Financial Shocks, Customer Capital and the Trade Collapse of 2008-2009*

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Abstract

The collapse in trade relative to GDP during 2008-09 was unusually large and also puzzling relative to the predictions of canonical two-country models. In a calibrated model of customer capital where firms must acquire a customer base before any sales can occur, we show that credit shocks can cause a fall in the trade-GDP ratio equal to 43 percent of the observed value. The key mechanism involves a reallocation of scarce marketing resources from international to domestic customers, who are acquired more cheaply. Bayesian estimation shows that financial shocks are important in accounting for recent fluctuations in the trade-GDP ratio. JEL Codes: E32; F41

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1 Introduction

World trade displayed an unusually large collapse during the Great Recession of 2008-2009. Focusing on the United States, total trade fell about 31 percent from peak (2008:Q3) to trough (2009:Q2). By comparison, GDP dropped only 3.4 percent over the same period. While trade usually falls more than GDP during US recessions, the relative collapse of international trade was unusually large, even after accounting for the large decline in output relative to other post-war US recessions. In order to highlight the severity of the trade collapse relative to output declines during the Great Recession, Figure 1 reports the ratio of total trade to GDP as well as the trend calculated using the Hodrick-Prescott filter over the post-war period. In levels, from peak to trough, the ratio fell 27.6 percent compared to an average drop of 13.02 percent over all recessions in the post war period.1 Interestingly, the collapse in trade is puzzling not only relative to past economic downturns but also relative to the quantitative predictions of canonical two-country business cycle models calibrated to the U.S., in that trade fell much more than would be predicted by the fall in overall economic activity or domestic absorption. Levchenko et al. (2010) shows that the “trade wedge” between the actual data and the canonical model’s prediction is extremely large during the recent collapse period. Also, Alessandria et al. (2010b), and Alessandria et al. (2013) study the trade wedge over the business cycle and show that while a two-country model with an inventory cycle embedded in it, can help explain some of the collapse in trade, a sizable trade wedge remains and it displayed an abnormal drop during 2008-2009. In order to offer further insight into the unusually large drop in the trade-GDP ratio, we build a quantitative dynamic general equilibrium model in which financial shocks reduce demand for both domestic and foreign goods, however, an endogenous reallocation of marketing inputs towards the domestic market by producers causes trade to fall more than GDP. Below, we discuss our modeling strategy in light of the large empirical literature that explores the trade collapse of 2008-2009 while also highlighting the related quantitative models.

The severity of the financial crisis accompanying the Great Recession, makes financial shocks

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1See Table 1 for a list of all recessions accompanied with the actual percentage drop in Trade-GDP ratio.
a natural candidate cause of the downturn in economic activity. Models with this feature can be found in Gilchrist et al. (2009), Gilchrist and Zakrajšek (2012), Gunn and Johri (2013), Imbs (2010), Jermann and Quadrini (2012), Kollmann et al. (2011), and Mendoza and Quadrini (2010) among others. To illustrate the co-movement between aggregate short term credit market activity and the trade collapse, we plot the percentage deviations from trend of two types of commercial paper outstanding (total and non-financial) and the trade-GDP ratio in Figure 2 for the period 2005-2014. It is clear from the graph that both series collapse together while commercial paper takes much longer to recover. As seen in Figure 2, while the trade-GDP ratio fell 16.5 percent below trend, non-financial commercial paper fell 25.6 percent below trend. Several studies have looked for related evidence linking the trade collapse to tightening conditions in trade finance. For example, Amiti and Weinstein (2011) and Chor and Manova (2012) provide evidence that tighter financial conditions caused the trade collapse. They argue that exporters are more reliant on trade credit than domestic producers and therefore suggest that difficulty in obtaining trade credit may have been responsible for the unusually large fall in international trade. Levchenko et al. (2010), on the other hand, casts doubt on the trade-credit story, finding that more trade-credit intensive sectors did not display larger trade collapses.

Unlike these studies, our model does not rely on a differentiated drop in credit to importers or exporters. Given the perceived imminent implosion of global financial markets around the collapse of Lehman Brothers, and the almost complete freezing up of inter-bank credit flows, we find it more natural to focus on financial shocks that symmetrically affect all trade, whether domestic or international. Given the evidence from Eaton et al. (2011) and Bems et al. (2010) that a large proportion of the variation in trade can be explained by a demand shock, we model the credit shock as affecting the demand side of the product markets in both countries, namely a firm’s customers. In addition, given the global nature of the financial crisis, we model the two countries in a symmetric way, so that both receive the same financial shock which leads to a symmetric fall in demand on both sides of the border.

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2In Appendix Figure A1, we report another often used measure of the health of the financial system, the spread between Libor and US T-bill rate. Once again, the rise in the spread is accompanied with a fall in the trade-GDP ratio.
The empirical literature also shows that export prices rose during and after the financial crisis which the authors view as evidence of a credit driven exporter supply shock - an increase in exporter’s costs relative to their domestic counterparts (see Ahn et al. (2011a) for example). We reiterate this by plotting the relative change of domestic prices to trade prices at the aggregate level in Figure 3. Both export and import price indices rose relative to domestic prices at the end of 2008 around the bankruptcy of Lehman Brothers and the start of the trade collapse. The mechanism built into our model involves a reallocation of resources away from international trade towards domestic markets. The ensuing decline in foreign goods relative to domestic goods is consistent with the data in that it puts upward pressure on the relative price of exports, even in the absence of a rise in exporters costs.

We explore the trade collapse in a two-country real business cycle model where firms must spend resources in order to build a customer base before selling their product. Models with this form of trading friction are known as customer capital models (see Gourio and Rudanko (2014); Drozd et al. (2014)). In our two country framework which builds on Drozd and Nosal (2012), firms wish to sell their product in both countries and therefore must accumulate a stock of customer capital on both sides of the border. A key feature of the accumulation process is an efficiency parameter which governs the relative ease of acquiring customers in any market. In our analysis, it is more expensive to acquire customers in the foreign market as compared to the domestic market. In response to a fall in demand for their product in both markets, firms choose to invest less

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3We use an import price index that excludes petroleum products to avoid the impact of the oil price collapse in 2007. We also looked at a de-trended version of the graph and found similar patterns (see Figure A2 in the Appendix.

4In contrast, Gopinath et al. (2012) do not find significant movement in trade prices using transaction-level data. They argue that the trade collapse is a quantity-driven phenomenon. In fact, the trade collapse generated by our model is largely a quantity-driven phenomenon, however, it can also generate a rise in trade prices relative to domestic prices that is consistent with the aggregate data.

5Another popular mechanism explored in the literature is a rise in protectionism, however, Eaton et al. (2011) and Kee et al. (2011) do not find evidence to support this hypothesis.

6Since Levchenko et al. (2010) provides evidence that the trade collapse was concentrated in intermediate good sectors, we model trade as occurring solely in intermediate goods that are combined together to produce the final good using a standard CES technology.

7See Drozd and Nosal (2012) for a discussion about the importance of enduring producer supplier relationships, the costs of switching and the implications of customer capital for breaking the law of one price in two-country business cycle models. Gourio and Rudanko (2014) provides additional motivation and evidence.
in building customer capital which in turn means less sales and production overall.\footnote{Behrens et al. (2013) find that virtually all of the trade collapse in Belgium occurs on the intensive margin with little evidence for exit at the firm or product level. Paravisini et al. (2015) also found similar pattern with Peruvian firm data. Chaney (2014) and Eaton et al. (2014) studied the trade dynamic where firm have to enter foreign markets (extensive margin) and then expand the network (intensive margin). Unlike these, our focus is on the intensive margin.} Moreover, due to the differentially higher cost of acquiring customers in the foreign market, firms choose to reallocate a greater share of the shrunken marketing resources away from the foreign market and towards the domestic market. As a result, customer capital falls more in the foreign market than in the domestic market which, in turn, implies that cross-border trade shrinks more than domestic trade. The fall in demand for the firm’s product is driven by a financial shock that reduces the ability of their customers to borrow in both countries. The customers are modeled as agents of a middleman who spends resources to get matched with both home country and foreign producers. (The middleman is a proxy for the substantial amount of resources spent by the economy in matching buyers and sellers. For example, in 2008, value added by the private wholesale trade sector in the U.S. was 6 percent of GDP. It fell by 5 percent from this level during the recession and slowly recovered to the same level over the next few years.) When an agent of the middleman and a producer meet, bargaining occurs to determine the price at which goods are acquired.\footnote{See also the work of Eaton et al. (2014) that tries to model and quantify these types of search costs and their impact on export dynamics. Arkolakis (2010) studies exporter’s entry and exit dynamics using market penetration costs that are convex, i.e., firms have to pay higher costs to reach additional customers.} These goods are then sold to households at a higher price. The matching costs must be paid in advance of payments by households so there is a need for working capital. Given an enforceability problem, lenders limit the amount of working capital loans available to the middleman which in turn limits the amount of goods that can be purchased from producers. A financial shock that exogenously tightens the enforceability constraint, causes the middleman to reduce the amount of resources spent on matching with producers, which in turn reduces the number of newly formed matches for a given amount of marketing expenditure by producers. As a result, there is a decline in the amount of customer capital and trade collapses relative to GDP.

Following the two-country business cycle literature, we parametrize the model to assess its quantitative ability to generate movements in the trade-GDP ratio in response to plausibly sized
credit shocks. We choose the credit shock to match the observed fall in GDP and compare the model’s predictions for trade relative to the data. A calibrated version of the model successfully accounts for 43 percent of the observed trade collapse while being consistent with a number of stylized facts of that episode including a rise in both import and export prices. Thus the paper complements the existing business cycle literature which offer alternative explanations for the trade collapse.\(^{10}\)

Given the paucity of empirical work on DSGE models of customer capital, we use Bayesian estimation techniques and US data on aggregate output, consumption, investment and trade to identify these parameters as well as shocks to total factor productivity, preference shocks and of course financial shocks. We find that the parameter values at the mode of the posterior distributions are not very far from our calibration exercise. In addition, the identified financial shocks play an important role in accounting for aggregate US data, especially the trade-gdp ratio.

The rest of the paper proceeds as follows. Section 2 describes the model. Section 3 provides our quantitative results. Section 4 outlines different variants of the model that highlight the importance of various model elements in delivering the trade collapse and shows the sensitivity of the quantitative model to several key parameters. The next section uses Bayesian inference methods to identify parameter values and shocks using US data. Section 6 concludes.

## 2 Model

Our model consists of two ex ante symmetric countries, home and foreign, each of which, has a stand-in household that supplies labor and capital to competitive firms in exchange for wage and rental payments. Both countries are subject to productivity shocks, preference shocks and financial shocks which are the only sources of uncertainty.\(^{11}\) A large number of identical firms, of unit

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\(^{10}\)In related work, Alessandria et al. (2010b) provides evidence and a general equilibrium model in which the inventory cycle plays an important role in generating a trade collapse in response to an exogenous rise in the interest rate paid by firms. Alessandria et al. (2010a) provides more detail on modeling the inventory cycle, while Novy and Taylor (2014) uses an inventory cycle model to generate trade fluctuations driven by an uncertainty shock.

\(^{11}\)Productivity and preference shocks are included in the model for calibration of certain parameters as well as in the estimation of the model in the penultimate section. They cannot, by themselves, generate a trade collapse in a
measure, produce country-specific tradable intermediate goods: a domestic good \((d)\) and a foreign
good \((f)\). There is a product market friction that makes sales between the households (who have
access to a CES technology for converting intermediate goods into final goods ) and the tradable
good firms non-trivial. A middleman who specializes in delivering these goods to the household
and matching with producers of both countries is required to resolve this friction.\(^{12}\) Time is discrete
and has an infinite horizon. An asterisk denotes variables in the foreign country. In the following,
we concentrate on developing various agent’s problems from the domestic country’s perspective,
while only discussing the foreign country problems where necessary. Figure 4 summarizes the
working of the model.

2.1 The Household

In each period, the household maximizes expected discounted lifetime utility by using their income
to purchase units of the domestic and foreign good \((d_t\) and \(f_t\) respectively) which are in turn
converted into the final consumption-investment good using an in-house technology. In addition,
households borrow using units of a non-state contingent, one-period, internationally traded bond,
\(D_{t+1}\) which must be repaid in next period. Income is obtained by choosing hours worked, \(N_t\),
renting out capital held, \(K_{t-1}\) to firms taking prices as given. In anticipation of the estimation
exercise to be carried out in a later section, we add a shock to preferences. Lifetime expected
discharged utility is given by:

\[
\sum_{t=0}^{\infty} \beta^t E_t \left( (z_{p,t}C_t)^\psi (1 - N_t)^{1-\psi} \right)^{1-\sigma} / (1 - \sigma)
\]

(1)

where the \(z_{p,t}\) is an exogenous preference shock following an AR(1) process:

\[
\log z_{p, t+1} = \rho_{zp} \log z_{p, t} + \epsilon_{z_{p, t}}, \text{ where } 0 < \rho_{zp} < 1
\]

\(\epsilon_{z_{p, t}}\)

\(^{12}\)These middleman can be thought of as wholesalers or distributors who have a lower cost of matching with producers. Previous work with middleman in an international context can be found in Ahn et al. (2011b) and Bai et al. (2013).
In period $t$, budget constraint for the household is given by

$$w_t N_t + r_t K_{t-1} + Q_t D_{t+1} + \Pi^M_t + \Pi^F_t \geq P_d d_t + P_f f_t + D_t$$

(3)

Here $P_d$ and $P_f$ refer to the price of the domestic and foreign good charged by the middleman. The household receives labor income at wage rate, $w_t$ and capital rental income at the rate $r_t$. Additionally, as owners of all firms, the household receives lump-sum transfers of profits from the middleman, $\Pi^M_t$, and firms, $\Pi^F_t$. The household also makes within period loans to the middleman to cover their matching cost. We assume the loan does not pay out any interest following Jermann and Quadrini (2012) and is returned at the end of the period, therefore, we omit notation for it here. The household can smooth consumption by using the international bond where $Q_t$ is the price of the bond and $D_{t+1}$ is the amount of bonds the household can buy or sell.

After the household purchases the domestic and foreign intermediate goods from the middleman, it uses the following technology to combine $d_t$ and $f_t$ into the final good, $G_t$, which is in turn allocated between investment, $I_t$, and consumption, $C_t$.

$$G_t = C_t + I_t$$

(4)

Here,

$$G_t = \left( \omega d_t^{(\gamma-1)/\gamma} + (1-\omega) f_t^{(\gamma-1)/\gamma} \right)^{\frac{\gamma}{\gamma-1}}, \quad \gamma > 0 \quad \text{and} \quad 1 > \omega > 0$$

(5)

where $\gamma$ determines the long-run trade elasticity, and $\omega$ determines the home bias. Physical capital, $K_{t-1}$, follows a standard law of motion,

$$K_t = (1-\delta_K) K_{t-1} + I_t, \quad 0 < \delta_K < 1$$

(6)

The foreign household is identical except for the bond price which is written as $Q_t/e_t$ since the bond is traded in units of home country’s consumption. Here $e_t$ denotes the real exchange rate in term of the consumption in the home country.
2.2 Producer Firm’s Problem

Producers in any country hire labor and capital, and use a standard, constant return to scale production function to produce output for sale in both the home country and the foreign country. Since all firms in a country are the same, anticipating a symmetric equilibrium in which all firms make the same decision, we eschew firm specific notation. To simplify the problem, we first solve for the unit cost function:

\[ v_d = \min_{k,n} \{ w_t n_t + r_t k_{t-1} \quad \text{s.t.} \quad z_t n_t^{1-\alpha} k_{t-1}^\alpha = 1 \} \]  

(7)

where \( z_t \) is an exogenous technology shock following an AR(1) process

\[ \log z_{t+1} = \rho_z \log z_t + \epsilon_{z,t}, \text{ where } 0 < \rho_z < 1 \]  

(8)

and \( v_d \) is also the marginal cost for the economy since the production function is constant returns to scale.

Following Drozd and Nosal (2012), the key departure from a canonical two-country model such as Backus et al. (1992) is the requirement that firms must build customer relationships before any sales can be made. Customers are acquired through a matching process that requires an input from firms which we call marketing capital. We interpret marketing capital in a broad sense to include advertisements, expenses on trade shows and sales staff, expenses that ease delivery of goods, other distribution costs, destination-specific packaging, cost to tailor the product for the counterpart, and so forth. The matching friction implies that building customer capital takes time, and thus sales and prices take time to change.

Taking marginal cost, \( v_d \), from the problem above, firms choose both the quantity of goods to produce and how much to invest in marketing capital in order to maximize the discounted profit stream:
\[
\max \sum_{t=0}^{\infty} Q_t \left\{ (q_{d,t} - v_{d,t}) d_t + (e_t q_{d,t}^* - v_{d,t}) d_t^* - \zeta_d v_{d,t} a_{d,t} - e_t v_{f,t} \zeta_d^* a_{d,t}^* \right\}
\]

The first term, \( (q_{d,t} - v_{d,t}) \), is the markup from selling one unit of the good, \( d \), to the domestic middleman while the second term represents the markup from selling to the middleman in the foreign country after adjusting for the exchange rate, each multiplied by the units sold at home and abroad respectively. The third and fourth terms measure the total marketing cost in the home and foreign country. Firms must use factors in the country where they wish to acquire customers so foreign marketing costs must be converted using the exchange rate in the fourth term. The ratio, \( \frac{\zeta_d^*}{\zeta_d} \), denotes the foreign to home marketing cost differential; a ratio greater one represents a higher cost for firms to market in the foreign country. These cost differentials can arise because of language barriers, informational frictions that are more severe in cross border trade, extra costs to maintain an office abroad, the cost to hire a foreign agent to run the marketing, and so forth.

Domestic producers maintain two lists of customers at home and abroad separately. Given the amount of matching agents (determined by the middleman, see below) and the marketing capital currently held by producers, they meet \( \pi_{dt} h_t \) new customers who get added to the customer list, \( H \), which evolves according to:

\[
H_{d,t} = (1 - \delta_h) H_{d,t-1} + \pi_{dt} h_t
\]

where \( \delta_H \) is an exogenous separation rate governing the loss of customers. An analogous accumulation equation for customers in the foreign market is:

\[
H_{d,t}^* = (1 - \delta_h) H_{d,t-1}^* + \pi_{dt}^* h_t^*
\]

The size of the customer list determines the amount of goods the producer can sell. Specifically, sales cannot exceed the number of customers the firm has contacts with,

\[
H_{d,t} \geq d_t \quad \text{and} \quad H_{d,t}^* \geq d_t^*
\]
The matching environment implies that producers must first match with an agent sent by a middleman, who will then deliver the “new contact” made to the middleman. Bargaining over prices occurs between middleman and producer and, in equilibrium, this new contact is added to the customer list. Domestic firms have to compete with foreign firms in matching with agents, \( h_t \), sent by the middleman. To simplify the problem, only the marketing capital, \( m \), held by a firm determines the probability of matching.\(^{13}\) A producer from the home country matches with a fraction of the agents operating in the domestic market, \( h_t \), which is given by \( \pi_d = \frac{m_{d,t}}{\bar{m}_t + m_{f,t}} = \frac{m_{d,t}}{\bar{m}_t} \), where \( \bar{m} \) refers to market averages. Similarly, foreign producers match with agents in the domestic market with probability \( \pi_f = \frac{m_{d,t}}{m_{d,t} + m_{f,t}} = \frac{m_{f,t}}{\bar{m}_t} \). In the foreign market, the home producer matches with a fraction of the agents, \( h^* \), given by \( \pi^*_d = \frac{m_{d,t}^*}{m_{d,t}^* + m_{f,t}^*} = \frac{m_{d,t}^*}{\bar{m}_t^*} \) while \( \pi^*_f = \frac{m_{f,t}^*}{m_{d,t}^* + m_{f,t}^*} = \frac{m_{f,t}^*}{\bar{m}_t^*} \) is the fraction of foreign agents that match with the foreign producer. We will refer to these fractions as market share in the paper.

The domestic producers accumulate marketing capital in the home country following the equation below:

\[
m_{d,t} = (1 - \delta_m)m_{d,t-1} + a_{d,t} - \phi \left( \frac{a_{d,t}}{m_{d,t-1}} - \delta_m \right)^2 m_{d,t-1}
\]

and similarly in the foreign market,

\[
m_{d,t}^* = (1 - \delta_m)m_{d,t-1}^* + a_{d,t}^* - \phi \left( \frac{a_{d,t}^*}{m_{d,t-1}^*} - \delta_m \right)^2 m_{d,t-1}^*
\]

Marketing capital from last period, \( m_{d,t-1} \), depreciates at rate, \( \delta_m \). Firms choose the amount of marketing input, \( a_{d,t} \), to adjust or maintain the current marketing capital level, \( m_{d,t} \). Following Drozd and Nosal (2012), the marketing capital accumulation equation involves depreciation as well as an adjustment cost, given by the last term in equations (12) and (13).

\(^{13}\)Gourio and Rudanko (2014) and Shi (2013) provide an environment where firms can use price to attract customers. In our model, the relative amount of marketing capital is the sole source determining the market share.
2.3 The Middleman

In each country, the middleman sends out agents who are responsible for acquiring trading relationships with intermediate goods producers from both countries. Once agents bring contacts to the middleman, an enduring relationship begins which involves a bilateral bargaining problem that determines the price, \( q_d \) or \( q_f \), at which one unit of the good in question is traded. We will refer to these prices as producer prices in the future. Middleman bargains over prices with all the old and new producers that they have a relationship with while also engaged in selling these acquired units of domestic and foreign goods to the household in competitive markets. The price differential between what the customer pays and the producer prices allow middleman to recover their costs and make a profit. The middleman chooses the number of agents, \( h_t \), sent into the matching market after observing aggregate shocks. Random matching governs whether any individual agent will match with a home producer or a foreign producer but the law of large numbers implies that they can assess the ex-ante probability of matching with domestic good firm, \( \pi_d \), and the foreign good firm, \( \pi_f \). Each match leads to an exchange of one unit of the relevant good in period \( t \) and subsequent trades in the future until separation. The middleman incurs an increasing and convex matching cost based on the number of agents employed, \( \chi h^2 \). In order to induce borrowing, we assume that these costs must be paid in advance of any trades by taking an intra-period loan which is limited by an enforcement constraint discussed below.\(^{14}\)

Taking the price at which households buy the goods (which we will refer to as customer prices) and the ex-ante probability of matching with domestic versus foreign producers as given, the middleman can calculate the expected per unit surplus from matching with a domestic producer, \( J_{d,t} \), and matching with a foreign producer, \( J_{f,t} \). Overall, the expected surplus from each match is

\[
J_t = \pi_{d,t} J_{d,t} + \pi_{f,t} J_{f,t}. \tag{14}
\]

The middleman chooses the number of agents, \( h \) to maximize profits given by:

\(^{14}\)The convex cost faced by middleman and the introduction of a time-varying enforcement constraint are the main differences in the model environment of middleman relative to Drozd and Nosal (2012)
\[ \Pi_t^M = J_t h_t - \chi h_t^2 \]  

subject to the borrowing constraint:

\[ \psi_{f,t} J_t h_t \geq \chi h_t^2. \]  

The enforcement parameter, \( \psi_{f,t} \), is governed by an AR(1) process:

\[ \log(\psi_{f,t+1}) = \rho_f \log \psi_{f,t} + \epsilon_{f,t} \]  

where \( 0 \leq \rho_f \leq 1 \), and \( \epsilon_{f,t} \) follows an i.i.d normal distribution with zero mean.

The idea of generating business cycles from variations in the severity of the borrowing constraint follows a similar use in Jermann and Quadrini (2012) in a closed economy context. We can think of \( \psi_{f,t} \) as a parameter that governs the ability of the lender to recover goods from the middleman in case the loan is not repaid. Lenders will limit the amount that the middleman can borrow in the absence of any commitment to repay the loan to a multiple of what can be recovered in default as is standard in this class of models. In this specific case, the lender can recover only a fraction of the match surplus, \( J_t \), either because the rest can be hidden or because it is lost in the default process. If \( \psi_{f,t} \) falls, lenders expect to recover a smaller fraction of middleman revenue in case of a default. As a result they would be willing to make a smaller loan to the middleman, who in turn, would be forced to send out fewer agents and this would lower the matching probability facing both domestic and foreign producers. The ensuing fall in customers, would cause production cutbacks and a fall in overall economic activity.\(^{15}\)

\(^{15}\)Since we are not interested in exploring the origins of the financial crisis in this paper, we follow the literature and generate an economic downturn in our model by exogenously decreasing \( \psi_{f,t} \).
2.4 Bargaining

There are four producer prices, \( q_i \), that need to be determined. The subscript \( i \) denotes which goods the middleman and producer are bargaining over, \( i \in \{ d, d^*, f, f^* \} \). The producer’s value function is the markup earned on selling a unit of the good plus the expected value of future sales to the customer taking into account the probability of the match breaking up.

\[
W_{i,t} = \max\{0, q_{i,t} - v_{i,t}\} + (1 - \delta_H)E_{t}Q_{t+1}W_{i,t+1}
\]  

(18)

Similarly, the middleman earns the difference between the customer price and the producer price, where the valuation equation takes into account that in the future the match may break and prices may change.

\[
J_{i,t} = \max\{0, P_{i,t} - q_{i,t}\} + (1 - \delta_H)E_{t}Q_{t+1}J_{i,t+1}
\]  

(19)

Based on these values, middleman and producers engage in Nash bargaining to determine the producer price, \( q_{i,t} \), paid in exchange for one unit of good. The parties renegotiate every period while remaining matched, thus the prices change based on the state in each period.

\[
q_i = \arg \max_q \{ J_{it}^\theta W_{it}^{1-\theta} \} = \arg \max_q \{ (P_{it} - q_{it})^\theta (q_{it} - v_{it})^{1-\theta} \}
\]

\[
q_{i,t} = (1 - \theta)P_{i,t} + \theta v_{i,t}
\]  

(20)

where \( \theta \) represents the bargaining power of the middleman. Equation (20) shows that the producer price, \( q_i \), is a weighted average of the customer price, \( P_i \), and the economy-wide marginal cost, \( v_i \).

\[\text{A producer price or value function with subscript } d \text{ denotes bargaining between the home middleman and home producer, subscript } d^* \text{ denote bargaining between foreign middleman and home producers, subscript } f \text{ is between home middleman and foreign producers, and subscript } f^* \text{ is between foreign middleman and foreign producer. And, note that } v_d = v_{d^*} \text{ and } v_f = v_{f^*}.\]
2.5 Equilibrium

We will focus on a symmetric equilibrium in which all agents who face identical problems make identical decisions. A symmetric equilibrium in this economy is defined by the following contingent infinite sequences that solve the respective optimization problems of each agent: $C_t, N_t, K_t, I_t, G_t, D_{t+1}, d_t$ and $f_t$ for the household in home country, $C^*_t, N^*_t, K^*_t, I^*_t, G^*_t, D^*_{t+1}, d^*_t$ and $f^*_t$ for the household in foreign country, $n_t, k_{t-1}, d_t, d^*_t, a_{d,t}, H_{d,t+1}, H_{d^*,t+1}, m_{d,t+1}$ and $m_{d^*,t+1}$ for the home firms, $n^*_t, k^*_{t-1}, f_t, f^*_t, a_{f,t}, H_{f,t+1}, H_{f^*,t+1}, m_{f,t+1}$ and $m_{f^*,t+1}$ for the foreign firms, $h_t$ for the home middleman, $h^*_t$ for the foreign middleman, prices, $Q_t, w_t, w^*_t, r_t, r^*_t, P_{d,t}, P^*_{d,t}, P_{f,t}, P^*_{f,t}, q_{d,t}, q^*_{d,t}, q_{f,t}, q^*_{f,t}$ and real exchange rate, $e_t$ that satisfy the following conditions.

The bond market clearing requires

$$D_t = D^*_t$$  \hspace{1cm} (21)

Intermediate goods market clearing requires that the output of each firm is fully used up in sales or marketing costs:

$$z_t n_t^{1-\alpha} k_{t-1}^\alpha = d_t + d^*_t + a_{d,t} + a^*_{d,t} \quad \text{and} \quad z_t^* n_{t}^{1-\alpha} k_{t-1}^* = f_t + f^*_t + a_{f,t} + a^*_{f,t}.$$  \hspace{1cm} (22)

Factor market clearing requires $N_t = \int_0^1 n_{i,t} di$ and $K_t = \int_0^1 k_{i,t} di$ where the integration is over the unit mass of producers in the home country. A similar set of equations apply to the foreign country factor markets. With the symmetry assumption on the two countries, the steady state prices are equal to

$$P_{d,t} = \Gamma P^*_{d,t} \quad \text{and} \quad P^*_{d,t} = \Gamma P_{f,t}$$  \hspace{1cm} (23)

where the $\Gamma$ is the price differential solely introduced by the marketing cost differential. Similarly,

$$P_{d,t} = P^*_{f,t} \quad \text{and} \quad P^*_{d,t} = P_{f,t}$$  \hspace{1cm} (24)

The proportion of middleman’s agents matched with producers from the Home country and from
the Foreign country add up to one:

\[
\pi_f = 1 - \pi_d \quad \text{and} \quad \pi_f^* = 1 - \pi_d^*
\]  

(25)

For future reference, we also define total trade, GDP and the trade - GDP ratio as calculated from the model as follows:

\[
GDP = P_{d,t}d_t + P_{f,t}f_t + q_{t,d}^*d_t^* - q_{f,t}f_t, \quad Trade = q_{d,t}d_t + q_{d,t}^*d_t^*
\]

\[
\frac{Trade}{GDP} = \frac{q_{d,t}d_t + q_{d,t}^*d_t^*}{P_{d,t}d_t + P_{f,t}f_t + q_{t,d}^*d_t^* - q_{f,t}f_t}
\]  

(26)

3 Quantitative Results

In this section we present quantitative results based on a calibrated version of the model to match some key features of the US economy. Other parameters are taken from the literature. Since, in the model, each period represents a quarter, data moments are calculated using quarterly data. We solve the model by linearizing the model equations around the stationary steady-state. The parameter values used in the simulation exercises are reported in Table 2.

3.1 Parametrization

Of the 16 parameters that we need to assign values to, eight are fairly common in the international business cycle literature while three are adopted directly from Drozd and Nosal (2012), the model structure most similar to ours. We begin with preference and technology parameters that are taken from the literature.

The discount factor, \(\beta\), is given a value of 0.99 which implies a 4 percent average annual risk-free real interest rate. We follow the literature and set the coefficient in the utility function, \(\sigma\), to 2 and capital depreciation rate, \(\delta_k\), to 0.025. We set the preference parameter on leisure, \(\psi\), equal to 0.364 in order to obtain steady state hours, \(N_t\), to 30 percent of the time endowment. The
parameter $\alpha$ in the production function is set to 0.36, in order to obtain a steady state share of labor income to GDP of 64 percent. Bargaining power between a middleman and a producer is governed by $\theta$ which is set to 0.5, in order to give equal bargaining power to both.\footnote{Drozd and Nosal (2012) find that the effect of bargaining power is mainly on pass-through. Since price movement plays only a small role in our work, this has a limited impact on our variables of interest. See section 4.} We also explore the sensitivity of changing this parameter on our results in section 4.

Next, we discuss the customer capital parameters. Following Drozd and Nosal (2012), the customer capital depreciation rate, $\delta_H$, is set equal to 0.10 and the marketing capital depreciation rate, $\delta_m$ is set to 0.2. The home bias parameter, $\omega$, and $\chi$, the parameter governing a middleman’s matching cost are jointly chosen to fit the following targets: a steady state import to GDP ratio of 13 percent, a steady state marketing cost share of 7.7 percent\footnote{7.7 percent is the upper limit reported in Arkolakis (2010).}, and a steady state producer markup of 10 percent (see Basu and Fernald (1997)).

Four additional parameters have to be fitted. The financial enforcement parameter, $\psi_f$, is chosen to be 0.1634, the value used in Jermann and Quadrini (2012). Since it is the relative marketing cost difference between domestic and foreign markets that is important for our work (as opposed to the absolute value), we normalize the cost of marketing to the home market, $\zeta$, to unity while calibrating the foreign cost, $\zeta^\ast$. By rearranging the optimality condition of $a_{d,t}, a_{d,t}^\ast, H_{d,t}, H_{d,t}^\ast, d_t, d_t^\ast, m_{d,t}$, and $m_{d,t}^\ast$ at the steady state produces:

$$\frac{\zeta^\ast}{\zeta} = \frac{q_d - v_d}{q_d^\ast - v_d}$$

Equation (27) implies that the ratio of $\frac{\zeta^\ast}{\zeta}$ determines the relative markup of selling abroad and at home. Crucini and Yilmazkuday (2014) estimate that the long run average price differences across borders is about 10 percent after controlling for relative wages, distances, city dummy variables, etc. Since cross-border cost differences have already been accounted for in their estimation exercise, we can view the price difference as a markup difference between selling at home and abroad. Using the 10 percent result, we can back out the parameter $\zeta^\ast$, to equal 1.61.

The adjustment cost parameter, $\phi$, in the marketing capital accumulation equation is chosen to
match the empirical value of the relative standard deviation of total trade to the standard deviation of GDP which is equal to 2.77 in US data from 1980Q1 to 2014Q4. Since this is a long-run moment, we use the TFP shock processes for both countries to match the data. We use the same productivity processes as in Drozd and Nosal (2012). We fit the shock process on the financial enforcement parameter by regressing detrended commercial paper on its lag. This yields a value of $\rho_f$ equal to 0.81.

### 3.2 Trade, Marketing and Financial Shocks

In this section, we ask if our model has the ability to quantitatively explain the large fall in the trade-GDP ratio in response to a financial shock. For this exercise we hit the model with a financial shock that generates a fall in simulated GDP of 2.80 percent, which equals the drop from the trend observed in the data during the trade collapse episode (approximately a 20% drop from the steady state value of $\psi_f$). Compared to a fall in the trade-GDP ratio of 16.50 percent in the data, the model is able to generate a 7.12 percent fall in trade-GDP ratio at the lowest point of the impulse response. In other words, the model response generates around 43 percent of the observed collapse. In order to judge whether the fall in credit generated by the shock in our model is reasonable, we compare it to data on short term debt which is proxied by commercial paper.\(^{19}\) De-trended commercial paper fell between 20-30 percent during this period while the simulated credit fall in the model is 24.39 percent. Model impulse responses to this financial shock are shown in Figure 5 and Figure 6.

Next, we report responses of other variables and analyze the underlying mechanism behind the trade collapse when the model economy receives a financial shock. First, the reduced working capital available to middleman causes them to send fewer agents, $h_t$, to the matching market. Interestingly, there are two opposing forces affecting the optimal choice of $h_t$. To understand this, we first derive the optimal solution for the number of agent, $h_t = \left( \frac{\psi_f + \Delta_t}{\chi} \right)$, by rearranging equation (16). While the financial shock acts as a negative force, there is a positive force coming from the

\(^{19}\)Commercial paper is used as short term debt; firms use it as instrument to roll over operational debt (Kacperczyk and Schnabl, 2010).
surplus, $J$, which rises above steady state (see Figure 5) due to the rise in the markup (see Figure 6) which is discussed further below. Intuitively, the middleman is able to obtain a higher markup and hence each match generates higher profit, when there are fewer agents in the market. Overall, our simulations show that the direct impact of the tighter credit conditions dominate leading to a large fall in agents in response to the financial shock. Recall that adding customers requires inputs from both sides of the matching market: producers expend marketing resources while the middleman sends out agents. In the face of a decline in agents, producers will add fewer new customers to their lists for the same amount of marketing capital. This will generate a reallocation in the marketing inputs.

Since marketing in the other country is more expensive than in one’s home country, under a symmetric shock, there is a further re-allocation effect through which producers switch marketing resources away from the foreign market and towards the domestic market. That is, the home marketing input $a_d$ rises then fall slowly while the foreign marketing input $a_d^*$ drops immediately and the ratio, $\frac{a_d^*}{a_d}$, decreases then returns to steady state. This reallocation effect exacerbates the fall in customers to whom the good can be sold, with a large decline in foreign customers and foreign sales accompanied with a small decline in domestic customers and sales. The decline in both imports and exports lead to the big fall in trade relative to GDP in the model.

Since the price of the home good in the foreign market increases (see below), the home producer spends more resources in foreign marketing as the economy recovers from the financial shock until the markup between the two markets converges. Quantitatively, the home market share rises by 2.66 percent on impact then increases to 3.14 percent at the peak while the foreign firm loses the same amount of the home market share.\footnote{We multiply the percentage deviation from steady state by the steady state value.} The increase in market share leads to higher probability of matching, however, the amount of new customers is lowered by the fall in agents sent out by the middleman. To understand the overall result, combining the customer accumulation
equation (9) and the sales constraint (11), we have

$$d_t = (1 - \delta_h)d_{t-1} + \pi_d h_t$$  \hspace{1cm} (28)$$

The amount of goods sold this period is a function of the amount of goods sold last period, market share, $\pi_d$, and number of matching agents, $h$. The effect from the fall in agents, $h$ dominates the effect from the increase in market share, $\pi_d$. So, the total sales of domestic goods falls even though the firm switches marketing resources toward the home country.

One of the key elements for the disproportionate fall in the trade-GDP ratio is the firm’s ability to price-to-market which allows for deviation from law of one price outside of the steady state. To understand this, we turn to the demand equation from a household’s optimality condition with respect to $d_t$ and $d^*_t$. We combine these two optimality conditions and the customer capital accumulation equation to obtain the pricing ratio equation:

$$\frac{P_{d,t}}{P_{d^*,t}} = \frac{\omega}{1 - \omega} \left( \frac{d^*_t (d^*_t, \frac{m_{d^*,t}}{m_{t}})}{d_t (d_{t-1}, \frac{m_{d,t}}{m_{t}})} \right)^{1/\gamma}$$  \hspace{1cm} (29)$$

This is similar to the typical price ratio equation in a two good-two country model with CES aggregation technology, but differs in the following aspects: (i) the period $t$ demand for the domestic good in home country and foreign country are functions of the marketing input and its level in the previous period, (ii) the law of one price does not hold under a symmetric shock.$^{22,23}$

By relaxing the law of one price in the short run, firms adjust their market shares in the two countries by adjusting the relative marketing inputs. As discussed above, after a shock, home

---

21Since it is costly to accumulate extra customers, a firm would never over-invest in $a_d$ or $a^*_d$. As a result, in equilibrium, $H_t = d_t$. We check for this binding condition in our simulations.

22The deviation from steady state of the two price ($P_d$ and $P^*_d$) part from each other as a result of the market segmentation. See Drozd and Nosal (2012) for detail.

23If the law of one price holds, the left hand side of (29) is just equal to a constant, $\Gamma$. Then, demand for the domestic good adjusts by a fixed proportion to the demand for foreign good when the world is under a symmetric shock as in the following equation.

$$d_t(d_{t-1}, a_{d,t}) = \left( \Gamma \frac{\omega}{1 - \omega} \right)^{\gamma} f_t(f_{t-1}, a_{f,t})$$
firm’s home market share increases while foreign market share decreases. From (29), the condition
implies that the price ratio would fall. Intuitively, the market share adjustments create scarcity of
foreign good since the customer accumulation and marketing input cost differential slow down the
market clearing. As a result, the consumption of domestic goods rises relative to the imported
goods and the price of imported good is higher than the domestic price, which is qualitatively in
accord with the actual price dynamics discussed in the introduction.

3.3 Prices and Markups

While the movement in quantities explains an important part of the trade collapse, prices also play
a role. Customer prices paid by the household have a hump-shaped response with the domestic
good price falling and the foreign good price rising, because the foreign good becomes relatively
scarce as a result of moving marketing inputs away from the foreign country. The hump-shape
response appears because of the slow customer-capital adjustment built into the model. The price
charged by the producer at home, $q_i$, falls roughly 1 percent while the price charged abroad, $q_i^*$,
falls less. To understand this movement, recall that producer prices are a weighted average of the
customer price and the marginal cost. As customer prices move in different directions while the
marginal costs are the same across the price at home and abroad, the bargaining power parameter,
$\theta$, determines the size of the difference between the two producer prices. Although the contribution
to the trade-GDP ratio is small, it fits the empirical literature in that the fall in price explains only a
small portion of the trade collapse. Last, both of the producer price ratio and customer price ratio,
$\frac{q}{q}$ and $\frac{P}{P}$, rise, however, the magnitude is relative small compared to U.S. aggregate data.

Turning to the behaviour of markups, we find that both middleman and producer markups
increase over their marginal costs in response to the financial shock driven recession and return to
steady state slowly, as consumer prices and marginal cost adjust slowly. Recall the definition of the
markup for the middleman is $P_i - q_i$, and for the producer is $q_i - v_i$. Both markups for producers
and the middleman increase, after a shock. The profit earned by the middleman displays a similar
path but the perk appear a few period later. To understand this, we first note that both the home and
foreign firms reduce labor and capital input as the total demand for goods decreases. Consequently, both the wage and rental rates fall which leads to a decline in the economy-wide marginal cost $v_i$. As a result, the total surplus, $P_i - v_i$, involved in each transfer of goods from the producer to the household increases. Nash bargaining determines the share of the higher surplus distributed to the middleman and producer by setting the producer price, $q_{i,t}$. Since the consumer price adjusts slowly but the fall in $v_i$ is immediate as the financial constraint tightens, both the markup for producer and the markup for the middleman increases. In result, we observe countercyclical behaviour in the middleman’s and producer’s per-unit gain.\(^{24}\)

4 Special Cases and Robustness Checks

In the next few subsections, we discuss various versions of our model in order to understand the contributions of key mechanisms. We begin with removing the marketing cost differential, then present two modifications of the customer capital accumulation process that bring out its importance in generating a large trade collapse, and finally discuss the sensitivity of the results to some key parameters.

4.1 No Marketing Cost Differential

One important result that drives the trade collapse in our model is that the marketing input ratio, $a_d/a_d^*$, rises in response to the drop in agents sent out by the middleman. This rise is the result of a marketing cost differential, $\zeta^* > \zeta$. To show this, we produce impulse responses from the model when there is no difference in marketing at home and aboard, i.e. $\zeta^* = 1$, in Figure 7. The marketing input ratio does not change because the two inputs cost the same so that there is little incentive to reallocate resources away from foreign markets. As a result, the domestic price falls by the same magnitude as the decline in foreign price, leaving the price ratios unchanged. Equation (29) implies that if the price ratio does not move, $d/f$ must remain constant, falling in proportion

\(^{24}\)Bils (1987) documents countercyclical markups in the data.
to each other. As a result, the quantity of trade falls roughly in proportion to GDP, as can be seen in Figure 7.

\subsection*{4.2 Static Market Share}

One notable feature of the model is that a producer can adjust how much to spend on the marketing input. In order to understand the importance of this choice, we study the case where a firm’s marketing input is predetermined and static. This implies that the accumulation of customer capital is driven only by the number of agents sent out by the middleman. Specifically, we remove equation (12) and equation (13), and replace $\pi_d$ and $\pi_d^*$ with constants that give the steady state trade-GDP ratio of 26 percent in both the home and foreign market. Replacing $H_t$, the list of customers with the quantity of goods sold $d_t$, the customer capital accumulation equation can be written as:

\begin{equation}
    d_t = (1 - \delta_H) d_{t-1} + \bar{\pi}_H h_t
\end{equation}

where $\bar{\pi}_H$ is a static market share. We parameterize this model using the same steady state targets as the benchmark model with the natural exception of the target for marketing expenditure which is removed since the marketing input variables are constant terms here. As shown in Figure 8, when the model is hit with tighter credit conditions as before, the fall in the trade-GDP ratio is much smaller despite a similar fall in the number of agents looking for matches with producers. The initial story remains the same in response to the financial shock: the middleman lowers $h$ and given the static market shares, slows down new customer acquisition and, this implies lower sales. Since no reallocation of marketing resources is possible, both foreign and domestic production is equally hit. As before, since price ratios remain much closer to steady state values, the trade-GDP ratio drops less than in the benchmark case and is driven only by the fall in producer prices as in the previous case where there is no difference in marketing cost.
4.3 No Customer Capital Accumulation

In this subsection, we show the importance of customer accumulation by comparing the benchmark simulation result with a case in which the model economy does not accumulate customers. This is achieved by setting the depreciation rate of both marketing capital, $\delta_m$, and customer capital, $\delta_H$, to unity as well as setting the adjustment cost on marketing to zero. Combining the equations and imposing the sales constraint, equation (11), as before, we have:

$$d_t = \frac{a_{d,t}}{m} h_t.$$ (31)

Sales of domestic goods at home is now a function of the marketing inputs and the number of agents sent out by the middleman. Note that in the absence of any persistence in the accumulation of customers, we should expect sales to respond immediately to any change in resources spent by either side of the product market matching process, $a$ or $h$. Note also that in this case, firms have no accumulated customers available to sell their products to. As a result, they must expend marketing resources each period in order to sell any product. This implies that the reallocation effect in response to a fall in agents is muted as can be seen in the impulse response graphs. As expected, the transitional dynamics of trade and GDP follow the path of credit back to steady state with no visible hump in the dynamics. Clearly the accumulation of customers plays an important role in propagation of the credit shock through the economy and especially for the dynamics of the trade-GDP ratio.

4.4 Sensitivity to Key Parameters

To test the robustness of the mechanism, we look into the sensitivity of each parameter in generating the trade collapse holding all other parameters constant. Figure (9) plots the impulse response of trade-GDP ratio for each sensitivity test on the following eight parameters: $\theta, \chi, \delta_H, \delta_m, \Psi_f, \omega, \Phi$, and $\rho_f$. Except for parameters $\theta, \omega$, and $\rho_f$ which are restricted to lie in the unit interval, for our robustness exercise, we use parameter values that are 50 percent higher or lower than their bench-
mark values. The responses are largely insensitive to the change in parameters except for two: the depreciation rate for the firm’s customer list, \( \delta_H \), and the depreciation rate for the firm’s marketing capital, \( \delta_m \). The trade-GDP ratio falls between 5.76 percent and 7.82 percent when we change \( \delta_m \), while it falls by 4.34 percent to 8.47 percent when we change \( \delta_H \). These two parameters do not only change the size of the trade collapse but also the persistence. Greater depreciation rates lead to a faster adjustment of the amount of goods sold and, thus, a larger fall in the trade-GDP ratio.

The fast collapse and recovery is a highlight of the recent trade collapse episode. The benchmark calibration of our model generates a slow recovery, however, our robustness exercises reveal that the depreciation rate of customer capital \( \delta_H \) and the auto-correlation parameter of the financial shock can have important effects on the persistence of the trade-GDP ratio. By increasing the depreciation rate of customer capital alone, we can generate a faster response and recovery. Eaton et al. (2014), documents the per firm matching duration as lasting less than two years on average. This may justify a higher \( \delta_H \). However, they capture only the per exporter-importer match relationship. In our model, it is different in the sense that our unit is per one unit of good. Therefore, we follow Drozd and Nosal (2012) for our benchmark case.

5 Estimating model parameters and shocks

Given the paucity of previous empirical work using DSGE models with customer capital as well as the sensitivity to certain parameters uncovered in the previous section, in this section we carry out a Bayesian estimation exercise using US macroeconomic data from 1981Q1 to 2014Q4. For this exercise, we allow for three aggregate shocks: a TFP shock, a financial shock and a shock to preferences. This allows us to use three data series to obtain estimates of model parameters and shocks. We use data on the log difference of the trade/GDP ratio, aggregate consumption, and aggregate investment, all of which are demeaned for comparison with the model variables which are deviations from steady state. To run the estimation, we first maximize the log posterior function and obtain the mode of the posterior distribution. Then, we calculate the marginal likelihood and
the whole posterior distribution by using Metropolis-Hastings algorithm.

In order to test the consistency of our calibration exercise with aggregate US data, we set the prior means of all parameters to the values used in the calibration exercise discussed above. Our assumptions regarding the priors and the estimated posterior values are reported in Table 3. As is typical in this literature, some parameters are not estimated. These are $\beta, \sigma, \psi, \alpha, \gamma, \psi_f$, and $\omega$. The values of these parameters are kept at the level reported in the calibration section (see Table 2). Our results imply that most parameters show relatively small movements from their prior means. Using these estimated values for model parameters, we re-run the exercise of hitting the model with a financial shock and studying the response of the trade-GDP ratio to this shock. We find that the collapse in the trade-GDP ratio caused by the financial shock is greater than in the calibrated section (8.44 percent) mainly because of the higher depreciation in marketing capital that was estimated. The value of this parameter increased from .2 to .2721.

The estimation exercise also gives us the implied shock series which are shown in Figure A3 in the appendix. In keeping with the theoretical model we maintain a symmetric structure for the two countries so that each country receives the same shock. The model is able to replicate the historical data quite well. These figures are also in the appendix in Figure 4. Our variance decomposition exercise implies that financial shocks play a large role in accounting for the observed movement in our three series. They account for 37.39 percent of the variation in the trade-GDP ratio (TFP shocks explain almost 61 percent), about 64.90 percent of the variation in investment and just over 25.04 percent of the variation in consumption (preference shocks explain about 38.55 percent). Table 4 reports these results.

6 Conclusion

What explains the unusual collapse in trade during the Great Recession? The behaviour of trade during this recession was unusual not only in its severity relative to past episodes but is also puzz-
zling relative to the predictions of international business cycle models where it is hard to generate movements in trade that are significantly larger than in GDP. We contribute to the existing literature by using a real two-country business cycle model with customer capital and financial shocks to generate a sizeable collapse in trade that explains roughly 43 percent of the fall in the trade-GDP ratio seen in the data. Key features of the model that contribute to trade moving more than GDP are a cost differential between marketing to customers in the home market and abroad and the presence of long-term customer relationships. The basic mechanism driving the drop in economic activity is as follows: tighter credit constraints create a drop in demand for the product of firms which respond by switching scarce marketing resources from the foreign country to the home country. As a result, cross-border trade drops more than domestic trade, leading to a large movement in the trade-GDP ratio. The model is estimated on US macroeconomic data using Bayesian inference techniques. The resulting parameter estimates remain quite close to our calibration numbers. We find that financial shocks play an important role in accounting for the observed variation in the trade-GDP ratio as well as aggregate consumption and investment over the last quarter century. TFP shocks and preference shocks are also relevant. The model, parameterized at the mean of our posterior estimates generates a 8.44 percent drop in the trade-GDP ratio when hit by a financial shock.
References


# Appendix

A.1 Graphs and Tables

Table 1: The fall in trade-GDP ratio during the U.S.' recession periods

<table>
<thead>
<tr>
<th>Period</th>
<th>Percentage fall in trade-GDP ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008Q4 - 2009Q2</td>
<td>27.61</td>
</tr>
<tr>
<td>1949Q2 - 1950Q1</td>
<td>21.33</td>
</tr>
<tr>
<td>2000Q4 - 2001Q4</td>
<td>18.27</td>
</tr>
<tr>
<td>1982Q1 - 1983Q1</td>
<td>15.59</td>
</tr>
<tr>
<td>1968Q4 - 1969Q1</td>
<td>15.11</td>
</tr>
<tr>
<td>1974Q4 - 1975Q3</td>
<td>13.11</td>
</tr>
<tr>
<td>1957Q1 - 1958Q1</td>
<td>11.31</td>
</tr>
<tr>
<td>1953Q3 - 1954Q1</td>
<td>07.98</td>
</tr>
<tr>
<td>1960Q2 - 1961Q2</td>
<td>06.26</td>
</tr>
<tr>
<td>1980Q1 - 1980Q3</td>
<td>03.81</td>
</tr>
<tr>
<td>1990Q4 - 1991Q2</td>
<td>02.88</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td><strong>13.02</strong></td>
</tr>
</tbody>
</table>

*Notes*: The reported periods with a fall in trade-GDP meet two criteria: (i) the drop began during a NBER recession period (ii) at least two negative consecutive periods were observed.

The fall in trade during the 1969Q4-1970Q3 recession do not meet the criteria.
### Table 2: Parameter values

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Purpose of the Parameter</th>
<th>Value</th>
<th>Source/Target</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\beta$</td>
<td>Discount factor</td>
<td>0.99</td>
<td>4% average annual risk-free real interest rate</td>
</tr>
<tr>
<td>$\sigma$</td>
<td>HH’s Utility</td>
<td>2.00</td>
<td>Backus et al. (1992)</td>
</tr>
<tr>
<td>$\psi$</td>
<td>HH’s Utility</td>
<td>0.364</td>
<td>Labour hour</td>
</tr>
<tr>
<td>$\alpha$</td>
<td>Production function</td>
<td>0.36</td>
<td>Capital Share</td>
</tr>
<tr>
<td>$\delta_k$</td>
<td>Capital depreciation</td>
<td>0.025</td>
<td>Investment-GDP Ratio</td>
</tr>
<tr>
<td>$\gamma$</td>
<td>Long-run Trade Elasticities</td>
<td>7.90</td>
<td>Head and Ries (2001)</td>
</tr>
<tr>
<td>$\psi_f$</td>
<td>Financial enforcement</td>
<td>0.1634</td>
<td>Jermann and Quadrini (2012)</td>
</tr>
<tr>
<td>$\theta$</td>
<td>Bargaining Power</td>
<td>0.5</td>
<td>Equal bargaining power</td>
</tr>
<tr>
<td>$\delta_m$</td>
<td>Marketing capital depreciation</td>
<td>0.2</td>
<td>Drozd and Nosal (2012)</td>
</tr>
<tr>
<td>$\delta_h$</td>
<td>Consumer capital depreciation</td>
<td>0.1</td>
<td>Drozd and Nosal (2012)</td>
</tr>
<tr>
<td>$\zeta_d$</td>
<td>Home marketing cost</td>
<td>1</td>
<td>Normalized to one</td>
</tr>
<tr>
<td>$\zeta_d^*$</td>
<td>Foreign marketing cost</td>
<td>1.61</td>
<td>Long run Price Dispersion see Crucini and Yilmazkuday (2014)</td>
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<tr>
<td>$\phi_m$</td>
<td>Marketing adjustment cost</td>
<td>0.00622</td>
<td>$\frac{sd(Trade)}{sd(GDP)} = 2.77$</td>
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<tr>
<td>$\omega$</td>
<td>Home Bias</td>
<td>0.53465</td>
<td>Import to GDP Ratio , 0.13</td>
</tr>
<tr>
<td>$\chi$</td>
<td>Search Cost</td>
<td>1.063</td>
<td>Marketing expenditure to GDP = 7.7% see Arkolakis (2010)</td>
</tr>
<tr>
<td>-</td>
<td>-</td>
<td>-</td>
<td>Producer Markup of 10% see Basu and Fernald (1997)</td>
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### Table 3: Parameter and shock estimates

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Prior distribution</th>
<th>Posterior distribution</th>
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</thead>
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<tr>
<td></td>
<td>type</td>
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<tr>
<td>$\rho_f$</td>
<td>beta</td>
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<tr>
<td>$\rho_p$</td>
<td>beta</td>
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</tr>
<tr>
<td>$\sigma_f$</td>
<td>inverse gamma</td>
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<tr>
<td>$\sigma_z$</td>
<td>inverse gamma</td>
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<tr>
<td>$\sigma_P$</td>
<td>inverse gamma</td>
<td>0.075</td>
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</table>

*Notes: Log data density is 1108.514654. The posterior distribution is calculated using the Metropolis-Hastings algorithm. Data used for estimation are consumption, trade to GDP ratio, and investment which is the total of private fixed investment, change in inventory, and consumer durables.*

### Table 4: Variance decomposition (in percent)

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<th>TFP</th>
<th>Financial Preference</th>
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<tr>
<td>Trade/GDP</td>
<td>60.77</td>
<td>37.39</td>
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<tr>
<td>Investment</td>
<td>21.85</td>
<td>64.9</td>
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<tr>
<td>Consumption</td>
<td>36.41</td>
<td>25.04</td>
</tr>
</tbody>
</table>
Figure 1: Trade to GDP ratio over time

Note: The trend is calculated using HP-filter with smoothing parameter of 1600.
Figure 2: % Deviation from Trend: Trade Collapse and Commercial Paper

*Note:* The trend is calculated using HP-filter with smoothing parameter of 1600.

Figure 3: Change in Import and Export Price relative to domestic price

*Note:* The variables are calculated as log change in $x$ less log change of $y$. 

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Figure 4: Resource Flow Diagram

Figure 5: Impulse Responses to a Financial Shock 1
Figure 6: Impulse Responses to a Financial Shock 2
Figure 7: IRF: Without Marketing Cost Differential
Figure 8: IRF: Specifications with Static Market Share and No Customer Capital Accumulation

Notes: BM: Benchmark; NA: No customer capital accumulation; SMS: Static market share. Parameters are calibrated to steady state targets for each cases. Shocks are adjusted to match a fall in GDP of 2.8%. 
Figure 9: Trade/GDP responses: Sensitivity to parameter changes