Essays on the Macroeconomics of Trade Flows

by

Logan T. Lewis

A dissertation submitted in partial fulfillment
of the requirements for the degree of
Doctor of Philosophy
(Economics)
in The University of Michigan
2011

Doctoral Committee:

Professor Linda L. Tesar, Co-Chair
Assistant Professor Jing Zhang, Co-Chair
Assistant Professor Andrei A. Levchenko
Assistant Professor Jagadeesh Sivadasan

To my wife, Kristin

ACKNOWLEDGEMENTS

I thank my committee, Andrei Levchenko, Jagadeesh Sivadasan, Linda Tesar, and Jing Zhang. Their suggestions, advice, and encouragement were invaluable. Jing has been a fantastic advisor since very early in my graduate career. I have also benefited enormously from collaboration with Andrei and Linda on several projects and their advice in all things large and small. I am also grateful for the comments and advice of many others, including Bob Barsky, Çağatay Bircan, Sebastien Bradley, Alan Deardorff, Kathryn Dominguez, Chris House, Lutz Kilian, Rahul Mukherjee, Kadee Russ, and others who participated in the University of Michigan International seminar and International/Macro workshop.

The third chapter of the dissertation is joint work with Andrei Levchenko and Linda Tesar. Çağatay Bircan provided excellent research assistance, examining the two previous recessions. In addition to those thanked above, we are grateful to Lionel Fontagné, Pierre-Olivier Gourinchas, Ayhan Kose, David Weinstein, and workshop participants at the University of Michigan, Federal Reserve Board of Governors, Dartmouth College, and the Paris conference for helpful suggestions. Andrei acknowledges financial support from Cepremap.

I would like to thank Joan Crary, George Fulton, and the rest of the Research Seminar in Quantitative Economics for a great year as a research assistant. They provided me with both a look at the forecasting world outside of economics departments and a great environment in which to work on my dissertation. I am also grateful for the Robert V. Roosa Dissertation Fellowship, which supported me during my final year.

Finally, I would not be here without the support of my family and most especially my wife, Kristin. They believed in me throughout and put up with me in my trek through graduate school. Kristin also valiantly helped with proofreading.

PREFACE

Many macroeconomic forces affect international trade. These include nominal uncertainty, exchange rate movements, and each country's business cycle. This dissertation consists of three essays which explore the impact of these macroeconomic forces.

In the first chapter, I consider the choice firms face between serving a foreign market through exports or producing abroad as a multinational. They face volatile nominal conditions in the foreign market, and I show how rising volatility shifts firms away from multinational production towards exporting. Exporting firms gain a greater advantage from foreign contractions because their goods become relatively cheaper in foreign currency terms. I use U.S. trade and multinational sales data and show that in countries with greater inflation volatility, we observe a higher proportion of exports.

In the second chapter, I examine whether our improved understanding of international price setting helps to explain international trade flows themselves when subject to exchange rate shocks. While menu cost models with strategic complementarities are capable of matching the observed characteristics of international prices, I find that they still perform relatively poorly in explaining trade flows. This class of models, despite having fairly low short-run pass-through to import prices, still implies a large trade value response to exchange rate changes. Furthermore, sectors with more flexible prices or more substitutable goods respond very similarly to those with stickier prices or less substitutable goods, contrary to the implications of the model.

Finally, in joint work with Andrei Levchenko and Linda Tesar, the third chapter studies the collapse of international trade during 2008-2009. We show how the composition of trade is important for understanding why it is so much more volatile over the business cycle. The U.S. trades disproportionately in sectors where domestic production or consumption also dropped significantly, like durable consumption and capital goods. On the other hand, we find no evidence for other commonly cited factors, like credit conditions or inventories.

TABLE OF CONTENTS

LIST OF FIGURES

Figure

LIST OF TABLES

Table

CHAPTER I

Exports versus Multinational Production under Nominal Uncertainty

1.1 Introduction

Multinational production plays an important role in how firms serve foreign markets. For a typical major trading partner, sales of foreign affiliates of U.S. firms are greater than exports. This paper considers how nominal uncertainty affects the decision firms make between serving the foreign market through multinational production or exports. There is strong evidence that U.S. export prices are very sticky and are denominated in dollars. Because multinational production is priced in the foreign currency, there is a potentially important distinction in how foreign nominal uncertainty affects the choice firms make on the margin.

I develop a model with heterogeneous firms and an endogenous decision to export or set up foreign production. Firms set prices and make production-location decisions in advance, so foreign nominal uncertainty affects expected profits. Nominal uncertainty takes the form of a stochastic money growth rate rule. I show that if both exports and multinational production are priced in the foreign currency, nominal uncertainty does not affect the choice of how to serve the foreign market. If, as in U.S. data, exports are instead priced in dollars, then exporting becomes relatively more attractive as foreign volatility rises. The intuition is that given a foreign nominal contraction, an exporter with a price stuck in dollars gains a pricing advantage over an equivalent multinational producer whose price is stuck in the foreign currency. This makes expected profits of exporters more convex in foreign volatility.

Recent work demonstrates that nominal uncertainty is important for understanding international transactions. Schoenle (2010) shows that U.S. export prices are more sticky than domestic U.S. prices, with durations of at least one year on average.

Gopinath and Rigobon (2008) provide evidence that nearly all such prices are denominated in US dollars. By contrast, production abroad is likely to be denominated in the local currency. This distinction is crucial for understanding how firms react to differences in nominal uncertainty in the model.

The analysis is based on the canonical Helpman, Melitz and Yeaple (2004) framework of trade and multinational production, extended to a stochastic environment. Firms are heterogeneous in productivity, and face higher fixed costs to produce abroad than to export. Firms with high productivity find it more desirable to produce abroad to avoid per-unit transportation costs. Uncertainty plays a role through the non-linear effects of monetary shocks on expected profits. This in turn affects the extensive margin of firm participation in each market. I start with a straightforward benchmark, where both exports and multinational production are priced in advance in the local currency. Here, nominal uncertainty affects neither the extensive nor intensive margin of exporting relative to multinational production. Because U.S. exports are priced in dollars rather than the local currency, however, I consider an alternative where exports are priced in the exporter's currency and multinational production is priced in the local currency. In this case, exporter profits are more convex in foreign nominal volatility. This in turn implies that as volatility rises, multinational production as a fraction of total foreign sales (multinational production plus exports) falls in the model.

I then consider the empirical evidence. Using bilateral data for U.S. exports and sales by foreign affiliates of U.S. multinationals, I examine the impact of inflation volatility on the relative choice. I find that, as predicted by the model, inflation volatility tends to decrease the share of MP relative to exports. Separating the regressions for each major sector, I find that the coefficient on volatility is significant for information, electrical, food, machinery, and transportation manufacturing. Other manufacturing sectors have the expected sign, while mining has a positive and insignificant sign. Since mining is a commodity industry where prices tend to be very flexibly spot-priced, this is unsurprising. The results underscore the importance of sectoral heterogeneity in short-term behavior caused in part by the price-setting characteristics of that sector.

On the other hand, exchange rate volatility has, if anything, the opposite effect. The coefficient on exchange rate volatility tends to be positive but not statistically significant. This suggests that while the mechanism in the model holds for inflation volatility, there may be additional effects from exchange rate volatility which may be derived from different underlying shocks. The mechanism in my model simply requires that the exchange rate volatility caused by nominal volatility goes in the modeled direction; that is, a foreign nominal contraction leads to a foreign exchange rate appreciation. Since exchange rate volatility can be caused by a multitude of other sources, the empirical results are consistent with the model. I conclude with a discussion of these results and mechanisms by which exchange rate volatility may have different effects from the nominal volatility typically modeled.

This paper contributes to a recent and rapidly growing literature on understanding the effects of various forms of uncertainty in general equilibrium. Most of the recent work focuses on real uncertainty, including Ramondo and Rappoport (2010), Irarrazabal and Opromolla (2009), Fillat and Garetto (2010), and Ramondo, Rappoport and Ruhl (2010). These papers study either country or firm-specific uncertainty about productivity under flexible prices. In particular, Ramondo et al. (2010) studies the choice of exporting versus multinational production given aggregate uncertainty about country output. They find that the U.S. exports more to countries with more volatile GDP.[1]

The literature considering nominal uncertainty is relatively sparse. In a partial equilibrium context, Giovannini (1988) studies the effects of exchange rates on exports given assumptions about the currency of prices set in advance. Goldberg and Kolstad (1995) study the production-location decision under a combination of exchange rate and demand shocks, with production capacity set in advance and flexible prices. The main results in that paper are driven by firms having some degree of risk aversion. In more recent general equilibrium work, Russ (2007) analyzes the effects of foreign versus domestic nominal uncertainty on multinational production (and by extension, FDI).[2] She demonstrates that while either source of volatility translates to exchange rate volatility, foreign volatility encourages multinational production in the foreign market while domestic volatility deters it. All prices are local-currency priced, and firms cannot export.

This paper differs from the literature in two respects. First, I study nominal uncertainty in the form of inflation volatility. Since we observe substantial price stickiness as noted above, it is important to understand how nominal volatility interacts with this stickiness to affects firms' decisions in general equilibrium. Second, the economic mechanism I propose in this paper is distinct, focusing on the difference between

[1]My model predicts the same basic comparative static with a completely different channel. I explore the empirical relationship between the two papers in Section 1.5.2.

[2]In addition, Cavallari (2010) studies real and nominal uncertainty with exports and multinational production in a model without firm heterogeneity and thus without an explicit choice of how to serve the foreign market. See also Cavallari (2008) and Cavallari (2007).

the currency denomination of exports compared to multinational production. Thus, differences in foreign volatility change how domestic firms serve the foreign market.

The rest of the paper is organized as follows. Section 2 presents the overall model environment. Section 3 details the specifics of the model in which exports are priced in the local currency. Section 4 describes the alternative model with exports priced in the producer's currency. Section 5 introduces the data and estimation strategy for testing the model. Section 6 concludes.

1.2 Model setup

Consider a 2-country model (home H and foreign F) inhabited by representative households that maximize utility over consumption, labor (leisure), and real money holdings. The countries trade a complete set of state-contingent bonds; this focuses the model's implications of uncertainty on firms. Each country has its own currency with a stochastic growth rate which is exogenously driven.

Firms face fixed costs for producing domestically, exporting, and serving foreign markets via multinational production (MP). Exporters face relatively smaller fixed costs but pay per-unit transportation costs, while multinationals avoid transportation costs and face higher fixed costs. This structure is the basis of Helpman et al. (2004) and a subsequent literature focusing on static determinants of trade and multinational patterns.

To keep the benchmark model as tractable as possible, prices are set one period in advance. With a period defined as a year, this is consistent with empirical evidence of export price durations of at least one year. Trade consists of monopolistically competitive intermediate goods and firms have heterogeneous production based on a permanent fixed draw from a productivity distribution. Labor is the only input of production.

1.2.1 Households

Each country is occupied by a representative household which maximizes the expected discounted stream of utility $U(\cdot)$, choosing consumption C_t, labor supplied L_t, bond holdings B, and real money balances M_t/P_t. For tractability, assume that utility is separable and of the form:

$$\max_{C_t,L_t,M_t} \sum_{t=0}^{\infty} \beta^t E_t \left[\frac{C_t^{1-\rho}}{1-\rho} - \kappa L_t + \chi \ln \left(\frac{M_t}{P_t} \right) \right].$$

The representative household faces a standard budget constraint:

$$P_tC_t + \sum_{s^{t+1}} Q(s^{t+1}|s^t)B(s^{t+1}) + M_t = M_{t-1} + W_tL_t + B(s^t) + \Pi_t + T_t,$$

where s^t denotes the state of the world at time t, $Q(s^{t+1}|s^t)$ are the price of state-contingent bonds, Π_t are profits from domestic firms, and T_t are transfers of seigniorage revenue from changes in the money supply. This leads to familiar first order conditions shown in the appendix.

Foreign households have an analogous problem, and the real and nominal exchange rates are solved by equating the price of state-contingent bonds $Q(s^{t+1}|s^t)$ and iterating backwards (see Chari, Kehoe and McGrattan (2002)). The nominal exchange rate, defined as the ratio of the home currency to the foreign currency, can be expressed as a function entirely of exogenous variables (see appendix):

$$S_t = \frac{M_t}{M_t^*}\frac{1-\beta\alpha}{1-\beta\alpha^*},$$

where $\alpha \equiv E_t\left[\frac{M_t}{M_{t+1}}\right]$, the expected inverse of the money growth rate, and α^* is its foreign counterpart. Intuitively, the nominal exchange rate in any given period depends on the ratio of the money supplies; an increase in home currency M leads to a depreciation (increase in S) of the home nominal exchange rate. The money growth rate terms are derived from the partial derivative of utility with respect to money holdings. As the volatility of the foreign money growth rate rises, so does α^*. This, all else equal, leads to a higher S_t (home currency depreciation).[3]

Households consume a basket of domestic and foreign varieties through CES aggregation, with a common elasticity of substitution θ:

$$C = \left[\int y(i)^{\frac{\theta-1}{\theta}}\, di\right]^{\frac{\theta}{\theta-1}}.$$

While there is no explicit home-bias in preferences over varieties in this setup, transportation costs and fixed costs will yield lower imports relative to a frictionless economy. In addition, complete markets and labor entering linearly in the utility function imply that wages between the two countries are equalized ($W_t = S_tW_t^*$). Section 1.3.6 discusses factor price equalization in more detail.

[3]Obstfeld and Rogoff (1998) discuss the effects of relaxing the log-utility assumption over money balances. They also emphasize that this result holds regardless of whether prices are sticky.

1.2.2 Monetary process

The uncertainty and volatility in the model stem from a stochastic money growth rate rule, found commonly in the literature[4]. I assume that the money supply grows at a stochastic log-normal rate with a mean-preserving spread:

$$\frac{M_t}{M_{t-1}} = e^{\epsilon_m}, \quad \epsilon_m \sim N\left(-\frac{\sigma_m^2}{2}, \sigma_m^2\right),$$

with a similar process for the foreign country. This implies that the inverse of the money growth rate $\alpha = e^{\sigma_m^2}$.[5]

1.2.3 Intermediate goods producers

Each firm i faces a linear production technology with heterogeneous productivity $\phi(i)$ and uses labor $l(i)$, so that $y(i) = \phi(i)l(i)$.

To maximize tractability and keep the focus on nominal uncertainty, I follow Helpman et al. (2004) and Russ (2007) and assume that firms face per-period fixed costs for domestic entry f, exporting f_X, and multinational production f_{MP}. Firms which export pay an iceberg trade cost $\tau > 1$ to have one unit arrive at the destination. For choices of f and f_X consistent with the data, no firm will choose to export but not produce domestically. As in Helpman et al. (2004), I assume that multinational production fixed costs are higher than export fixed costs $f_{MP} > f_X$, consistent with data on firm sales.[6]

1.3 Model with exports priced in the local currency

In this section, I demonstrate that if exports and multinational production are both priced in the foreign currency (local currency pricing), then nominal uncertainty does not affect the relative choice of how to serve the foreign market. I derive the optimal price setting behavior and feed this into the zero-profit cutoff conditions for being an exporter or a multinational producer.

[4] e.g. Obstfeld and Rogoff (1998), Chari et al. (2002), Russ (2007).

[5] For notational simplicity, I abstract from a constant growth rate term, which does not qualitatively affect the results.

[6] While in principle firms could produce abroad for re-export to the home market, transportation costs work in both directions and thus this will be undesirable without some sort of cost advantage. If factor price equalization does not hold and re-exports were permitted, this would be dependent on the calibration of transportation costs versus the wage differentials. For simplicity in all setups, I exclude the possibility of foreign affiliates exporting back to the parent country. Such production technology is often associated with vertical integration and is outside the scope of this paper.

1.3.1 Price setting

To fix intuition, first consider the the optimal flexible price. With CES demand over varieties, this is the familiar condition that prices are set as a fixed markup $\frac{\theta}{\theta-1}$ over marginal costs. For a home firm selling in the home market, those marginal costs are $\frac{W_t}{\phi}$, where ϕ is the productivity of the firm. For a home firm exporting to the foreign market, those costs are $\frac{W_t \tau}{\phi S_t}$ (denominated in the foreign currency), as the firm must pay the iceberg trade cost. Finally, multinationals face marginal costs in the foreign currency of $\frac{W_t^*}{\phi}$.

1.3.1.1 Domestic price setting in advance

Domestic firms set prices for domestic sales through the following optimization:

$$\max_{p_{H,t}} E_{t-1}\left[d_t(p_{H,t}y_{H,t} - W_t l_{H,t})\right],$$

where $d_t \equiv \beta \frac{P_{t-1}C_{t-1}^{\rho}}{P_t C_t^{\rho}}$ is the stochastic discount factor of the investors. One can show that the optimal price choice is then:

$$p_{H,t}(\phi) = \frac{\theta}{\theta-1}\frac{1}{\phi}\frac{E_{t-1}\left[d_t W_t P_t^{\theta} C_t\right]}{E_{t-1}[d_t P_t^{\theta} C_t]},$$

where again ϕ is the productivity of the firm.[7]

1.3.1.2 MP price setting in advance

Consider home firms who choose to engage in multinational production in the foreign market.[8] I make the reasonable assumption that these prices are pre-set in the foreign currency (LCP), as the products are produced and consumed entirely in the foreign country. The maximization problem takes the form:

$$\max_{p_{H,MP,t}} E_{t-1}\left[d_t S_t \left(p_{H,MP,t}y_{H,MP,t} - \frac{W_t^*}{\phi} y_{H,MP,t}\right)\right],$$

[7] Note that if P_t is non-stochastic (e.g. if all prices are set in the local currency), then it may be canceled out of the expectation operators. This proves crucial in simplifying the expressions analytically, making the case of producer cost pricing in Section 1.4 substantially more difficult.

[8] For the purposes of this paper, I restrict firms to either serve the foreign market through MP or exporting, but not both. It can be shown that with export prices set in the local currency, firms will never wish to both export and produce abroad.

where $p_{H,MP,t}$ is the price choice of home-owned multinationals in the foreign market, and ϕ is the productivity of the firm. This yields the following optimal price choice:

$$p_{H,MP,t}(\phi) = \frac{\theta}{\theta-1}\frac{1}{\phi}\frac{E_{t-1}\left[d_t P_t^{*\theta} C_t^* S_t W_t^*\right]}{E_{t-1}\left[d_t P_t^{*\theta} C_t^* S_t\right]}. \tag{1.1}$$

1.3.1.3 Exporter price setting in advance, local currency pricing

Consider now home firms who choose to serve the foreign market through exporting. Empirically, whether exports are producer cost priced (PCP) or local currency priced (LCP) depends on the particular bilateral relationship. I do not endogenize the choice here,[9] but rather take the choice as given and examine the implications. I find that the currency choice has important implications for the effects of uncertainty.

First I consider the case where exports, like multinational production, are LCP. Denote this price choice as $p_{H,LCP,t}$. The maximization problem of the firm is then:

$$\max_{p_{H,LCP,t}} E_{t-1}\left[d_t\left(S_t p_{H,LCP,t} y_{H,LCP,t} - \tau\frac{W_t}{\phi} y_{H,LCP,t}\right)\right].$$

Since $p_{H,LCP,t}$ is set in the foreign currency, this revenue is repatriated with the nominal exchange rate S_t. Real demand depends only on the relative price and foreign demand, $y_{H,LCP,t} = \left(\frac{P_t^*}{p_{H,LCP,t}}\right)^\theta C_t^*$. Substituting this into the maximization problem and solving for the optimal price,

$$p_{H,LCP,t}(\phi) = \frac{\theta}{\theta-1}\frac{1}{\phi}\tau\frac{E_{t-1}\left[d_t P_t^{*\theta} C_t^* W_t\right]}{E_{t-1}\left[d_t P_t^{*\theta} C_t^* S_t\right]}. \tag{1.2}$$

Factor price equalization implies that $W_t = S_t W_t^*$. Thus, it is straightforward to see that for a given productivity ϕ, the relative price choice is simply $p_{F,MP,t}/p_{F,LCP,t} = \tau^{-1}$. That is, none of the expectations play a role in the optimal price choice between multinational production and an exporter who sets prices in the local currency. This result is intuitive in that with factor price equalization holding both in expectation and ex-post, firms should not set different prices except to account for transportation costs.

[9]See Gopinath, Itskhoki and Rigobon (2010), Bhattarai (2009), and Engel (2006) for examples of papers which endogenize this choice.

1.3.2 Export cutoff

Define $\hat{\phi}_{X,t}$ as the cutoff productivity at time t for a home firm looking to enter the foreign market. If a firm has a productivity above this level, it will either choose to export to the foreign market or set up a factory there. The marginal firm at the cutoff condition receives zero expected profit net of the fixed cost of exporting, f_X. That is,

$$E_{t-1}\left[d_t\left(\underbrace{S_t p_{H,LCP,t}(\hat{\phi}_{X,t}) y_{H,LCP,t}(\hat{\phi}_{X,t})}_{\text{revenue}} - \underbrace{\frac{W_t y_{H,LCP,t}(\hat{\phi}_{X,t})}{\hat{\phi}_{X,t}}\tau}_{\text{labor costs}}\right)\right] - E_{t-1}\left[d_t \underbrace{S_{t-1}P_t^* f_X}_{\text{fixed costs}}\right] = 0 \equiv \xi(\hat{\phi}_X), \quad (1.3)$$

where again d_t is the stochastic discount factor of the home firm, $p_{H,LCP,t}$ is the price of the good paid by foreign households (in the foreign currency), $y_{H,LCP,t}$ is the demand of the good at that price, and W_t is the home wage. Define $\xi(\phi)$ as the net profit from exporting for a firm with productivity ϕ.

1.3.3 Multinational production cutoff

Define $\hat{\phi}_{MP,t}$ as the cutoff productivity at time t above which a firm optimally chooses to serve the foreign market through multinational production rather than exporting. It is the productivity at which expected profits net of fixed costs are equal between the two methods of serving the foreign market. That is,

$$E_{t-1}\left[d_t\left(\underbrace{S_t p_{H,MP,t}(\hat{\phi}_{MP,t}) y_{H,MP,t}(\hat{\phi}_{MP,t})}_{\text{revenue}} - \underbrace{S_t\frac{W_t^* y_{H,MP,t}(\hat{\phi}_{MP,t})}{\hat{\phi}_{MP,t}}}_{\text{labor costs}}\right)\right] - E_{t-1}\left[\underbrace{S_{t-1}P_t^* f_{MP}}_{\text{fixed costs}}\right] - \underbrace{\xi(\hat{\phi}_{MP,t})}_{\text{profit from exporting}} = 0, \quad (1.4)$$

where the first term is expected export profits of a firm with productivity $\hat{\phi}_{MP,t}$ and the second term is expected multinational profits of the same firm. With further assumptions about the nature of firm price setting, these cutoff expressions can be written in terms of the underlying exogenous variables.

1.3.4 Results

Consider now the case in which prices are set one period in advance, and both export and multinational prices are set in the foreign currency. In this case, the ratio of the export price relative to the multinational price charged by a firm with productivity ϕ is given by equations (1.1) and (1.2):

$$\frac{p_{H,LCP,t}}{p_{H,MP,t}} = \tau \frac{E_{t-1}[d_t P_t^{*\theta} C_t^* W_t]}{E_{t-1}[d_t P_t^{*\theta} C_t^* S_t W_t^*]}.$$

If factor price equalization holds, the expectations cancel and the firms charge the same price after accounting for trade costs. It can then be shown that the relative cutoff is simply:

$$\left(\frac{\hat{\phi}_{MP}}{\hat{\phi}_X}\right)^{\theta-1} = \frac{f_{MP} - f_X}{f_X\left(\tau^{\theta-1} - 1\right)}.$$

Thus, the relative extensive margin is unaffected by nominal uncertainty. The extensive margin is illustrated in Figure 1.1. Here, profits are shown on the vertical axis, and productivity (to the power $\theta - 1 > 0$) is shown in the horizontal axis. The dotted lines represent the initial (stochastic) steady state, and the solid (green) lines depict the change after an increase in foreign volatility.

Firms engage in domestic production if their expected profits exceed the fixed cost f; this is where the expected profit line crosses the x-axis. A foreign firm with productivity higher than $\hat{\phi}_D^*$ will produce in the foreign market. Similarly, a firm will export if its expected profits exceed the fixed cost f_X. Since exports are subject to a transportation cost, these profit lines have a flatter slope and even with the same fixed cost as domestic production, there would be a higher threshold $\hat{\phi}_X$ to export. Finally, very productive firms will find it optimal to switch to multinational production if the expected profit from producing abroad exceeds the expected profit from exporting; that is, the cutoff $\hat{\phi}_{MP}$ lies where the expected profits from exporting $E[\pi_X]$ and multinational production $E[\pi_{MP}]$ intersect.

An increase in foreign volatility has a negative impact on the foreign producers, while it encourages both exports and multinational production. The intuition is that foreign volatility is good for home producers because a foreign monetary contraction coincides with a foreign currency appreciation, more than compensating the home producers. So both cutoffs fall. But what about actual trade flows and multinational sales? For that, I must be more explicit about the shape of the firm distribution. Proposition I.1 demonstrates sufficient conditions under which the export and multinational sales changes are proportional.

Proposition I.1. *If firm productivity is characterized by a Pareto distribution, exports are priced in the foreign currency, and factor price equalization holds, then the ratio of multinational sales to exports is unaffected by uncertainty.*

Proof. See appendix.

The basic intuition of the proof is that if relative prices are unaffected by nominal volatility, then the relative sales of multinationals and exporters depends only on the mass of firms of each type and the ratio of average productivities. With a Pareto distribution, it can be shown that the ratio of average productivities and ratio of the mass of firms remain constant as volatility changes.

1.3.5 A note on the flexible price case

It is useful to understand the model's implications under flexible prices for the extensive margin choice between multinational production and exporting. The only decision made in advance is that of whether and how to produce for the foreign market. The cutoff conditions are still a function of expected profits, which could be influenced by any number of shocks. The following proposition demonstrates formally that so long as factor price equalization holds, the relative extensive margin is unaffected by any uncertainty about future consumption, exchange rates, prices, etc.

Proposition I.2. *With flexible prices and factor price equalization, the relative extensive margin between exports and multinational production is unaffected by uncertainty.*

Proof. With the export price $p_{H,X,t}(\phi) = \frac{1}{S_t}\frac{\theta}{\theta-1}\frac{W_t}{\phi}$, the export cutoff (1.3) becomes:

$$\hat{\phi}_{X,t}^{\theta-1} = \frac{E_{t-1}[d_t P_t^* S_{t-1} f_x]}{\tau^{1-\theta}\left(\left(\frac{\theta}{\theta-1}\right)^{1-\theta} - \left(\frac{\theta}{\theta-1}\right)^{-\theta}\right) E_{t-1}\left[d_t S_t^{\theta} P_t^{*\theta} C_t^* W_t^{1-\theta}\right]}.$$

With flexible prices, the multinational price is $p_{F,MP,t}(\phi) = \frac{\theta}{\theta-1}\frac{W_t^*}{\phi}$ and the multinational cutoff (1.4) becomes:

$$\hat{\phi}_{MP,t}^{\theta-1} = \frac{E_{t-1}[d_t P_t^* S_{t-1}(f_{MP} - f_X)]}{\left(\left(\frac{\theta}{\theta-1}\right)^{1-\theta} - \left(\frac{\theta}{\theta-1}\right)^{-\theta}\right)\left(E_{t-1}\left[d_t S_t P_t^{*\theta} C_t^* W_t^{*1-\theta}\right] - \tau^{1-\theta} E_{t-1}\left[d_t S_t^{\theta} P_t^{*\theta} C_t^* W_t^{1-\theta}\right]\right)}.$$

More informative is the relative cutoff expression:

$$\left(\frac{\hat{\phi}_{MP,t}}{\hat{\phi}_X}\right)^{\theta-1} = \frac{f_{MP} - f_X}{f_X\left(\tau^{\theta-1}\frac{E_{t-1}\left[d_t S_t P_t^{*\theta} C_t^* W_t^{*1-\theta}\right]}{E_{t-1}\left[d_t S_t^{\theta} P_t^{*\theta} C_t^* W_t^{1-\theta}\right]} - 1\right)}.$$

Here, we can see that the effects of uncertainty reduce down to a ratio $\frac{E_{t-1}\left[d_t S_t P_t^{*\theta} C_t^* W_t^{*1-\theta}\right]}{E_{t-1}\left[d_t S_t^{\theta} P_t^{*\theta} C_t^* W_t^{1-\theta}\right]}$. Note that if factor price equalization holds, i.e. $S_t W_t^* = W_t$, then this ratio equals 1. Then the relative cutoff expression becomes $\frac{f_{MP}-f_X}{f_x}(\tau^{\theta-1} - 1)^{-1}$, exactly that found by Helpman et al. (2004) in a deterministic setting. Thus, with flexible prices, any effect of uncertainty on the relative extensive margin requires factor price equalization not to hold. This is true regardless of the presence of other sectors with sticky prices and regardless of the underlying shock process.

1.3.6 Factor price equalization

Factor price equalization holds in the baseline model because of complete markets and labor entering linearly in the utility function, as noted by Devereux and Engel (1999). This leads to the first order conditions $W_t = P_t C_t^{\rho}$ and $W_t^* = P_t^* C_t^{*\rho}$. Because the real exchange rate is the ratio of marginal utilities of consumption, it follows that the nominal exchange rate $S_t = \frac{P_t C_t^{\rho}}{P_t^* C_t^{*\rho}}$, and thus $W_t = S_t W_t^*$.

One can relax the assumption about complete markets or the assumption about labor entering linearly. Relaxing incomplete markets will not provide very large deviations from factor price equalization, as the exchange rate will follow roughly similar dynamics (Chari et al. 2002). Labor entering with an exponent $1 + \nu$ and $\nu > 0$, can break factor price equalization more substantially. Here, the first order conditions become $W_t = P_t C_t^{\rho} l_t^{\nu}$. Thus, as more labor is utilized for a given level of consumption, wages must rise to compensate households.

While this is certainly a reasonable assumption, it produces wage dynamics soundly rejected by the data. Maintaining the assumption of FPE, we have in logs $\hat{W}_t = \hat{S}_t + \hat{W}_t^*$. In the data, the wage-based real exchange rate (from relative unit labor costs) corresponds to $\frac{W_t}{S_t W_t^*}$, which is far from constant, and tracks the nominal exchange rate closely. That is, $\hat{W}_t \approx \hat{W}_t^*$. With non-linear labor, the model implies that given a home monetary expansion, home wages rise more than foreign wages expressed in the home currency. That is, $\hat{W}_t > \hat{S}_t + \hat{W}_t^*$. This makes nominal wages even more volatile, contrary to the data.

1.4 Model where exports are priced in the producer's currency

1.4.1 Exporter price setting in advance, producer cost pricing

Suppose instead that exporters set prices in their own currency. This is the predominant case for the U.S., where 97% of exports are priced in dollars (Gopinath and Rigobon 2008). That is, $p_{H,PCP,t}$ is dollar-denominated, and changes to the nominal exchange rate S_t have complete pass-through to the foreign-currency price faced by households $p_{H,PCP,t}/S_t$.

The firm's price optimization then takes the following form:

$$\max_{p_{H,PCP,t}} E_{t-1}\left[d_t\left(p_{H,PCP,t}y_{H,PCP,t}-\tau\frac{W_t}{\phi}y_{H,PCP,t}\right)\right].$$

Note that here, output is:

$$y_{H,PCP,t}=\left(\frac{P_t^*}{p_{H,PCP,t}/S_t}\right)^{\theta}C_t^*.$$

Standard optimization leads to the following optimal price:

$$p_{H,PCP,t}=\frac{\theta}{\theta-1}\tau\frac{1}{\phi}\frac{E_{t-1}\left[d_tW_tS_t^{\theta}P_t^{*\theta}C_t^*\right]}{E_{t-1}\left[d_tS_t^{\theta}P_t^{*\theta}C_t^*\right]}. \tag{1.5}$$

The export cutoff condition becomes:

$$E_{t-1}\left[d_t\left(p_{H,PCP,t}(\hat{\phi}_X)y_{H,PCP,t}(\hat{\phi}_X)-\tau\frac{W_t}{\hat{\phi}_X}y_{H,PCP,t}(\hat{\phi}_X)\right)\right]=E_{t-1}[d_tS_{t-1}P_t^*f_x]. \tag{1.6}$$

where $y_{H,PCP,t}=\left(\frac{P_t^*}{p_{H,PCP,t}S_t^{-1}}\right)^{\theta}C_t^*$. (1.6) can be rewritten as:

$$E_{t-1}\left[d_tS_t^{\theta}P_t^{*\theta}C_t^*\left(p_{H,PCP,t}^{1-\theta}-\tau\frac{W_t}{\hat{\phi}_X}p_{H,PCP,t}^{-\theta}\right)\right]-E_{t-1}[d_tS_{t-1}P_t^*f_x]=0\equiv\xi(\hat{\phi}_X).$$

Where $\xi(\phi)$ is the net profit of an exporter for any productivity ϕ. Using this, the multinational cutoff can be written:

$$E_{t-1}\left[d_t\left(\underbrace{S_t p_{H,MP,t}(\hat{\phi}_{MP,t}) y_{H,MP,t}(\hat{\phi}_{MP,t})}_{\text{revenue}} - \underbrace{S_t \frac{W_t^* y_{H,MP,t}(\hat{\phi}_{MP,t})}{\hat{\phi}_{MP,t}}}_{\text{labor costs}}\right)\right] - E_{t-1}\left[\underbrace{S_{t-1} P_t^* f_{MP}}_{\text{fixed costs}}\right] - \underbrace{\xi(\hat{\phi}_{MP,t})}_{\text{profit from exporting}} = 0.$$

1.4.2 A numerical illustration

With producer cost pricing, multinational revenue and export revenue are now affected differently by nominal volatility. Multinational revenue is a function only of demand C_t^*, since the price is set in advance in the foreign currency. Export revenue varies with the exchange rate as pass-through to export prices in the foreign currency is complete.

Since export prices now vary with the exchange rate, the price index P_t^* becomes uncertain at date $t-1$. This substantially complicates solving the model analytically, so I proceed numerically by discretizing the state space for the foreign money supply M^* and computing the stochastic steady state for various $\sigma^2_{m^*}$.

To do this, I must calibrate the model parameters.[10] Table 2.1 outlines the parameters in the model. Most parameters are very standard; as is common in the trade literature, I use an elasticity of substitution between varieties of 5, in the middle of most estimates.[11] The Pareto shape parameter k governing the distribution of firm productivities is taken to be very close to the elasticity of substitution, as in Russ (2007). Iceberg trade costs of 20% are within the range of estimated tariffs and freight costs. This leaves the fixed costs. I set the fixed costs of domestic production and export to be the same, as the focus here is on multinational production.[12] I set the fixed costs of multinational production to be consistent with 60% of the value of foreign sales to come from multinational affiliates, consistent with the average of the data used in Section 1.5.

As the variance of the foreign money supply grows, exporting becomes relatively more attractive compared to multinational production. Consider an unexpected for-

[10]Experimentation with the model parameters reveals that the main qualitative results are not sensitive to the precise parameters chosen.

[11]See Ruhl (2008) for a survey.

[12]These fixed costs imply that 35% of potential entrants export and 90% produce domestically under no uncertainty.

eign contraction. Demand C_t^* falls for both multinational firms and exporters, and the foreign exchange rate appreciates (S_t rises). This makes profits denominated in the home currency higher for both exporters and multinationals.[13] In addition, the exporter's price, set in the home currency, becomes relatively cheaper in foreign currency terms. This stimulates greater demand, and the home exporter's price is closer to its profit-maximizing point. This automatic adjustment of the price makes a PCP exporter relatively better off in the presence of higher foreign uncertainty. This effect tends to dominate regardless of the correlation between foreign demand C_t^* and the exchange rate S_t, say, from other sources of shocks.

To better understand this, consider first Figure 1.2. It plots the profit of a home exporter against realizations of the foreign money supply M^*. Each point represents a value of the foreign money supply on the discretized grid. Starting from the median of about 1, the probability of moving one point left is equal to the probability of moving one point right. Clearly, exporter profit is highly convex in the foreign money supply. The exporter benefits dramatically more from foreign contractions than it suffers from foreign expansions.

As foreign nominal volatility rises, it increases the likelihood that the firm finds itself further away from the median point. Since the likelihood of a significant foreign contraction increases, this increases the expected profit of an exporter.

A multinational benefits from foreign volatility as well. Yet the multinational does not gain the advantage of having its price automatically lowered in foreign currency terms as a PCP exporter does. Figure 1.3 shows the relative impact of expected profit for a sample firm as volatility increases. Multinational profit increases slightly, but it is dwarfed by the dramatic increase in expected profit for an exporter.

Expected profit is exactly what determines the extensive margin from (1.6). As expected profit of a potential exporter rises, it draws in firms from both margins: firms which would otherwise only produce domestically and firms which would otherwise be multinationals. Figure 1.4 shows the relative impact on the extensive margin for exporters and multinationals. As volatility rises, many multinationals become exporters, reducing their mass. Note that because there are many more exporters, a similar percentage gain in the mass of exporters represents a much larger mass of firms.

In terms of quantity, this translates to a relatively small drop in multinational sales; the lowest productivity multinational firms become exporters, so their total

[13]This is also the basic result from Russ (2007), showing that higher foreign volatility is relatively better for home firms over foreign firms in the foreign market.

effect is relatively small. For exporters, on the other hand, these new firms are the most productive and translate to a large increase in trade. This can be seen in Figure 1.5.

Finally, because the effects of volatility may work through additional unmodeled channels, I focus on the fraction of multinational sales as a portion of total foreign sales in Figure 1.6. In both value and quantity terms, the fraction of foreign sales from multinationals falls as volatility rises. Given the current calibration, going from no volatility to a volatility of 0.03 leads to a drop in multinational sales from about 60% to below 50%.

1.5 Data

I move now to consider evidence based on U.S. exports and U.S. multinational foreign affiliate sales. I use multinational sales data from the BEA for 1999-2007 (the latest year currently available) and match it to export data from the U.S. International Trade Commission. This data exists at the sector, country, year level. Full details of the data used in the regressions are available in Tables 1.5 and 1.6 in the appendix.

It is important to keep in mind that both measures are in nominal U.S. dollars. For trade, the Bureau of Labor Statistics does not construct price indices for each export destination. Similarly, there are no multinational sales-specific price indices available by destination country. The analysis in the forthcoming sections will be in terms of nominal ratios, but these may not necessarily correspond to the real goods quantity ratios.

I exclude a small number of countries which experienced currency or debt crises during this time sample.[14] Robustness analysis in Section 1.5.2 shows that the main results of the preferred specification are unaffected by including them.

1.5.1 Results

There are several measures of volatility one might consider to proxy for the nominal volatility in the model. At its most basic, the model has implications for the money supply growth rate; yet this is a theoretical stand-in for many such nominal demand forces which an economy may face. Since the data on money supplies is lacking for some countries in the sample, it makes sense to consider a more widely available measure: consumer price inflation. In the model, the nominal volatility directly translates to inflation volatility. On the other hand, it also translates into

[14] These countries are Argentina, Turkey, Venezuela, Brazil, and the Dominican Republic.

exchange rate volatility; this may seem like the most logical volatility variable, yet because exchange rates are influenced by a large number of other shocks, we will see that inflation can have a very different effect on multinational production compared to exchange rate volatility.

It is reasonable to think that there could be a large number of shocks affecting both exports and multinational sales; it makes sense, then, to consider exports and sales jointly and look for a relative effect. To that end, I estimate the following:

$$\frac{sales_{i,t}}{sales_{i,t} + EX_{i,t}} = \beta_0 + \beta_1 \sigma(\Delta \ln(P_{i,t})) + \beta_2 \sigma(\Delta \ln(\mathrm{S}_{i,t})) + \gamma Z_{i,t} + \epsilon_{i,t}. \tag{1.7}$$

where *sales* is sales by foreign affiliates of U.S. multinationals in country i, mapped to the data as total foreign sales of U.S. affiliates. EX are total exports to country i. Both are in current U.S. dollars. Thus, the dependent variable is the fraction of multinational sales as a share of multinational sales and exports. The variable of interest on the right hand side is $\sigma(\Delta \ln(P_{i,t}))$, the volatility of the price level in country i for year t.[15] The volatility of the nominal exchange rate is $\sigma(\Delta \ln(S_{i,t}))$, Z consists of a number of country/time specific variables as controls, and $\epsilon_{i,t}$ is the regression residual. Given the limitations of cross-country regressions, β_1 is best considered a conditional correlation, controlling for other likely determinants of the dependent variable.

The results pooling available sectors, countries, and years together are presented in Table 1.2. Each regression has both industry and year dummies, which controls for changes in the overall business cycle and the particular characteristics of each industry.[16] There is a robust negative coefficient on inflation volatility. Economically, this means an increase in one standard deviation of inflation volatility decreases multinational sales as a fraction of total foreign sales by 5 percentage points, or about one-seventh of a standard deviation in the pooled ratios.

The regressions include a number of controls in columns 2 and 3. Whether the country is a member of the OECD (generally a developed country status) tends to have a positive impact on the ratio of multinational sales to exports; this is consistent with many explanations, including that developed countries have good institutions which permit horizontal FDI to be more profitable. On the other hand, Mexico and Canada tend to have lower multinational sales relative to exports; this is consistent with the relatively low transportation costs and tariffs from being members of

[15] The CPI measures are monthly, and the standard deviation is taken for each year.
[16] The results are very similar with industry-year dummies.

NAFTA. GDP per-capita and distance do not have a statistically significant effect, though the sign on distance is the expected one.

Given that the industry dummies do not control for a heterogeneous impact of inflation volatility by sector, I re-run the analysis for each sector individually in Table 1.3. Here, we see that information, electrical, food, machinery, and metals sectors all have negative and significant coefficients. Chemical manufacturing has a negative coefficient but it is relatively small and statistically insignificant. The outlier is mining, an industry which does not lend itself to horizontal FDI in many cases. Exchange rate volatility is positive and insignificant in all regressions except information.

1.5.2 Robustness

I subject the pooled results of Section 1.5.1 to a series of robustness checks. The results are shown in Table 1.4. Column 1 reports the results adding back in the crisis countries, showing that the results are not sensitive to those outliers. Column 2 includes a number of additional controls, including real GDP volatility with a significant, negative coefficient, and an array of gravity-equation variables: common language, former colony, currency union, and landlocked status. In this specification, none of these additional explanatory variables are statistically significant.

Column 3 performs the same exercise as column 2, but leaves the crisis countries in. Again, inflation volatility is significantly negative and of similar magnitude, but now real GDP volatility is not significant. Column 4 instead clusters the errors by industry rather than country, showing that the statistical significance of inflation volatility is not sensitive to this choice. Exchange rate volatility, on the other hand, is now significant and positive.

Columns 5 and 6 report similar regressions with a different dependent variable: the log of the sales/export ratio. This is the measure used by Ramondo et al. (2010) in the context of GDP volatility. Without the crisis countries, I find a positive and insignificant response of inflation volatility, and with the crisis countries the coefficient becomes negative and insignificant. Exchange rate volatility is positive and significant in both cases, while real GDP volatility is negative and insignificant.

Note that the log ratio puts substantial weight on observations with relatively small multinational sales or relatively small exports. In the data, there are a number of such observations that I plot in Figure 1.7. Some of these observations in the tails are the result of either zero multinational sales or zero exports; I eliminate them in Figure 1.8, showing that a substantial proportion remain.[17] The log ratio by construction eliminates the extreme points while heavily weighting the near extreme points, making it less suitable for industry-level analysis with a large number of countries. This would only be compounded with more disaggregated data.

1.5.3 Discussion of exchange rate volatility

The empirical results in Section 1.5.1 support the model's prediction that increased nominal volatility as measured by inflation volatility should reduce the ratio of multinational sales as a fraction of total foreign sales. Yet the results for exchange rate volatility go in the opposite direction, if anything. The model does imply that nominal volatility affects the firm's choice *through* the exchange rate, and as inflation volatility rises so should exchange rate volatility. This is not necessarily inconsistent with the empirical evidence, however.

Eichenbaum and Evans (1995) provide empirical evidence supporting the notion that a contractionary monetary policy shock appreciates the U.S. dollar relative to various foreign currencies.[18] While based on U.S. monetary policy, this evidence is consistent with the model's mechanism that a foreign monetary contraction will lead to a foreign nominal exchange rate appreciation.

Exchange rates are not driven entirely by any one shock, however. Another underlying source of exchange rate fluctuations could have the opposite effect on exporting or multinational firms' profits through another channel. Exchange rate volatility may also affect firms if the firm itself is risk averse.[19] Because exchange rate volatility is not robustly significant in the preferred specifications, I do not explicitly model the potential effects of risk aversion on this channel. My results do suggest, however, that one should not conflate the nominal volatility of the sort modeled in this paper with nominal exchange rate volatility.

1.6 Conclusion

International trade theory has recently made significant progress in modeling the endogenous choice of how to serve a foreign market. Yet the standard static considerations are only part of a firm's consideration; this paper contributes to this growing

[17]If I run pooled regression (3) using only those observations with non-zero exports and non-zero multinational sales, I obtain a point estimate for the effects of inflation volatility on the fraction of multinational production relative to total foreign sales of -4.19 significant at the 10% level.

[18]Landry (2009) provides more recent evidence.

[19]Examples of this include Cushman (1985) and Goldberg and Kolstad (1995).

literature by considering how nominal uncertainty affects this choice. This is of particular policy relevance since inflation volatility is commonly seen as something that can be tamed by modern monetary policy.

I show how in a general equilibrium model where exports are priced in the producer's currency and multinational production is priced in the local currency, an increase in foreign nominal volatility decreases the fraction of foreign sales coming from multinational production. Using bilateral, multi-sector trade and multinational sales from the U.S., I find support for this result in the data.

The model predicts that if the country's exports are LCP, then volatility will not matter. As more data becomes available about the activity of multinationals, this can be tested by examining the export and multinational behavior of other countries. Future work should also incorporate vertical production as well as horizontal production, to generate predictions which better match the available trade and multinational sales data. The data suggest that future empirical studies of the effects of volatility on trade or foreign investment should distinguish between exchange rate volatility in general and other forms of uncertainty such as inflation volatility.

1.7 Technical appendix

1.7.1 Derivation of S_t

The representative household faces the following budget constraint, written in nominal home currency:

$$P_t C_t + \sum_{s^{t+1}} Q(s^{t+1}|s^t)B(s^{t+1}) + M_t = M_{t-1} + W_t L_t + B(s^t) + \Pi_t + T_t.$$

where Π_t are profits from domestic firms and T_t are lump-sum transfers of seigniorage revenues from the government. As standard in the literature, s^t denotes the state of the world (including the history up to time t), and is used to construct a complete set of securities $B(s^{t+1})$.

The first order conditions are then very standard,[20] with Lagrange multiplier λ_t :

$$\begin{aligned}
C_t &: U_C(\cdot) = \lambda_t P_t \\
L_t &: U_L(\cdot) + \lambda_t W_t = 0 \\
M_t &: U_M(\cdot) + \beta E_t(\lambda_{t+1}) = \lambda_t \\
B_{t+1} &: Q(s^{t+1}|s^t)\lambda_t = E_t(\beta\lambda_{t+1}).
\end{aligned}$$

Using the first order condition for bond holdings, one obtains the expression for the stochastic discount factor:

$$\begin{aligned}
Q(s^{t+1}|s^t)\lambda_t &= \beta E_t \lambda_{t+1} \\
Q(s^{t+1}|s^t) &= \beta \frac{P_t C_t^\rho}{P_{t+1} C_{t+1}^\rho} \equiv d_{t+1}.
\end{aligned}$$

The utility function has real money balances in logs, yielding an exact log-linear solution as shown by Obstfeld and Rogoff (1998).

[20] For notational convenience, I omit explicitly writing out the probability of transitioning from state s^t to s^{t+1}.

Starting with the M_t first order condition:

$$\begin{aligned}
U_M + \beta E_t \lambda_{t+1} &= \lambda_t \\
\frac{\chi}{M_t} + \beta E_t \frac{1}{P_{t+1} C_{t+1}^{\rho}} &= \frac{1}{P_t} C_t^{\rho} \\
\frac{P_t C_t^{\rho} \chi}{M_t} + \beta E_t \frac{P_t C_t^{\rho}}{P_{t+1} C_{t+1}^{\rho}} &= 1 \\
\frac{P_t C_t^{\rho}}{M_t} &= 1 - E_t d_{t+1}.
\end{aligned}$$

Following Obstfeld and Rogoff (1998), consider

$$\begin{aligned}
1 = \frac{\chi P_t C_t^{\rho}}{M_t} + E_t \left[\beta \frac{P_t C_t^{\rho}}{P_{t+1} C_{t+1}^{\rho}} \right] &= \frac{\chi P_t C_t^{\rho}}{M_t} + \beta \frac{\chi P_t C_t^{\rho}}{M_t} E_t \left[\frac{M_t}{P_{t+1} C_{t+1}^{\rho}} \right] \\
&= \frac{\chi P_t C_t^{\rho}}{M_t} + \beta \frac{\chi P_t C_t^{\rho}}{M_t} E_t \left[\frac{M_t}{M_{t+1}} \frac{M_{t+1}}{\chi P_{t+1} C_{t+1}^{\rho}} \right].
\end{aligned}$$

A candidate solution is one in which $\frac{\chi P_t C_t^{\rho}}{M_t}$ is a constant for all t. Let $\alpha \equiv E_t \left[\frac{M_t}{M_{t+1}} \right]$. Then,

$$\begin{aligned}
1 &= \frac{\chi P_t C_t^{\rho}}{M_t} + \beta E_t \left[\frac{M_t}{M_{t+1}} \right] \\
1 - \beta \alpha \equiv E_t \left[\frac{M_t}{M_{t+1}} \right] &= E_{t-1} \left[\frac{M_{t-1}}{M_t} \right] \\
\Rightarrow \quad C_t^{\rho} &= \frac{M_t}{P_t} \frac{1 - \beta \alpha}{\chi}.
\end{aligned}$$

The foreign budget constraint is analogous:

$$P_t^* C_t^* + \sum_{s^{t+1}} Q(s^{t+1}) B^*(s^{t+1}) \frac{1}{S_t} + M_t^* = M_{t-1}^* + W_t^* L_t^* + \Pi_t^* + T_t^* + B^*(s^t) \frac{1}{S_t}.$$

The equivalent expression for the same bond prices Q is then:

$$Q(s^{t+1} | s^t) = \frac{E_t \lambda_{t+1}^*}{\lambda_t^*} = E_t \left[\frac{U_{c,t+1}^*}{P_{t+1}^* S_{t+1}} \right] \frac{P_t^* S_t}{U_{c,t}^*}.$$

With complete markets, the exchange rate is solved by equating the price of state-contingent bonds $Q(s^{t+1}|s^t)$ and iterating backward. Chari et al. (2002) provide a detailed derivation of this. Iterating this backwards:

$$
\begin{aligned}
E_t\left[\frac{1}{P_t C_t^\rho}\right] P_{t-1}C_{t-1}^\rho &= E_{t-1}\left[\frac{1}{C_t^{*\rho} P_t^* S_t}\right] S_{t-1}P_{t-1}^* {C_{t-1}^*}^\rho \\
E_{t-1}\left[\frac{P_0 C_0^\rho}{P_t C_t^\rho}\right] &= S_0 P_0^* C_0^* E_{t-1}\left[\frac{1}{S_t P_t^* C_t^{*\rho}}\right] \\
\frac{S_0 P_0^* C_0^{*\rho}}{P_0 C_0^\rho} &\equiv 1 \\
\Rightarrow \quad S_t &= \frac{P_t C_t^\rho}{P_t^* C_t^{*\rho}}.
\end{aligned}
$$

With the expression for C_t^ρ, the exchange rate can be expressed as a function of exogenous variables:

$$S_t = \frac{M_t}{M_t^*}\frac{1-\beta\alpha}{1-\beta\alpha^*}.$$

1.7.2 Proof of proposition I.1

The weighted-average exporter productivity is

$$\tilde{\phi}_X^{\theta-1} = \frac{1}{G(\hat{\phi}_{MP}) - G(\hat{\phi}_X)} \int_{\hat{\phi}_X}^{\hat{\phi}_{MP}} \phi^{\theta-1} g(\phi)\, d\phi. \tag{1.8}$$

and the weighted-average multinational productivity is

$$\tilde{\phi}_{MP}^{\theta-1} = \frac{1}{1 - G(\hat{\phi}_{MP})} \int_{\hat{\phi}_{MP}}^{\infty} \phi^{\theta-1} g(\phi)\, d\phi.$$

The representative exporter charges the following price:

$$\tilde{p}_{H,X,t}^* = \frac{\theta}{\theta-1}\frac{1}{\tilde{\phi}_X}\tau\frac{E_{t-1}[d_t W_t C_t^*]}{E_{t-1}[d_t S_t C_t^*]}.$$

Using factor price equalization, one can also express the representative multinational firm price:

$$\tilde{p}_{H,MP,t}^* = \frac{\theta}{\theta-1}\frac{1}{\tilde{\phi}_{MP}}\frac{E_{t-1}[d_t W_t C_t^*]}{E_{t-1}[d_t S_t C_t^*]}.$$

Thus, the relative price is simply

$$\frac{\tilde{p}_{H,MP,t}^*}{\tilde{p}_{H,X,t}^*} = \frac{\tilde{\phi}_X}{\tilde{\phi}_{MP}\tau}.$$

Since demand depends only on the price, the ratio of multinational production to exports is simply

$$\frac{N_{MP,t}\tilde{y}^*_{H,MP,t}}{N_{X,t}\tilde{y}^*_{H,X,t}} = \frac{N_{MP,t}}{N_{X,t}}\left(\frac{\tilde{\phi}_X}{\tilde{\phi}_{MP}\tau}\right)^{-\theta},$$

where $N_{MP,t}$ is the fraction of the unit mass of home firms which produce abroad, and $N_{X,t}$ is the fraction which export. To show that nominal uncertainty does not affect this intensive margin, it is necessary to demonstrate that the average productivities $\tilde{\phi}_X$ and $\tilde{\phi}_{MP}$ are themselves unaffected by nominal uncertainty. In addition, the ratio of firm masses must also be unaffected by nominal uncertainty.

To derive expressions for these average productivities, consider imposing the common assumption that firm productivities follow a Pareto distribution with parameter k. Previous work, including Helpman et al. (2004), has found that the Pareto distribution captures well the distribution of firm sizes seen in the data. Recall that if the minimum productivity of any firm is normalized to be 1, the PDF of the Pareto distribution is $g(\phi) = k\phi^{-k-1}$ and the corresponding CDF is $G(\phi) = 1 - \phi^k$.

Above we showed that $\hat{\phi}_{MP}/\hat{\phi}_X$ is a constant. Let γ_X be the value of this ratio. Now we seek to prove that if γ_X is constant, then $\tilde{\phi}_X/\tilde{\phi}_{MP}$ is also constant.

As is now common in the literature, it is straightforward to show that the average multinational productivity depends only on the elasticity of substitution θ, the shape parameter k, and the productivity cutoff $\hat{\phi}_{MP}$:

$$\tilde{\phi}^{\theta-1}_{MP} = \left(\frac{k}{k-\theta+1}\right)\hat{\phi}^{\theta-1}_{MP}.$$

Using the definition of the average productivity (1.8) above, one can also show that

$$\tilde{\phi}_X = \frac{1}{\hat{\phi}^{-k}_X - \hat{\phi}^{-k}_{MP}}\frac{k}{k-\theta+1}\left[\hat{\phi}^{\theta-k-1}_{MP} - \hat{\phi}^{\theta-k-1}_X\right].$$

Using $\hat{\phi}_{MP} = \gamma_X\hat{\phi}_X$ with $\gamma_X > 1$, one can show:

$$\tilde{\phi}^{\theta-1}_X = \frac{\gamma^{\theta-k-1}_X - 1}{1-\gamma^{-k}_X}\frac{k}{k-\theta+1}\hat{\phi}^{\theta-1}_X.$$

Since γ_X is a constant, this implies that the ratio

$$\frac{\tilde{\phi}_X}{\tilde{\phi}_{MP}} = \frac{\gamma^{\theta-k-1}_X - 1}{1-\gamma^{-k}_X}\left(\frac{\hat{\phi}_X}{\hat{\phi}_{MP}}\right)^{\theta-1}$$

is also constant with respect to nominal uncertainty.

Finally, consider the mass of firms engaged in multinational production. This is simply

$$N_{MP} = \hat{\phi}_{MP}^{-k}.$$

and

$$N_X = \hat{\phi}_X^{-k} - \hat{\phi}_{MP}^{-k}.$$

With $\hat{\phi}_{MP} = \gamma_X \hat{\phi}_X$, we have $N_X = \hat{\phi}_X^{-K}(1 - \gamma_X^{-k})$ and thus

$$\frac{N_{MP}}{N_X} = \left(\frac{\hat{\phi}_{MP}}{\hat{\phi}_X}\right)^{-k} \frac{1}{1 - \gamma^{-k}}.$$

That is, nominal uncertainty does not affect the relative extensive margin $\hat{\phi}_{MP}/\hat{\phi}_X$, or the relative mass of firms $N_{MP,t}/N_{X,t}$. Thus, it does not affect the relative intensive margin $\tilde{y}_{H,MP,t}/\tilde{y}_{H,X,t}$.

1.7.3 Numerical solution

The model with PCP exports no tractable analytical solutions for the stochastic steady state. Instead, I employ numerical techniques to characterize the equilibrium. The basic premise is to discretize the exogenous, stochastic variable (M^*), and solve the model such that the pricing, cutoff, and equilibrium conditions hold in every state of the economy. That is, the expectations are solved by discretizing the exogenous process with quadrature methods. Since the export choice and pricing decisions are made one period in advance, the equilibrium need only be solved for period t given conditions in $t-1$.

M^* is discretized with Gaussian quadrature methods using 30 nodes. Then, using numerical search over $\hat{\phi}_H$, $\hat{\phi}_X$, $\hat{\phi}_{MP}$, p_H, $p_{H,PCP}$, $p_{H,X}$, I calculate the other endogenous variables.[21] The numerical algorithm iterates until the following equilibrium conditions hold:

[21]The model can be solved for one country without calculating the endogenous variables of the other country, saving substantial numerical search space. In practice, for notational convenience, I solve the model discretizing M and solving for foreign firms serving the home market. To match the exposition in the paper, however, I provide the equilibrium conditions for the symmetric case here.

1. The foreign firm cutoff condition:

$$E_{t-1}\left[d_t^* P_t^{*\theta} C_t^* \left(p_{F,t}(\hat{\phi}_{F,t})^{1-\theta} - \frac{1}{\hat{\phi}_{F,t}} W_t^* p_{F,t}(\hat{\phi}_{F,t})^{-\theta}\right)\right] - E_{t-1}\left[d_t^* P_t^* f\right] \ = \ 0.$$

2. The home exporter profit condition, expressed in foreign terms:[22]

$$E_{t-1}\left[d_t^* S_t^{\theta-1} P_t^{*\theta} C_t^* \left(p_{H,PCP,t}(\hat{\phi}_{X,t})^{1-\theta} - \frac{1}{\hat{\phi}_{X,t}} W_t^* S_t \tau p_{H,PCP,t}(\hat{\phi}_{X,t})^{-\theta}\right)\right] - E_{t-1}\left[d_t^* \frac{S_{t-1}}{S_t} P_t^* f_x\right] = 0.$$

3. The home multinational production cutoff condition:

$$E_{t-1}\left[d_t^* P_t^{*\theta} C_t^* \left(p_{H,MP,t}(\hat{\phi}_{MP,t})^{1-\theta} - \frac{1}{\hat{\phi}_{MP,t}} W_t^* p_{H,MP,t}(\hat{\phi}_{MP,t})^{-\theta}\right)\right] - E_{t-1}\left[d_t^* S_t^{\theta-1} P_t^{*\theta} C_t^* \left(p_{H,PCP,t}(\hat{\phi}_{MP,t})^{1-\theta} - \frac{1}{\hat{\phi}_{MP,t}} W_t^* S_t \tau p_{H,PCP,t}(\hat{\phi}_{MP,t})^{-\theta}\right)\right] - E_{t-1}\left[d_t^* \frac{S_{t-1}}{S_t} P_t^* (f_{MP} - f_x)\right] = 0.$$

4. The foreign price condition:

$$p_{F,t}(\tilde{\phi}_F) = \frac{\theta}{\theta-1} \frac{1}{\tilde{\phi}_F} \frac{E_{t-1}\left[d_t^* P_t^{*\theta} C_t^* W_t^*\right]}{E_{t-1}\left[d_t^* P_t^{*\theta} C_t^*\right]}.$$

5. The exporter price condition:

$$p_{H,PCP,t}(\tilde{\phi}_X) = \frac{\theta}{\theta-1} \frac{\tau}{\tilde{\phi}_X} \frac{E_{t-1}\left[d_t^* P_t^{*\theta} C_t^* S_t^{\theta} W_t^*\right]}{E_{t-1}\left[d_t^* P_t^{*\theta} C_t^* S_t^{\theta-1}\right]}.$$

6. The multinational production price condition:

$$p_{H,MP,t}(\tilde{\phi}_{MP}) = \frac{\theta}{\theta-1} \frac{1}{\tilde{\phi}_{MP}} \frac{E_{t-1}\left[d_t^* P_t^{*\theta} C_t^* W_t^*\right]}{E_{t-1}\left[d_t^* P_t^{*\theta} C_t^*\right]}.$$

[22]Note that $d_t = \frac{S_{t-1}}{S_t} d_t^*$ and $S_{t-1} = \frac{1-\beta\alpha}{1-\beta\alpha^*}$.

Table 1.1: Model parameters

β	0.96	Annual discount rate
ρ	2	Standard risk-aversion
θ	5	Elasticity of substitution
k	$\theta + 0.1$	Pareto shape parameter
τ	1.2	20% iceberg trade cost
$f_X = f$	0.035	Fixed cost of local firms and exporters
f_{MP}	1	60% of foreign sales from multinationals

Table 1.2: The response of trade and multinational sales to inflation volatility

	(1)	(2)	(3)
Inflation Volatility	-15.79**	-15.42***	-16.14***
	(5.927)	(5.096)	(4.908)
Exchange Rate Volatility		2.156	1.903
		(1.492)	(1.271)
Inflation Level	-3.523	4.661	14.73**
	(7.906)	(6.106)	(5.953)
OECD		0.187***	0.150**
		(0.0483)	(0.0612)
US Border		-0.174***	-0.0170
		(0.0401)	(0.0642)
ln(real GDP per capita)			0.0326
			(0.0244)
ln(distance)			0.113**
			(0.0456)
Industry dummies	yes	yes	yes
Year dummies	yes	yes	yes
Observations	2,809	2,809	2,525
R-squared	0.294	0.382	0.397

Notes: The dependent variable is sales/(sales + exports). *** p<0.01, ** p<0.05, * p<0.1, standard errors clustered by country in parentheses

Table 1.3: Total multinational sales as a fraction of total multinational sales and exports, by industry

Industry	Inflation volatility	Exrate volatility	Obs.
Information	-9.36*	0.85**	329
Manufacturing (chemical)	-4.12	2.78	349
Manufacturing (computers)	-11.88	0.18	310
Manufacturing (electrical)	-32.77**	3.10	303
Manufacturing (food)	-29.46**	0.96	326
Manufacturing (machinery)	-14.27*	1.81	317
Manufacturing (metals)	-10.78	3.09	300
Manufacturing (transportation)	-32.29**	4.34	301
Mining	16.52	0.62	274

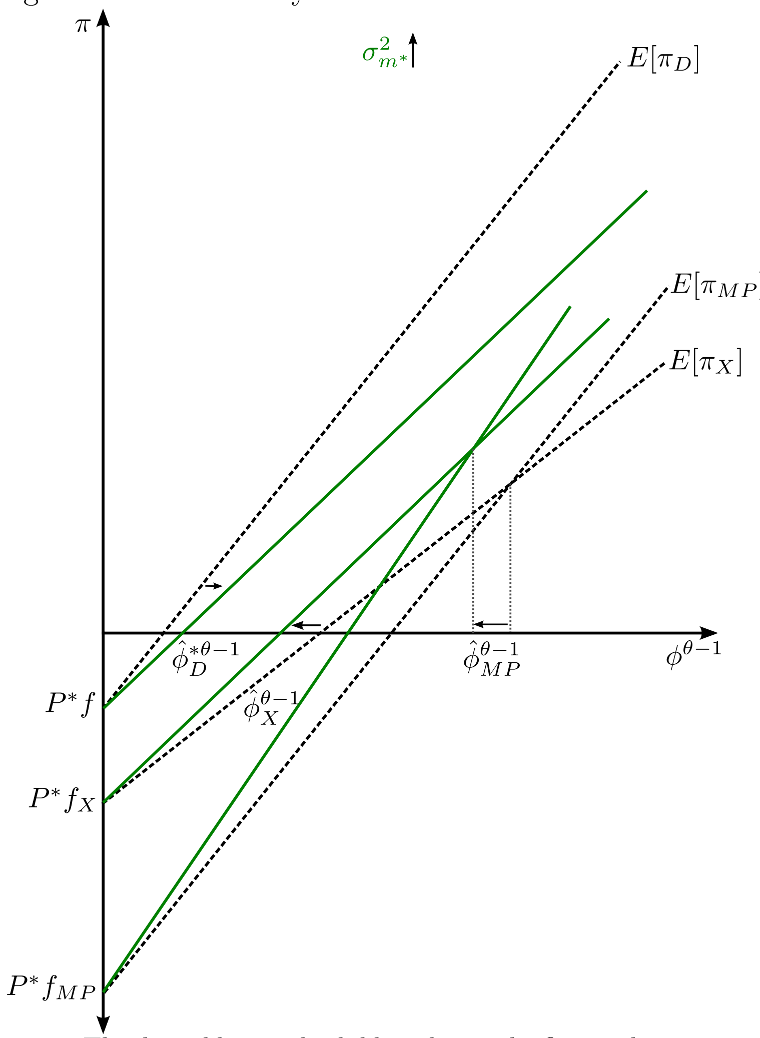
Notes: The dependent variable is sales/(sales + exports). Inflation level, U.S. border, OECD, year dummies included in all regressions. *** p<0.01, ** p<0.05, * p<0.1, clustered by country

Table 1.4: Robustness exercises of pooled regressions

	(1)	(2)	(3)	(4)	(5)	(6)
		sales/(sales + exports)			ln(sales/exports)	
Inflation Volatility	-17.09***	-12.64**	-14.71***	-12.64***	8.275	-9.913
	(3.533)	(5.604)	(3.645)	(3.628)	(27.25)	(27.55)
Exchange Rate Volatility	2.660*	1.074	2.251*	1.074***	17.99***	21.09***
	(1.426)	(0.923)	(1.288)	(0.303)	(6.338)	(5.422)
Real GDP Volatility		-6.811**	-0.904	-6.811**	-27.04	-7.971
		(3.289)	(1.546)	(2.355)	(20.48)	(8.837)
Inflation Level	-0.424	8.396	2.258	8.396*	18.74	-53.56***
	(4.088)	(5.489)	(4.542)	(4.489)	(43.23)	(17.45)
OECD	0.151***	0.0896	0.0635	0.0896**	0.503	0.223
	(0.0464)	(0.0786)	(0.0742)	(0.0360)	(0.462)	(0.412)
US Border	-0.155***	-0.0289	-0.00770	-0.0289	-1.797***	-1.752***
	(0.0384)	(0.111)	(0.110)	(0.106)	(0.566)	(0.547)
ln (real GDP per capita)		0.0286	0.0314	0.0286	0.0851	0.0752
		(0.0254)	(0.0238)	(0.0207)	(0.124)	(0.128)
ln (distance)		0.0851	0.0775	0.0851	-0.372	-0.513
		(0.0667)	(0.0689)	(0.0471)	(0.372)	(0.364)
Common Language		0.0270	-0.0213	0.0270	0.157	-0.0367
		(0.0572)	(0.0628)	(0.0213)	(0.311)	(0.314)
Former Colony		0.0339	0.107	0.0339	0.0595	0.380
		(0.0656)	(0.0768)	(0.0448)	(0.333)	(0.418)
Currency Union		-0.0282	-0.153**	-0.0282	-1.064**	-1.773***
		(0.0671)	(0.0614)	(0.0494)	(0.408)	(0.352)
Landlocked		0.0515	0.0597	0.0515	0.248	0.373
		(0.0573)	(0.0624)	(0.0542)	(0.336)	(0.403)
Observations	3,159	2,525	2,875	2,525	2,162	2,458
R-squared	0.379	0.426	0.408	0.426	0.564	0.540
Industry dummies	yes	yes	yes	yes	yes	yes
Year dummies	yes	yes	yes	yes	yes	yes
Drop crisis countries	no	yes	no	yes	yes	no
Clustered by	country	country	country	industry	country	country

Notes: Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

Figure 1.1: Domestic, export, and FDI cutoffs before (dotted) and after (solid) an increase in foreign nominal volatility



The dotted line and solid line depict the first and second steady states, respectively. The second steady state represents a higher foreign volatility.

Figure 1.2: Convexity of the exporter profit function

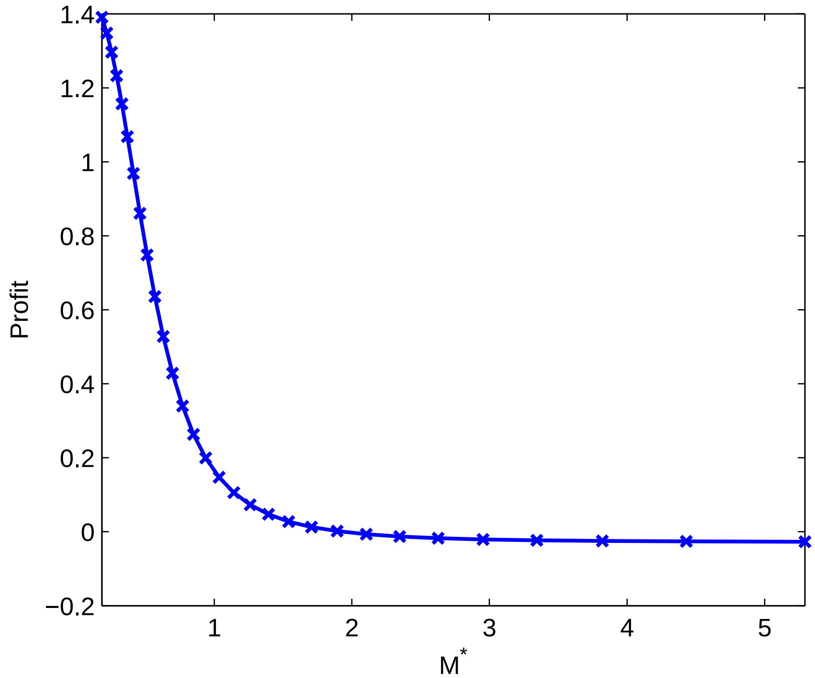


Figure 1.3: Expected profit for an example firm

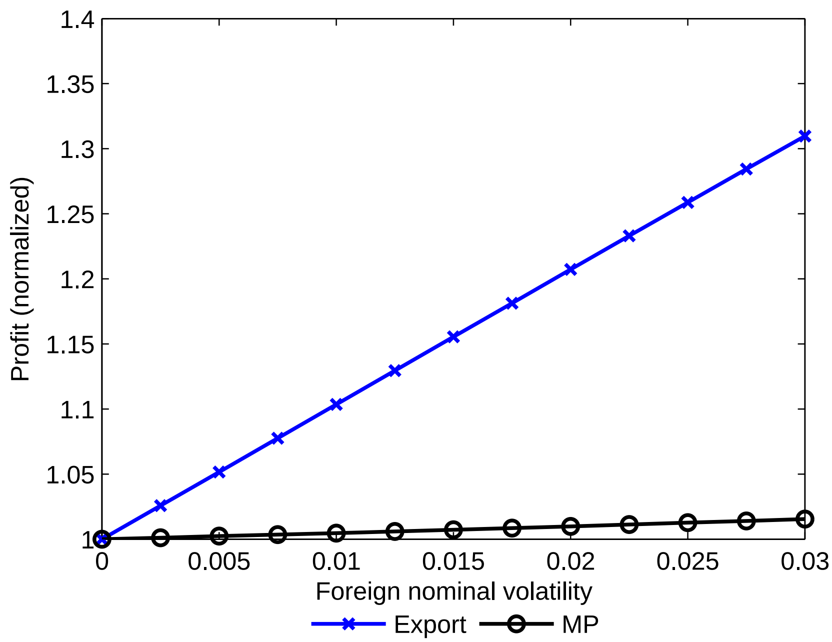


Figure 1.4: The extensive margin of exporters and multinationals

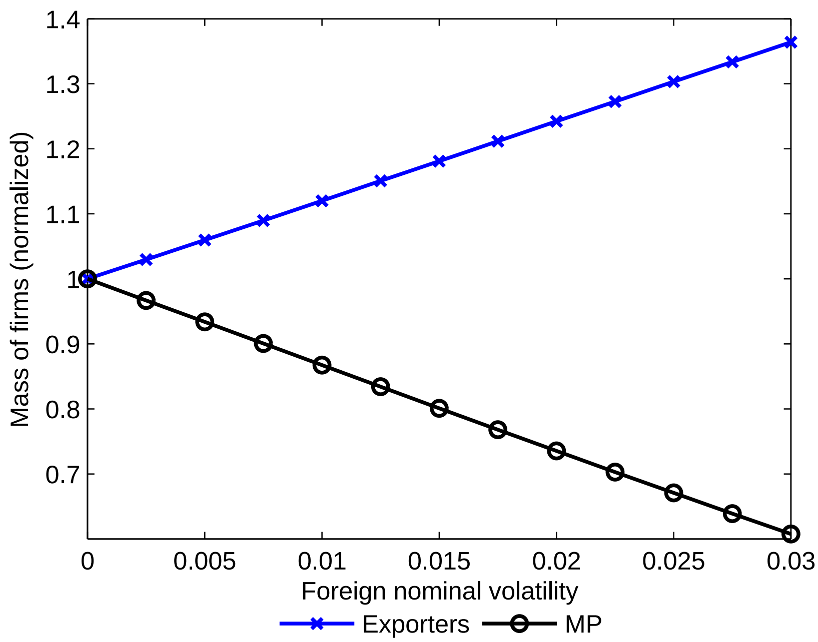


Figure 1.5: Quantity sales by exporters and multinationals

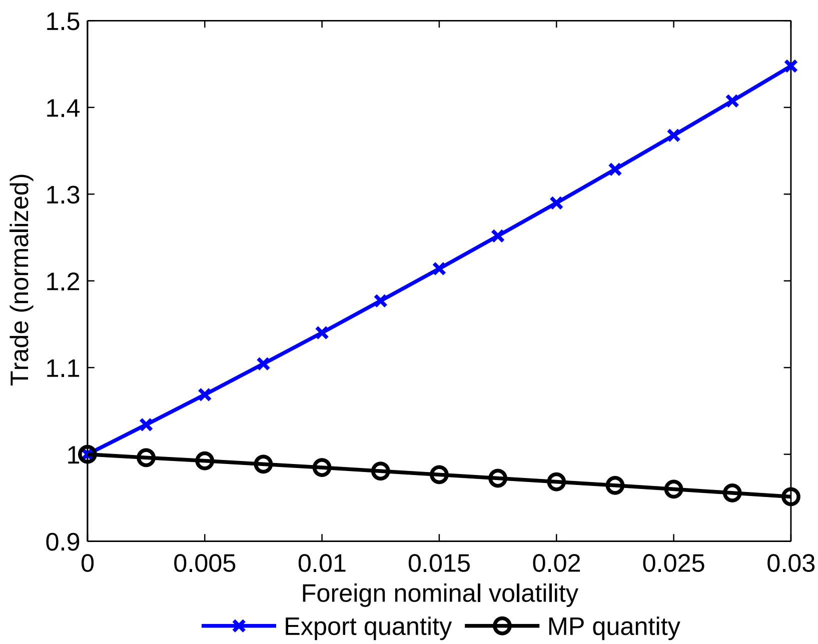


Figure 1.6: The fraction of total foreign sales from multinationals

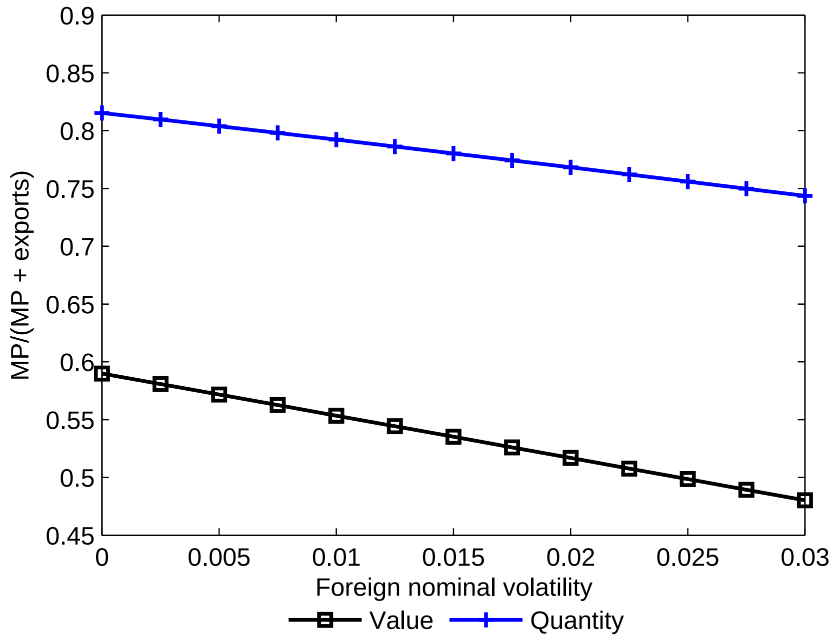


Figure 1.7: The distribution of multinational sales as a fraction of total foreign sales.

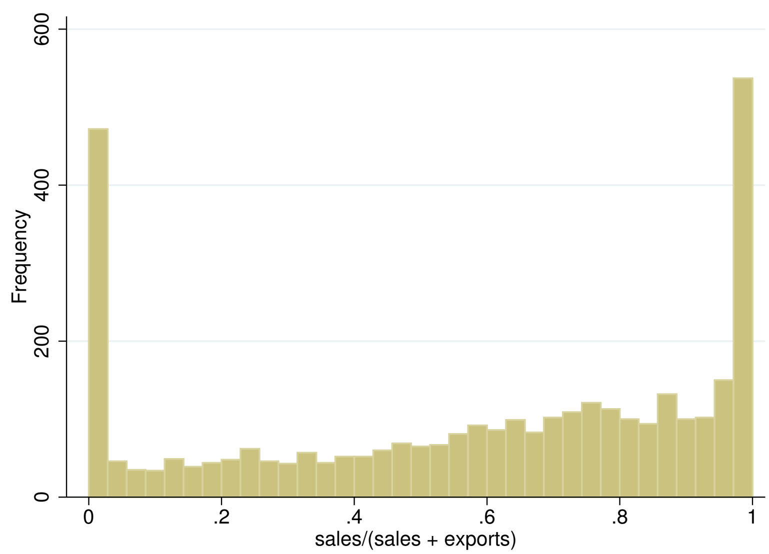
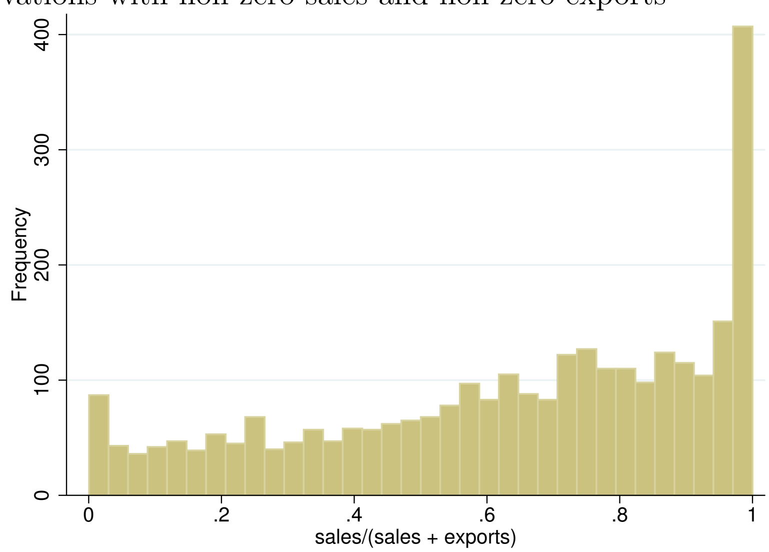


Figure 1.8: The distribution of multinational sales as a fraction of total foreign sales, for only observations with non-zero sales and non-zero exports



1.8 Data appendix

1.8.1 Data description

Table 1.5 lists the sources of the variables used in the estimation procedure. Table 1.6 provide summary statistics for each variable.

Table 1.5: Data sources

Variable description	Source
Sales by majority-owned foreign affiliates of U.S. multinational firms	Bureau of Economic Analysis
Exports by major industry	USITC
Inflation ($\Delta \ln$ CPI), nominal exchange rate	IMF International Financial Statistics
Real GDP per capita, distance, common language, colony, currency union, landlocked	Rose (2005)

Table 1.6: Summary statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
sales/(sales + exports)	3485	0.581	0.35	0	1
ln(sales/exports)	2962	1.095	2.53	-7.516	13.016
Inflation Volatility	3159	0.005	0.00	0.001	0.039
Inflation Level	3159	0.004	0.01	-0.003	0.044
Exchange Rate Volatility	3485	0.019	0.02	0	0.225
Landlocked	3225	0.064	0.25	0	1
Common Language	3225	0.336	0.47	0	1
Colony	3225	0.044	0.20	0	1
Currency Union	3225	0.018	0.13	0	1
Log Distance	3225	8.501	0.50	6.981	9.154
ln(real GDP per capita)	3458	9.009	1.25	5.883	10.936
Real GDP Volatility	3485	0.019	0.02	0.004	0.087
Crisis	3485	0.100	0.30	0	1
OECD	3485	0.446	0.50	0	1

CHAPTER II

Trade Flows, Menu Costs, and Exchange Rate Volatility

2.1 Introduction

Our understanding of international price setting has dramatically expanded in recent years with the availability of micro price data. This data has led to a class of models designed to replicate the patterns seen in that transaction-level data. In this paper, I test the trade flow implications of those models to see if the primary frictions that are thought to be responsible for pricing behavior also help to understand trade values themselves. The benchmark model is an industry-level analysis where firms set prices while faced with exchange rate shocks, productivity shocks, and menu costs. This model is capable of fitting these price-setting facts well, so I contrast its trade flow behavior against flexible price and time-dependent (Calvo) alternatives. I find that matching the price behavior does little to improve the model's performance for trade flows.

Recent work by Gopinath and Rigobon (2008) uses firm- and product-level micro data to analyze the price-setting behavior of U.S. imports and exports. A principal finding is significant heterogeneity in the frequency of price adjustment and substantial price stickiness with durations of about one year on average. In follow up work, Gopinath and Itskhoki (2010) find that a menu cost model is capable of fitting the observed long-run pass-through of exchange rates to prices well. In a related paper, Gopinath et al. (2010) find that strategic complementarities are important for understanding the choice of local currency pricing in U.S. imports.

This work, however, does not directly address trade flows themselves. Gust, Leduc and Sheets (2009) examine the impact of low exchange-rate pass-through with a focus on the trade balance. They find, in the context of their DSGE model, that changes in pass-through do not significantly affect external adjustment. Their model uses variable markups and Calvo-style price setting. In this paper, I focus on imports and exports separately using menu costs in the benchmark model. I compare the results of this model against disaggregated, short-run trade data.

In the closed economy literature, the primary purpose behind understanding high frequency price setting is to understand the implications of nominal shocks on real activity. Correctly measuring these nominal shocks and their implications on aggregate real variables is the focus of a truly enormous literature. Studying the closed economy is hampered by difficulties in identification of monetary shocks and a limited amount of high-frequency domestic production data. In an open economy, on the other hand, we have very volatile, well-measured exchange rate movements and relatively good data about trade flows. I use these advantages to better understand both the price and quantity implications of modern models of firm behavior.

This paper sets up an industry-level analysis of trade in an environment where firms face idiosyncratic productivity shocks and exchange rate shocks. I examine the implications of state-dependent pricing (menu costs) versus time-dependent (Calvo) and flexible price alternatives and examine their trade flow implications under a variety of settings. I show quantitatively how strategic complementarity in price setting in the model affects trade flows and compare those responses to the data. I use disaggregated, quarterly, bilateral trade data with the U.S. to better understand the short-run dynamics of U.S. imports and exports to exchange rate changes. I also use sectoral heterogeneity of these effects to shed light on the underlying mechanisms in the model.

After setting up the model, I compare the numerical results to those found in the data. The first results take average (pooled) magnitude responses of trade flows to exchange rate changes. Using a large sample of disaggregated industries and partner countries, I find that U.S. imports are basically unresponsive to exchange rate changes; if anything, imports actually fall slightly in response to an exchange rate appreciation. Exports are more responsive in the expected direction, but far too weak relative to the models considered. Moreover, while increasing the impact of price stickiness makes the import result better, it makes the export result worse. Thus, this class of models is unable to simultaneously match both price and trade facts.

To further examine these results, I consider the comparative statics implied by the model and compare it to those estimated from the disaggregated sector-level data. The first is price duration, since some industries are characterized by flexibly priced goods while others have sticky prices. I find almost no difference between sectors split into groups based on their price duration. This is in contrast to the model, where such large changes in price stickiness via menu costs imply larger differences in the response of trade flows. Second, I use elasticities of substitution estimated from medium-run data; again, the differences in the response of these sectors in the data are fairly small, yet the model implies large changes. This suggests that neither price stickiness nor "true" elasticity are well-suited to explaining the sectoral heterogeneity in the data.

I conduct two further exercises as a check on the results based off of price duration and medium-run elasticities. One is to use the different price-setting behavior of sectors as classified by Rauch (1999), where some sectors are traded on organized exchanges, others have reference prices, and some are more differentiated. More differentiated sectors should generally correspond with lower elasticities of substitution and stickier prices. Again, I find relatively little difference in the import and export behavior of these three types of sector, with the model actually implying the wrong comparative static in the case of imports. Finally, I examine durable versus non-durable goods. Chapter III shows how this distinction is important for understanding the elasticity of trade with respect to output, and there is reason to believe it might affect the elasticity with respect to prices (though the sign is unclear). Here too I find relatively little difference in the import and export responses. This implies that either the forces affecting durable versus non-durable are small or that they cancel each other out.

I conclude with a discussion of possible mechanisms which might help to explain these results. While the pooled results are related to the classic elasticity puzzle described in Ruhl (2008), matching the comparative statics across industries presents an additional hurdle which cannot be resolved by simply assuming implausibly low elasticities of substitution.

2.2 Model setup

The benchmark model of this paper is a partial equilibrium analysis of a monopolistically competitive industry. This level of aggregation is common in the menu cost literature, among others (see e.g. Alessandria, Kaboski and Midrigan 2010b). The (real) exchange rate process is taken to be exogenous, which is generally a reasonable assumption given the relative lack of connection between movements in the exchange rate and underlying fundamentals, especially at higher frequencies. The basic setup of the model follows closely that of Gopinath et al. (2010), but similar models can be found in Schoenle (2010) and Neiman (2011). Generally speaking, this class of models is considered to be capable of reproducing the basic known facts about international pricing and exchange rate pass-through.

A large number of foreign firms compete monopolistically in the home industry. Firms set their prices in advance, given an idiosyncratic process for the menu costs it faces in the future.[1] Firms produce with only labor supplied with an exogenous wage.

2.2.1 Demand

The heart of the model is the demand a firm faces for its product given prevailing economic conditions.

Constant elasticity of substitution (CES) is the standard demand setup for models of monopolistic competition, which provides very tractable demand equations depending only on the firm's price p_i in the home currency, the aggregate price index P, and total real demand C:

$$q_i = \left(\frac{P}{p_i}\right)^{\theta} C,$$

where θ is the elasticity of substitution between varieties. This leads to the optimal, flexible price charged by a firm to be a constant markup $\theta/(\theta-1)$ over marginal cost.

In recent work, Gopinath et al. (2010) and Gopinath and Itskhoki (2010) find that variable markups are important in producing the low exchange rate pass-through observed in micro trade price data. Typical explanations – nominal rigidity in the short run and local distribution costs – cannot explain the observation that individual import prices at the dock do not pass-through changes in the exchange rate, even after adjusting.

This variable markup can be generated from micro sources,[2] but it is often convenient to characterize them in a way consistent with the formulation in Kimball (1995). Klenow and Willis (2006) provide one such aggregator, which in its approximate form used by Gopinath and Itskhoki (2010) generates the following effective demand elasticity:

$$\tilde{\theta} = \frac{\theta}{1 - \epsilon \ln(\frac{p_i}{P})},$$

[1] This structure nests two special cases: flexible prices simply set the menu costs to zero, while time-dependent Calvo-style pricing involves an arbitrarily high menu cost with some probability, otherwise it faces no menu cost.

[2] See, e.g. Atkeson and Burstein (2008).

where ϵ is the "super-elasticity" controlling the variable markup and P is approximately a geometric average of industry prices. As $\epsilon \to 0$, the demand specification collapses to CES. As $p_i \to P$, the elasticity returns to the constant markup.[3]

2.2.2 The firm's problem

All three price-setting formulations can be characterized by the same set of Bellman equations. Let $V^a(p, e, a)$ denote the value of the firm with price p, exchange rate e, and productivity a. V^n is the value if the firm does not adjust its price. A firm pays f_{mc} to change its price, it earns profit $\pi(p, e, a)$. The Bellman equations can be characterized as:

$$V^a(p, e, a) = \max_p \pi(p, e, a) - ef_{mc}pq + \beta E[\max\{V^a(p', e', a'), V^n(p', e', a')\}]\}], \quad (2.1)$$

$$V^n(p, e, a) = \pi(p, e, a) + \beta E[\max\{V^a(p', e', a'), V^n(p', e', a')\}]. \quad (2.2)$$

where β is a constant discount rate and primes denote the future period. The value of the firm at any time is simply $\max\{V^a, V^n\}$. Flow profit in each period is $\pi(p, e, a) = pq - qe^{\phi}/a$ for a firm which sets its price in its own currency (producer cost pricing), and ϕ denotes the degree to which costs are in the foreign currency. This captures a degree of vertical production using intermediate goods or foreign labor to produce a good for a particular market. If on the other hand a firm prices its products in the foreign currency, the local currency priced (LCP) profit is $\pi(p, e, a) = epq - qe^{\phi}/a$.

This formulation can in principle embed all three price setting types: with flexible prices $f_{mc} = 0$ and $V = V^a$, and with menu costs firms choose between V^a and V^n each period. With Calvo-style price setting, f_{mc} takes an arbitrarily high value with probability ψ, and a value of 0 with probability $1 - \psi$.

The exchange rate is exogenous and assumed to follow a persistent AR(1) process:

$$\ln e' = \rho_e \ln e + \epsilon_e.$$

Similarly, for each firm the idiosyncratic productivity follows an AR(1) process:

$$\ln a_i' = \rho_a \ln a_i + \epsilon_{a,i}.$$

Given that demand y depends on the relative price of a good to the overall price

[3] With trade costs, this specification seems to imply that the markup for foreign firms would permanently differ from the markup for domestic firms.

index P, firms must know its expected evolution. In principle, this could be determined as the result of an additional fixed point problem.[4] For tractability, I follow Gopinath et al. (2010) and assume that the price index follows a known, calibrated path:

$$\ln P' = \alpha \ln P + (1-\alpha)\ln \bar{P} + (1-\alpha)\bar{\phi}\ln e.$$

where $\bar{P}$ is the steady state price level $\theta/(\theta-1)$, and $\bar{\phi}$ controls the degree to which the exchange rate passes through to the overall price index. This parameter would be endogenized in a more fully specified model.

2.2.3 Calibration

Table 2.1 provides the benchmark calibration. I follow Gopinath et al. (2010) for the benchmark which they use to match import price dynamics. Generally speaking, this model and these parameters are capable of roughly matching low exchange rate pass-through, infrequent price changes, the size of price changes, and the autocorrelation of new prices.

For imports, prices are set in the destination currency, reflecting the prevailing local currency pricing observed in U.S. data. For exports, prices are set in the exporter's currency, again reflecting U.S. data. This asymmetry leads sticky prices to have significantly different effects on imports and exports, as seen later.

2.2.4 Solution strategy

The numerical model is solved by discretizing the state space and employing value function iteration to solve for (2.1) and (2.2). Once the value function converges, I solve for the policy function. Then a model economy is simulated for a large number of firms (1000) over a long horizon (10000 months). The computational details of the solution strategy can be found in the appendix. All firms face the same aggregate exchange rate shocks but have independent idiosyncratic productivity shocks. Price change statistics like the mean, median, variance, and frequency are calculated from this data.

This simulated trade data is then aggregated to a single sector at a quarterly frequency and estimated similarly to (2.3), discussed below.[5] The resulting impulse responses can then be plotted alongside the impulse responses estimated from the data.

[4]This is the approach of Gopinath and Itskhoki (2010).

[5]Aggregate GDP is held constant and assumed to be independent of the exchange rate shocks.

2.3 Data

Given that price stickiness is on the order of one year (Gopinath and Rigobon 2008), higher frequency data is required to understand the implications of pricing on the dynamic response of trade flows. Since these newly-available price facts are derived from U.S. imports and exports, it makes sense to focus on these disaggregated trade flows. Unlike price data, which is sampled by the BLS and only available for a few large bilateral groups (e.g. Near East Asia), the Census records the universe of bilateral trade at a disaggregated frequency.[6] The bilateral nature of the data allows exploitation of cross-country heterogeneity in exchange rate movements, rather than average trade-weighted changes in the exchange rate.

Trade Data

The most comprehensive data is available back to 1989, which forms the beginning of the analysis. I focus on bilateral pairs which are members of the OECD. These comprise the largest trading partners (e.g. Canada, Mexico, Japan, the UK, Germany, France, etc.) with the obvious exception of China. Focusing on relatively developed countries also emphasizes the presumably substitutable nature of these (largely manufactured) goods.

The trade data used in this paper are comprised of two separate classification systems: harmonized system (HS) 4-digit categories and NAICS 6-digit categories. There are over 1200 distinct HS4 categories and over 400 distinct NAICS6 categories. This data is mapped to various sector-level classifications discussed below.

Elasticity of substitution

The elasticity of substitution is a crucial parameter of the model, regardless of other underlying price-setting frictions. The focus of this paper is essentially on the short-run elasticity of trade values to exchange rate changes, which is generally influenced by short-run price-setting frictions. Yet a sector's structural elasticity is perhaps better captured by more medium run data, and one such estimation strategy can be found in Broda and Weinstein (2006a). I use these estimates to classify HS4 categories into "high", "medium", and "low" elasticities. Grouping elasticities into bins allows for a large number of sectors to be averaged into estimating each set of impulse responses. In addition, it does not depend on precise estimates of the medium run elasticities, instead using the estimates only to establish a ranking.

[6] The underlying confidential micro-data identifies the country of origin/destination, but the data is still insufficiently detailed to construct reliable price indices for each bilateral pair.

Price duration

Recent analysis of Bureau of Labor Statistics micro data on U.S. import and export prices by Gopinath and Rigobon (2008) reveals substantial sectoral heterogeneity in the duration of prices.[7] The duration of prices ranges from 1 month (the unit of observation) to 24.3 months, but their listing does not encompass all of goods trade.[8] Still, the model has significant implications for price durations over this range, so I match the trade data to the most disaggregated 2- or 4-digit classification provided by Gopinath and Rigobon (2008) for this exercise.

Pricing classification

The model, like most models of price setting behavior, is built around monopolistically competitive firms. The degree to which a firm can price set is dependent on its product, however. Rauch (1999) classifies goods into three categories: goods traded on an organized exchange (homogeneous goods), goods for which a published "reference price" is available, and differentiated goods. Clearly, sticky prices with lower elasticities of substitution are likely to be found in the last group. We should expect the first two groups to have relatively more flexible prices and higher elasticities of substitution.

Durability

Alternatively, consumer demand may respond differently to price changes based on whether they consume it as a non-durable or hold a stock of it as a durable. While the model does not speak directly to how durable goods might be different, a number of scenarios are plausible. First, durable goods consist of larger goods, for which consumers may be making more deliberate, discrete purchasing choices. When buying an automobile, for example, price is an important consideration between a car produced in Japan and Germany. A change between the relative exchange rates of the yen and euro that filters into dollar prices would lead consumers on the margin to switch their purchases relatively freely. A second possibility is that a potential car buyer has some ability to re-time her purchase if pricing is currently unfavorable. On the flip side, durable goods tend to be more complex and require several stages of production. Since trade largely consists of intermediate goods, a car manufacturer might be stuck with a specific supplier of a car part in the short run; either the buyer

[7]They point out, however, that there is more heterogeneity of price duration within sectors than between.

[8]This is likely due to confidentiality of the underlying data as well as the use of sampling methods for prices rather than a survey of all trade.

or the seller would be exposed to the exchange rate change depending on the currency of pricing, and it would not be feasible to quickly shift from a Japanese supplier to a German or Canadian one.

In terms of the model, such considerations are essentially reduced down to changes in the elasticity of substitution between varieties, with the caveat that the short run elasticity may differ from the long run elasticity.

I use the same classification of durable goods as in chapter III. There, we created a simple classification at the 3-digit NAICS level. Durable sectors include 23X (construction) and 325-339 (chemical, plastics, mineral, metal, machinery, computer/electronic, transportation, and miscellaneous manufacturing). All other 1XX, 2XX, and 3XX NAICS categories are considered non-durable for this exercise.

Bilateral, disaggregated data allows the use of industry-time fixed effects, which capture the industry-specific supply and demand changes occurring within the United States and the world as a whole. In this way, the regressions can isolate the common effect on trade flows of different industries for an exchange rate change. The substitutability implicit in the estimation strategy is between different foreign trading partners. It seems reasonable to think that goods within the same disaggregated category from two different trading partners are fairly substitutable, rather than the typical home versus foreign substitutability considered in many two-country international macro models. This in turn will feed into what demand elasticity is reasonable to assume in the numerical model analysis.

2.3.1 Estimation strategy

The estimation strategy takes five parts: pooled regressions to determine an "average" effect of exchange rate changes on imports and exports, and splitting the sample according to classifications of the goods' frequency of price changes, their medium-run elasticity of substitution, their price-setting classification from Rauch (1999), and whether they are durable or non-durable. The first exercise can be thought of as a macro (albeit partial equilibrium) analysis of the average effects, while the other exercises inform the comparative statics of the model presented in section 2.2.

The basic estimating equation for sector i, country j, at time t is:

$$\Delta \ln \mathit{Trade}_{ijt} = \beta_0 + \sum_{k=0}^{8} \beta_{1,k} \Delta \ln e_{jt-k} + \sum_{k=0}^{3} \beta_{2,k} \Delta \ln y_{jt-k} + Z_{ijt} + \epsilon_{ijt}, \tag{2.3}$$

where y is the GDP volume of country j, and Z is a series of dummies (country and sector-time).[9] The estimating equation follows the standard pass-through literature as in Campa and Goldberg (2005), but applied to trade values. The exchange rate variables have a long lag, acknowledging the possibility that given price stickiness and possible strategic complementarity, exchange rate changes may take up to two years to fully take effect. For imports, foreign income helps proxy for supply side effects. For exports, foreign income plays a direct role proxying for changes in demand from the business cycle.[10]

2.4 Results

2.4.1 Time-dependent pricing and the selection effect

First, I contrast the results of a state-dependent (menu cost) pricing model with that of a time-dependent (Calvo) pricing model. The distinction will be very dramatic in terms of the value of trade, a result that echos the results in the closed economy literature.[11] The central reasoning is also similar: a strong selection effect occurs under menu cost pricing, where the firms that most need to adjust their price will; with a fixed menu cost, this leads firms to generally not be far from their profit-maximizing price.

I use a combination of the trade value data and the estimated results from the models to help inform this distinction. I consider two extreme cases of the selection effect: the fixed menu cost model where the selection effect is very strong, and a Calvo pricing model where the selection effect is essentially eliminated. Modeling techniques such as multi-product firms, stochastic menu costs, etc., which help reduce the selection effect, can generally be seen as some combination of these extremes.

2.4.2 Pooled results

Consider the results of estimating (2.3) pooled across HS4 sectors. Rather than presenting the regression results in table form, it is easier to consider the implied

[9] At this level of disaggregation, there are a significant number of zeros in the data set. Traditional gravity equation estimations tend to drop these zeros, but this can lead to inconsistent estimates as argued by Silva and Tenreyro (2006). Since the estimating strategy here uses (log) differences, I conduct robustness exercises using an alternative difference formula which explicitly allows for zero observations; this follows from work in the labor literature (Davis, Haltiwanger, Jarmin, Miranda, Foote and Nagypal 2006), and the log differences are replaced by $2\frac{x_{ij,t}-x_{ij,t-1}}{x_{ij,t}+x_{ij,t-1}}$. The estimates are generally similar to those with log differences. For ease of interpretation, I report log differences.

[10] While these proxies are not perfect, they are implied by most international business cycle models as indicators of supply and demand changes.

[11] For a detailed discussion of this in a closed economy context, see Midrigan (2010).

impulse responses for horizon h by calculating $\sum_{k=0}^{h} \beta_{1,k}$. These impulse responses are shown for a 1% exchange rate appreciation with 95% confidence bands[12] in Figure 2.1 for imports and Figure 2.2 for exports.

First, notice that in the data, the response of imports is quite low, even negative for the first two quarters. In the models, imports rise as the exchange rate appreciation makes them relatively cheaper. With flexible prices, dollar-priced goods are adjusted to be relatively cheaper and their demand rises immediately. In the menu cost model, this reaction is not complete as some firms choose not to update their price right away. In the Calvo model, firms slowly respond and when they do, the strategic complementarities induce them not to respond fully as well. This combination implies a very small response of trade flows, but quantitatively they are still positive and significantly different from the data.

With exports, the response in the data is substantially stronger, almost half a percent in the first quarter compared to a near-zero result for imports. The result is also of the expected (negative) sign. Yet the models with producer-cost priced (PCP) exports imply very strong results. Here, flexible prices fit the best, because the quick response to the exchange rate change implies that the prices faced by foreigners did not automatically rise because of the domestic exchange rate appreciation. The menu cost model and Calvo models have dramatic responses because of this price stickiness. In the data, however, export prices are more sticky than import or domestic prices (Schoenle 2010). Clearly, these standard modeling techniques do not fit the trade data well.

To shed light on the possible explanations and their plausibility, I use the disaggregated nature of the data to test the relevant comparative statics of the model.

2.4.3 Variation in duration

There is significant variation in price duration between HS sectors, as documented by Gopinath and Rigobon (2008). I use this variation to break up the categories into three "bins" of duration, short, medium, and long respectively. For imports, this corresponds to durations of roughly 5, 12, and 17 months, while for exports this is roughly 8, 14, and 20 months.

For a model comparison, I run the menu cost model under the baseline calibration but vary the menu cost to obtain roughly comparable frequencies of price adjustment. This corresponds to menu costs of 1%, 15%, and 25% of monthly revenues for imports

[12]These confidence bands are generated by asymptotic Wald-based tests of the of the summed coefficients.

and 2%, 25%, and 30% for exports. The results are plotted in Figure 2.3.

Clearly, the model performs poorly with this comparative static as well. For imports, the initial response drops from about 1.2% to 0.5%, yet the estimated initial impact hardly changes in terms of the point estimate. For exports, the initial response rises from -2.6% to almost -4% in the model, yet the estimated response is also basically unchanged by comparison.

With a menu cost model, however, duration is a function of nearly all parameters of the model. This exercise suggests that the variation in duration might come from heterogeneity in some other mechanism. Alternatively, some mechanism might shut down the menu cost's ability to affect the magnitude of trade flows. One obvious mechanism is the elasticity of substitution. Yet as the next section shows, it is unreasonable to assume low elasticities of substitution for all goods in this sample.

2.4.4 Variation in medium-run elasticity

The elasticity of substitution is obviously critical to the trade responses. Here, price stickiness and strategic complementarity both affect pass-through of exchange rate changes to prices; for imports, this mitigates the trade value response as seen in Figure 2.1, yet price stickiness worsens the model's ability to match the data, seen in Figure 2.2. The baseline elasticity in these exercises was 5, a value used commonly in the trade literature and also by Gopinath and Itskhoki (2010). The international business cycle literature, by contrast, tends to use much lower values. The latter literature tends to focus on aggregate trade, which Imbs and Mejean (2009) argue can cause an aggregation bias in estimation of the elasticity of substitution. In addition, disaggregated trade data allows for comparison across bins of sectors with varying elasticities.

Therefore, I make use of the disaggregated elasticities estimated by Broda and Weinstein (2006a) using medium-run data. These elasticities are generally in the vicinity of those found in the trade literature. I aggregate the elasticities from the HS10 level to the HS4 level by using medians.[13] Like the duration bins, I split the sample into three bins: low (average elasticity 1.9), medium (2.9), and high (11.3). Thus, there is substantial heterogeneity at the HS4 level even when using medians across HS10 categories and averages across bins of HS4 categories.

The results are plotted in Figure 2.4. The data shows little variation in the

[13] The data is very right-tailed, causing means to be relatively large. Using means will make the models fit even more poorly. In addition, the data set from this paper is only available for imports, so I assume that export elasticities are similar.

response of imports by elasticity. The model, on the other hand, implies dramatic changes. In addition, the model's dynamics imply a reduction in trade over time as firms choose to change their prices and the sectoral price responds to the exchange rate.[14]

With exports, again there is little variation in the data between bins of sectors. Yet the model's changes are dramatic, as there is very high pass-through of exchange rate changes, since prices are set in dollars. With higher elasticities of substitution, the trade response is dramatic and unsupported by the data. Even with an elasticity of 1.9, in line with that used by macro models but with counterfactual price and markup implications, the response is still 3-4 times too strong in the first two quarters.

2.4.5 Variation in pricing classification

Given that the model is one of sticky prices and monopolistically competitive firms, it is important to understand if that pricing and market type really plays a significant role in how imports and exports respond to exchange rates. Figure 2.5 plots estimated impulse responses for three types of good, as defined by Rauch (1999). Organized exchange goods are most homogeneous, with firms having little pricing power. Since prices are set on organized exchanges, they exhibit little stickiness. Reference-priced goods are those for which a published price for that type of good is available, separate from a particular supplier. It might best be thought of as a type of good somewhere in between homogeneous goods and differentiated goods. Finally, differentiated goods are those most likely to have sticky prices and lower elasticities of substitution.

As the figure shows, there is little difference in the import response of the three types of goods. If anything, differentiated goods look least like the impulse responses of Figure 2.1. Exports, on the other hand, show a clearer pattern. The more differentiated the good, the more negative and significant the response. Once again, however, this is contrary to the prediction of the model with regard to the elasticity of substitution. Highly differentiated goods should imply a low elasticity of substitution, and thus a smaller response. On the other hand, Figure 2.2 shows that the stickier the prices, the larger the response given producer cost pricing. To replicate the pattern seen in the data, the exchange-traded and reference-priced goods must have quite effective low elasticities of substitution, despite their relative homogeneity. The greater response of differentiated goods could be the result of sticky prices with an otherwise similarly low elasticity of substitution. Of course, economically such low elasticities are contrary to the notion of homogeneous goods; this suggests that

[14] Recall that this sectoral price response is exogenously imposed.

other frictions in the economy are dominating trade flows, and that these frictions are important even for exchange-traded and reference-priced goods.

2.4.6 Variation in durability

Goods can also vary by their use, specifically, whether they are durable or non-durable. Engel and Wang (2011) show how important durability can be in understanding trade movements over the business cycle; that is, durability strongly affects the aggregate income elasticity through a composition effect. Yet durability might also affect the elasticity of exchange rate changes as well; the more durable a good is, the easier it is to intertemporally substitute its purchase. This intertemporal substitution might be important if exchange rates are mean reverting, or if purchasers can afford to take the time to substitute towards cheaper alternatives from other sources (foreign or domestic).

To this end, I perform the estimation over NAICS trade categories, which correspond to production industries reasonably suitable for being defined as durable or non-durable. The results are plotted in Figure 2.6. The total results are very similar to those found with HS4 sectors from section 2.4.2. For imports, non-durable sectors appear to have a stronger price response than durable sectors, contrary to the hypothesis. Both are small and often indistinguishable from zero, however. For exports, we see a slightly stronger response for durable goods than non-durable. There is relatively little evidence that durability plays a significant role in influencing the response of trade flows from exchange rate changes.

2.5 Conclusion

Using disaggregated sector-level, bilateral U.S. imports and exports, I test the implications of new models of firm pricing when faced with nominal rigidities. Even restricting the analysis to those goods which should be quite sensitive to exchange rate changes – those with high long-run elasticities, low price durations, or durable goods – the response is remarkably muted.

For imports, time-dependent pricing and strategic complementarities combined to provide a remarkably low import response, even given a "true" elasticity of substitution of five. On the other hand, the data show that imports if anything *fall* in response to a U.S. exchange rate appreciation. The selection effect works in the opposite direction for U.S. exports, producing the strongest trade responses given that U.S. exports are priced in dollars.

While there is clear heterogeneity in both the long-run elasticity and the price duration of goods across sectors, these translate into rather mild differences in their trade responses to exchange rate changes. Furthermore, sectors with very different pricing schemes and degrees of differentiation have fairly similar trade responses. Finally, there is little distinction between the trade responses of durable and non-durable goods.

The model is not yet capable of lessening trade responses to exchange rates sufficiently without assuming that even the highly-substitutable goods identified in the sample have a fairly low elasticity in the model. Further work is required to identify the pricing mechanisms which might dampen this response without resorting to a low structural elasticity. Modern international macro models like Engel and Wang (2011) simply assume a fixed cost of adjustment of trade flows, like that of capital. While such a modeling mechanism can improve the fit of aggregated models, it is unappealing without understanding the precise mechanisms involved. Possibilities include distribution contracts, firm-specific production, search costs to find new suppliers, and time to ship. Ideally, such mechanisms are tested not only via models and aggregate data but explicitly tested by using disaggregated data and the large heterogeneity between sectors and even firms. I believe this is a fruitful direction for future work.

2.6 Computational algorithm

The computational model in section 2.2 is solved via discretization of the state space and value function iteration for each set of calibrated parameters.[15] The basic solution method is similar to Gopinath et al. (2010).[16] The (log) sectoral price level is centered around the steady state markup $\theta/(\theta-1)$, with 81 grid points used for the individual firm price, 75 for the sectoral price level, 31 for the exchange rate, and 15 for the idiosyncratic productivity. The AR(1) processes for the exchange rate and productivity have grid points and transition matrices calculated with the method described in Adda and Cooper (2003).

The demand function defined by Klenow and Willis (2006) has the potential to

[15] I also experimented with collocation methods, but the value functions were not well approximated by the commonly-used Chebyshev polynomials, requiring spline interpolation; the computational speed was substantially slower than the more common discretization method with relatively few benefits in numerical precision.

[16] I thank Gita Gopinath and Oleg Itskhoki for making their model's code available for comparison.

be negative for a sufficiently large real price, so I follow Gopinath et al. (2010) and set demand to be nil if the price is sufficiently high. Profits are denominated and maximized in the exporter's currency.

Once the value function converges and the policy function is derived, the simulation begins at the steady state with 1000 period burn-in. The remaining 9000 periods for 1000 firms forms the basis of the statistical analysis for each given calibration. The simulated data is aggregated to a quarterly frequency in order to match the data used in the estimation procedure using actual trade data. The sector-level trade values are simple averages over the 1000 firms, the result of the implicit cost minimization problem in CES aggregation. Given the large number of periods, the model's implied impulse responses are estimated fairly precisely.

Table 2.1: Model parameters

β	$0.94^{1/12}$	Monthly discount rate
θ	5	Elasticity of substitution
$\bar{\phi}$	0.5	Exchange rate pass-through to sectoral price level
α	0.93	Autocorrelation of sectoral price level
ϕ	0.75	25% of production costs in foreign currency
ϵ	3	Super-elasticity of demand for KW demand
ρ_a	0.95	Persistence of idiosyncratic shocks
ρ_e	0.99	Persistence of exchange rate shocks
σ_a	0.08	Std. dev. of idiosyncratic shocks
σ_e	0.025	Std. dev. of exchange rate shocks

Figure 2.1: Impulse responses for pooled import HS4 categories with baseline model results

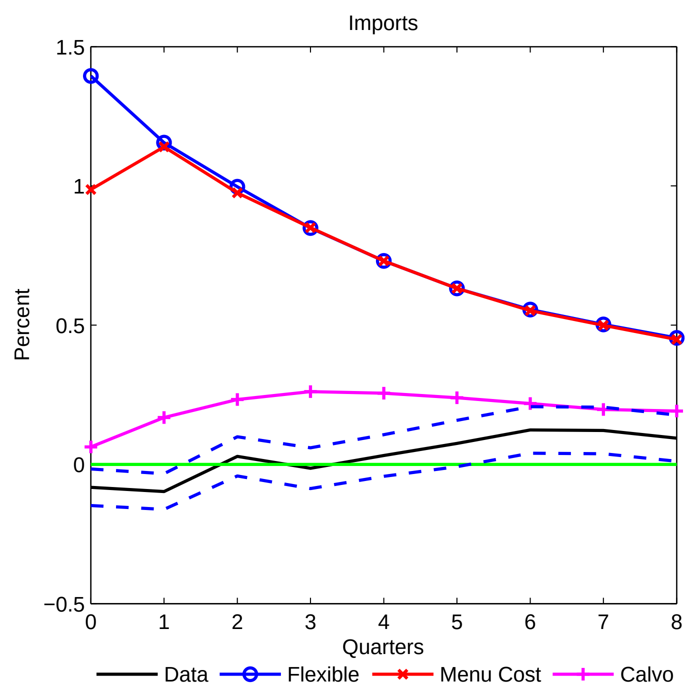


Figure 2.2: Impulse responses for pooled export HS4 categories with baseline model results

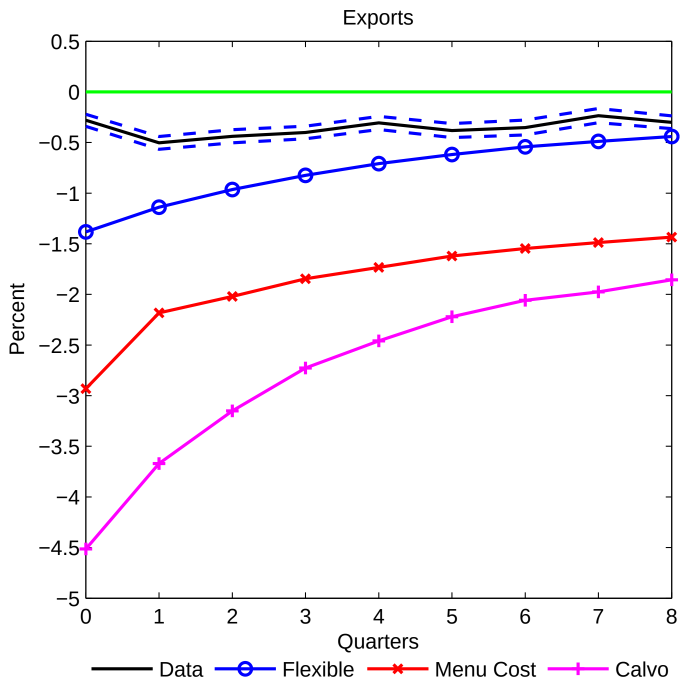


Figure 2.3: Impulse responses by duration bins (solid), and the menu cost model IRF (with markers)

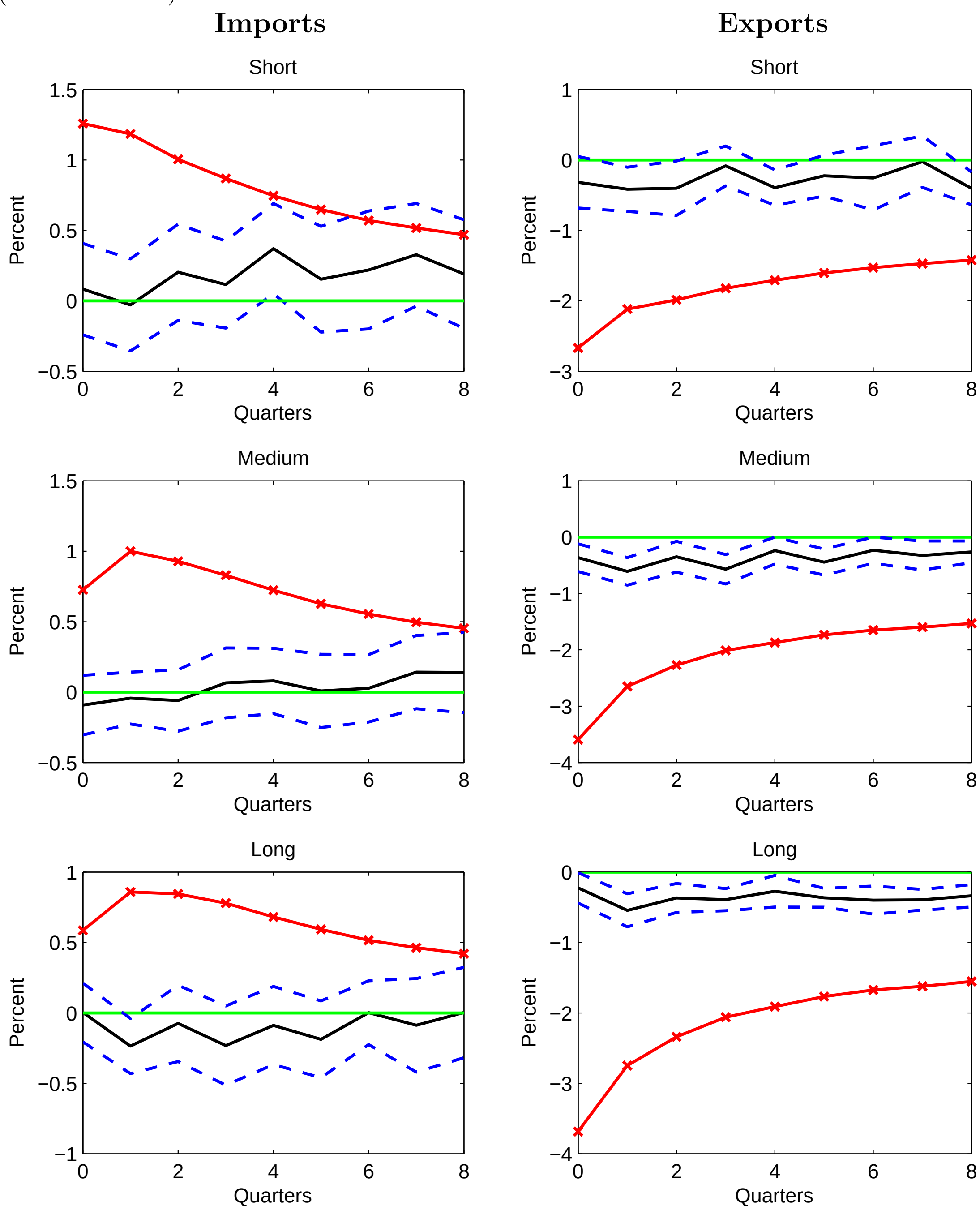


Figure 2.4: Impulse responses by elasticity bins (solid), and the menu cost model IRF (with markers)

Imports **Exports**

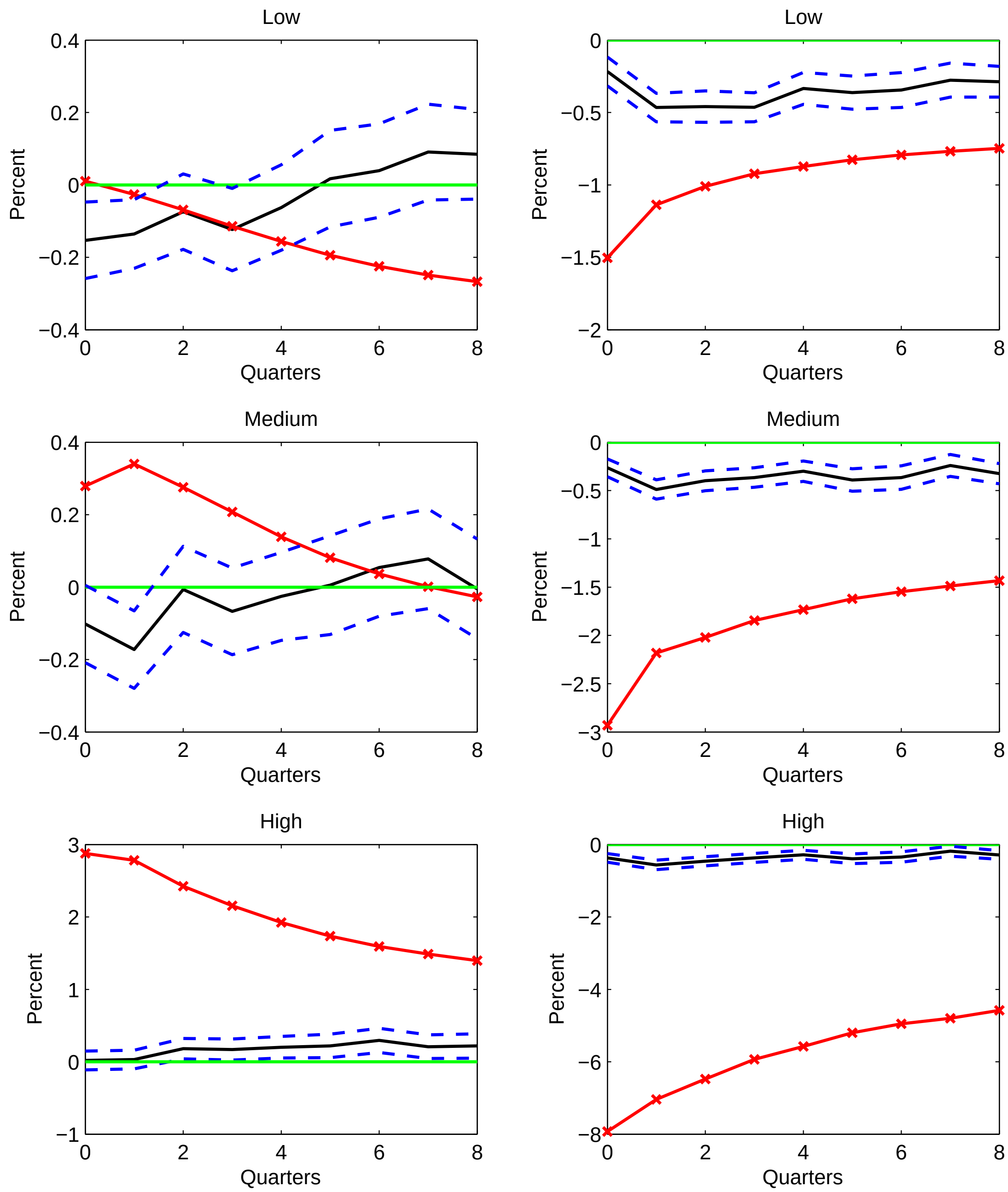


Figure 2.5: Impulse responses by pricing type

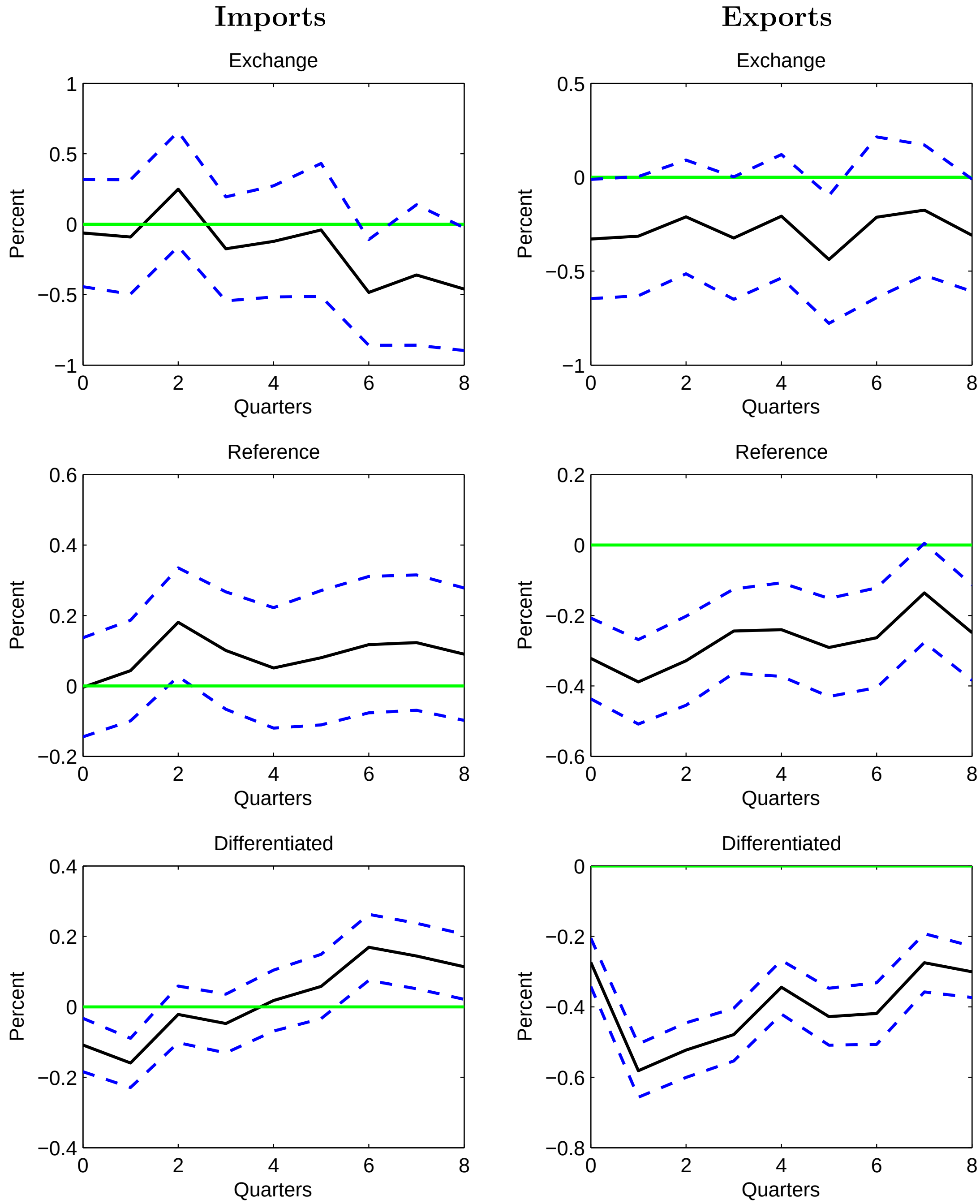
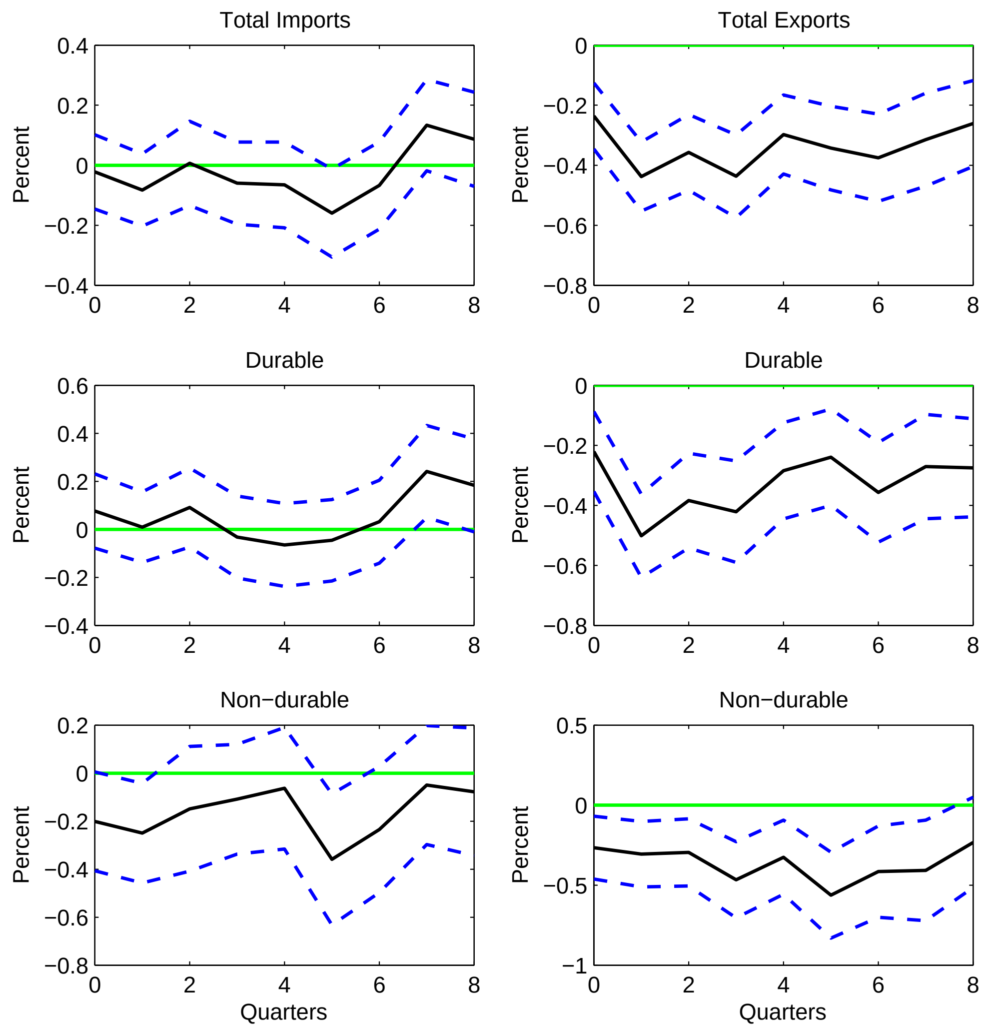


Figure 2.6: Impulse responses for NAICS categories, total and split into durable and non-durable



CHAPTER III

The Collapse of International Trade During the 2008-2009 Crisis: In Search of the Smoking Gun[1]

3.1 Introduction

A remarkable feature of the recent crisis is the collapse in international trade. This collapse is global in nature (WTO 2009), and dramatic in magnitude. To give one example, while U.S. GDP has declined by 3.8% from its peak to the current trough, real U.S. imports fell by 21.4% and real exports fell by 18.9% over the same period. Though protectionist pressures inevitably increased over the course of the recent crisis, it is widely believed that the collapse is not due to newly erected trade barriers (Baldwin and Evenett 2009).

While these broad facts are well known, we currently lack both a nuanced empirical understanding of the patterns and a successful economic explanation for them. This paper has three main parts. The first uses high-frequency (quarterly and monthly) foreign trade data for the United States to document the patterns of collapse at a disaggregated level. We focus on the U.S. in part due to its central role in the global downturn and because it offers up-to-date, detailed monthly data. The second part uses data on domestic absorption, domestic price levels, as well as quantities and prices of imports to perform a simple "trade wedge" exercise in the spirit of Cole and Ohanian (2002) and Chari, Kehoe and McGrattan (2007). It allows us to assess whether the evolution of trade volumes is in line with the overall domestic demand and relative prices. Finally, the third part uses monthly sector-level data to examine a range of potential explanations for the trade collapse proposed in the policy literature.

Our main findings can be summarized as follows. The recent collapse in inter-

[1]This chapter is joint work with Andrei Levchenko and Linda Tesar. A slightly shorter version is published in the *IMF Economic Review*, Vol. 58, No. 2 (Dec. 2010), pp. 214-253.

national trade is indeed exceptional by historical standards. Relative to economic activity, the drop in trade is an order of magnitude larger than what was observed in the previous postwar recessions, with the exception of 2001. The collapse appears to be broad-based across trading partners: trade with virtually all parts of the world fell by double digits. Across sectors, the sharpest percentage drops in trade are in automobiles, durable industrial supplies and capital goods. Those categories also account for most of the absolute decrease in trade. Another way to assess whether the recent trade collapse is exceptional is to use information on prices and examine the wedges. The time series behavior of the international trade wedge exhibits a drastic deviation from the norm during the recent episode. In the second quarter of 2009, the overall trade wedge has reached -40%, revealing a collapse in trade well in excess of what is predicted by the pace of economic activity and prices. This is indeed exceptional: over the past 25 years the mean value of the wedge is only 1.6%, with a standard deviation of 6.6%. We conclude from this exercise that the recent trade collapse does represent a puzzle, in the sense that any import demand function derived from a standard international real business cycle model would predict a far smaller drop in imports given observed overall economic activity and prices.[2] Finally, using detailed trade data, we shed light on which explanations are consistent with cross-sectoral variation in trade flow changes. We find strong support for the role of vertical linkages, as well as for compositional effects. Sectors that are used intensively as intermediate inputs, and those with greater reductions in domestic output experienced significantly greater reductions in trade, after controlling for a variety of other sectoral characteristics. By contrast, trade credit does not appear to play a significant role: more trade credit-intensive sectors did not experience greater trade flow reductions.

We begin by presenting a comprehensive set of stylized facts about the trade collapse, across time, sectors, and destination countries, as well as separating movements in prices and quantities to examine whether the fall is mainly real or nominal. Moving beyond the stylized facts, our next goal is to establish whether the collapse in trade is indeed "extraordinary" relative to what we should expect. In order to do that, we need a benchmark. The starting point of the second exercise is the canonical

[2] Chinn (2009) estimates an econometric model of U.S. exports, and shows that the recent level of exports is far below what would be predicted by the model. Freund (2009) analyzes the behavior of trade in previous global downturns, and shows that the elasticity of trade to GDP has increased in recent decades, predicting a reduction in global trade in the current downturn of about 15%. Our methodology looks at U.S. imports rather than U.S. or global exports, and takes explicit account of domestic and import prices at the quarterly frequency.

international real business cycle model of Backus, Kehoe and Kydland (1995). It assumes that domestic agents value a CES aggregate of domestic and foreign varieties in a particular sector – a common feature of virtually every model in international macroeconomics. In this setup, we derive an import demand equation that expresses the total imports as a function of the overall domestic absorption, domestic prices, and import prices. The "trade wedge" is then defined as the deviation between actual imports and the imports as implied by these variables. Using this simple optimality condition allows us to explore two questions: first, is the recent trade collapse truly a puzzle? That is, the wedge exercise that accounts for both domestic and foreign prices and quantities is the appropriate benchmark to evaluate whether the recent decrease in international trade is in any sense extraordinary. Second, by pitting against the data conditions that would have to hold period-by-period in virtually any quantitative model of international transmission, we can offer a preliminary view on whether – and which – DSGE models can have some hope of matching the magnitude of the recent collapse in international trade.

The analysis of wedges indeed reveals a large shortfall in imports relative to what would be expected based on the pace of economic activity and relative prices. In the third exercise, we use highly disaggregated trade data to test a series of hypotheses about the nature of the trade collapse. We record the percentage changes in exports and imports during the crisis at the 6-digit NAICS level of disaggregation (about 450 distinct sectors), and relate the variation in these changes to sectoral characteristics that would proxy for the leading explanations. The first is that trade may be collapsing because of the transmission of shocks through vertical production linkages. When there is a drop in final output, the demand for intermediate inputs will suffer, leading to a more than proportional drop in trade flows.[3] To test for this possibility, we build several measures of intermediate input linkages at the detailed sector level based on the U.S. Input-Output tables, as well as measures of production sharing based on data on exports and imports within multinational firms. The second explanation we evaluate is trade credit: if during the recent crisis, firms in the U.S. are less willing to extend trade credit to partners abroad, trade may be disrupted.[4]

[3]Hummels, Ishii and Yi (2001) and Yi (2003) document the dramatic growth in vertical trade in recent decades, and di Giovanni and Levchenko (2010) demonstrate that greater sector-level vertical linkages play a role in the transmission of shocks between countries.

[4]Raddatz (2011) shows that there is greater comovement between sectors that have stronger trade credit links, while Iacovone and Zavacka (2009) demonstrate that in countries experiencing banking crises, export fell systematically more in financially dependent industries. Amiti and Weinstein (2009) show that exports by Japanese firms in the 1990s declined when the bank commonly recognized as providing trade finance to the firm was in distress.

We therefore use U.S. firm-level data to construct measures of the intensity of trade credit use in each sector. Finally, the collapse in trade could be due to compositional effects. That is, if international trade happens disproportionately in sectors whose domestic absorption (or production) collapsed the most, that would explain why trade fell more than GDP. Two special cases of the compositional story are investment goods (Boileau 1999, Erceg, Guerrieri and Gust 2008) and durable goods (Engel and Wang 2011). Since investment and durables consumption are several times more volatile than GDP, trade in investment and durable goods would be expected to experience larger swings than GDP as well. Thus, we collect measures of domestic output at the most disaggregated available level, and check whether international trade fell systematically more in sectors that also experienced the greatest reductions in domestic output. In addition, we build an indicator for whether a sector produces durable goods.

This paper is part of a growing literature on the features of the 2008-2009 global crisis in general, and on the collapse in international trade in particular. Blanchard, Das and Faruqee (2010) and Lane and Milesi-Ferretti (2010) analyze the crisis experience in a large sample of countries, to establish which country characteristics can best explain the cross-sectional variation in the severity of downturns. Imbs (2010) documents the remarkable synchronicity of the crisis across a large set of countries. Chor and Manova (2010) demonstrate that credit conditions in exporting countries affected international trade during the current crisis. Bricongne, Fontagné, Gaulier, Taglioni and Vicard (2009) and Behrens, Corcos and Mion (2010) use detailed firm-level data to document the changes in trade at the micro level for France and Belgium, respectively. Alessandria, Kaboski and Midrigan (2010a), Bems, Johnson and Yi (2010), and Eaton, Kortum, Neiman and Romalis (2010) assess whether particular channels, such as input-output linkages or inventory adjustment, can account for the trade collapse in quantitative models. Our approach is deliberately agnostic, testing empirically a wide range of hypotheses proposed in the literature. Our results thus complement quantitative modeling efforts, by highlighting which of the mechanisms appear most relevant empirically.

The rest of the paper is organized as follows. Section 3.2 presents a set of stylized facts on the recent trade collapse using detailed quarterly data on U.S. imports and exports. Section 3.3 describes the construction of the international trade wedges, and presents the behavior of those wedges over time and in different sectors. Section 3.4 uses detailed data on sectoral characteristics to assess whether the variation across sectors is consistent with the main explanations proposed in the policy literature.

Section 3.5 concludes.

3.2 Facts

This section uses disaggregated quarterly data on U.S. imports and exports to establish a number of striking patterns in the data. We discuss three aspects of the recent episode: (i) its magnitude relative to historical experience; (ii) the sector- and destination- level breakdown; and (iii) the behavior of prices and quantities separately. The total imports, exports, and GDP data come from the U.S. National Income and Product Accounts (NIPA). The trade flows and prices disaggregated by sector are from the Bureau of Economic Analysis' Trade in Goods and Services Database, while trade flows disaggregated by partner are from the U.S. International Trade Commission's Tariffs and Trade Database.

Fact 1. As a share of economic activity, the collapse in U.S. exports and imports in the recent downturn is exceptional by historical standards. Only the 2001 recession is comparable.

Figure 3.1(a) plots quarterly values of imports and exports normalized by GDP over the past 63 years, along with the recession bars. Visually, the 2008-09 collapse appears larger than most changes experienced in the past.[5] It is also clear, however, that a similar drop occurred in 2001, a fact that appears underappreciated. Table 3.1 reports the change in the ratios of imports and exports to GDP during the 2008 and 2001 recessions, as well as the average changes in those variables during the recessions that occurred between 1950 and 2000. For the 2008 and 2001 recessions, the total declines are calculated both during the official NBER recession dates, and with respect to the peak value of trade/GDP around the onset of the recession. It is apparent that both the imports and exports to GDP decline by 14 to 30% during the last two recessions, depending on the measure. By contrast, in all the pre-2000 recessions, the average decline in exports is less than 1 percentage point, and the average change in imports is virtually nil. As an alternative way of presenting the historical series, Figure 3.1(b) plots the deviations from trend in real imports, exports, and GDP over the same period. To detrend the series, we use the Hodrick-Prescott filter with the standard parameter of 1600. The recent period is characterized by

[5]The concurrent change in the exchange rate is relatively subdued. Figure 3.11 plots the long-run path of the nominal and real effective exchange rates for the United States. Over the period coinciding with the trade collapse, the U.S. dollar appreciated slightly in real terms, but the change has been less than 10%.

large negative deviations from trend for both imports and exports. We can see that these are greater in magnitude than the deviation from trend in GDP.[6]

An important question is how large is the contribution of the collapse in the price of oil, and the consequent reduction in the value of oil imports. The dotted line in Figure 3.1(a) reports the evolution of non-oil imports as a share of GDP.[7] It appears that non-oil imports experience a similar percentage decline as a share of GDP as the total imports. This conclusion is confirmed in Table 3.1, that reports the change in non-oil imports as a share of GDP in the 2008-2009 and 2001 recessions. While the overall imports to GDP ratio does decline more than non-oil imports during the current crisis, the non-oil imports to GDP still decline by more than 20%.

Fact 2. For both U.S. exports and imports, the sharpest percentage drops are in the automotive and industrial supplies sectors, with consumer goods trade experiencing a far smaller percentage decrease. For imports, the decrease in the petroleum category alone accounts for one third of the total decline.

Panel A of Table 3.2 reports the reductions in exports and imports by sector for the recent trade collapse. While the overall reduction in nominal exports is about 26%, exports in the automotive sector (which comprises both vehicles and parts) drop by 47%, and in industrial supplies by 34%. By contrast, exports of consumer goods (−12%), agricultural output (−19%), and capital goods (−20%) experience less than average percentage reductions. The table also reports the share of each of these sectors in total exports at the outset of the crisis, as well as the absolute reductions in trade. It is clear that industrial supplies and automotive sectors accounted for almost 40% of all U.S. goods exports, and their combined decrease accounts for more than half of the total collapse of U.S. exports.

Total imports decline by 34%. The petroleum and products category has the largest percentage decrease at −54%. It also accounts for some 20% of the pre-crisis imports, and about 1/3 of the total absolute decline. The total non-oil imports

[6] How much of this decline in international trade is due to the extensive margin, that is, disappearing import categories? While we do not have up-to-date information on the behavior of individual firms, we can use highly disaggregated data on trade flows to shed light on this question. To that end, we examined monthly import data at the Harmonized Tariff Schedule 8-digit classification, which contains about 10,000 sectors. The number of HTS 8-digit categories with non-zero imports does decline during this crisis, but the change is very small: while the U.S. recorded positive monthly imports in 9,200-9,300 categories during the year leading up to June 2008, in the first half of 2009 that number fell to about 9,100. These disappearing categories account for less than 0.5% of the total reduction in imports over this period. Thus, when measured in terms of highly disaggregated import categories, the role of the extensive margin in the current trade collapse appears to be minimal.

[7] This series starts in 1967, as the breakdown of imports into oil and non-oil is not available for the earlier period.

decline by 29%. As with exports, the next largest percentage declines are in the automotive (−49%) and industrial supplies (−47%) sectors. By contrast, consumer goods decrease by only 15%, and agricultural products by 9%.

Figures 3.2 and 3.3 illustrate the collapse in real trade over time. Figure 3.2 displays the trade in real goods and services separately. We can see that goods trade is both larger in volume, and the decrease is more pronounced than in services. Figure 3.3 breaks total goods trade into real durables and non-durables, to highlight that the reduction in the trade categories considered durable is more pronounced, for both imports and exports. These figures indicate that in order to understand the collapse in real trade flows, it is reasonable to focus on goods trade and examine durable goods more closely. We follow this strategy in Sections 3.3 and 3.4.

Fact 3. The collapse in U.S. foreign trade is significant across the major U.S. trading partners, all of whom register double-digit percentage reductions in both imports and exports.

Panel B of Table 3.2 reports the reduction, in absolute and percentage terms, of exports and imports to and from the main regions of the world and the most important individual partners within those regions. To be precise, the first three columns, under "Exports," report the exports from the U.S. to the various countries and regions. Correspondingly, the columns labeled "Imports" report the imports to the U.S. from these countries. The broad-based nature of the collapse is remarkable. With virtually every major partner, U.S. exports are dropping by more than 20% (with China and India being the notable exceptions at −15% and −13%), while imports are dropping by 30% or more (with once again China and India as the main exceptions at −16% and −21% respectively).

Fact 4. Both quantities and prices of exports and imports decreased, with changes in real quantities explaining the majority of the nominal decrease in trade.

Figure 3.4 plots both nominal and real trade, each normalized to its 2005q1 value. While nominal exports fall by 26% from its peak, the fall in real exports accounts for about three quarters of that decline, 19%. For imports, the role of declining import prices is greater. In addition, the peak in real imports occurred 3 quarters earlier than the peak of nominal imports, due largely to the timing of the oil price collapse. Nonetheless, real quantities account for about 60% of the total nominal decline in imports. In order to abstract from the role of oil in the evolution of total imports, the dotted lines report the real and nominal non-oil imports. The evolution of non-oil trade is similar to the total, though the run-up in nominal trade and the subsequent reduction are less pronounced. Table 3.3 presents the nominal, real, and price level changes in each export and import category. It is remarkable that in some important sectors, such as automotive, capital goods, and consumer goods, the prices did not move much at all, and the entire decline in nominal exports and imports is accounted for by real quantities. By contrast, prices moved the most in industrial supplies, especially petroleum. Figure 3.5 presents the contrast between nominal and real graphically. It plots the nominal declines in each sector against the real ones, along with the 45-degree line. For points on the 45-degree line, all of the nominal decrease in trade is accounted for by movements in real quantities, with no change in prices. For points farther from the line, price changes account for more of the nominal change in trade. There are several things to take away from this figure. First, we can see that some important sectors are at or very near the 45-degree line: all of the change in nominal trade in those sectors comes from quantities. Second, petroleum imports is by far the biggest exception, as the only sector in which most of the change comes from prices. Finally, in most cases import and export prices experienced a drop – the bulk of the points are below the 45-degree line. This implies that in the recent episode, trade prices and quantities are moving in the same direction.

3.3 Wedges

The discussion of nominal and real quantities foreshadows the exercise in this section. In particular, we ask, is there any way to assess whether the trade changes during the recent crisis are in some sense "exceptional" or "abnormal"? That is, how would we expect trade flows to behave in the recent recession? To provide a model-based benchmark for the behavior of trade flows, we follow the "wedge" methodology of Cole and Ohanian (2002) and Chari et al. (2007). We set down an import demand equation that would be true in virtually any International Real Business Cycle (IRBC) model, and check how the deviation from this condition, which we call the "trade wedge," behaves in the recent crisis relative to historical experience. As the derivation is standard, we detail it in section 3.6.

The import demand relationship, in log changes denoted by a caret, is given by:

$$\widehat{y}^f = \varepsilon\left(\widehat{P} - \widehat{p}^f\right) + (\widehat{C + I}), \tag{3.1}$$

where y^f is demand for imports, $C + I$ is overall aggregate demand (consumption plus investment), P is the overall domestic price level, and p^f is the price of imports.

This equation provides a benchmark for evaluating whether the recent trade collapse represents a large deviation from business as usual.[8] They will hold exactly in any model that features CES aggregation of foreign and domestic goods, a quite common one in the IRBC literature. Economically, it ties real import demand to (i) overall real domestic absorption $(C + I)$; (ii) the overall domestic price level (P); and (iii) import prices p^f. Since all of these are observable, we proceed by using equation (3.1) to compute the log deviation from it holding exactly, calling it the "trade wedge." On the left-hand side is the log change in real imports. The term $(\widehat{C + I})$ is captured by the log change in the sum of real consumption and real investment in the national accounts data; $\widehat{P}$ is the change in the GDP deflator,[9] and $\widehat{p}^f$ is the change in the import price deflator. We must also choose a value of the elasticity of substitution ε. We report results for two values: $\varepsilon = 1.5$, which is the "classic" IRBC value of the elasticity of substitution between domestic and foreign goods (Backus et al. 1995); and $\varepsilon = 6$, which is a common value in the trade literature (Anderson and van Wincoop 2004).[10]

We use quarterly data and compute year-to-year log changes in each variable. Column 1 in Table 3.4 presents the value of the year-to-year wedge for 2009q2 (com-

[8] Our approach is related to another benchmark for analyzing trade volumes: the gravity equation. Starting from equation (3.8), the total nominal trade volumes can be expressed in terms of prices and the nominal output as: $p_t^f y_t^f = (1 - \omega) \left(\frac{P_t}{p_t^f} \right)^{\varepsilon - 1} X_t$, where $X_t \equiv P_t (C_t + I_t)$ is nominal GDP. The gravity approach proceeds to express p_t^f as a function of trade costs and the source country characteristics, usually the source country nominal GDP, X_t^*. The advantage of the gravity approach is that it uses less information, as it does not rely on knowing domestic and import prices. The main disadvantage is that it imposes additional assumptions on the supply side, by taking a stand on what determines p_t^f. This leads to an unnecessarily restrictive interpretation of the current experience: any shortfall of actual imports from what is implied by the evolution of nominal GDPs must be attributed to an increase in trade costs (see, e.g., Jacks, Meissner and Novy 2009). In a sense, by subsuming domestic prices and making strong assumption on import prices, the gravity approach forces actual trade to be on the model-implied demand and supply curves exactly. By contrast, our approach uses explicit information on domestic and import prices to gauge how far we are from the model-implied demand curve.

[9] We also constructed a price index for just consumption and investment based on the consumption and investment prices in the National Income and Product Accounts, and used that instead of the GDP deflator. The results were virtually unchanged.

[10] Throughout this section, we assume that the taste parameter ω is not changing. If ω is thought of as a taste shock in the demand for foreign goods, an alternative interpretation of the wedge would be that it reveals what this taste shock must be in each period to satisfy the first-order condition for import demand perfectly. In the IRBC literature, the parameter ω is sometimes thought of as a trade cost, and its value calibrated to the observed share of imports to GDP. Under this interpretation, it may be that during this crisis trade costs went up, thereby lowering imports. While we do not have comprehensive data on total trade costs at high frequencies, anecdotal evidence suggests that if anything shipping costs decreased dramatically in the course of the recent crisis, due in part to the oil price collapse (Economist 2009). Thus, taking explicit account of shipping costs would make the wedge even larger.

puted relative to 2008q2) for the two elasticities. We choose to report the values for 2009q2 because it represents the trough in both international trade and the wedges during the current trade collapse episode. The wedge is indeed quite large, at −40% for the more conservative choice of ε. The negative value indicates, not surprisingly, that imports fell by 40% *more* than overall U.S. domestic demand and price movements would predict. To get a sense whether the current level of the wedge is out of the ordinary, Figure 3.6 plots the quarterly values of the year-on-year wedge for the period 1968 to the present. The recent period is indeed exceptional. Over the entire sample period going back to 1968, the long-run average of the wedge is actually slightly positive, at 2.9%, with a standard deviation of 10.2%.[11] After 1984 – a year widely considered to be a structural break, also evident in Figure 3.6 – the average wedge is 1.6%, with a standard deviation of 6.6%. Thus, the current value of the wedge is more than 6 standard deviations away from the mean, and from zero, when compared to the post-1984 period. Note that a more muted instance of the "collapse in the wedge" occurred in the 2001 recession. However, in that episode the wedge reached −20%, well short of the current value.[12]

We can also determine whether price or quantity movements make up the bulk of the current wedge. Real imports (the left-hand side of equation 3.1) fell by 21%, while the total final demand $(\widehat{C+I})$ fell by 6.7%. This implies that in the absence of any relative price movements, the wedge would have been about −14%. The price movements conditioned by the elasticity of substitution make up the rest of the difference: the GDP deflator went up by 1.5%, while import prices actually fell by 16%.

The second column of Table 3.4 repeats the exercise for the non-oil imports. Abstracting from oil reduces the wedge to −28%, a value that is still quite exceptional. The post-1984 standard deviation in the non-oil wedge is 5.2%, with a mean of 1.3%. Thus, the 2009q2 value of the non-oil wedge is more than 5 standard deviations away from either its historical mean or zero.

[11] We conjecture that the positive long-run average value over this period may reflect a secular reduction in trade costs, which we do not incorporate explicitly into our exercise.

[12] In the baseline analysis we compute the wedges based on log changes over time – in our case, year-on-year changes in quarterly data. An alternative would be to compute them based on deviations from trend in each variable. To do this, we HP-detrended each series, and built a wedge using equation (3.1) such that the caret means the log deviation from trend. This procedure yields qualitatively similar results. In 2009q2 the overall wedge stands at −20%. This is considerably smaller in magnitude than the baseline value we report. However, it is still quite exceptional by historical standards. In the post-1984 period, the standard deviation of the deviation-from-trend wedge is 4.8%, and its mean is very close to zero. This implies that the value of 2009q2 wedge is 4.3 standard deviations away from the historical average.

3.3.1 Durable goods

Beyond the simple structure of the canonical IRBC model, this methodology can be applied to construct a wedge for any sector that would be modelled as a CES aggregate of domestic and foreign varieties. The key data limitation that prevents the construction of wedges for disaggregated industries is the availability of domestic absorption and price levels at the detailed level. We can make progress, however, for one important sector: durable goods. Engel and Wang (2011) demonstrate that both imports and exports are about 3 times more volatile than GDP in OECD countries, and propose a compositional explanation. It is well known that durable goods consumption is more volatile than overall consumption, and that much of international trade is in durable goods. Putting the two together provides a reason for why trade is more volatile than GDP: it is composed of the more volatile durables. This hypothesis can be extended to apply to the recent crisis. It may be that imports and exports fell so much relative to GDP because their composition is different from the composition of GDP.

The wedges methodology can be used to shed light on the potential for this explanation to work. If the reason for the fall in trade is compositional, then the wedges should disappear (or at least get smaller) when we compute them on the durable goods separately. By standard CES cost minimization, the "durable trade wedge" has the familiar form:

$$\widehat{d^f} = \varepsilon \left(\widehat{P_D} - \widehat{p}^f_D \right) + \widehat{D}, \tag{3.2}$$

where, as above, P_D is the domestic price level of the durable spending, and p^f_D is the price of the foreign durables. To construct the durable wedge, we use the BEA definition of durable goods imports.[13] Using sector-level price and quantity import data, we construct the log change in real durable imports $\widehat{d^f}$ and in the prices of durable imports $\widehat{p}^f_D$. To proxy for real durable demand $\widehat{D}$ we combine domestic spending on consumer durables and fixed investment, building the corresponding domestic durable price level.[14]

The third column of Table 3.4 reports the 2009q2 (to-date trough) value of the year-to-year wedge. It is clear that the compositional explanation does have some bite: for $\varepsilon = 1.5$ the durable wedge stands at -21%, or about half of the overall

[13] This roughly corresponds to the sum of capital goods; automotive vehicles, engines, and parts; consumer durables; and durable industrial supplies and materials.

[14] Our calculation includes in $\widehat{D}$ structures and residential investment in addition to machinery and equipment. This inclusion tends to make the durable wedge smaller, as real estate prices fell more than overall investment goods prices, shrinking the price component of the durable wedge.

wedge value. At the same time, even the durable wedge's value is exceptional in this period: it is about 4 standard deviations away from its post-1984 mean. Relative to the overall wedge, the contribution of the real quantities to the durable wedge is greater. Real durable imports fell by 34%, while the real durable domestic spending fell by 18%. This implies that in the complete absence of relative price movements, the "quantity wedge" would be about 16%. The rest of the wedge comes from relative prices.

3.3.2 Final goods

We can make progress in shedding light on the compositional explanations in another way. It may be that equation (3.7) is not a good description of the production structure of the economy. One immediate possibility is that consumption and investment goods are very different. Indeed, Section 3.2 shows that consumption and capital goods experienced different price and quantity movements. We can glean further where the data diverge from the model by positing a production structure in which investment and consumption goods are different, but both are produced from domestic and foreign varieties (see, e.g., Boileau 1999, Erceg et al. 2008). Going through the same cost minimization calculation, we obtain the import demands for consumption and investment goods expressed in log changes:

$$\widehat{c^f} = \varepsilon \left(\widehat{P}_C - \widehat{p^f_C} \right) + \widehat{C}, \tag{3.3}$$

$$\widehat{i^f} = \sigma \left(\widehat{P}_I - \widehat{p^f_I} \right) + \widehat{I}. \tag{3.4}$$

These equations now relate the real reduction in consumption goods imports to the overall domestic real consumption, the consumption price index, and the price index of imported consumption goods, and same for investment. Provided that we have data on all of these prices and quantities, we can calculate the "consumption trade wedge" and the "investment trade wedge," and determine which one reveals greater deviations from the theoretical benchmark.

To construct these, we isolate imports of consumer goods (about 20% of total U.S. imports at the outset of the crisis), and compute the real change in consumer goods imports $\widehat{c^f}$, and the corresponding import price change $\widehat{p^f_C}$. We then match these up to the change in real consumption expenditures on goods $\widehat{C}$, and the domestic consumption price index. Column 4 of Table 3.4 reports the results. The consumption wedge is much smaller, at -6.4%. Figure 3.7 displays the time path of the year-on-year consumption wedge since 1968. It is clear that the recent episode is completely unexceptional if we confine our attention to consumer goods trade. The consumption wedge has a post-1984 mean of 4.4% and a standard deviation of 5.6%.

To construct the investment trade wedge, we isolate imports of capital goods (also about 20% of U.S. imports at the outset of the crisis), and match them up with investment data in the National Accounts. Column 5 of Table 3.4 presents the results. The investment wedge is also quite small, at −10%. As Figure 3.7 shows, it is unexceptional by historical standards: the mean investment wedge post-1984 is 2.5%, with a standard deviation of 5.9%. This implies that the current level of the investment wedge is about one and a half standard deviations away from the historical mean, or from the model implied value of zero.

These results tell us that the puzzle in the recent trade collapse is not in final goods, be it consumption or investment. Instead, the discrepancy between the large overall wedge and the small consumption and investment wedges appears to be in the intermediate goods sectors, and these partially overlap with durable goods. This suggests that modeling exercises that focus on movements in the final domestic demand are unlikely to match the data well. Instead, explanations that focus on trade in intermediates appear potentially more fruitful.

3.3.3 Other countries

Figure 3.8 reports the overall trade wedge, (3.1), for the other major developed countries: Japan, Germany, U.K., France, Italy, and Canada. Within this group, there is a fair bit of variation in the current behavior of the wedge.[15] In only one country, Japan, the current wedge has reached the level comparable to that or the U.S., exceeding −60%. Germany, France, and Italy all experience large negative wedges, of about −25%. While this does point to a shortfall in imports relative to what would be predicted by the simple model, it is clearly much less drastic when compared to both the current shortfalls in the U.S. and Japan, as well as these countries' historical variation in the wedge. By contrast, Canada and the U.K. exhibit only a small departure from the norm in the current crisis, suggesting that the behavior of imports in these countries is easily rationalized simply by movements in aggregate demand and relative prices. Figure 3.9 reports the overall trade wedges for selected emerging markets. Here, the experiences are just as diverse: while Korea, Turkey, and the Czech Republic record wedges in the range of −20% to −30%, in Mexico, for instance, the wedge is very close to zero.

[15] All the data used in this subsection come from the OECD.

To summarize, in both developed countries and emerging markets, there appears to be a great deal of heterogeneity in the behavior of the trade wedges. This is in spite of the fact that international trade itself collapsed in all of these countries to a similar degree. This suggests that behind the superficial similarity in country experiences, there is important heterogeneity in the underlying shocks and transmission mechanisms. Sorting out this variation remains a fruitful direction for future research.

3.4 Empirical evidence

The framework set out in Section 3.3 is useful for framing a set of possible explanations for the trade collapse and of hypotheses to test. When we focus on the overall trade, we uncover a large shortfall in real imports, relative to what would be implied by the final demand $(C + I)$. What could be responsible for this large divergence between the model and the data? The first possibility is that the model is not rich enough. For instance, confining our attention to final goods imports reveals that for consumption and investment goods, the shortfall is far less dramatic. Thus, one of the potential explanations is trade in intermediate inputs and vertical linkages. Second, it may be that the model is adequate, but agents – be it households or firms – face additional constraints that prevent them from being on their demand curve. This suggests that another potential explanation for the increase in the wedge is a tightening of a financial constraint. Finally, it may be that when we compare the total imports to total domestic demand, we are not comparing the same bundle of goods, and thus it is important to examine the composition of trade. This last hypothesis also points to the importance of looking at this phenomenon at a more disaggregated level.

This is what we do in this section. In order to carry out empirical analysis, we collect monthly nominal data for U.S. imports and exports vis-à-vis the rest of the world at the NAICS 6-digit level of disaggregation from the USITC. This the most finely disaggregated NAICS trade data available at the monthly frequency, yielding about 450 distinct sectors. To reduce the noise in the monthly trade data, we aggregate it to the quarterly frequency. For each sector, we compute the percentage drop in trade flows over the course of a year ending in June 2009, and estimate the following specification:

$$\gamma_i^{trade} = \alpha + \beta \text{CHAR}_i + \boldsymbol{\gamma} \mathbf{X}_i + \epsilon_i.$$

In this estimating equation i indexes sectors, γ_i^{trade} is the percentage change in the trade flow, which can be exports or imports, and CHAR_i is the sector-level variable meant to capture a particular explanation proposed in the literature.[16]

We include a vector of controls $\mathbf{X}_i$ in each specification. Because we do not have the required data at this level of disaggregation to construct the sector-level wedges and their components, our regression estimates do not have a structural interpretation. However, the functional form of the import demand equation, (3.1), is informative about the kinds of variables we should control for. First, we control for the elasticity of substitution between goods within a sector, sourced from Broda and Weinstein (2006b). Second, we must try to proxy for the movements in domestic demand and sector-level prices. To control for sector size, we include each industry's share in total imports (resp. exports) over the period 2002-2007, as well as labor intensity computed from the U.S. Input-Output table. These are indicators available for both non-manufacturing and manufacturing industries. To check robustness, we also control for skill and capital intensity sourced from the NBER productivity database, and the level of inventories from the BEA, which are unfortunately only available for manufacturing industries.[17]

Our strategy is to exploit variation in sectoral characteristics to evaluate three main hypotheses: vertical production linkages, trade credit, and compositional effects/durables demand. We now describe each of them in turn. The vertical linkages view, most often associated with Yi (2003), suggests that since much of international trade is in intermediate inputs, and intermediates at different stages of processing often cross borders multiple times, a drop in final consumption demand associated with the recession will decrease cross-border trade in intermediate goods. This can matter for the business cycle: di Giovanni and Levchenko (2010) show that trade in intermediate inputs leads to higher comovement between countries, both at sectoral and aggregate levels. The simplest way to test the vertical linkage hypothesis is to classify goods according to the intensity with which they are used as intermediate inputs. We start with the 2002 benchmark version of the detailed U.S. Input-Output

[16]The change in trade is computed using the total values of exports and imports in each sector, implying that it is a nominal change. As an alternative, we used import price data from the BLS at the most disaggregated available level to deflate the nominal flows. The shortcoming of this approach is that the import price indices are only available at a more coarse level of aggregation (about 4-digit NAICS). This reduces the sample size, especially for exports, and implies that multiple 6-digit trade flows are deflated using the same price index. Nonetheless, the main results were unchanged.

[17]We also re-estimated all of the specifications while dropping oil sectors: NAICS 211111 (Crude Petroleum and Natural Gas Extraction), 211112 (Natural Gas Liquid Extraction), and 324110 (Petroleum Refineries). All of the results below were unchanged.

matrix available from the Bureau of Economic Analysis, and construct our measures using the Direct Requirements Table. The (i, j)th cell in the Direct Requirements Table records the amount of a commodity in row i required to produce one dollar of final output in column j. By construction, no cell in the Direct Requirements Table can take on values greater than 1. To build an indicator of "downstream vertical linkages," we record the average use of a commodity in row i in all downstream industries j: the average of the elements across all columns in row i. This measure gives the average amount of good i required to produce one dollar worth of output across all the possible final output sectors. In other words, it is the intensity with which good i is used as an intermediate input by other sectors.

We build two additional indicators of downstream vertical linkages: the simple number of sectors that use input i as an intermediate, and the Herfindahl index of downstream intermediate use. The former is computed by simply counting the number of industries for which the use of intermediate input i is positive. The latter is an index of diversity with which different sectors use good i: it will take the maximum value of 1 when only one sector uses good i as an input, and will take the minimum value when all sectors use input i with the same intensity.

A related type of the vertical linkage story is the "disorganization" hypothesis (Kremer 1993, Blanchard and Kremer 1997). In a production economy where intermediate inputs are essential, following a disruption such as the financial crisis, shocks to even a small set of intermediate inputs can create a large drop in output. For instance, Blanchard and Kremer (1997) document that during the collapse of the Soviet Union, output in more complex industries – those that use a greater number of intermediate inputs – fell by more than output in less complex ones. This view suggests that we should construct measures of "upstream vertical linkages," that would capture the intensity and the pattern of intermediate good use by industry (in column) j. The three indices we construct parallel the downstream measures described above. We record the intensity of intermediate good use by industry j as total spending on intermediates per dollar of final output. We also measure an industry's complexity in two ways: by counting the total number of intermediate inputs used by industry j, and by computing the Herfindahl index of intermediate use shares in industry j.[18]

Burstein, Kurz and Tesar (2008) propose another version of the vertical linkage hypothesis. They argue that it is not trade in intermediate inputs per se, but how production is organized. Under "production sharing," inputs are customized and the

[18]For more on these product complexity measures, see Cowan and Neut (2007) and Levchenko (2007).

factory in one country depends crucially on output from a particular factory in another country. In effect, inputs produced on different sides of the border become essential, and a shock to one severely reduces the output of the other. To build indicators of production sharing, we follow Burstein et al. (2008) and use data on shipments by multinationals from the BEA. In particular, we record imports from foreign affiliates by their U.S. parent plus imports from a foreign parent company by its U.S. affiliate as a share of total U.S. imports in a sector. Similarly, we record exports to the foreign affiliate from their U.S. parents plus exports to a foreign parent from a U.S. affiliate as a share of total U.S. exports. In effect, these measures of production sharing are measures of intra-firm trade relative to total trade in a sector. We use the BEA multinational data at the finest level of disaggregation that is publicly available, which is about 2 or 3 digit NAICS, and take the average over the period 2002-2006 (the latest available years).

The second suggested explanation for the collapse in international trade is a contraction in trade credit (see, e.g., Auboin 2009, IMF 2009). Under this view, international trade is disrupted because importing domestic companies no longer extend trade credit to their foreign counterparties. Without trade credit, foreign firms are unable to produce and imports do not take place. Indeed, there is some evidence that sectors more closely linked by trade credit relationships experience greater comovement (Raddatz 2011). To test this hypothesis, we used Compustat data to build standard measures of trade credit intensity by industry. The first is accounts payable/cost of goods sold. This variable records the amount of credit that is extended to the firm by suppliers, relative to the cost of production. The second is accounts receivable/sales. This is a measure of how much the firm is extending credit to its customers. These are the two most standard indices in the trade credit literature (see, e.g., Love, Preve and Sarria-Allende 2007). To construct them, we obtain quarterly data on all firms in Compustat from 2000 to 2008, compute these ratios for each firm in each quarter, and then take the median value for each firm across all the quarters for which data are available. We then take the median of this value across firms in each industry.[19] Since coverage is uneven across sectors, we ensure that we have at least 10 firms over which we calculate trade credit intensity. This implies that sometimes the level of variation is at the 5-, 4-, and even 3-digit level, though the trade data are at the 6-digit NAICS level of disaggregation.[20]

[19] We take medians to reduce the impact of outliers, which tend to be large in firm-level data. Taking the means instead leaves the results unchanged.

[20] Amiti and Weinstein (2009) emphasize that trade credit in the accounting sense and trade finance are distinct. Trade credit refers to payments owed to firms, while trade finance refers to

Finally, another explanation for the collapse of international trade has to do with composition. It may be that trade fell by more than GDP simply because international trade occurs systematically in sectors that fell more than overall GDP. A way to evaluate this explanation would be to control for domestic absorption in each sector. While we do not have domestic absorption data, especially at this level of aggregation, we instead proxy for it using industrial production indices. These indices are compiled by the Federal Reserve, and are available monthly at about the 4-digit NAICS level of disaggregation. They are not measured in the same units as import and export data, since industrial production is an index number. Our dependent variables, however, are percentage reductions in imports and exports, thus we can control for the percentage reduction in industrial production to measure the compositional effect. Two special cases of the compositional channel are due to Boileau (1999), Erceg et al. (2008), and Engel and Wang (2011). These authors point out that a large share of U.S. trade is in investment and durable goods, which tend to be more volatile than other components of GDP. In order to explore this possibility, we classify goods according to whether they are durable or not, and examine whether durable exports indeed fell by more than nondurable ones.[21]

Table 3.12 reports the summary statistics for all the dependent and independent variables used in estimation.

3.4.1 Vertical linkages

Table 3.5 describes the results of testing for the role of downstream vertical linkages in the reduction in trade. In this and all other tables, the dependent variable is the percentage reduction in imports (Panel A) or exports (Panel B) from 2008q2 to 2009q2.[22] All throughout, we report the standardized beta coefficients, obtained by first demeaning all the variables and normalizing each to have a standard deviation of 1. Thus, the regression coefficients correspond to the number of standard deviations change in the left-hand side variable that would be due to a one standard deviation change in the corresponding independent variable. We do this to better gauge the

short-term loans and guarantees used to cover international transactions. We are not aware of any reliable sector-level measures of trade finance used by U.S. firms engaged in international trade.

[21]We created a classification of durables at the 3-digit NAICS level. Durable sectors include 23X (construction) and 325-339 (chemical, plastics, mineral, metal, machinery, computer/electronic, transportation, and miscellaneous manufacturing). All other 1XX, 2XX, and 3XX NAICS categories are considered non-durable for this exercise.

[22]The peak of both total nominal imports and total nominal exports in the recent crisis is August 2008. An alternative dependent variable would be the percentage drop from the peak to the trough. However, that measure is more noisy because of seasonality. Therefore, we consider a year-on-year reduction, sidestepping seasonal adjustment issues.

relative importance of the various competing explanations, especially since the right-hand side variables of interest have very different scales. In addition, in each column we report the partial R^2 associated with the variable(s) of interest. This allows us to assess how successful each explanation is at accounting for the cross-sectoral variation.

There is evidence that downstream linkages play a role in the reduction in international trade, especially for imports into the United States. Goods that are used intensely as intermediates ("Average Downstream Use") experienced larger percentage drops in imports and exports. In addition, other proxies such as the number of sectors that use an industry as an intermediate input as well as the Herfindahl index of downstream intermediate use, are significant for imports, though not for exports. The most successful indicatior of downstream linkages has a beta coefficient of -0.2, implying that a one standard deviation increase in Average Downstream Use leads to a reduction in trade that is 0.2 standard deviations larger. There is also some evidence that the measure of production sharing based on trade within the multinational firms are significantly correlated with a drop in imports, though not exports. In terms of accounting for the variation in the data, the best downstream indicator has a partial R^2 of 0.04, same as the R^2 that can be accounted for by the rest of the controls: sector size, elasticity of substitution, and labor intensity.[23]

Table 3.6 examines instead the role of upstream vertical linkages, with more mixed results. While some of the measures are significant for either imports or exports, and all have the expected signs, there is no robust pattern of significance. The beta coefficients are lower than the downstream coefficients, and the partial R^2's are on the order of 1% in the best of cases.

3.4.2 Trade credit

Table 3.7 examines the hypothesis that trade credit played a role in the collapse of international trade. In particular, it tests for whether imports and exports experienced greater percentage reductions in industries that use trade credit intensively. As above, Panel *A* reports the results for imports, and Panel *B* for exports. There appears to be no evidence that sectors that either use, or extend, trade credit more intensively exhibited larger changes in trade flows. For imports, the beta coefficients are all less than 5%, and the partial R^2's are virtually zero.

[23] Another feature of the vertical linkage hypothesis is that imports and exports will be positively correlated within a sector. To check whether this affects the results, we estimated a Seemingly Unrelated Regression model on the imports and exports equations jointly. The coefficients and the standard errors were very similar to the simple OLS estimates reported in the Tables.

Chor and Manova (2010) use monthly U.S. import data disaggregated by partner country and sector, and a difference-in-differences approach to show that trade from countries that experienced a greater credit contraction fell disproportionately more in sectors that rely on external finance, have fewer tangible assets, or use more trade credit. However, the question remains whether the differential effect of the credit conditions emphasized by those authors translates into greater average reductions in trade from countries hit especially hard by the credit crunch. To check whether this is the case, we calculated, in each sector, the trade-weighted increase in the interbank lending rate, Chor and Manova (2010)'s preferred indicator of the severity of credit contraction:

$$TWCC_i^{trade} = \sum_{c=1}^{N} \Delta IBRATE_c \times a_{ic}^{trade}, \tag{3.5}$$

where $\Delta IBRATE_c$ is the change in the interbank lending rate over the period of the crisis in country c, and a_{ic} is the pre-crisis share of total U.S. trade in sector i captured by country c. In the import equation, a_{ic} is thus the share of total U.S. imports coming from country c in sector i, while in the export equation, a_{ic} is the share of total U.S. exports in sector i going to country c. The variable name $TWCC_i^{trade}$ stands for "trade-weighted credit contraction." In case of imports, its value will be high if in sector i, a greater share of U.S. pre-crisis imports same from countries that experienced a more severe credit crunch. Correspondingly, its value will be relatively low if U.S. imports in that sector are dominated by countries that did not experience a credit crunch during this period. The logic is similar for the export-based measure.[24]

Table 3.7 reports the results of using these measures. There is no evidence that imports into the U.S. fell by more in sectors dominated by countries that experienced largest credit crunches.[25] Paradoxically, for U.S. exports the coefficient is statistically significant but has the "wrong" sign, implying that U.S. sectors that export predominantly to countries with larger credit contractions grew more (fell by less) than other sectors, all else equal. Our results are not in direct contradiction with those of Chor and Manova (2010), as the bulk of that paper estimates the differential effects of the credit crunch across sectors depending on their characteristics, such as external

[24]We are grateful to Davin Chor and Kalina Manova for sharing the interbank lending rate data used in their paper. Their sample of countries is does not cover all of the U.S. imports and exports in each sector, but it comes close, with the mean of 95% and medians of 97% for exports and 98% for imports in our sample of 6-digit NAICS sectors.

[25]These results could be sensitive to the timing of the credit contraction. The Table reports the estimates in which $\Delta IBRATE_c$ is taken over the 12 month period from April of 2008 to April 2009 (the end point of the Chor-Manova dataset). The results are unchanged if we instead lag $\Delta IBRATE_c$ by a further 6 or even 12 months.

finance dependence. The difference-in-differences approach adopted by those authors can only answer the question of whether trade changed differentially across sectors depending on their reliance on trade credit or external finance. It does not answer whether trade from countries experiencing greater credit contractions fell by more or not. Thus, it is perfectly plausible that while changing credit conditions affect sectors differentially, the average effect is nil – which is what we find. This point is underscored by the fact that over the period during which trade collapsed – mid-2008 to mid-2009 – the interbank rates used by these authors actually fell in most countries, reflecting aggressive monetary policy easing (see Figure 2 in Chor and Manova 2010). If one believes the credit contraction hypothesis, this should have increased overall trade rather than reduced it, *ceteris paribus*.

We can also examine the time evolution of trade credit directly. The Compustat database contains information on accounts payable up to and including the first quarter of 2009 for a substantial number of firms. While there are between 7,000 and 8,000 firms per quarter with accounts payable data in the Compustat database over the period 2007-2008, there are 6,250 firms for which this variable is available for 2009q1. While this does represent a drop-off in coverage that may be non-random, it is still informative to look at what happens to trade credit for those firms over time. With this selection caveat in mind, we construct a panel of firms over 2000-2009q1 for which data are available at the end of the period, and trace out the evolution of accounts payable as a share of cost of goods sold. The median value of this variable across firms in each period is plotted in Figure 3.10(a). The dashed line represents the raw series. There is substantial seasonality in the raw series, so the solid black line reports it after seasonal adjustment. The horizontal line plots the mean value of this variable over the entire period.[26] There is indeed a contraction in trade credit during the recent crisis, but its magnitude is very small. The 2009q1 value of this variable is 55.2%, just 1.3% below the period average of 56.5%, and only 3 percentage points below the most recent peak of 58.1% in 2007q4. We conclude from this that the typical firm in Compustat experienced at most a small contraction in trade credit

[26]It is suggestive from examining the raw data that there is no time trend in this variable. We confirm this by regressing it on a time trend: the coefficient on the time trend turns out to be very close to zero, and not statistically significant.

it receives from other firms.[27]

Figure 3.10(b) presents the median of the other trade credit indicator, accounts receivable/sales over the period 2004q1-2009q1. The coverage for this variable is not as good: there are very few firms that report it before 2004, and there are only around 6,000 observations per quarter in 2007-2008. In 2009q1, there are 4,967 firms that report this variable, and we use this sample of firms to construct the time series for the median accounts receivable. Once again, the decrease during the recent crisis is very small: the 2009q1 value of 56.3% is only 1 percentage point below the period average of 57.3%, and just 2 percentage points below the 2007q4 peak of 58.5%. Indirectly, accounts receivable may be a better measure of the trade credit conditions faced by the typical firm in the economy, as it measures the credit extended by big Compustat firms to (presumably) smaller counterparts. But the picture that emerges from looking at the two series is quite consistent: there is at most a small reduction in trade credit during the recent downturn.

3.4.3 Composition

Finally, Table 3.8 tackles the issue of composition and durability. There appears to be robust evidence that compositional effects play a role. Both exports and imports tend to collapse more in industries where industrial production contracted more. The beta coefficients are relatively high (0.34 and 0.21 for industrial production, 0.20 and 0.11 for the durable dummy), and the partial R^2's are also high relative to other potential explanatory variables. The coefficient on the durable 0/1 dummy implies that on average imports in durable sectors contracted by 9.2 percentage points more than non-durable ones, and exports in durable sectors contracted by 4.8 percentage points more. These results further support the conclusions of Section 3.3.1, which shows that accounting explicitly for the durables sector reduces the magnitude of the wedge considerably.

There is an alternative way to examine how much composition may matter. We can compare the data on percentage reductions in exports and imports with data on industrial production at sector level. According to the compositional explanation, imports and exports will drop relative to the level of overall economic activity if in-

[27]It may be that while the impact on the median firm is small, there is still a large aggregate effect due to an uneven distribution of trade credit across firms. To check for this possibility, we built the aggregate accounts payable/cost of goods sold series, by computing the ratio of total accounts payable for all the firms to the sum of all cost of goods sold for the same firms. The results from using this series are even more stark: it shows an increase during the crisis, and its 2009q1 value actually stands above its long-run average.

ternational trade flows are systematically biased towards sectors in which domestic absorption fell the most. Composition will account for all of the reduction in imports and exports relative to economic activity if at sector level, reductions in trade perfectly matched reductions in domestic absorption, and all that was different between international trade and economic activity was the shares going to each sector. By contrast, composition will account for none of the reduction in trade relative to output if there are no systematic differences in the trade shares relative to output shares, at least along the volatility dimension. Alternatively, composition will not explain the drop in trade if imports and exports simply experienced larger drops within each sector than did total absorption.

With this logic in mind, we construct a hypothetical reduction in total trade that is implied purely by compositional effects:

$$\tilde{\gamma}^{trade} = \sum_{i=1}^{\mathcal{I}} a_i^{trade} \gamma_i^{IP}.$$

In this expression, $i = 1, ..., \mathcal{I}$ indexes sectors, a_i^{trade} is the initial share of sector i in the total trade flows, and γ_i^{IP} is the percentage change in industrial production over the period of interest. That is, $\tilde{\gamma}^{trade}$ is the percentage reduction in overall trade that would occur if in each sector, trade was reduced by exactly as much as industrial production. Following the rest of the empirical exercises in this section, we compute γ_i^{IP} over the period from 2008q2 to 2009q2, and apply the trade shares a_i^{trade} as they were in 2008q2.

Table 3.9 reports the results. For both imports and exports, the first column reports the percentage change in nominal trade, the second column the percentage change in real trade, and the third column reports $\tilde{\gamma}^{trade}$, the hypothetical reduction in trade that would occur if in each sector, trade fell by exactly as much as industrial production. Because goods trade data are available for a greater range of sectors than industrial production data, the last column reports the share of total U.S. trade flows that can be matched to industrial production. We can see that we can match 88% of exports and 94% of imports to sectors with IP data. Nonetheless, the fact that this table does not capture all trade flows explains the difference between the values reported there and in Table 3.2. For ease of comparison, the last line of the table reports the percentage change in the total industrial production. By construction, the actual and implied values are identical.

We can see that industrial production fell by 13.5%, while the matching nominal imports and exports fell by 34.3% and 35.0%, respectively. Comparing the actual changes in nominal trade to the implied ones in column 3, we can see that composition "explains" about half: the implied reduction in exports is 18.1%, and the implied reduction in imports 16.1%. As expected, both of these are larger than the fall in industrial production itself. The real reductions in trade (column 2) are smaller, as we saw above. Thus, $\tilde{\gamma}^{trade}$ is about two-thirds of the real change in exports, and 83% of the change in real imports.

We conclude from this exercise that the actual pattern of trade is consistent with the presence of compositional effects: it does appear that international trade is systematically biased towards sectors with larger domestic output reductions. The simple assumption that trade in each sector fell by the same amount as industrial production can "account" for between 50% and almost 85% of the actual drop in trade flows. Several caveats are of course in order to interpret the results. First and foremost, this is an accounting exercise rather than an economic explanation. We do not know why trade flows are systematically biased towards sectors with larger falls in domestic output, nor do we have a good sense of why some sectors had larger output reductions than others.[28] It also does not explain why the trade collapse during this recession is so different from most previous recessions. Second, it is far from clear that trade falling by the same proportion as output is an accurate description of what happened. Indeed, as evidenced by columns 1 and 3 of Table 3.8, the percentage change in IP as a dependent variable explains only 11% of the variation in imports, and 4.4% of the variation in exports.[29] Finally, industrial production may not be an entirely appropriate benchmark, since it captures domestic output, while a more conceptually correct measure would be domestic absorption. Nonetheless, our exercise does provide suggestive evidence of compositional effects.

To combine the above results together, Table 3.10 reports specifications in which all the distinct explanations are included together. The first column presents results for all sectors and the baseline set of control variables. The second column reports the results for manufacturing sectors only, which allows us to include additional controls such as capital and skill intensity. The bottom line is essentially unchanged: both

[28]Indeed, benchmarking the trade drop to the drop in industrial production leaves open the question of why the reduction in industrial production itself is so much larger than in GDP: while total GDP contracted by 3.8% in the recent episode, industrial production fell by 13.5%.

[29]While the table reports the standardized beta coefficient, the simple OLS coefficient on the change in industrial production is about 0.58, implying that a given change in IP is associated with a change in trade of just over half the magnitude. While this coefficient may be biased due to measurement error in IP data, taken at face value it implies a less than one-for-one relationship between IP and trade changes.

downstream linkages and compositional effects are robustly significant for imports, while upstream linkages and trade credit are not.[30] When it comes to magnitudes, it appears that the downstream linkage variable and the durable indicator are roughly of the same magnitude, on both on the order of 0.2-0.3. All together, the regressors of interest – downstream and upstream linkages, trade credit, and composition – explain about 9% of the cross-sectoral variation in the full sample, and 12% in the manufacturing sample. For exports, there is also suggestive evidence that downstream linkages and compositional effects continue to matter, but the results are less robust.

In the subsample of the manufacturing sectors in columns 2 and 4, we also control for inventories. We use monthly inventory data for 3-digit NAICS sectors from the BEA. Unfortunately, this coarse level of aggregation implies that we only have 20 distinct sectors for which we can record inventory levels. The particular variable we use is the ratio of inventories to imports (resp., exports) at the beginning of the period, 2008q2.[31] The initial level of inventories is not significant, and its inclusion leaves the rest of the results unchanged. In addition, it appears to have the "wrong" sign: sectors with larger initial inventories had *smaller* reductions in imports, all else equal. These estimates are not supportive of the hypothesis that imports collapsed in part because agents decided to deplete inventories as a substitute to buying more from abroad.[32]

3.4.4 Aggregation

How much of the aggregate reduction in trade can be accounted for by the leading explanations evaluated above? The magnitude and significance of the coefficients of interest are informative about how successful they are in explaining the cross-sectoral variation. However, it is not clear whether these explanations have an appreciable

[30]Indeed, in the manufacturing-only sample, the trade credit variable is significant but with the "wrong" sign for both imports and exports: it implies that trade in credit-intensive industries fell by *less*.

[31]Alternatively, we used the average level of inventories to imports (resp., exports) over the longer period, 2001-2007, and the results were unchanged. We also used the percentage change in inventories that happened contemporaneously with the reduction in trade, and the coefficient was insignificant: it appears that there is no relationship between changes in inventories and changes in trade flows over this period.

[32]Alessandria et al. (2010a) argue for the importance of inventory adjustment as an explanation for why trade fell by more than output. The quantitative exercise in that paper focuses on the auto sector. As evident from Table 3.2, while the auto sector experienced large reductions in cross-border trade, it is far from the only sector that did so. In addition, as reported in Table 3.2, at the outset of the crisis the auto sector accounted for 9% of U.S. exports and 11% of U.S. imports. Thus, at a purely mechanical level, the auto sector accounted for at most one-sixth of the total reduction in either imports and exports.

impact on changes in the aggregate trade. For instance, it may be that goods with greatest downstream linkages – that fell systematically more, as indicated by our estimates – are also responsible for a tiny share of the overall imports. In this case, downstream linkages, though statistically significant, would not account for much of the aggregate reduction in trade.

To shed light on these issues, we perform an aggregation exercise in the spirit of ((di Giovanni and Levchenko 2010)2009, 2010). The aggregate reduction in total trade flow (imports or exports), γ^A, can be written as:

$$\begin{aligned}\gamma^A &= \sum_{i=1}^{\mathcal{I}} a_i \gamma_i \\ &= \sum_{i=1}^{\mathcal{I}} a_i \left(\widehat{\gamma}_i + \epsilon_i\right)\end{aligned}$$

where, once again, i indexes sectors, a_i is the share of sector i in the aggregate trade flow, and γ_i is the actual percentage reduction in trade in sector i. The second line writes the actual reduction in trade in sector i as the sum of the predicted reduction $\widehat{\gamma}_i$ and the residual – an equality that holds by construction. Since the predicted change in trade in sector i can be expressed in terms of the actual values of the right-hand side variables and the estimated coefficients, the actual change in aggregate trade can be decomposed as:

$$\begin{aligned}\gamma^A = &\underbrace{\sum_{i=1}^{\mathcal{I}} a_i \widehat{\beta}_{DUR} * \text{Durable}_i}_{\text{Composition Effect}} + \underbrace{\sum_{i=1}^{\mathcal{I}} a_i \widehat{\beta}_{DS} * \text{Downstream}_i}_{\text{Downstream Effect}} + \\ &\underbrace{\sum_{i=1}^{\mathcal{I}} a_i \widehat{\beta}_{US} * \text{Upstream}_i}_{\text{Upstream Effect}} + \underbrace{\sum_{i=1}^{\mathcal{I}} a_i \widehat{\beta}_{TC} * \text{TradeCredit}_i}_{\text{Trade Credit Effect}} + \\ &\underbrace{\sum_{i=1}^{\mathcal{I}} a_i \widehat{\boldsymbol{\gamma}}_C * \mathbf{X}_i}_{\text{Controls}} + \underbrace{\widehat{\alpha}}_{\text{Constant}} + \underbrace{\sum_{i=1}^{\mathcal{I}} a_i \epsilon_i}_{\text{Residuals}} .\end{aligned} \tag{3.6}$$

Note that the last term, Residuals, equals zero by construction. In order to perform this decomposition, we use the coefficient estimates in columns 1 and 3 of Table 3.10, in which all of the explanations are included together in the full sample of sectors. The point estimates and the standard errors are reported in Table 3.11. For imports, the Composition Effect can account for a 6.9% reduction in trade, out of a total 29.9% drop.[33] The Downstream Effect accounts for a further 4% reduction. By contrast, the Trade Credit Effect goes the "wrong" way, showing a 5.9% increase in trade, though of course it is not statistically significant. The remaining controls together imply a 10.2% reduction. Surprisingly, the Upstream Effect is the largest, showing a 13.4% drop in trade. However, as evident from the regression table, the coefficient on the Upstream variable is not robustly statistically significant. For exports, both the Composition and the Downstream Effects are smaller, at 3.4 and 2.2%, respectively. Controls account for more than half of the observed reduction, 18.5%.

We conclude from this exercise that the two robustly statistically significant explanations – composition and downstream linkages – are also relevant quantitatively, together accounting for some 40% of the observed reduction in imports, and nearly 20% of exports.

3.4.5 Is the 2008-2009 crisis different?

We can use our estimation approach to examine the changes in international trade during previous economic downturns. To that end, we assembled monthly data on imports and exports, as well as the data on sectoral characteristics, for the two previous recessions, 1991 and 2001. Since the NAICS classification did not exist in 1991, all of the data are recorded in the SIC classification for that episode. For the 1991 recession, the indicators of intermediate input linkages (both downstream and upstream) were re-calculated based on the 1987 Benchmark Input-Output Table, and trade credit variables were computed from the pre-1990 data in Compustat. Similarly, measures of factor intensity were calculated based on the I-O Table and the NBER Productivity Database for the pre-1990 period. Finally, we also collected data for inventories and industrial production for the 1980s and early 1990s.[34] For the 2001 recession, we continue to use the intermediate input indicators based on the 2002 Benchmark Input-Output Tables that were used in the main analysis, as it is unlikely that the I-O structure would have experienced noticeable changes between 2001 and 2002. The other variables – trade credit intensity, export and import shares, factor intensity, and inventories – were re-computed using pre-2001 data.

[33] Once again, the total reductions in imports and exports reported in this table are different from what appears in the summary statistics, as the regression specification underlying this table does not cover all sectors due to the unavailability of some regressors of interest.

[34] The historical IP data are no longer publicly available in the SIC classification. We are very grateful to Charlie Gilbert at the Federal Reserve Board for providing these data.

To keep the approach consistent with the main analysis above, we average monthly trade data at the quarterly frequency, and take the year-on-year changes to avoid seasonality issues. For the 1991 recession, there is no dramatic change in trade. Thus, we take the difference between 1991q4 and 1990q4 as our left-hand side variable. For the 2001 recession, the peak in both imports and exports is December 2000, also coinciding with the peak of the business cycle. Thus, we take the 2000q4 to 2001q4 change as the dependent variable.[35]

Table 3.13 reports the results. The first main conclusion is that the sectoral characteristics have much less explanatory power in accounting for the sectoral cross-section of trade changes. While the overall R^2 that we could achieve for the 2008-09 crisis could be as high 13.5% for all sectors and 20% for manufacturing, the best we can do for 1991 and 2001 is about 3 to 7% for all sectors and 10% for manufacturing. This is not surprising: while the average changes in cross-border trade flows were much smaller in these two episodes, their standard deviations were quite similar across the three recessions. Thus, idiosyncratic sectoral shocks – essentially the error term in our regressions – were relatively more important in 1991 and 2001. Paradoxically, while in the current recession the aggregate trade changes are much more of a puzzle as evidenced by Section 3.3, we have a much better handle on the cross-sectoral variation.

Second, the only consistently robust explanatory variable in 1991 and 2001 is the Durable indicator. It is significant for all but the 2001 exports. The magnitudes of the beta coefficients are smaller, but roughly in line, with what we found for the 2008-09 recession. There is some evidence that vertical linkages mattered for some trade flows, but it is not robust across episodes and flows.

3.5 Conclusion

This paper uses highly disaggregated monthly data on U.S. imports and exports to examine the anatomy of the recent collapse in international trade. We show that this collapse is exceptional in two ways: it is far larger relative to economic activity than what has been observed in previous U.S. downturns; and it is far larger than what would be predicted by the evolution of domestic absorption and prices over the same period. Cross-sectional patterns of declines are consistent with vertical specialization and compositional effects as (at least partial) explanations for the collapse. By con-

[35] We experimented with various start dates for both recessions, and the results were not materially affected.

trast, we do not detect any impact of trade credit on the reduction in international trade.

An important next step in this research agenda is to develop a theoretical framework that can be quantitatively successful at replicating this collapse in trade. Doing so will enable us to use this episode as a laboratory to distinguish between the different models of international transmission. Our hope is that the empirical results in this paper can offer some guidance as to which channels are likely to be most promising. In particular, our findings on compositional effects and vertical linkages point to the crucial importance of developing quantitative models featuring a realistic sectoral production structure and trade patterns. This will allow the researcher to model both input-output linkages and systematic differences in the sectoral composition of production and trade patterns. Recent advances in the closed economy (Carvalho 2008), and open economy settings (Boileau 1999, Erceg et al. 2008, Engel and Wang 2011, Imbs 2010, Jin 2009) appear promising in this regard. By contrast, we do not find much of a role for financial variables in the collapse of trade. This of course does not imply that the financial crisis did not have macroeconomic consequences. Rather, financial shocks appear to have affected trade insofar as they had an impact on overall economic activity, rather than through a direct finance-trade channel.

3.6 Wedges derivation

We begin with the simplest 2-good IRBC model of Backus et al. (1995). There are two countries, Home and Foreign, and two intermediate goods, one produced in Home, the other in Foreign. There is one final good, used for both consumption and investment. The resource constraint of the Home country in each period is given by:

$$C_t + I_t = \left[\omega^{\frac{1}{\varepsilon}} \left(y_t^h\right)^{\frac{\varepsilon-1}{\varepsilon}} + (1-\omega)^{\frac{1}{\varepsilon}} \left(y_t^f\right)^{\frac{\varepsilon-1}{\varepsilon}}\right]^{\frac{\varepsilon}{\varepsilon-1}}, \tag{3.7}$$

where C_t is Home consumption, I_t is Home investment, y_t^h is the output of the Home intermediate good that is used in Home production, and y_t^f is the amount of the Foreign intermediate used in Home production. In this standard formulation, consumption and investment are perfect substitutes, and Home and Foreign goods are aggregated in a CES production function. The parameter ω allows for a home bias in preferences.

The household (or, equivalently, a perfectly competitive final goods producer), chooses the mix of Home and Foreign intermediates optimally:

$$\begin{aligned}
&\min_{y_t^h, y_t^f} \left\{p_t^h y_t^h + p_t^f y_t^f\right\} \\
&s.t. \\
&C_t + I_t \leq \left[\omega^{\frac{1}{\varepsilon}} \left(y_t^h\right)^{\frac{\varepsilon-1}{\varepsilon}} + (1-\omega)^{\frac{1}{\varepsilon}} \left(y_t^f\right)^{\frac{\varepsilon-1}{\varepsilon}}\right]^{\frac{\varepsilon}{\varepsilon-1}}
\end{aligned}$$

where p_t^h is the price of the domestically-produced good and p_t^f is the price of the imported good, both expressed in the home country's currency. This yields the standard demand equations:

$$\begin{aligned}
y_t^h &= \omega \left(\frac{P_t}{p_t^h}\right)^{\varepsilon} (C_t + I_t) \\
y_t^f &= (1-\omega) \left(\frac{P_t}{p_t^f}\right)^{\varepsilon} (C_t + I_t),
\end{aligned} \tag{3.8}$$

where $P_t = \left[\omega \left(p_t^h\right)^{1-\varepsilon} + (1-\omega) \left(p_t^f\right)^{1-\varepsilon}\right]^{\frac{1}{1-\varepsilon}}$ is the standard CES price level.

Log-linearizing these, we obtain the import demand relationship in log changes given in equation (3.1).

The derivation is essentially the same for subcomponents of final demand. In particular, suppose that durable goods consumption in the Home country, D_t, is an aggregate of Home and Foreign durable varieties:

$$D_t = \left[\omega^{\frac{1}{\varepsilon}} {d_t^h}^{\frac{\varepsilon-1}{\varepsilon}} + (1-\omega)^{\frac{1}{\varepsilon}} {d_t^f}^{\frac{\varepsilon-1}{\varepsilon}} \right]^{\frac{\varepsilon}{\varepsilon-1}}, \tag{3.9}$$

where d_t^h is the domestic durable variety consumed in Home, and d_t^f is the Foreign durable variety consumed in Home. In other words, a "final durable goods" producer aggregates domestically-produced durable intermediates with foreign-produced durable intermediates to create a durable good that can be used either as purchases of new durable consumption goods or capital investment.[36] Cost minimization then produces the expression for the durable wedge in equation (3.2).

Similarly, suppose that investment and consumption goods are different, but both are produced from domestic and foreign varieties

$$C_t = \left[\omega^{\frac{1}{\varepsilon}} \left(c_t^d\right)^{\frac{\varepsilon-1}{\varepsilon}} + (1-\omega)^{\frac{1}{\varepsilon}} \left(c_t^f\right)^{\frac{\varepsilon-1}{\varepsilon}} \right]^{\frac{\varepsilon}{\varepsilon-1}},$$

$$I_t = \left[\zeta^{\frac{1}{\sigma}} \left(i_t^d\right)^{\frac{\sigma-1}{\sigma}} + (1-\zeta)^{\frac{1}{\sigma}} \left(i_t^f\right)^{\frac{\sigma-1}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}}.$$

In this formulation, domestic consumption goods c_t^d are different from domestic investment goods i_t^d, and the same holds for the foreign consumption and investment goods. These production functions then lead to the consumption and investment wedges in equations (3.3) and (3.4).

[36] This formulation may appear to sidestep the special feature of durable goods, namely that it is the stock of durables that enters utility. In our formulation, equation (3.9) defines the flow of new durable goods, rather than the stock. Our assumption is then that the flow of new durable goods is a CES aggregate of the *flows* of foreign and domestic durable purchases, d_t^h and d_t^f. We can then define the stock of durables by its evolution $\mathcal{D}_t = (1-\delta)\mathcal{D}_{t-1} + D_t$, with the stock $\mathcal{D}_t$ entering the utility function. An alternative assumption would be that foreign and domestic durables have separate *stocks*, and consumer utility depends on a CES aggregate of domestic and foreign durable stocks (this is the assumption adopted by Engel and Wang 2011). A priori, we find no economic reason to favor one set of assumptions over the other, while our formulation is much more amenable to analyzing prices and quantities jointly. This is because statistical agencies record quantities and prices of purchases, which are flows.

Table 3.1. Changes in Exports/GDP and Imports/GDP during recessions

	2008	
	Recession	From Peak
Exports/GDP	-14.6%	-19.7%
Imports/GDP	-24.9%	-29.5%
Non-Oil Imports/GDP	-21.5%	-23.3%
	2001	
	Recession	From Peak
Exports/GDP	-14.2%	-17.1%
Imports/GDP	-13.5%	-16.0%
Non-Oil Imports/GDP	-11.5%	-14.5%
	Average 1950s-1990s	
	Recession	
Exports/GDP	-0.9%	
Imports/GDP	-0.3%	

Notes: This table reports the percent reductions in Exports/GDP and Imports/GDP during the 2008 and 2001 recessions and the average for all the downturns from 1950 to 2000. Column "Recession" reports the change in the trade variables during the official NBER recession (2007-2009 recession to 2009q2). Column "From Peak" reports the change from the peak of the trade ratios to the trough (for 2001), and to the current trough (2009q2). Source: National Income and Product Accounts.

Table 3.2. Disaggregated trade flows, nominal

	Exports			Imports		
	Share	Abs. Change	% Change	Share	Abs. Change	% Change
Total	1.00	-348.1	-26%	1.00	-765.7	-34%
Total, excluding petroleum				0.78	-495.8	-29%
Panel A: By Sector						
Foods, feeds, and beverages	0.09	-21.5	-19%	0.04	-8.2	-9%
Industrial supplies and materials	0.30	-134.9	-34%	0.15	-155	-47%
Durable goods	0.10	-50.3	-36%	0.08	-84.2	-50%
Nondurable goods	0.20	-84.6	-33%	0.07	-70.8	-44%
Petroleum and products				0.22	-269.9	-54%
Capital goods, except automotive	0.35	-94.6	-20%	0.21	-123.7	-26%
Civilian aircraft, engines, and parts	0.06	-3.7	-5%	0.02	-6.7	-18%
Computers, peripherals, and parts	0.04	-11.0	-24%	0.05	-23.7	-22%
Other	0.26	-79.9	-23%	0.15	-93.3	-29%
Automotive vehicles, engines, and parts	0.09	-58.1	-47%	0.11	-121.4	-49%
Consumer goods, except automotive	0.12	-19.5	-12%	0.22	-75.5	-15%
Durable goods	0.07	-23.0	-24%	0.12	-50.2	-18%
Nondurable goods	0.05	3.6	5%	0.10	-25.2	-11%
Other	0.04	-19.6	-35%	0.04	-11.8	-12%
Panel B: By Destination						
Canada	0.19	-80.6	-33%	0.17	-157.7	-43%
Asia	0.25	-80.2	-26%	0.34	-170.2	-24%
China	0.06	-10.5	-15%	0.15	-51.4	-16%
India	0.01	-2.3	-13%	0.01	-5.1	-21%
Japan	0.05	-20.3	-31%	0.07	-61.2	-42%
Taiwan	0.02	-10.9	-42%	0.02	-10.0	-28%
EU25	0.22	-68.0	-25%	0.18	-120.1	-31%
Germany	0.04	-16.2	-30%	0.05	-40.5	-39%
United Kingdom	0.04	-13.8	-25%	0.03	-17.1	-28%
Eastern Europe	0.01	-4.8	-49%	0.01	-3.8	-31%
Latin America	0.21	-76.8	-29%	0.18	-132.6	-33%
Brazil	0.02	-7.8	-28%	0.01	-13.9	-43%
Mexico	0.11	-37.6	-28%	0.11	-67.3	-29%
OPEC	0.04	-9.9	-18%	0.10	-146.5	-60%
Australia	0.02	-5.5	-26%	0.00	-4.0	-35%

Notes: This table reports the percentage decrease in nominal U.S. exports and imports over the period 2008q2 to 2009q2, disaggregated by sector (Panel A) and by destination (Panel B). Source: National Income and Product Accounts and U.S. International Trade Commission.

Table 3.3. Nominal trade flows, real trade flows, and prices

	Exports			**Imports**		
	Nominal	Real	Price	Nominal	Real	Price
Total	-26.2%	-18.9%	-9.0%	-34.4%	-21.4%	-16.5%
Total, excluding petroleum				-28.7%	-24.5%	-5.6%
Foods, feeds, and beverages	-18.5%	-6.7%	-12.7%	-9.1%	-4.7%	-4.8%
Industrial supplies and materials	-33.9%	-13.8%	-23.3%	-47.1%	-30.3%	-24.0%
Durable goods	-36.4%	-20.2%	-20.3%	-50.2%	-35.0%	-23.4%
Nondurable goods	-32.6%	-10.3%	-24.9%	-43.8%	-25.6%	-24.5%
Petroleum and products				-54.2%	-7.1%	-50.7%
Capital goods, except automotive	-20.2%	-19.0%	-1.5%	-26.3%	-25.3%	-1.4%
Civilian aircraft, engines, and parts	-4.8%	-9.4%	5.0%	-17.6%	-21.7%	5.3%
Computers, peripherals, and parts	-23.7%	-16.8%	-8.2%	-21.9%	-16.3%	-6.7%
Other	-23.2%	-21.6%	-2.0%	-28.8%	-28.6%	-0.4%
Automotive vehicles, engines, and parts	-46.6%	-46.8%	0.6%	-48.9%	-49.1%	0.3%
Consumer goods, except automotive	-11.9%	-11.4%	-0.6%	-15.2%	-14.6%	-0.7%
Durable goods	-24.5%	-25.0%	0.6%	-18.4%	-17.2%	-1.5%
Nondurable goods	5.2%	7.5%	-2.2%	-11.3%	-11.5%	0.2%
Other	-34.7%	-28.5%	-8.8%	-12.4%	-11.3%	-1.2%

Notes: This table reports the percentage decrease in nominal U.S. exports and imports over the period 2008q2 to 2009q2, the percentage change in real U.S. exports and imports, and the percentage change in the price of exports and imports, by sector. Source: National Income and Product Accounts.

Table 3.4. Trade wedges

	(1)	(2)	(3)	(4)	(5)
ε	Overall	Overall, Non-Oil	Durable	Consumption	Investment
1.5	-0.401	-0.278	-0.205	-0.064	-0.105
6	-1.190	-0.648	-0.342	0.072	-0.203

Notes: This table reports the wedges calculated for 2009q2 with respect to 2008q2 (year-on-year). Source: National Income and Product Accounts and authors' calculations.

Table 3.5. Trade changes and downstream production linkages

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Panel A: Percentage Change in Imports				*Panel B: Percentage Change in Exports*			
Average Downstream Use	-0.200***				-0.094**			
	(0.043)				(0.042)			
Number of Downstream Industries		-0.145***				-0.061		
		(0.041)				(0.042)		
Downstream Herfindahl			0.134***				-0.018	
			(0.046)				(0.048)	
Production Sharing				-0.087**				-0.01
				(0.043)				(0.051)
Share in Total	-0.077**	-0.091***	-0.123***	-0.096***	-0.206***	-0.220***	-0.229***	-0.229***
	(0.032)	(0.028)	(0.028)	(0.028)	(0.063)	(0.060)	(0.056)	(0.055)
Elasticity of Substitution	-0.071	-0.079	-0.075	-0.036	-0.045	-0.047	-0.037	-0.036
	(0.057)	(0.058)	(0.059)	(0.058)	(0.081)	(0.082)	(0.081)	(0.080)
Labor Intensity	-0.162***	-0.151***	-0.161***	-0.141**	-0.173***	-0.168***	-0.179***	-0.176***
	(0.055)	(0.055)	(0.056)	(0.055)	(0.047)	(0.047)	(0.048)	(0.047)
Observations	437	437	437	443	437	437	437	443
R^2	0.080	0.061	0.059	0.042	0.094	0.089	0.086	0.088
Partial R^2	0.041	0.021	0.018	0.007	0.009	0.004	0.000	0.000

Notes: Standardized beta coefficients reported throughout. Robust standard errors in parentheses; * significant at 10%; ** significant at 5%; *** significant at 1%. The dependent variable is the percentage reduction in U.S. Imports (Panel A) and the percentage reduction in exports (Panel B) in a 6-digit NAICS category from 2008q2 to 2009q2 (year-to-year). *Average Downstream Use* is the average usage output in a sector as an intermediate input in other sectors; *Number of Downstream Industries* is the number of industries that use a sector as an intermediate; *Downstream Herfindahl* is the Herfindahl index of the usage of a sector as an intermediate in other sectors. These three indicators are computed based on the U.S. 2002 Benchmark Input-Output Table. *Production Sharing* is the share of intra-firm imports in total U.S. imports (Panel A), or the share of intra-firm exports in total U.S. exports (Panel B), computed from the BEA multinationals data, and averaged over the period 2002-2006. *Share in Total* is the share of a sector in total U.S. imports (Panel A), or exports (Panel B). *Elasticity of Substitution* between varieties in a sector is sourced from Broda and Weinstein (2006b). *Labor Intensity* is the compensation of employees as a share of value added, from the U.S. 2002 Benchmark Input-Output Table.

Table 3.6. Trade changes and upstream production linkages

	(1)	(2)	(3)	(4)	(5)	(6)
	Panel A: Percentage Change in Imports			*Panel B: Percentage Change in Exports*		
Intermediate Use Intensity	-0.116*			-0.025		
	(0.063)			(0.055)		
Number of Intermediates Used		-0.120**			-0.128***	
		(0.047)			(0.047)	
Herfindahl of Intermediate Use			-0.032			0.009
			(0.045)			(0.052)
Share in Total	-0.097***	-0.089***	-0.104***	-0.229***	-0.195***	-0.233***
	(0.028)	(0.027)	(0.027)	(0.057)	(0.060)	(0.057)
Elasticity of Substitution	-0.045	-0.045	-0.039	-0.038	-0.045	-0.036
	(0.058)	(0.058)	(0.058)	(0.079)	(0.079)	(0.080)
Labor Intensity	-0.116*	-0.120**	-0.165***	-0.168***	-0.136***	-0.176***
	(0.061)	(0.056)	(0.055)	(0.053)	(0.049)	(0.047)
Observations	443	443	443	443	443	443
R^2	0.047	0.048	0.036	0.088	0.101	0.088
Partial R^2	0.012	0.013	0.001	0.001	0.015	0.000

Notes: Standardized beta coefficients reported throughout. Robust standard errors in parentheses; * significant at 10%; ** significant at 5%; *** significant at 1%. The dependent variable is the percentage reduction in U.S. Imports (Panel A) and the percentage reduction in exports (Panel B) in a 6-digit NAICS category from 2008q2 to 2009q2 (year-to-year). *Intermediate Use Intensity* is spending on intermediate inputs per dollar of final sales; *Number of Intermediates Used* is the number intermediates a sector uses in production; *Herfindahl of Intermediate Use* is the Herfindahl index of the intermediate good usage in a sector. These three indicators are computed based on the U.S. 2002 Benchmark Input-Output Table. *Share in Total* is the share of a sector in total U.S. imports (Panel A), or exports (Panel B). *Elasticity of Substitution* between varieties in a sector is sourced from Broda and Weinstein (2006b). *Labor Intensity* is the compensation of employees as a share of value added, from the U.S. 2002 Benchmark Input-Output Table.

Table 3.7. Trade changes and trade credit intensity

	(1)	(2)	(3)	(4)	(5)	(6)
	Panel A: Percentage Change in Imports			*Panel B: Percentage Change in Exports*		
Accounts Payable/Cost of Goods Sold	0.017			-0.016		
	(0.069)			(0.058)		
Accounts Receivable/Sales		-0.031			0.05	
		(0.065)			(0.057)	
TWCC			-0.071			0.138**
			(0.068)			(0.063)
Share in Total	-0.124***	-0.116***	-0.106***	-0.233***	-0.240***	-0.239***
	(0.036)	(0.027)	(0.027)	(0.060)	(0.058)	(0.055)
Elasticity of Substitution	-0.035	-0.038	-0.047	-0.035	-0.03	-0.039
	(0.059)	(0.059)	(0.059)	(0.085)	(0.081)	(0.076)
Labor Intensity	-0.175***	-0.176***	-0.163***	-0.165***	-0.164***	-0.159***
	(0.055)	(0.057)	(0.052)	(0.048)	(0.047)	(0.046)
Observations	419	419	441	419	419	443
R^2	0.041	0.042	0.046	0.082	0.084	0.106
Partial R^2	0.000	0.001	0.005	0.000	0.003	0.020

Notes: Standardized beta coefficients reported throughout. Robust standard errors in parentheses; * significant at 10%; ** significant at 5%; *** significant at 1%. The dependent variable is the percentage reduction in U.S. Imports (Panel A) and the percentage reduction in exports (Panel B) in a 6-digit NAICS category from 2008q2 to 2009q2 (year-to-year). *Accounts Payable/Cost of Goods Sold* and *Accounts Receivable/Sales* are measures of trade credit used and extended, respectively, computed using firm-level information from the Compustat database. *TWCC* is the measure of trade-weighted credit contraction, computed from country-specific changes in the interbank interest rates and U.S. bilateral trade shares according to equation (3.5). *Share in Total* is the share of a sector in total U.S. imports (Panel A), or exports (Panel B). *Elasticity of Substitution* between varieties in a sector is sourced from Broda and Weinstein (2006b). *Labor Intensity* is the compensation of employees as a share of value added, from the U.S. 2002 Benchmark Input-Output Table.

Table 3.8. Trade changes and compositional effects

	(1)	(2)	(3)	(4)
	Panel A: Percentage Change in Imports		*Panel B: Percentage Change in Exports*	
Percentage Change in Industrial Production	0.338***		0.211***	
	(0.045)		(0.052)	
Durable dummy		-0.200***		-0.106**
		(0.047)		(0.049)
Share in Total	-0.101**	-0.091***	-0.233***	-0.210***
	(0.045)	(0.031)	(0.065)	(0.056)
Elasticity of Substitution	-0.009	-0.047	-0.011	-0.042
	(0.069)	(0.061)	(0.089)	(0.081)
Labor Intensity	-0.078	-0.103*	-0.083*	-0.148***
	(0.055)	(0.054)	(0.048)	(0.049)
Observations	401	443	402	443
R^2	0.144	0.072	0.116	0.097
Partial R^2	0.109	0.038	0.044	0.011

Notes: Standardized beta coefficients reported throughout. Robust standard errors in parentheses; * significant at 10%; ** significant at 5%; *** significant at 1%. The dependent variable is the percentage reduction in U.S. Imports (Panel A) and the percentage reduction in exports (Panel B) in a 6-digit NAICS category from 2008q2 to 2009q2 (year-to-year). *Percentage Change in Industrial Production* is the decline in the index of industrial production in a sector; *Share in Total* is the share of a sector in total U.S. imports (Panel A), or exports (Panel B). *Elasticity of Substitution* between varieties in a sector is sourced from Broda and Weinstein (2006b). *Labor Intensity* is the compensation of employees as a share of value added, from the U.S. 2002 Benchmark Input-Output Table.

Table 3.9. Compositional effects: change in trade flows as implied by industrial production.

	(1) Nominal Change	(2) Real Change	(3) Implied by IP change $\left(\tilde{\gamma}^{trade}\right)$	(4) Share of Trade Corresponding to IP
Exports	-34.3%	-25.0%	-18.1%	0.88
Imports	-35.0%	-19.4%	-16.1%	0.94
IP		-13.5%	-13.5%	1.00

Notes: Changes in nominal and real exports over 2008q2 to 2009q2 for NAICS sectors where industrial production (IP) data are available. Weights calculated from share of nominal trade and used to generate the third column. The fourth column indicates the fraction of overall nominal trade that can be matched to IP data.

Table 3.10. Trade changes and and all explanatory variables together

	(1)	(2)	(3)	(4)
	Panel A: Percentage Change in Imports		*Panel B: Percentage Change in Exports*	
Average Downstream Use	-0.171***	-0.205***	-0.094**	-0.053
	(0.043)	(0.052)	(0.044)	(0.048)
Intermediate Use Intensity	-0.119*	-0.063	-0.019	-0.03
	(0.066)	(0.112)	(0.063)	(0.086)
Accounts Payable/Cost of Goods Sold	0.065	0.180**	0.010	0.191***
	(0.084)	(0.069)	(0.067)	(0.062)
Durable Dummy	-0.229***	-0.302***	-0.098	-0.244***
	(0.062)	(0.060)	(0.062)	(0.065)
Share in Total	-0.077	0.014	-0.189***	-0.242***
	(0.050)	(0.063)	(0.068)	(0.067)
Elasticity of Substitution	-0.083	-0.076	-0.05	-0.02
	(0.061)	(0.078)	(0.086)	(0.065)
Labor Intensity	-0.069	0.048	-0.128**	-0.062
	(0.063)	(0.117)	(0.064)	(0.117)
Capital Intensity		0.181		0.127
		(0.137)		(0.131)
Skill Intensity		-0.105		0.012
		(0.097)		(0.076)
Inventories		0.095		0.041
		(0.062)		(0.059)
Observations	415	350	415	351
R^2	0.135	0.212	0.097	0.178
Partial R^2	0.092	0.120	0.018	0.053

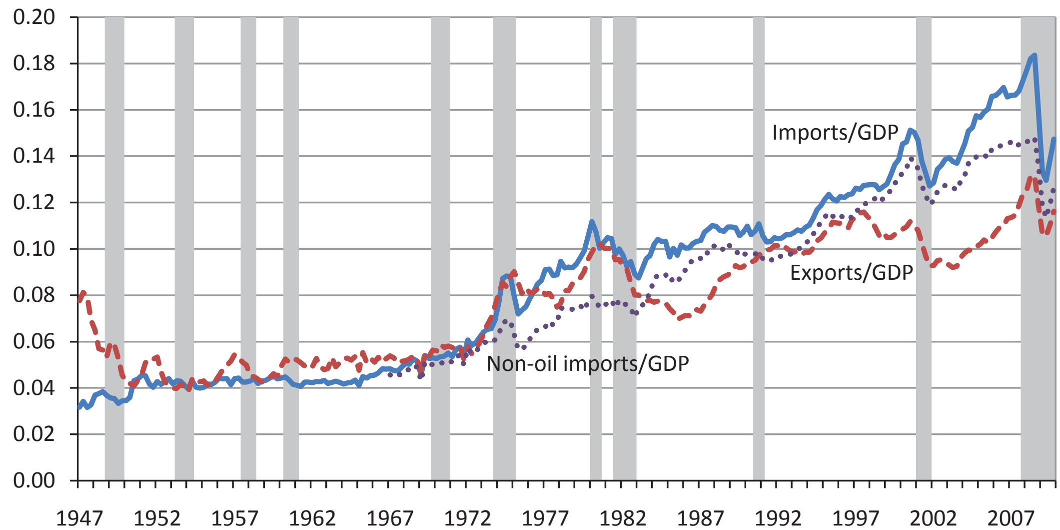
Notes: Standardized beta coefficients reported throughout. Robust standard errors in parentheses; * significant at 10%; ** significant at 5%; *** significant at 1%.

Table 3.11. Decomposition of the aggregate reduction in trade

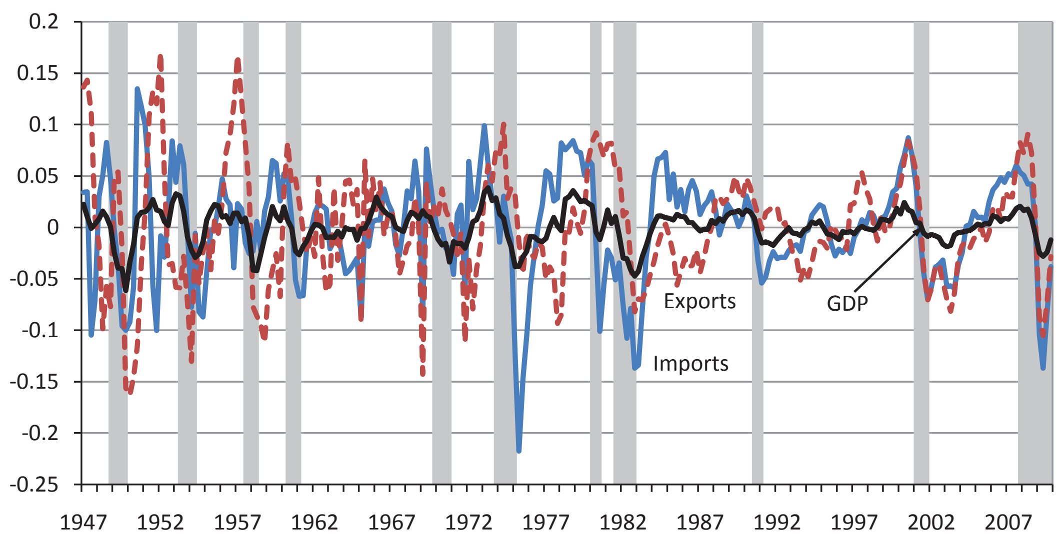
(1) Total (γ^A)	(2) Composition Effect	(3) Downstream Effect	(4) Upstream Effect	(5) Trade Credit Effect	(6) Controls	(7) Constant
			Imports			
-0.299	-0.069	-0.040	-0.134	0.059	-0.102	-0.014
	(0.019)	(0.010)	(0.075)	(0.076)	(0.045)	(0.084)
			Exports			
-0.304	-0.034	-0.022	-0.021	0.007	-0.185	-0.050
	(0.021)	(0.010)	(0.069)	(0.048)	(0.052)	(0.075)

Notes: This table presents a decomposition of the actual aggregate change in trade into components given in equation (3.6). Standard errors are reported in parentheses.

Figure 3.1. Historical trends in aggregate trade, 1947-2009.



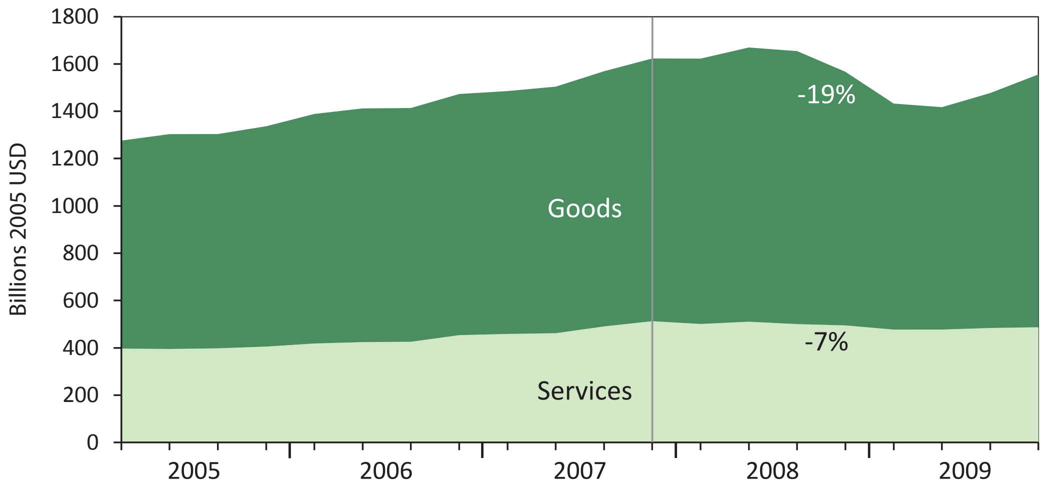
(a) Imports/GDP and Exports/GDP



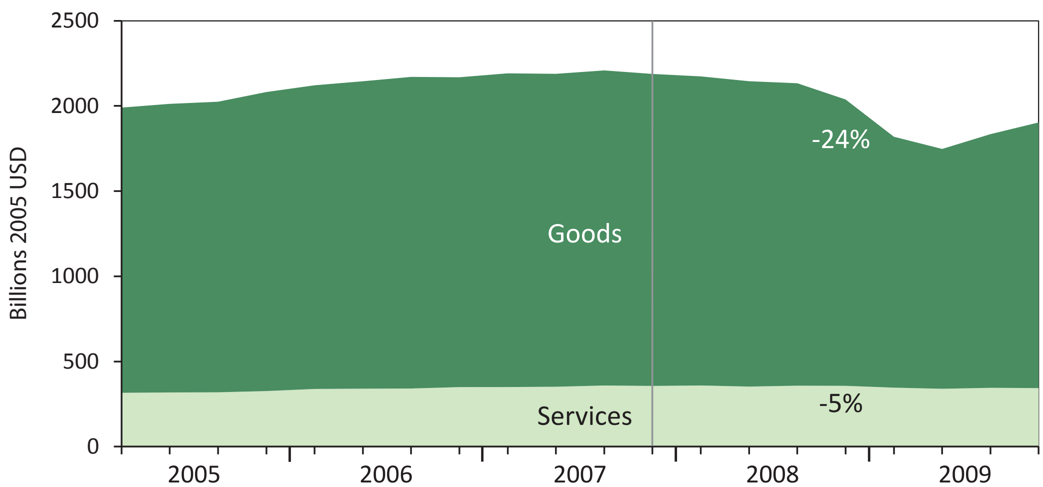
(b) Imports, Exports, and GDP in Deviations from Trend

Notes: The top panel plots the ratios of imports/GDP and exports/GDP for the U.S., along with the NBER recession bars. The bottom panel plots total imports, exports, and GDP in deviations from HP trend with parameter 1600. Source: National Income and Product Accounts.

Figure 3.2. Goods and services trade



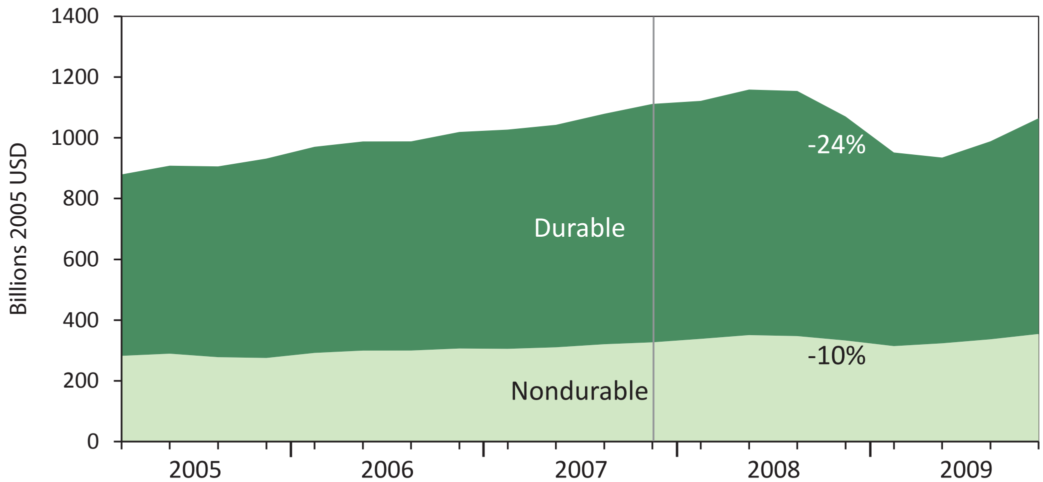
(a) Exports



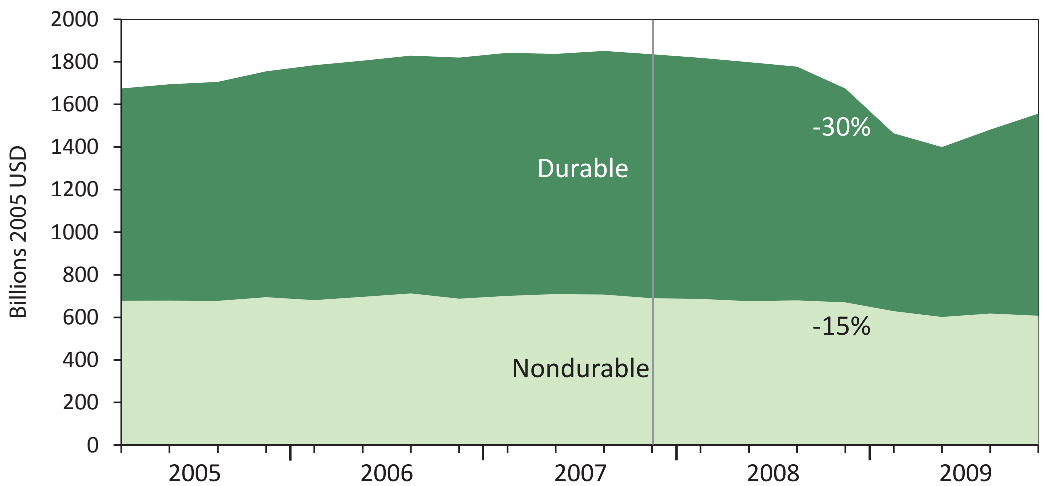
(b) Imports

Notes: This figure reports the total real exports (top panel) and real imports (bottom panel), of both goods and services. Source: National Income and Product Accounts.

Figure 3.3. Durables and non-durables trade



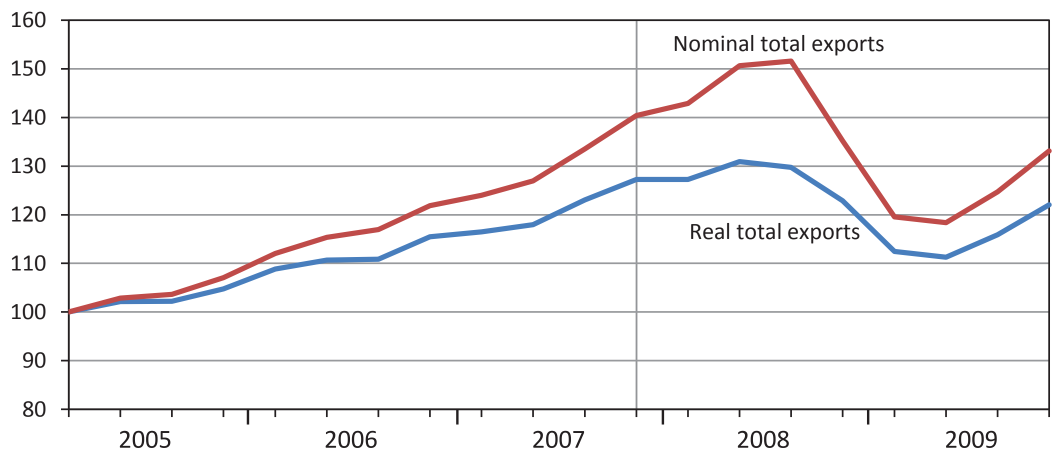
(a) Exports



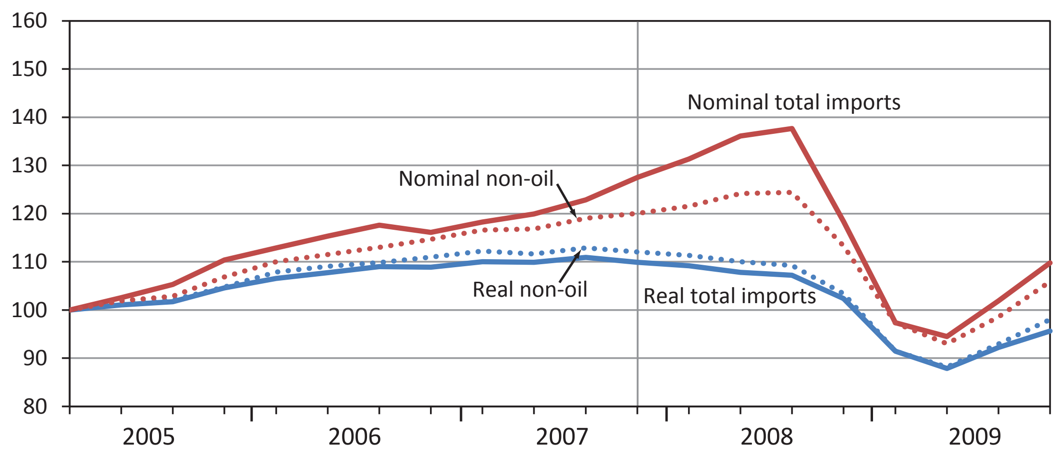
(b) Imports

Notes: This figure reports the total real exports (top panel) and real imports (bottom panel), of both durable and non-durable goods. Source: National Income and Product Accounts.

Figure 3.4. Real and nominal trade



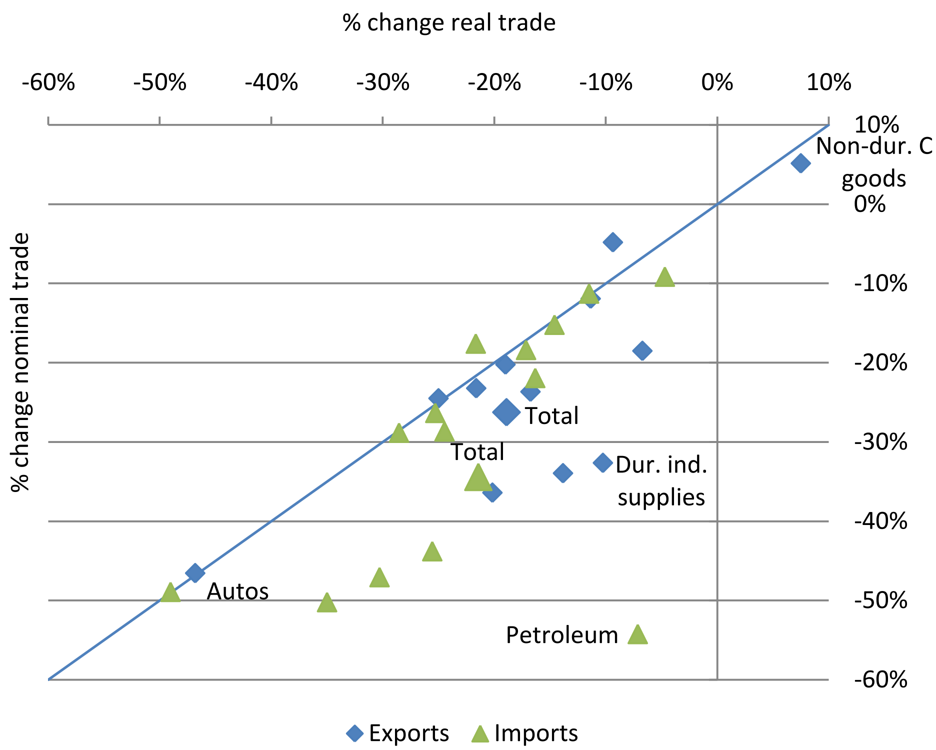
(a) Exports



(b) Imports

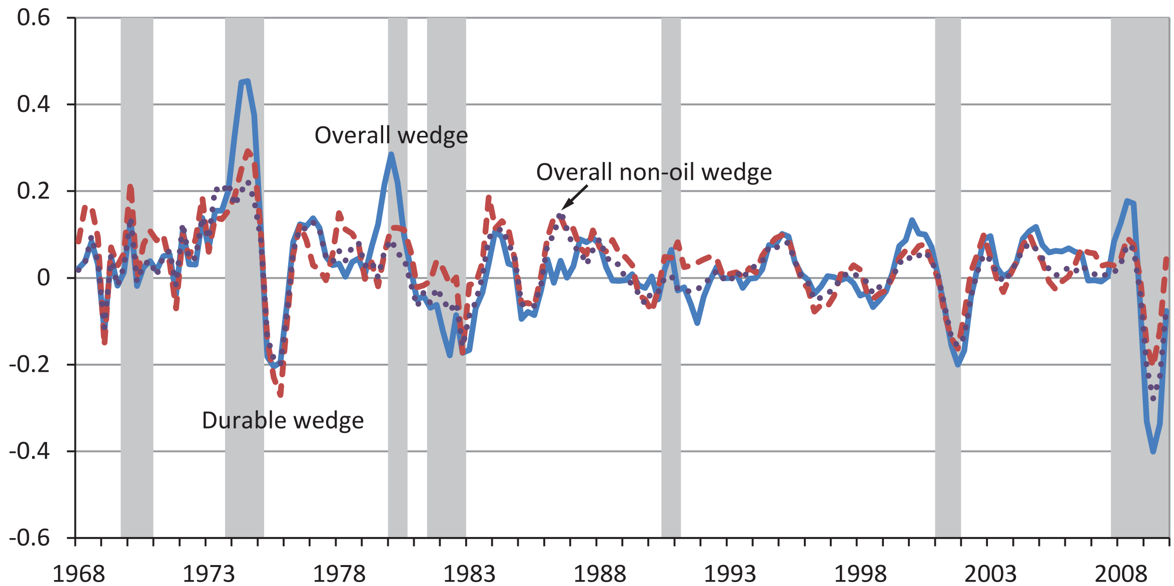
Notes: This figure reports the evolution of nominal and real exports (top panel) and imports (bottom panel). Both the nominal and real series are normalized to 2005. Source: National Income and Product Accounts.

Figure 3.5. Real and nominal changes in trade, by sector



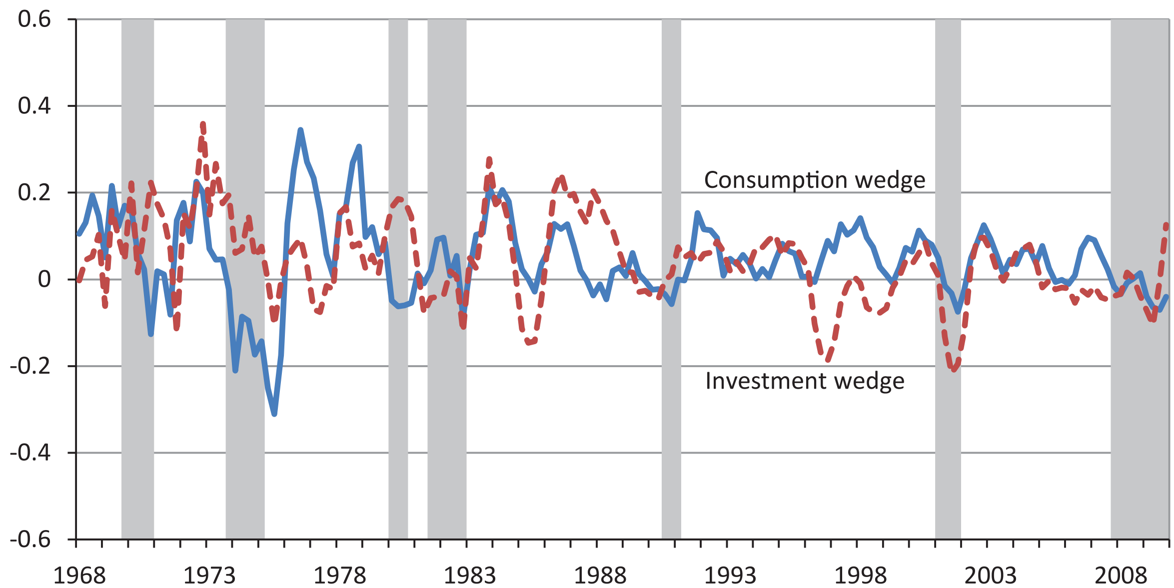
Notes: This figure plots the percentage changes in real imports and exports against the percentage changes in nominal imports and exports, by EndUse sector, along with a 45-degree line. Source: National Income and Product Accounts.

Figure 3.6. Overall and durable wedges



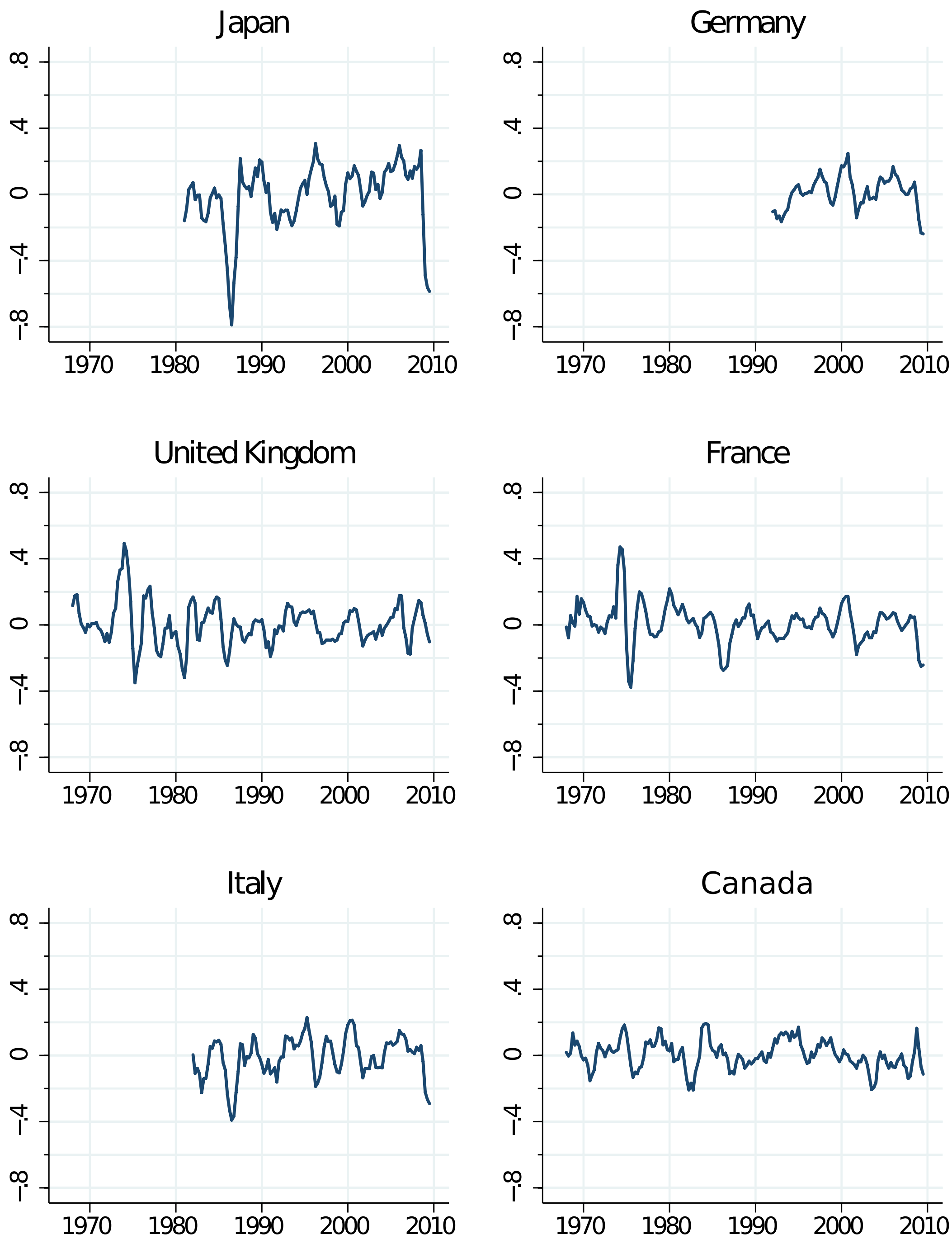
Notes: This figure plots the wedges for total imports and the durable imports. Source: National Income and Product Accounts and authors' calculations.

Figure 3.7. Consumption and investment wedges



Notes: This figure plots the wedges for consumption imports and investment imports. Source: National Income and Product Accounts and authors' calculations.

Figure 3.8. Overall wedges, large industrial countries

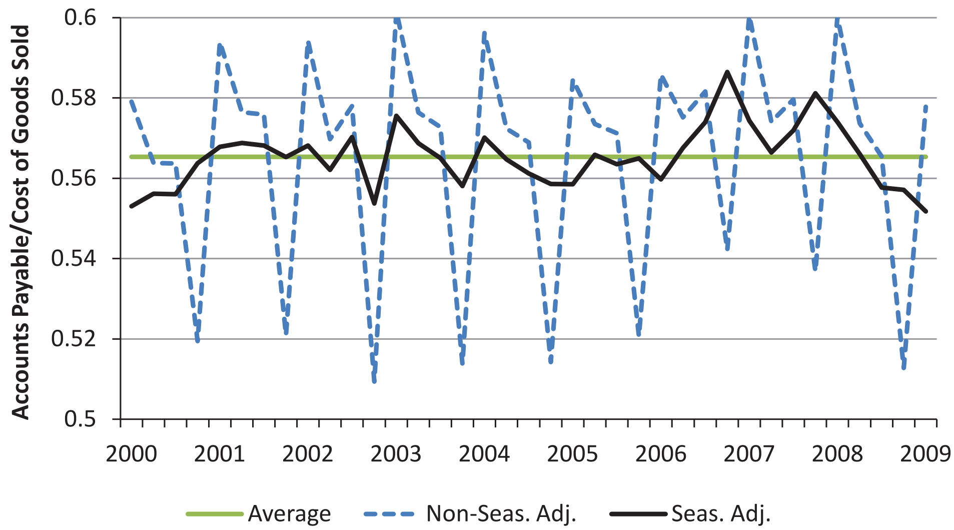


Notes: This figure plots the wedges for total imports for a selected set of countries. Source: OECD and authors' calculations.

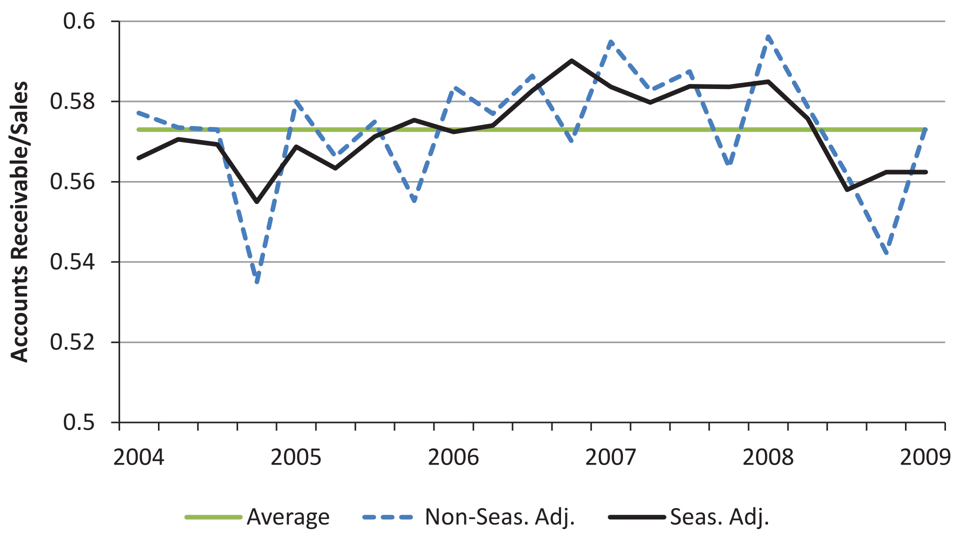
Figure 3.9. Overall wedges, selected emerging markets

Notes: This figure plots the wedges for total imports for a selected set of countries. Source: OECD and authors' calculations.

Figure 3.10. The evolution of trade credit



(a) Accounts Payable/Cost of Goods Sold



(b) Accounts Receivable/Sales

Notes: The top panel of this figure displays the median value of accounts payable/cost of goods sold across firms in each period. The bottom panel reports the median value of accounts receivable/sales across firms in each period. Source: Compustat.

Table 3.12. Summary statistics

	Mean	Std. Dev.	Min	Max
Independent Variables				
Percentage Change in Imports	-0.253	0.227	-1.000	0.861
Percentage Change in Exports	-0.209	0.214	-0.969	0.744
Downstream Indicators				
Average Downstream Use	0.001	0.002	0.000	0.013
Number of Downstream Industries	102	111	1	419
Downstream Herfindahl	0.220	0.223	0.009	1.000
Production Sharing (exports)	0.196	0.133	0.005	0.612
Production Sharing (imports)	0.150	0.139	0.000	0.577
Upstream Indicators				
Intermediate Use Intensity	0.631	0.122	0.254	0.949
Number of Intermediates Used	113	26	46	218
Herfindahl of Intermediate Use	0.094	0.066	0.028	0.532
Credit Indicators				
Accounts Payable/Cost of Goods Sold	0.469	0.141	0.194	1.733
Accounts Receivable/Sales	0.532	0.131	0.156	0.817
TWCC (imports)	-2.691	0.493	-5.594	-1.178
TWCC (exports)	-2.721	0.392	-4.190	-0.411
Compositional Indicators				
Percentage Change in Industrial Production	-0.179	0.121	-0.757	0.036
Durable dummy	0.588	0.493	0	1
Control Variables				
Share in Total Imports	0.002	0.007	0.000	0.088
Share in Total Exports	0.002	0.005	0.000	0.045
Elasticity of Substitution	6.8	10.7	1.2	103
Labor Intensity	0.633	0.229	0.049	0.998

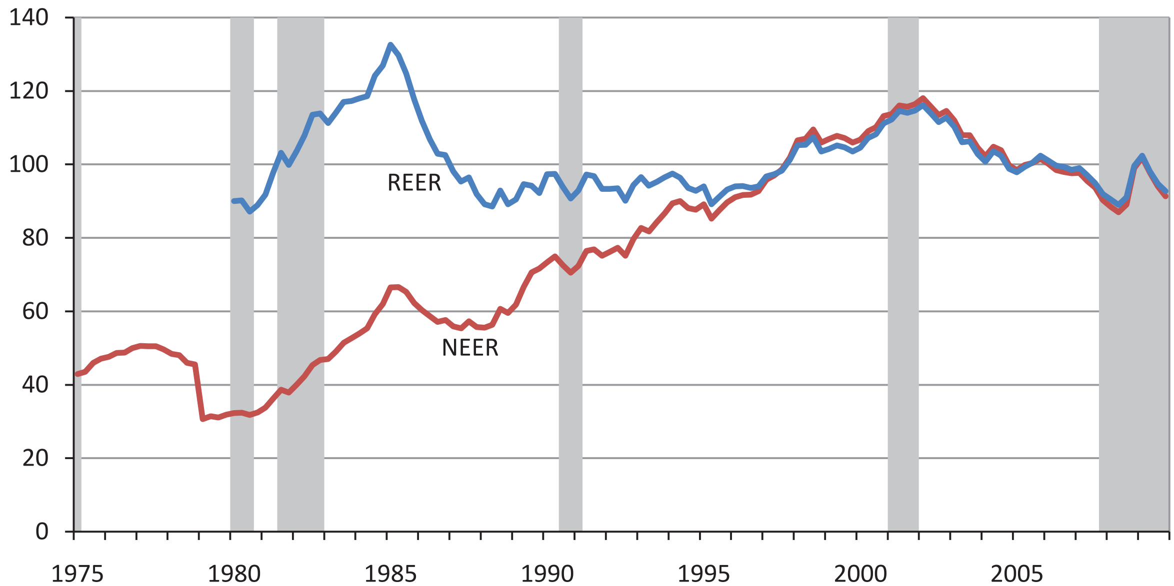
Notes: This table presents the summary statistics for the variables used in the estimation. Variable definitions and sources are described in detail in the text.

Table 3.13. Trade in the 1991 and 2001 recessions

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	1991 Recession				2001 Recession			
	Panel A: Percentage Change in Imports		*Panel B: Percentage Change in Exports*		*Panel C: Percentage Change in Imports*		*Panel D: Percentage Change in Exports*	
Average Downstream Use	0.065	0.074	-0.114***	-0.101**	-0.049	-0.08	-0.073	-0.048
	(0.048)	(0.048)	(0.041)	(0.042)	(0.043)	(0.051)	(0.050)	(0.057)
Intermediate Use Intensity	-0.118*	0.038	-0.035	0.082	0.059	-0.068	0.131**	0.04
	(0.067)	(0.073)	(0.065)	(0.105)	(0.064)	(0.084)	(0.056)	(0.089)
Accounts Payable	-0.114**	0.045	-0.105	0.115**	-0.079	0.052	-0.042	-0.023
	(0.045)	(0.048)	(0.100)	(0.050)	(0.056)	(0.069)	(0.060)	(0.078)
Durable Dummy	-0.069	-0.146**	-0.131**	-0.193***	-0.104**	-0.134**	-0.005	-0.031
	(0.057)	(0.065)	(0.061)	(0.071)	(0.053)	(0.062)	(0.052)	(0.066)
Share in Total	0.024	0.051*	0.026	0.016	-0.108*	-0.049	-0.052	-0.071
	(0.028)	(0.029)	(0.062)	(0.071)	(0.060)	(0.055)	(0.040)	(0.049)
Elasticity of Substitution	-0.118**	-0.058	-0.155**	-0.112	-0.014	-0.028	0.015	0.006
	(0.049)	(0.056)	(0.064)	(0.070)	(0.068)	(0.088)	(0.064)	(0.078)
Labor Intensity	-0.018	0.249***	-0.073	0.094	-0.189***	-0.032	-0.150**	-0.117
	(0.020)	(0.083)	(0.061)	(0.106)	(0.065)	(0.119)	(0.061)	(0.118)
Capital Intensity		0.416***		0.180		-0.021		-0.030
		(0.103)		(0.128)		(0.118)		(0.131)
Skill Intensity		-0.190***		-0.039		-0.084		0.032
		(0.069)		(0.082)		(0.095)		(0.110)
Inventories		-0.071		0.107		0.213***		-0.016
		(0.044)		(0.066)		(0.053)		(0.070)
Observations	400	383	398	380	408	350	414	351
R^2	0.037	0.107	0.063	0.095	0.074	0.115	0.032	0.021
Partial R^2	0.022	0.021	0.044	0.043	0.028	0.023	0.019	0.005

Notes: Standardized beta coefficients reported throughout. Robust standard errors in parentheses; * significant at 10%; ** significant at 5%; *** significant at 1%. The dependent variable is the percentage reduction in U.S. Imports (Panels A and C) and the percentage reduction in exports (Panels B and D) in a 4-digit SIC category from 1990q4 to 1991q4 (1991 Recession) or 6-digit NAICS category from 2000q4 to 2001q4 (2001 Recession).

Figure 3.11. Nominal and real effective exchange rates for the U.S..



Notes: This figure displays the Nominal Effective Exchange Rate and the Real Effective Exchange Rate for the United States. Source: International Monetary Fund.

REFERENCES

Adda, Jérôme and Russell W. Cooper, *Dynamic Economics: Quantitative Methods and Applications*, The MIT Press, 2003.

Alessandria, George, Joseph P Kaboski, and Virgiliu Midrigan, "The Great Trade Collapse of 2008–09: An Inventory Adjustment?," *IMF Economic Review*, September 2010, *58* (2), 254–294.

____ , ____ , and ____ , "Inventories, Lumpy Trade, and Large Devaluations," *American Economic Review*, December 2010, *100* (5), 2304–2339.

Amiti, Mary and David E. Weinstein, "Exports and Financial Shocks," *National Bureau of Economic Research Working Paper Series*, December 2009, *No. 15556.*

Anderson, James and Eric van Wincoop, "Trade Costs," *Journal of Economic Literature*, 2004, *42* (3), 691–751.

Atkeson, Andrew and Ariel Burstein, "Pricing-to-Market, Trade Costs, and International Relative Prices," *American Economic Review*, December 2008, *98* (5), 1998–2031.

Auboin, Marc, "Restoring Trade Finance: What the G20 Can Do," in Richard Baldwin and Simon Evenett, eds., *The Collapse of Global Trade, Murky Protectionism, and the Crisis: Recommendations for the G20*, London: CEPR, 2009, chapter 15, pp. 75–80.

Backus, David K., Patrick J. Kehoe, and Finn E. Kydland, "International Business Cycles: Theory and Evidence," in Thomas Cooley, ed., *Frontiers of Business Cycle Research*, Princeton: Princeton University Press, 1995, pp. 331–356.

Baldwin, Richard and Simon Evenett, "Introduction and Recommendations for the G20," in Richard Baldwin and Simon Evenett, eds., *The Collapse of Global Trade, Murky Protectionism, and the Crisis: Recommendations for the G20*, London: CEPR, 2009, chapter 1, pp. 1–9.

Behrens, Kristian, Gregory Corcos, and Giordano Mion, "Trade Crisis? What Trade Crisis?," February 2010. Mimeo, UQAM, NHH, and LSE.

Bems, Rudolfs, Robert C Johnson, and Kei-Mu Yi, "Demand Spillovers and the Collapse of Trade in the Global Recession," *IMF Economic Review*, November 2010, *58* (2), 295–326.

Bhattarai, Saroj, "Optimal Currency Denomination of Trade: Theory and Quantitative Exploration," 2009. Mimeo, Princeton University.

Blanchard, O. J, M. Das, and H. Faruqee, "The initial impact of the crisis on emerging market countries," *Brookings Papers on Economic Activity, Spring*, 2010, *41* (2), 263–307.

Blanchard, Olivier and Michael Kremer, "Disorganization," *Quarterly Journal of Economics*, 1997, *112*, 1091–1126.

Boileau, Martin, "Trade in capital goods and the volatility of net exports and the terms of trade," *Journal of International Economics*, August 1999, *48* (2), 347–365.

Bricongne, Jean-Charles, Lionel Fontagné, Guillaume Gaulier, Daria Taglioni, and Vincent Vicard, "Firms and the global crisis: French exports in the turmoil," December 2009. Bank of France Working Paper 265.

Broda, Christian and David E. Weinstein, "Globalization and the Gains from Variety*," *Quarterly Journal of Economics*, May 2006, *121* (2), 541–585.

____ **and David Weinstein**, "Globalization and the Gains from Variety," *Quarterly Journal of Economics*, May 2006, *121* (2), 541–85.

Burstein, Ariel, Christopher Kurz, and Linda L. Tesar, "Trade, Production Sharing, and the International Transmission of Business Cycles," *Journal of Monetary Economics*, 2008, *55*, 775–795.

Campa, Jose Manuel and Linda S. Goldberg, "Exchange Rate Pass-Through into Import Prices," *Review of Economics and Statistics*, November 2005, *87* (4), 679–690.

Carvalho, Vasco, "Aggregate Fluctuations and the Network Structure of Intersectoral Trade," June 2008. Mimeo, CREI-Universitat Pompeu Fabra.

Cavallari, Lilia, "A Macroeconomic Model of Entry with Exporters and Multinationals," *The B.E. Journal of Macroeconomics*, September 2007, *7* (1).

____ , "Macroeconomic Interdependence with Trade and Multinational Activities," *Review of International Economics*, 2008, *16* (3), 537–558.

____ , "Exports and foreign direct investments in an endogenous-entry model with real and nominal uncertainty," *Journal of Macroeconomics*, March 2010, *32* (1), 300–313.

Chari, V V, Patrick J Kehoe, and Ellen R McGrattan, "Can sticky price models generate volatile and persistent real exchange rates?," *The Review of Economic Studies*, July 2002, *69* (240), 533.

Chari, V.V., Patrick J. Kehoe, and Ellen R. McGrattan, "Business Cycle Accounting," *Econometrica*, May 2007, *75* (3), 781–836.

Chinn, Menzie, "What Does the Collapse of US Imports and Exports Signify?," June 23 2009.

Chor, Davin and Kalina Manova, "Off the cliff and back? Credit conditions and international trade during the global financial crisis," *Journal of International Economics*, 2010. Forthcoming.

Cole, Harold and Lee Ohanian, "The U.S. and U.K. Great Depressions through the Lens of Neoclassical Growth Theory," *American Economic Review, P&P*, May 2002, *92* (2), 28–32.

Cowan, Kevin and Alejandro Neut, "Intermediate Goods, Institutions, and Output Per Worker," 2007. Central Bank of Chile Working Paper No. 420.

Cushman, David O., "Real Exchange Rate Risk, Expectations, and the Level of Direct Investment," *The Review of Economics and Statistics*, May 1985, *67* (2), 297–308.

Davis, Steven J., John Haltiwanger, Ron Jarmin, Javier Miranda, Christopher Foote, and Eva Nagypal, "Volatility and Dispersion in Business Growth Rates: Publicly Traded versus Privately Held Firms [with Comments and Discussion]," *NBER Macroeconomics Annual*, 2006, *21*, 107–179.

Devereux, Michael B. and Charles Engel, "The Optimal Choice of Exchange-Rate Regime: Price-Setting Rules and Internationalized Production," *National Bureau of Economic Research Working Paper Series*, March 1999, *No. 6992.* published as Topics in Empirical International Economics: Festschrift in Honor of Robert Lipsey, Blomstrom, Magnus and Linda Goldberg, eds., Chicago: University of Chicago Press and NBER.

di Giovanni, Julian and Andrei A Levchenko, "Putting the Parts Together: Trade, Vertical Linkages, and Business Cycle Comovement," *American Economic Journal: Macroeconomics*, April 2010, *2* (2), 95–124.

Eaton, Jonathan, Sam Kortum, Brent Neiman, and John Romalis, "Trade and the Global Recession," February 2010. Mimeo, Penn State University and University of Chicago.

Economist, "Shipping in the Downturn: Sea of Troubles," June 30 2009.

Eichenbaum, Martin and Charles L. Evans, "Some Empirical Evidence on the Effects of Shocks to Monetary Policy on Exchange Rates," *The Quarterly Journal of Economics*, November 1995, *110* (4), 975–1009.

Engel, Charles, "Equivalence Results for Optimal Pass-Through, Optimal Indexing to Exchange Rates, and Optimal Choice of Currency for Export Pricing," *Journal of the European Economic Association*, December 2006, *4* (6), 1249–1260.

____ **and Jian Wang**, "International trade in durable goods: Understanding volatility, cyclicality, and elasticities," *Journal of International Economics*, January 2011, *83* (1), 37–52.

Erceg, Christopher J., Luca Guerrieri, and Christopher Gust, "Trade adjustment and the composition of trade," *Journal of Economic Dynamics and Control*, August 2008, *32* (8), 2622–2650.

Fillat, José and Stephania Garetto, "Risk, Returns, and Multinational Production," October 2010. Mimeo.

Freund, Caroline, "The Trade Response to the Global Downturn: Historical Evidence," August 2009. World Bank Policy Research Working Paper 5015.

Giovannini, Alberto, "Exchange rates and traded goods prices," *Journal of International Economics*, February 1988, *24* (1-2), 45–68.

Goldberg, Linda S. and Charles D. Kolstad, "Foreign Direct Investment, Exchange Rate Variability and Demand Uncertainty," *International Economic Review*, November 1995, *36* (4), 855–873.

Gopinath, Gita and Oleg Itskhoki, "Frequency of Price Adjustment and Pass-Through*," *Quarterly Journal of Economics*, May 2010, *125* (2), 675–727.

____ **and Roberto Rigobon**, "Sticky Borders*," *Quarterly Journal of Economics*, May 2008, *123* (2), 531–575.

____ **, Oleg Itskhoki, and Roberto Rigobon**, "Currency Choice and Exchange Rate Pass-Through," *American Economic Review*, March 2010, *100* (1), 304–336.

Gust, Christopher, Sylvain Leduc, and Nathan Sheets, "The adjustment of global external balances: Does partial exchange-rate pass-through to trade prices matter?," *Journal of International Economics*, November 2009, *79* (2), 173–185.

Helpman, Elhanan, Marc J. Melitz, and Stephen R. Yeaple, "Export versus FDI with Heterogeneous Firms," *The American Economic Review*, March 2004, *94* (1), 300–316.

Hummels, David, Jun Ishii, and Kei-Mu Yi, "The Nature and Growth of Vertical Specialization in World Trade," *Journal of International Economics*, June 2001, *54*, 75–96.

Iacovone, Leonardo and Veronika Zavacka, "Banking Crises and Exports: Lessons from the Past," May 2009. World Bank Policy Research Working Paper 5016.

Imbs, Jean, "The First Global Recession in Decades," *IMF Economic Review*, October 2010, *58* (2), 327–354.

Imbs, Jean M. and Isabelle Mejean, "Elasticity optimism," 2009. Mimeo.

IMF, "Survey of Private Sector Trade Credit Developments," February 2009. memorandum.

Irarrazabal, Alfonso A and Luca David Opromolla, "A Theory of Entry and Exit into Exports Markets," Technical Report, Mimeo, New York University 2009.

Jacks, David S., Christopher M. Meissner, and Dennis Novy, "The role of trade costs in the great trade collapse," in Richard Baldwin, ed., *The great trade collapse: Causes, Consequences and Prospects*, VoxEU.org Ebook, 2009, chapter 18.

Jin, Keyu, "International Business Cycles with Heterogenous Sectors," October 2009. Mimeo, LSE.

Kimball, Miles S., "The Quantitative Analytics of the Basic Neomonetarist Model," *Journal of Money, Credit and Banking*, November 1995, *27* (4), 1241–1277.

Klenow, Peter J. and Jonathan L. Willis, "Real rigidities and nominal price changes," 2006. Mimeo.

Kremer, Michael, "The O-Ring Theory of Economic Development," *Quarterly Journal of Economics*, August 1993, *108* (3), 551–75.

Landry, Anthony, "State-Dependent Pricing, Local-Currency Pricing, and Exchange Rate Pass-Through," *Globalization and Monetary Policy Institute Working Paper*, 2009.

Lane, Philip R and Gian Maria Milesi-Ferretti, "The Cross-Country Incidence of the Global Crisis," *IMF Economic Review*, November 2010, *59* (1), 77–110.

Levchenko, Andrei A., "Institutional Quality and International Trade," *Review of Economic Studies*, 2007, *74* (3), 791–819.

Love, Inessa, Lorenzo A. Preve, and Virginia Sarria-Allende, "Trade Credit and Bank Credit: Evidence from Recent Financial Crises," *Journal of Financial Economics*, 2007, *83*, 453–469.

Midrigan, Virgiliu, "Menu Costs, Multi-Product Firms and Aggregate Fluctuations," *Econometrica*, 2010. Forthcoming.

Neiman, Brent, "A State-Dependent Model of Intermediate Goods Pricing," *Journal of International Economics*, 2011. Forthcoming.

Obstfeld, Maurice and Kenneth Rogoff, "Risk and Exchange Rates," *National Bureau of Economic Research Working Paper Series*, August 1998, *No. 6694.*

Raddatz, Claudio, "Credit Chains and Sectoral Comovement: Does the Use of Trade Credit Amplify Sectoral Shocks?," *Review of Economics and Statistics*, May 2011, *92* (4), 985–1003.

Ramondo, Natalia and Veronica Rappoport, "The role of multinational production in a risky environment," *Journal of International Economics*, July 2010, *81* (2), 240–252.

___ , ___ , and Kim J. Ruhl, "The Proximity-Concentration Tradeoff under Uncertainty," 2010. Mimeo.

Rauch, James E., "Networks versus markets in international trade," *Journal of International Economics*, June 1999, *48* (1), 7–35.

Rose, Andrew, "Which International Institutions Promote International Trade?," *Review of International Economics*, September 2005, *13* (4), 682–698.

Ruhl, Kim J., "The International Elasticity Puzzle," 2008. Mimeo.

Russ, Katheryn, "The endogeneity of the exchange rate as a determinant of FDI: A model of entry and multinational firms," *Journal of International Economics*, 2007, *71*, 344–372.

Schoenle, Raphael, "International Menu Costs and Price Dynamics," January 2010. Mimeo, Princeton University.

Silva, J. M. C. Santos and Silvana Tenreyro, "The Log of Gravity," *Review of Economics and Statistics*, November 2006, *88* (4), 641–658.

WTO, "World Trade Report," July 2009.

Yi, Kei-Mu, "Can Vertical Specialization Explain the Growth of World Trade?," *Journal of Political Economy*, February 2003, *111* (1), 52–102.