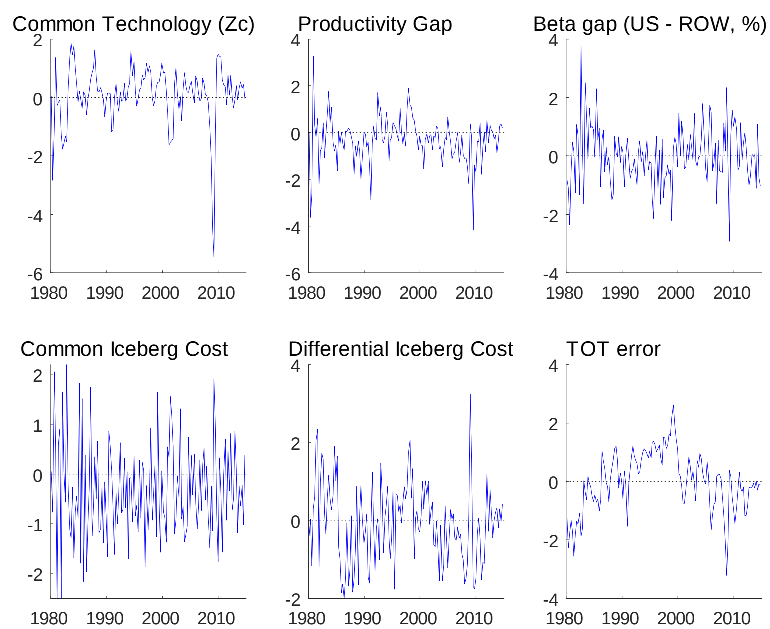


Figure 8: Dynamics of Trade Costs and Productivity: Expected and Actual

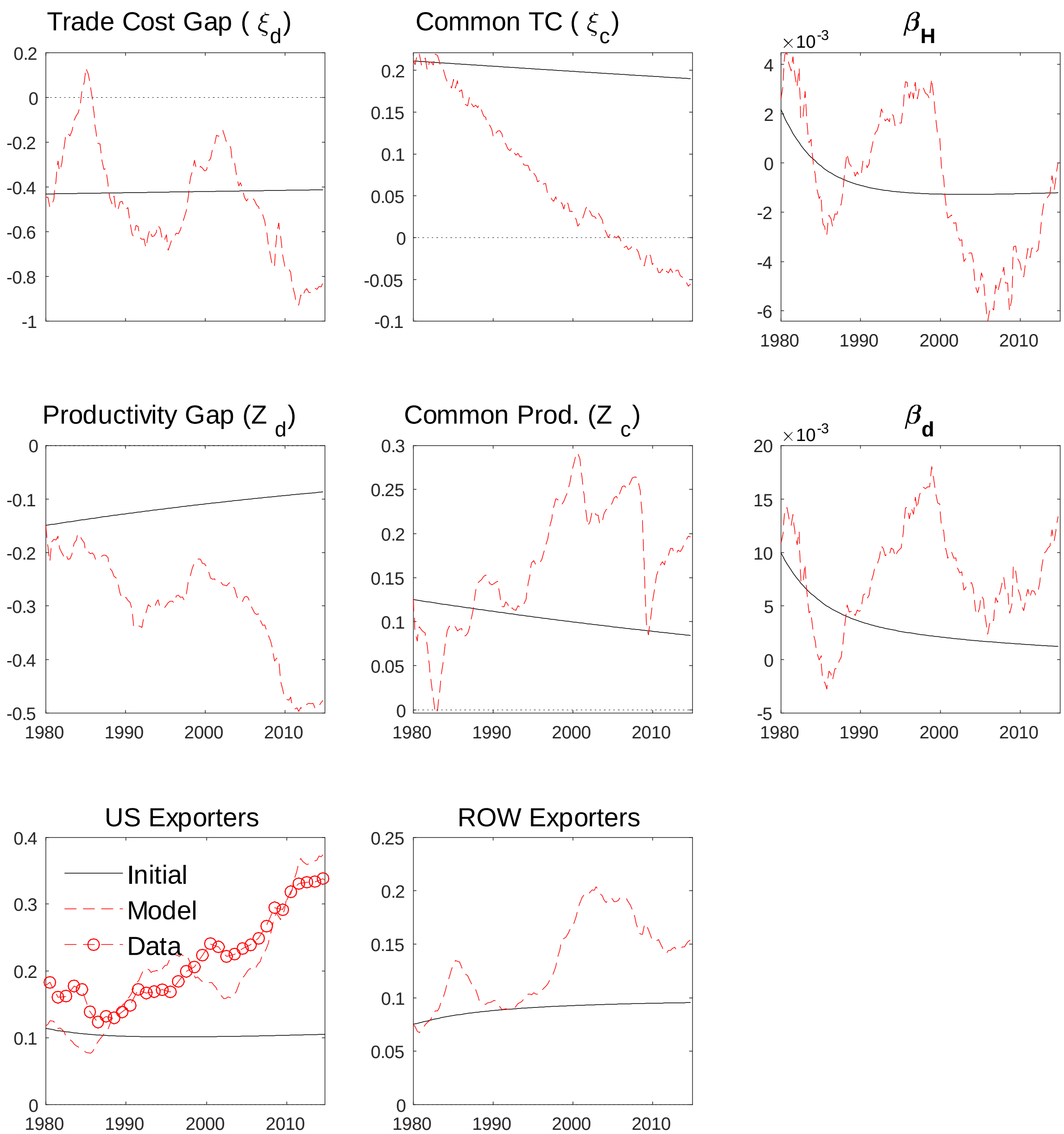
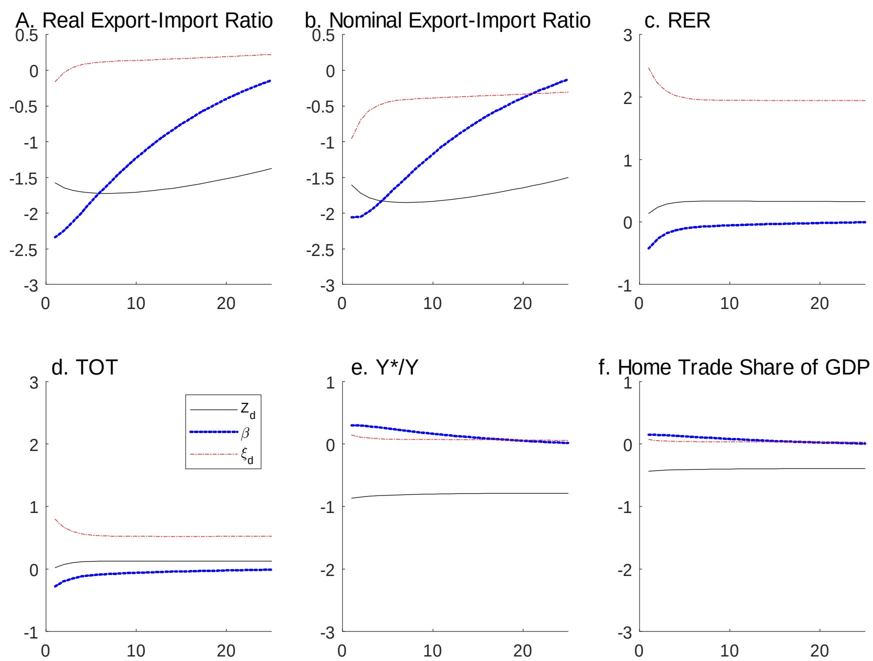


Figure 9: Impulse Response

A. Differential Shocks



B. Common Shocks

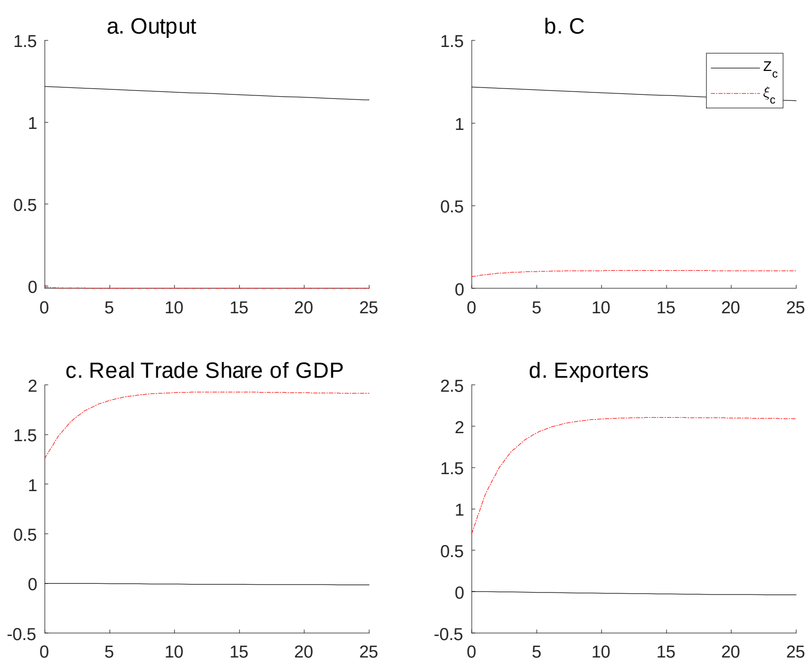
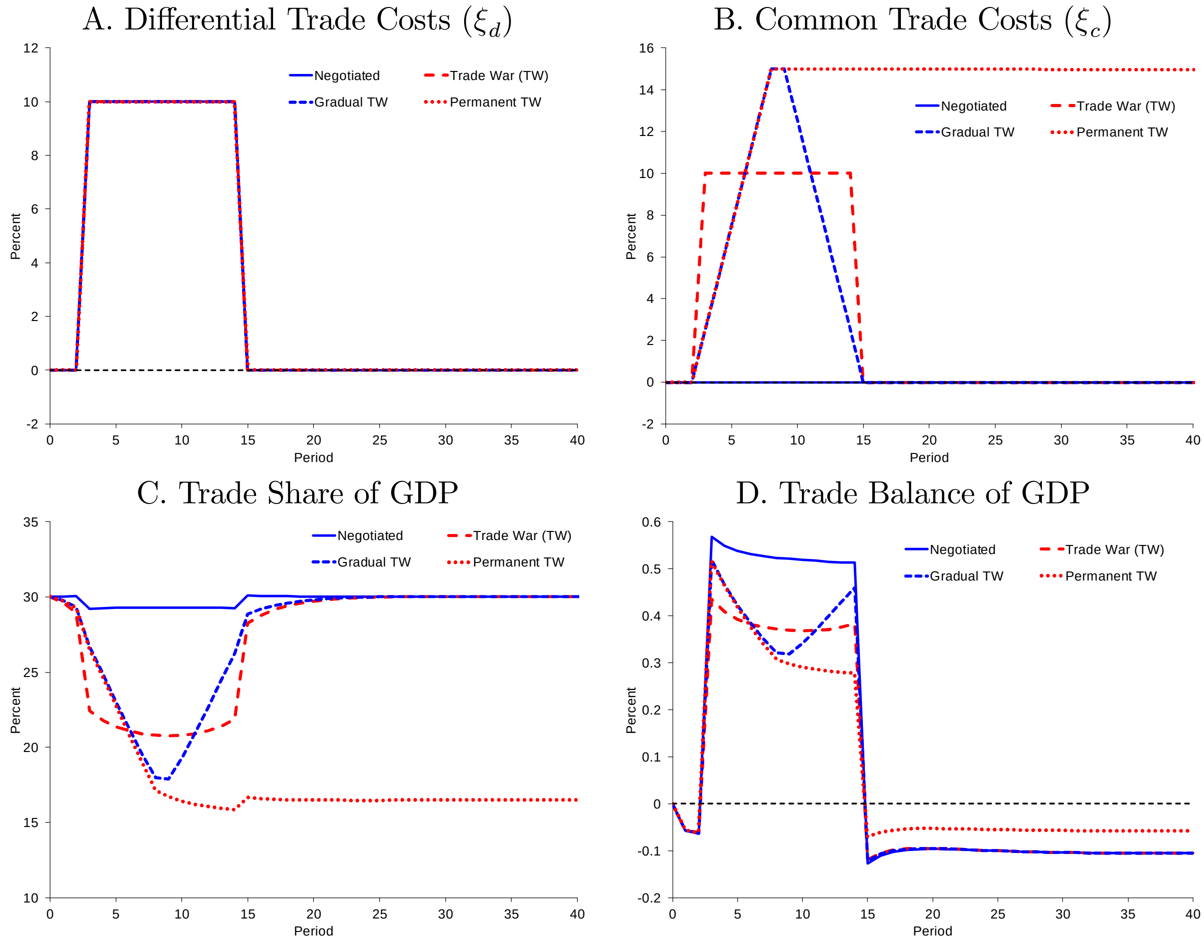


Figure 10: Temporary Trade Protection



Trade War Dynamics - Dynamic and Static Models

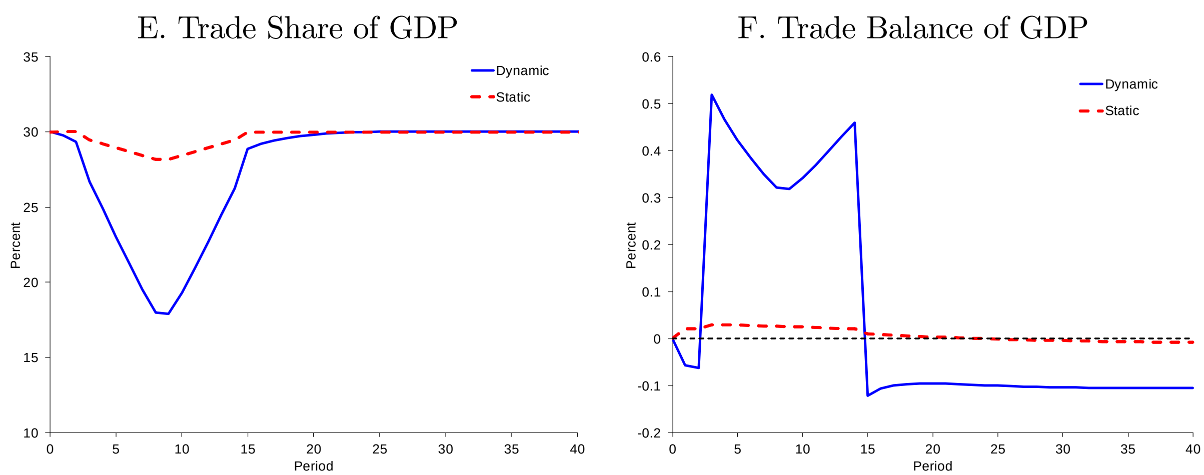


Figure 11: Decomposition Tade, Export-Import Ratio and Trade Balance

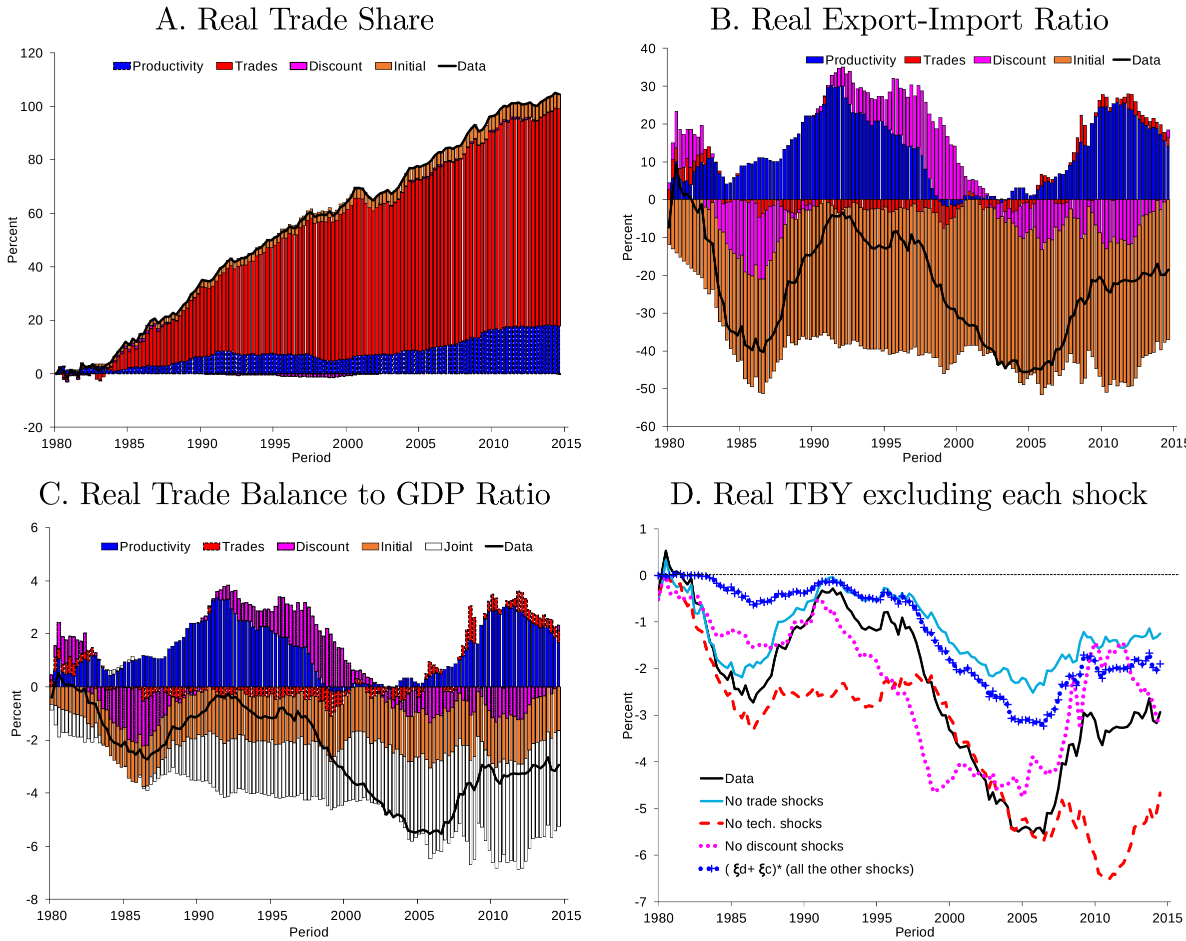


Figure 12: Estimated Time series in model with no Asymmetric Trade Shocks

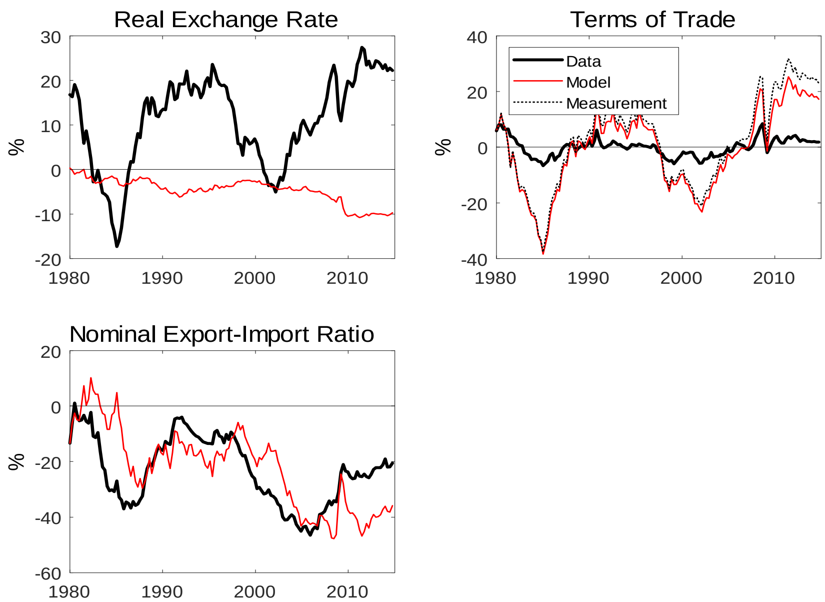
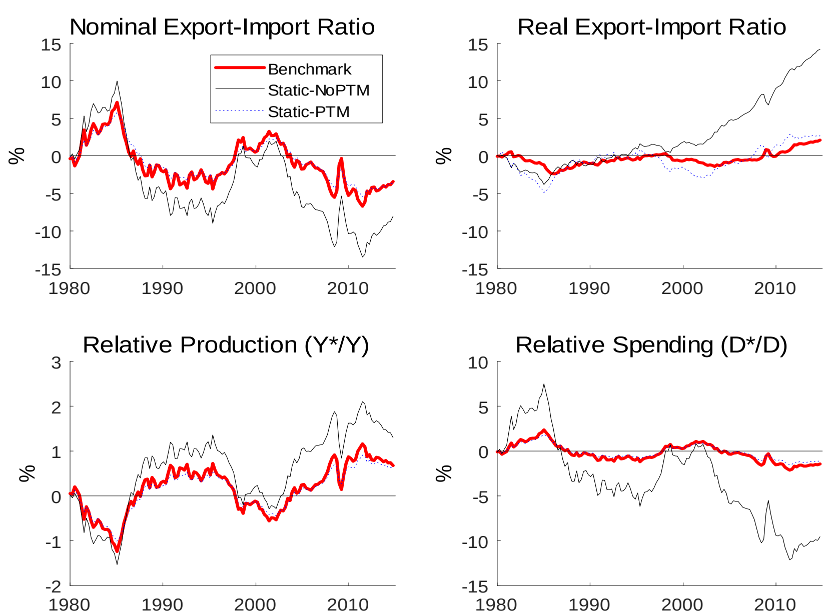


Figure 13 : Contribution of Asymmetric Trade Costs and Pricing-to-market



Appendix 2 (not for publication)

A. Empirical Sensitivity

In our estimates of the partial equilibrium model, our use of rest of world industrial production as a proxy for world demand introduces a bias. Here we show the bias is relatively small. The main problem is that industrial production may differ from expenditures owing to the ROW trade balance. We can construct a foreign measure of real expenditures by recognizing that the US trade balance will account for the difference between production and spending in the rest of the world.

$$D^N = Y^N + IM^N - EX^N$$

Assuming a steady state with all prices equal to 1 we can rewrite

$$D^R = Y^R \left(1 + \frac{IM^R - EX^R}{Y^R}\right) = Y^R \left(1 - tby^{US} \frac{Y^{US}}{Y^R}\right)$$

Using this equation, we construct a new measure of foreign expenditures. The following table reports our original findings along with this alternative measure of foreign demand with various controls. In general, we find that price elasticities seem to be slightly lower with this measure while the response to the gap in spending is slightly higher as the gap in spending is now smaller than the gap in production. These regressions explain about 5 percent more of the fluctuations in the export-import ratio but our finding that there is substantial unexplained component and net trade flows respond gradually remain robust.

The following figure shows the pattern of trade wedges, common and the gap, are quite similar to our benchmark case and still differ in substantial ways compared to a static trade model.

B. Common Trade Wedge Computation

Using the empirical estimates, we compute home and foreign trade wedges with the equations for demands imported and exported goods, ω_{Ht} and ω_{Ft}, respectively. Then, we estimate the common trade wedge, ω_{Ct}, using a common factor model with

$$\begin{aligned}
\omega_{Ht} &= \alpha_H + \omega_{Ct} + v_{Ht}, \\
\omega_{Ft} &= \alpha_F + \omega_{Ct} + v_{Ft}, \\
\omega_{Ct} &= \rho_C \omega_{Ct-1} + \varepsilon_{ct}, \\
v_{Ht} &= \rho_H \nu_{Ht-1} + \varepsilon_{Ht}, \\
v_{Ft} &= \rho_F \nu_{Ft-1} + \varepsilon_{Ft},
\end{aligned}$$

with the constraint of $SD(\varepsilon_{Ht}) = SD(\varepsilon_{Ft})$.

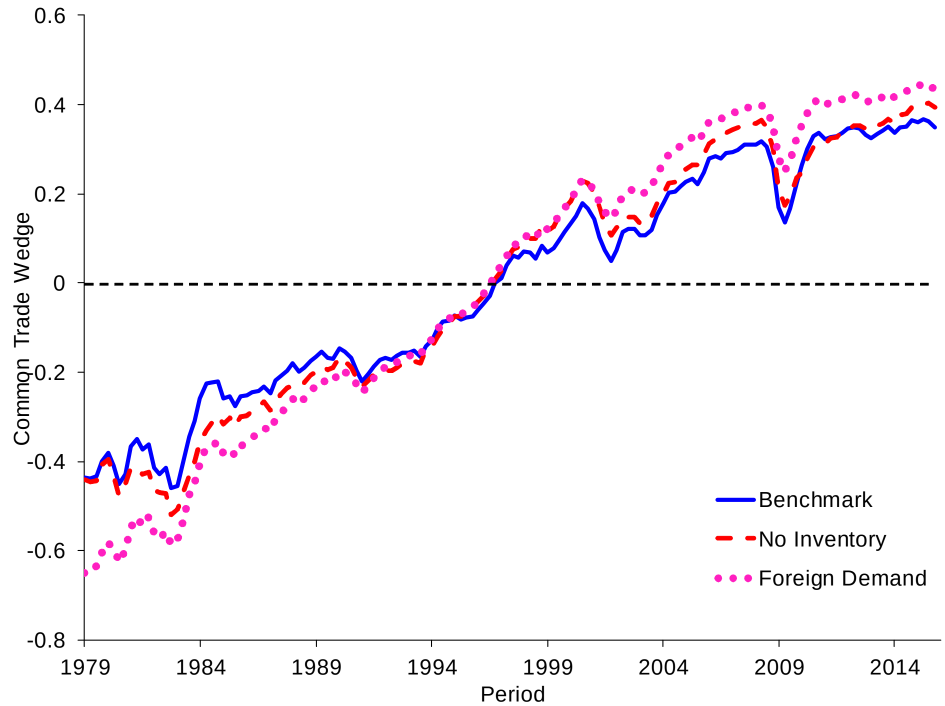
Table A1: Estimates of US Export-Import Ratio

	IP*	IP*	D*	D*	D*	D*
Short-Run						
Price	0.204***	0.202***	0.171***	0.171**	0.168**	0.168**
	(7.98)	(7.63)	(7.54)	(7.43)	(7.25)	(7.19)
$\Delta NIIY_{-2}$	1.351**	1.385**	1.315**	1.334**	0.992*	0.991*
	(4.74)	(4.84)	(5.34)	(5.39)	(5.74)	(5.70)
$\Delta NIIY_{-1}$	-1.530*	-1.513*	-1.090	-1.081	-1.145	-1.145
	(8.45)	(8.49)	(6.60)	(6.58)	(7.44)	(7.36)
Spending	0.576***	0.590***	0.690***	0.698***	0.671***	0.672***
	(4.01)	(4.09)	(5.81)	(5.89)	(4.55)	(4.52)
Adjustment	0.0687***	0.0752***	0.0775***	0.0810***	0.0727***	0.0730***
	(3.98)	(3.99)	(4.51)	(4.66)	(4.01)	(3.93)
Long Run						
Price	1.124***	0.977**	0.938***	0.868**	0.949**	0.941**
	(5.77)	(5.63)	(5.8)	(5.91)	(6.79)	(6.56)
Spending		1.290***		1.145***		1.016***
		(12.86)		(17.58)		(15.72)
$NIIY$	9.985**	10.67**	9.783**	10.16**		
	(2.82)	(3.04)	(4.17)	(4.27)		
N	148	148	148	148	148	148
rmse	0.0187	0.0188	0.0178	0.0179	0.0180	0.0181
R_a^2	0.437	0.436	0.490	0.488	0.481	0.477

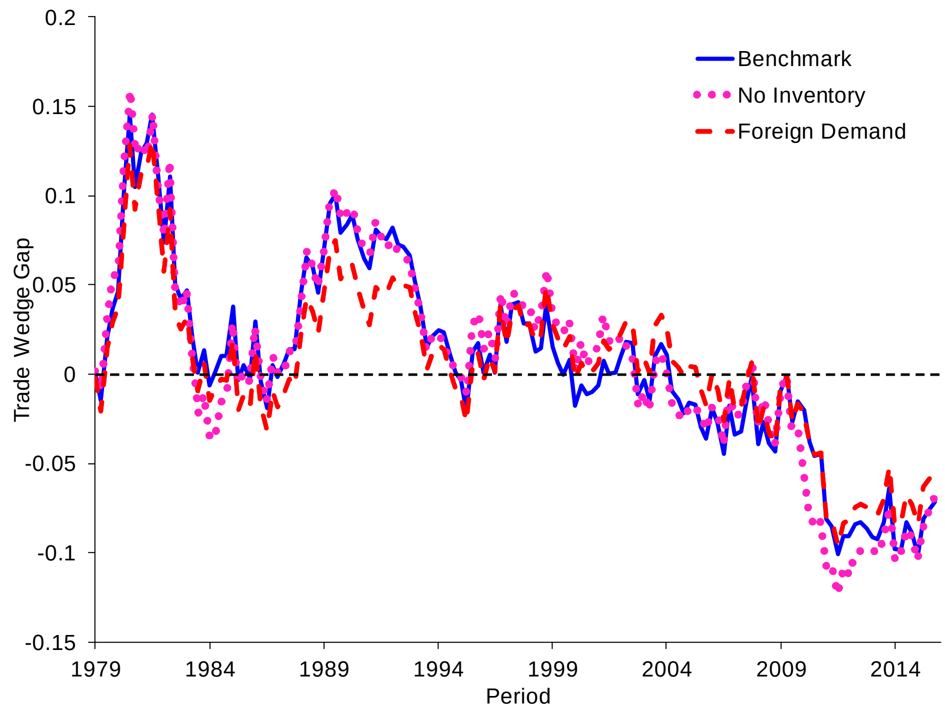
Period: 1979Q1-2015Q4. T-stats based on Newey-West s.e. in parentheses, ECM stands for error correction model.* p<0.05** p<0.01*** p<0.001". No LR Spending coefficient implies=1.

Figure A1: Trade Wedges

a. Common Trade Wedge



b. Trade Wedge Gap



Note: 1979Q1 to 2015Q4