How Trade Restrictions Disperse: Policy Dynamics with Firm Selection

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Abstract

In this paper, I explore the aggregate effects of trade restrictions in a two-country, dynamic, stochastic, general equilibrium (DSGE) model with firm selection and variable adjustment of markup. As a response to the trade collapse in the global crisis of 2008 and 2009, temporary trade restrictions have emerged in several countries. With analyzing the dynamics of a negative macroeconomic shock in the home economy first, and the subsequent introduction of trade restrictions in the foreign economy second, I show that both economies are in a worse position than they were during the economic downturn. The follow-ups to the recession and trade restrictions are investigated through three mechanisms: a) variable markup as a new avenue of increasing competitive pressure for producers (e.g. more competitive firms lower their markups.); b) average individual firms' specific productivity cut-off, which induces their optimum export choice (e.g. an increase in the export productivity cut-off means exporting becomes more difficult than before.); and c) the movement of international relative prices (e.g. the real exchange rate and terms of trade).

Keywords: Trade Restrictions, Entry, Heterogeneity, Variable Markup, Cut-off Productivity, IRBC, Trade Policy
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1 Introduction

During the economic crisis episode of 2008 and 2009, world output experienced the sharpest fall since the Great Depression in the 1930s. At the same time, world exports and imports in goods and services also collapsed tremendously. As illustrated in Figures 1 and 2, world exports and imports in goods and services declined steeply during 2009 down to 2006 levels. This phenomenon happened not only in OECD countries, but also in most countries around the world. According to Gawande, Hoekman & Cui (2011) and Kee, Neagu & Nicita (2010)[1], the cause of this sudden and severe trade collapse was the global economic downturn[2] itself, and international trade-limiting measures during the crisis had only a minor impact. Even so, trade restrictions have emerged in several countries in response to the global crisis. Evenett (2009, 2010) reported more than 1,400 new measures have employed between November 2008 and the end of 2010 that discriminate against foreign products and they are unfavorable to foreign investment. For example, in 2009, European Commission imposed anti-dumping duties on imports of Chinese leather shoes and preserved fruits from China, and iron and steel products from Belarus and Russia. According to a WTO report, there were 155 anti-dumping measure investigations in 2008 that were implemented as trade remedies to shield domestic industries. A report in The Economist published on September 8th, 2012[3] noted that protectionism has been intensifying and suggested this is one of the causes of the recent drag on global trade. All of these examples clearly show the negative impact of protectionist measures. In this paper, I carefully analyze the follow-ups of a recession and trade restrictions as a short period reaction[4] along international business cycles, and I find that the result for both analyzed economies (home and foreign) are worse after the

[1]They quantify trade policy changes and their trade impact for one hundred countries during the trade collapse.

[2]The possible causes of the trade collapse are a large demand shock (Bussire, Callegari, Ghironi, Sestieri & Yamano (2011), Chen (2010)), composition effect (Engel & Wang (2011)), vertical production linkages (Gawande et al. (2011), Yi (2009)), and drying up of trade credit (Amiti & Weinstein (2009)).

[3]See http://www.economist.com/node/21562221.

[4]Blanchard (2009) point out that technological waves capture behavior of output not only in the medium and long run, but also in the short run.

implementation of trade restrictions. Bown & Crowley (2013) has strong empirical support finding negative relationship between macroeconomic shocks and import restrictions among emerging economies between 1996 and 2010.

Figure 1: Yearly World Exports, 2000-2010 (OECD database)

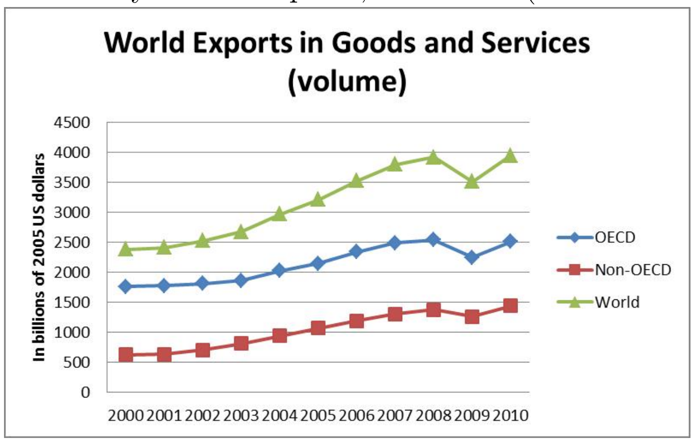
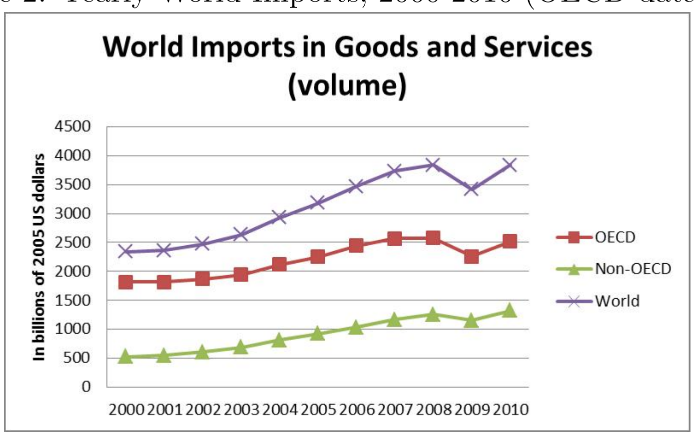


Figure 2: Yearly World Imports, 2000-2010 (OECD database)



Conventional international real business cycle (IRBC) models[5] assume international trade paradigms are exogenously given. A becoming known class of IRBC models (using a New International Macroeconomic framework) adopts endogenous trade patterns from heterogenous firms in order to study macroeconomic dynamics. This class of IRBC models are capable of reproducing a variety of empirical regularities with an environment in which only the most productive firms become exporters and firms with relatively lower productivity are driven

[5]See Heathcote & Perri (2002), Kehoe & Perri (2002), Stockman & Tesar (1995), and Backus, Kehoe & Kydland (1994, 1992).

out of the market or sell only in the domestic market. To achieve the objective of this paper, the benchmark model is built based on this emerging class of trade micro-founded IRBC models that are appropriate for analyzing the aggregate effects of change in trade policy such as tariffs and quotas. Ghironi & Melitz (2005) analyze precise endogenous Harrod-Balassa-Samuelson effect[6] using endogenous tradability with heterogeneous firm-specific productivity, extending the Melitz (2003) model to embed it in a dynamic and stochastic framework. However, they only analyze the long-run consequences. Alessandria & Choi (2007) study the link between sunk entry costs for producers and business cycles. They conclude that entry costs only matter for the firm-level dynamics, but have little effect on aggregate fluctuations. They use endogenous labor and capital as inputs, but they do not consider the entry process and treat the fraction of exporters as constant. Bergin & Corsetti (2008) and Bilbiie, Ghironi & Melitz (2008) study monetary policy, incorporating firm entry and nominal price rigidities. They find that a monetary shock has significant effects on firm entry. Bilbiie et al. (2008) document that profits are positively correlated and markups are negatively correlated with income in their model. These are features of the data that previous IRBC models had difficulty explaining.

I present a two-country, dynamic, stochastic, general equilibrium (DSGE) model with firm selection and variable adjustment of markup. As in Bergin & Glick (2007) and Ghironi & Melitz (2005), the model incorporates firms' entry and exit decisions along with firm heterogeneity. Firms know their productivity only after entry and the tradability of its good is endogenously determined. This endogenous tradability determines the firm's export condition where the least productive firms sell only in the domestic market, and the most productive firms sell in the foreign market. The model also incorporates a sunk entry cost and iceberg trade costs that affect the decisions of monopolistically competitive intermediate goods producers. Before entering the market, producers have to pay a fixed

[6]The Harrod-Balassa-Samuelson (HBS) or Balassa-Samuelson (BS) effect is that wealthier economies have higher average prices relative to their trading partners. As a result either the terms of trade or the exchange rate appreciate when there is a positive aggregate productivity shock in the home economy.

entry cost. Afterwards, they learn productivity, which is drawn from a Pareto distribution. Also, variable markups are introduced as a new avenue of increasing competitive pressure for producers: firms charge lower markups and aggregate productivity is higher. The variable adjustment of markups is generated from the non-homothetic preferences of the final goods technology taken from Melitz & Ottaviano (2008) and Ottaviano, Tabuchi & Thisse (2002). Melitz & Ottaviano (2008) derive the intra-industry reallocation effects[7] and monopolistically competitive producers as in Melitz (2003), but add a new pro-competitive effect of trade through lowering markup[8]. They use a non-homothetic quasilinear-quadratic function for consumer utility that makes the general equilibrium model difficult to handle.[9] Therefore, I use household utility function as in Ghironi & Melitz (2005), but instead use non-homothetic and non-constant elasticity of substitution aggregates in the final goods production function. I assume that the financial asset markets are incomplete, exhibiting some degree of international risk sharing mechanisms,[10] but are not perfect.

There is a growing line of literature that uses non-constant elasticity of substitution to explain behavior of international relative prices and how the composition of aggregate income affects trade patterns. Recently, several micro trade theory papers have incorporated non-homothetic preferences into their models. Foellmi, Hepenstrick & Zweimller (2011) explore the non-homothetic preferences into the new trade theory framework and compare its equilibrium outcomes with the case of standard homothetic preferences. Markusen (2010) and Simonovska (2010) aggregate differentiated consumer goods using variable elasticity of

[7] Micro trade literature strongly approve these reallocation effects of trade with heterogeneous firms. These effects arise from firm selection of export status or trade liberalization. See Chaney (2008), Bernard, Jensen & Schott (2006), Bernard, Eaton, Jensen & Kortum (2003), Pavcnik (2002), Aw, Chung & Roberts (2000), and Bernard & Bradford Jensen (1999).

[8] These predictions match well the empirical findings of Campbell & Hopenhayn (2005), Syverson (2004) and Caballero & Hammour (1994). Campbell & Hopenhayn (2005) and Syverson (2004) found that U.S. retail trade industries in larger cities are more productive and competition is tougher. Caballero & Hammour (1994) show in their model that more efficient production units are created and less efficient ones are destroyed in which their model is essential for understanding growth and business cycles.

[9] Melitz & Ottaviano (2008) derive a partial equilibrium model to study the implications of different market sizes and trade policies.

[10] People cannot purchase an unemployment insurance policy that reimburse when they become unemployed. Countries cannot explicitly and efficiently insure against shocks.

substitution preferences and explain several existing trade puzzles. Goksel (2009) present a multi-country general equilibrium model of trade with non-homothetic preferences and find that differences in income with trading partners acts as a trade barrier. This approach is seen not only in the papers related to trade dynamics, but also in the business cycle literature. Ottaviano (2011) presents a business cycle model with a non-homothetic utility function defined over a continuum of horizontally differentiated products, exogenous labor, and endogenous capital. He argues that existing models overstate the role of heterogeneous firms and endogenous entry as a transmission of aggregate productivity shocks because of the asymmetric size effect of firms on aggregate fluctuations. Sakane (2011) studies the terms of trade dynamics, incorporating non-homothetic preference into the consumption index with endogenous labor supply. Using vector autoregression (VAR) and maximum forecast error variance identification, she analyzes the consequences of the US labor productivity shock on the terms of trade in different asset market assumptions. Rodriguez-Lopez (2011) studies exchange rate pass-through,[11] building a model with sticky wages, heterogeneous firms and endogenous markups. Davis & Huang (2010) incorporate endogenous markups into a model with nominal rigidities and investigate IRBC properties, but their model does not have entry and exit dynamics.

There is also much literature on deregulation, gains from trade, analyzing the long-run equilibrium of models. Melitz (2007) proposes a dynamic model of firm-level adjustment to trade liberalization that captures the entry, exit, export, and innovation decisions of heterogeneous firms. They find that the timing and the speed of trade liberalization matters for firm-level productivity improvements and the entry decisons to the export market. Alessandria & Choi (2011) estimate the effect of reducing tariffs on welfare, trade, and export participation, and find that the tariff equivalent of the sunk exporting costs is around 30 percentage points. Antras & Caballero (2010) study the long-run effects of trade liberal-

[11]The elasticity of the price with respect to the terms of trade is the rate of exchange rate pass-through. Incomplete exchange rate pass-through arise when the movement of international relative prices tend to have a smaller impact on the price of imports. The following results is the exchange rate appreciation.

ization with a dynamic general equilibrium model that incorporates financial constraints and the savings rate. Bernard et al. (2003) build a dynamic model with Bertrand competition in which heterogeneous firms are competing in prices and markups respond endogenously to these prices. In simulation results, they find that a 5 percent reduction of trade barriers lead to 4 percent increase in aggregate productivity and 4.7 percent increase in gross job creation. As opposed to the approaches taken in the papers above, this current study focuses on the aggregate effects of trade restrictions as a short-run feedback to a trading partner's economic slump.

As a quantitative study, I start by analyzing the impulse responses of aggregate variables to a temporary, negative productivity shock in the home economy. When the home economy is in an economic downturn, consumption and key measure of output, GDP decline. Demand for varieties also declines with negative productivity shock and fewer firms enter the home market than before. Reduced entry in the home market generate less competition among firms, markups for all producers increase, and the cut-off productivity of home exporting firms increases since exporting becomes more difficult than before. Foreign producers exporting to the home economy become relatively more competitive, lowering their markups and increasing their exporting profits. This allows additional foreign firms to enter the home market. Therefore, the cut-off productivity of foreign exporting firms decreases during a recession of its trading partner and the terms of trade for the home economy depreciate. Next, I analyze the consequences of the trade restrictions imposed by the foreign economy to protect its domestic industries as a response to an economic downturn of its trading partner. The results show that both analyzed economies end up in a position worse than the one they would have found themselves in otherwise. The terms of trade for the home economy further depreciates, while consumption and income for both economies also continues to decrease. In the foreign economy, firms respond to this trade policy change in a number of ways. The profits of firms selling domestically increase and their markups go down, but the profits of exporting firms decrease and their markups increase with trade restrictions. However, the loss of profits of the exporting firms and the consumers in the foreign economy far outweigh the gains of the domestic profits, and put itself into a less competitive position than it was during the economic slowdown of its trading partner.

Second, international business cycle statistics of the simulated model are analyzed with a 1 percent home aggregate productivity shock, and with calibration along the lines of micro trade literature. Aggregate volatilities are well observed as a simillar pattern as the data. For the correlation between a variable and GDP, domestic co-movement matches well, except for counter-cyclical net exports. Average profits are positively correlated, and markup is negatively correlated with GDP. This feature of the data is in line with the empirical findings of Bilbiie et al. (2008). Regarding international correlations, my results share the same failure as that of the conventional IRBC model. The model produces higher cross-country consumption correlations than output correlations. Also, the international correlations of labor and entry are strongly negatively correlated. However, due to the incomplete asset market, risk sharing between countries dampens demands of the goods and allows consumption smoothing, so international correlations of output are not strongly negatively correlated and the correlations of consumption across countries are smaller compared to conventional IRBC models. The model also succeeds in replicating the correlation between international relative prices and the consumption ratio across countries.

The paper is organized as follows. Section 2 provides stylized facts of international business cycle data. Section 3 describes the benchmark model that incorporates heterogeneous firms with selection to export and variable adjustment of markup in an incomplete asset market setting. Section 4 is the quantitative analysis, providing calibration, the transition dynamics of the economic slump and import restrictions, and international business cycle statistics of the model compared with data. Section 5 performs a sensitivity analysis, varying several key mechanisms of the model. Section 6 concludes.

2 Stylized Facts of International Business Cycle Data

This section provide stylized facts on international business cycle data. I start by plotting the time series for GDP, consumption, investment, and labor for the U.S. over the sample post-Bretton Woods period, 1973Q1-2009Q4[12]. The time series plots are shown in Figure 3. The time series display large fluctuations about its trend at shorter frequencies, and consumption, investment, and labor time series comove with the GDP series. To make a comparison of the model dynamics with the business cycle properties of the data, cyclical components of the data need to be extracted. As in the analysis by King & Rebelo (1999) and Backus et al. (1992), the Hodrick & Prescott (1997) filter[13] with a smoothing parameter of 1600 is applied to the natural log of each series.

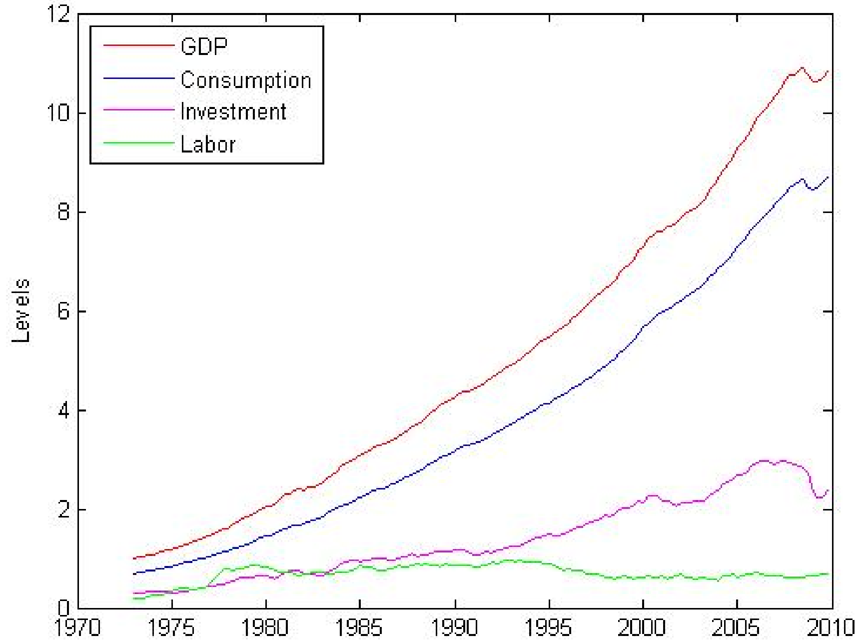
The data is organized into four categories: (1) the standard deviations of a variable relative to that of the log of output, (2) the correlation between a variable and the log of output as a domestic comovement, (3) the international correlations between home variables and foreign variables, and (4) the correlation between relative consumption and the terms of trade. Table 1 provides the U.S. business cycle statistics, 1973Q1-2009Q4 and its correlations with GDP. As is commonly known, investment is almost 4 times more volatile (3.87) than output, and consumption (0.72), and labor (0.58) are less volatile than output. For the domestic comovement, consumption, investment and labor are pro-cyclical (0.86, 0.89, 0.79, respectively). Terms of trade is defined as the relative price of imports to exports. It is almost 1.5 times more volatile than output and its correlation with output is negative (-0.25). Table 2 provides international correlations between U.S. and European aggregates,[14] as well as the correlation between the terms of trade and relative consumption. Cross-country

[12]U.S. quarterly data for GDP, consumption, investment is obtained from the International Financial Statistics provided by the International Monetary Fund (http://elibrary-data.imf.org/). The data for labor is obtained from the Bureau of Labor Statistics (http://www.bls.gov/) and OECD.StatExtracts (http://stats.oecd.org). More details about the U.S. time series are found in the appendix.

[13]Time series data consists of a cyclical component (y_t^c) and a trend component (y_t^d). To extract cyclical component, an HP filter is used. It is measurable by subtracting variations in the second difference of the trend minimizing $\left\{\sum_{t=0}^{T}(y_t - y_t^d)^2 + \lambda\sum_{t=2}^{T-1}((y_{t+1}^d - y_t^d) - (y_t^d - y_{t-1}^d))^2\right\}$.

[14]The quarterly data for the U.S. and Europe are taken from International Financial Statistics. European countries include: Austria, Finland, France, Germany, Italy, Sweden, Switzerland and the U.K.

Figure 3: Times Series using U.S. data



output correlations (0.55) are larger than cross-country consumption correlations (0.42), in contrast to conventional IRBC models which produce higher consumption correlations than output correlations. Investment and labor tend to be positively correlated across countries (0.39 and 0.28, respectively) in the data. The standard models fail to account for this feature and have counter-factually negative international correlations of investment and labor. Last, the terms of trade and the ratio of consumption are negatively linked in the data (-0.35),[15]

Table 1: U.S. Business Cycle Statistics (1973Q1-2009Q4)

	Volatility	Domestic Comovement
	% S.D. relative to GDP	Correlations with GDP
GDP	1	1
Consumption	0.72	0.86
Investment	3.87	0.89
Employment	0.58	0.79
TOT	1.44	-0.25

[15] This data is taken from Corsetti, Dedola & Leduc (2008).

but standard setups wrongly predict that they should be positively linked.

Table 2: International Correlations and Other Correlation (1973Q1-2008Q3)

GDP, GDP^*	0.55
C, C^*	0.42
X, X^*	0.39
L, L^*	0.28
TOT, Relative Consumption	-0.35 (CDL)

To evaluate the success and failure of the model, the data in this section is compared with the simulated model in section 4.

3 A Model with Firm Selection and Variable Markup

In this section, I present a two-country, dynamic, stochastic, general equilibrium (DSGE) model that contains firm selection and variable adjustment of markups. The basic framework is built upon the models of Bergin & Glick (2007) and Ghironi & Melitz (2005) in which producers have heterogeneous firm-specific productivity and endogenous export participation with a sunk entry cost, and an ice-berg trade cost. The variable markups are introduced using the non-homothetic preferences framework of Melitz & Ottaviano (2008) that gives a linear demand system for differentiated varieties. The world economy consists of two countries of equal size: home and foreign. The foreign variables are donoted by *. Each economy is composed of infinitely lived representative households, perfectly competitive final goods producers, and monopolistically competitive intermediate goods producers. I assume that international financial markets are incomplete, allowing only for trade in uncontingent home and foreign bonds. I restrict attention to the behaviors of domestic agents unless otherwise specified.

3.1 The Household's Behavior

In each period, the representative household of each country supplies L (L^*) units of labor inelastically at the wage rate W_t (W_t^*). The expected discounted intertemporal lifetime utility function is characterized by: $E_0\left[\sum_{t=0}^{\infty}\beta^t\frac{C_t^{1-\eta}}{1-\eta}\right]$ where C_t denotes consumption. Here, the parameter $\beta \in (0,1)$ is the intertemporal discount factor and $\eta > 0$ is the inverse of the intertemporal elasticity of substitution. A unit mass of households in the home country face the sequence of budget constraints,

$$
\begin{aligned}
&P_tC_t + P_tB_{H,t+1} + P_t^*B_{F,t+1} + \frac{n}{2}\left(P_tB_{H,t+1}^2 + P_t^*B_{F,t+1}^2\right) + \tilde{v}_t(N_{A,t} + N_{E,t})q_{t+1} \\
&\qquad = (1+i_t)P_tB_{H,t} + (1+i_t^*)P_t^*B_{F,t} + N_{A,t}(\tilde{d}_t + \tilde{v}_t)q_t + W_tL + \pi_t \quad (1)
\end{aligned}
$$

where P_t denotes welfare-based price. $B_{H,t}$ and $B_{F,t}$ are home and foreign bond holdings in which pay an interest rate i_t and i_t^* each. Here, W_tL is the income from labor and W_t is the wage rate. As in Boileau & Normandin (2008), I assume a small quadratic portfolio cost (QPC) to avoid indeterminacy and non-stationarity of the steady states. The parameter that determines the cost of adjusting the holdings of bonds, n, is to be small, but positive. q_t is the shares in a mutual fund of home firms that pays an average total profits of firms $\tilde{d}_t$ as dividends. The price of traded shares in the stock market is $\tilde{v}_t$, therefore, $\tilde{v}_tN_{A,t}q_{t+1} + \tilde{v}_tN_{E,t}q_{t+1}$ is the total amount of resources allocated to accumulate shares in mutual funds. $N_{A,t}$ is the number of firms that are already operating at the time t, and $N_{E,t}$ is the number of new firms. Following Ghironi & Melitz (2005), I assume there is a one period time lag driven by depreciation in production. Therefore, at time t+1, only $(1-\delta_d)(N_{A,t}+N_{E,t})$ firms survive to produce. Here, δ_d is an exogenous death shock that hits firms at the end of period t. π_t is the rebate of resources using QPC to households, which is equal to $\frac{n}{2}(P_tB_{H,t+1}^2+P_t^*B_{F,t+1}^2)$ in equilibrium. Similarly, foreign households face the following sequence of budget constraints:

$$P_t^* C_t^* + P_t^* B_{F,t+1}^* + P_t B_{H,t+1}^* + \frac{n^*}{2}\left(P_t^* B_{F,t+1}^{*2} + P_t B_{H,t+1}^{*2}\right) + \tilde{v}_t{}^*(N_{A,t}^* + N_{E,t}^*)q_{t+1}^*$$
$$= (1+i_t^*)P_t^* B_{F,t}^* + (1+i_t)P_t B_{H,t}^* + N_{A,t}^*(\tilde{d}_t^* + \tilde{v}_t^*)q_t^* + W_t^* L^* + \pi_t^* \quad (2)$$

The first order conditions to the representative hosehold are achieved by maximizing the utility function subject to (1) by the Lagrangian method. The optimal condition for consumption is

$$\lambda_t P_t = C_t^{-\eta}, \quad (3)$$

where λ_t is the Lagrangian multiplier. The Euler equations for domestic and foreign bond holdings are

$$\lambda_t P_t (1 + n B_{H,t+1}) = \beta(1 + i_{t+1}) E_t \left\{P_{t+1}\lambda_{t+1}\right\} \quad (4)$$

and

$$\lambda_t P_t^* (1 + n B_{F,t+1}) = \beta(1 + i_{t+1}^*) E_t \left\{P_{t+1}^*\lambda_{t+1}\right\}. \quad (5)$$

Finally, the Euler equation for shares in a mutual fund is

$$\tilde{v}_t \lambda_t = \beta(1 - \delta_d) E_t \left\{\lambda_{t+1}(\tilde{d}_{t+1} + \tilde{v}_{t+1})\right\}. \quad (6)$$

3.2 Final Goods Producers

The final goods in the home country are produced by aggregating a set (Ω) of intermediate goods. The maximization problem of the final goods producer is

$$\max_{f_t(i)} P_t F_t - \int_{i\in\Omega} p_t(i) f_t(i) di \quad (7)$$

subject to the quasilinear non-constant elasticity of substitution technology that aggregates a continuum of horizontally differentiated intermediate goods as in Melitz & Ottaviano (2008) and Ottaviano et al. (2002):

$$F_t = \alpha \int_{i\in\Omega} f_t(i)di - \frac{\gamma}{2}\int_{i\in\Omega}[f_t(i)]^2 di - \frac{\xi}{2}\left[\int_{i\in\Omega} f_t(i)di\right]^2. \tag{8}$$

Here, F_t is the production of final goods and $f_t(i)$ is the demand for varieties. $i \in \Omega$ denotes a continuum of differentiated varieties. I assume there is no homogenous good.[16]. Here, α measures the strength of the preference for differentiated products and ξ governs the substitutability of varieties. γ is a product differentiation index between intermediate goods in which consumers care more about the distribution of production across varieties as γ increases[17]. The solution to this problem gives the linear demand function for each variety:

$$f_t(i) = \frac{\alpha}{\gamma} - \frac{p_t(i)}{\gamma P_t} - \frac{\xi}{\gamma}\int_{i\in\Omega} f_t(i)di. \tag{9}$$

In the home economy, total number of producers are N_t. Therefore, all the varieties produced in home economy is found by integrating (9) over N_t:

$$\begin{aligned}\int_{i\in\Omega} f_t(i)di &= N_t\frac{\alpha}{\gamma} - \frac{1}{\gamma P_t}\int_{i\in\Omega} p_t(i)di - \frac{\xi}{\gamma}N_t\int_{i\in\Omega} f_t(i)di \\ &= \frac{\gamma}{\gamma+\xi N_t}\left[\frac{\alpha N_t}{\gamma} - \frac{1}{\gamma P_t}\int_{i\in\Omega} p_t(i)di\right] \\ &= \frac{\alpha N_t}{\gamma+\xi N_t} - \frac{N_t\tilde{p}_t}{P_t(\gamma+\xi N_t)}\end{aligned}$$

where $\tilde{p}_t = \frac{1}{N_t}\int_{i\in\Omega} p_t(i)di$. Now, plugging this into (9) gives the expression for the variety demand without integral:

$$f_t(i) = \frac{\alpha}{\gamma} - \frac{p_t(i)}{\gamma P_t} - \frac{\xi}{\gamma}\left(\frac{\alpha N_t}{\gamma+\xi N_t}\right) + \frac{\xi}{\gamma}\frac{N_t\tilde{p}_t}{P_t(\gamma+\xi N_t)}. \tag{10}$$

[16]In Melitz & Ottaviano (2008), preference includes a homegenous good f_0 chosen as numeraire.
[17]When γ is zero, differentiated varieties are perfect substitutes.

The price bound, $p_{bound,t}$, is attained at which linear demand for each variety, $f_t(i)$ is driven to 0. If price is lower than $p_{bound,t}$, a firm would have zero demand. This price bound is the driving force for the variable adjustment of markups and the cut-off productivity strategy of firms as it will be shown in the behavior of the intermediate goods producers.

$$p_{bound,t} = \frac{\alpha\gamma P_t + \xi N_t \tilde{p}_t}{\gamma + \xi N_t} \tag{11}$$

Notice that this price bound or threshold cost, $p_{bound,t}$ goes down when the total number of firms, N_t goes up or the average price, $\tilde{p}_t$ goes down. Both of which denote an increase in competitive pressure at the micro firm-level dynamics.

3.3 Intermediate Goods Producers

Now, I consider the problem of monopolistically competitive intermediate goods producers in the home economy. These firms are endogenously segmented into domestic markets and foreign markets in their production and they maximize profits based on their linear variety demand system found as solutions to the problem of the final goods producers.

3.3.1 Firm Selection

There are $N_t(N_t^*)$ total mass of producers in the home (foreign) country and exporters pay sales with an ice-berg trade cost τ_t for each unit of goods. Given these definitions, the monopolistically competitive intermediate goods producers maximize their profits subject to the input demand functions for domestically produced varieties (13) and (14). Per-period profits for intermediate goods producers, $d_t(a)$ are divided into domestic sales profits, $d_{D,t}(a)$, and export sales profits, $d_{X,t}(a)$:

$$d_t(a) = d_{D,t}(a) + d_{X,t}(a). \tag{12}$$

Producers maximize their profits separately and decide how much to produce for each market. Producers selling domestically maximize $d_{D,t}(a) = p_{D,t}(a) f_{D,t}(a) - \frac{W_t}{aZ_t} f_{D,t}(a)$ subject to

$$f_{D,t}(a) = \frac{\alpha}{\gamma} - \frac{p_{D,t}(a)}{\gamma P_t} - \frac{\xi}{\gamma}\left(\frac{\alpha N_t}{\gamma + \xi N_t}\right) + \frac{\xi}{\gamma}\frac{N_t \tilde{p}_t}{P_t(\gamma + \xi N_t)} \tag{13}$$

while exporting producers maximize $d_{X,t}(a) = p_{X,t}(a) f_{X,t}(a) - \frac{W_t}{aZ_t}\tau_t f_{X,t}(a)$ subject to

$$f_{X,t}(a) = \frac{\alpha}{\gamma} - \frac{p_{X,t}(a)}{\gamma P_t^*} - \frac{\xi}{\gamma}\left(\frac{\alpha N_t^*}{\gamma + \xi N_t^*}\right) + \frac{\xi}{\gamma}\frac{N_t^* \tilde{p}_t^*}{P_t^*(\gamma + \xi N_t^*)}. \tag{14}$$

They take the total number of firms, N_t and the average price, $\tilde{p}_t$ as given. Here, $\frac{W_t}{aZ_t}$ is the marginal cost of production. Each producer faces a different marginal cost curve differentiated by individual specific productivity a. However, all firms are subject to a common aggregate productivity Z_t. Therefore, Z_t affects the production of all goods homogeneously while a is the firm-specific productivity.

Now, I write the price, $p_{D,t}(a)$ and $p_{X,t}(a)$, in the demand functions $f_{D,t}(a)$ and $f_{X,t}(a)$. They are total inverse demand functions: $p_{D,t}(a) = \frac{\alpha\gamma P_t + \xi N_t \tilde{p}_t}{\gamma + \xi N_t} - \gamma P_t f_{D,t}(a)$ and $p_{X,t}(a) = \frac{\alpha\gamma P_t^* + \xi N_t^* \tilde{p}_t^*}{\gamma + \xi N_t^*} - \gamma P_t^* f_{X,t}(a)$. I plug them back into the profit function, and find the first order conditions with respect to $f_{D,t}(a)$ and $f_{X,t}(a)$:

$$f_{D,t}(a) = \frac{p_{D,t}(a) - \frac{W_t}{aZ_t}}{\gamma P_t}$$

$$f_{X,t}(a) = \frac{p_{X,t}(a) - \frac{W_t}{aZ_t}(a)\tau_t}{\gamma P_t^*}$$

Consequently, the optimal prices are found as follow.

$$p_{D,t}(a) = \frac{1}{2}\left[\frac{W_t}{aZ_t} + \frac{\alpha\gamma P_t + \xi N_t \tilde{p}_t}{\gamma + \xi N_t}\right] = \frac{\frac{W_t}{aZ_t} + p_{bound,t}}{2} \tag{15}$$

$$p_{X,t}(a) = \frac{1}{2}\left[\frac{W_t \tau_t}{aZ_t} + \frac{\alpha\gamma P_t^* + \xi N_t^* \tilde{p}_t^*}{\gamma + \xi N_t^*}\right] = \frac{\frac{W_t}{aZ_t}\tau_t + p_{bound,t}^*}{2}. \tag{16}$$

Here, $p_{bound,t}$ is defined as the price bound for the producers with domestic sales. If its price is lower than $p_{bound,t}$, a firm would have zero demand. Therefore, it is the threshold cost for the firms who are having domestic sales, and is equal to $p_{D,t}(a_{D,t})$ and $\frac{W_t}{a_{D,t}Z_t}$. Similarly, the price bound of producers with export sales, $p^*_{bound,t}$ is defined when $f_{X,t}(a_{X,t})$ is zero. Therefore, it is the threshold cost for the firms with export sales, and is equal to $p_{X,t}(a_{X,t})$ and $\frac{W_t}{a_{X,t}Z_t}$.

Since demand functions are written in the function of the price function, I plug optimal prices and the threshold cost for the producers back into demand function and yield:

$$f_{D,t}(a) = \frac{1}{\gamma P_t}\left[\frac{\frac{W_t}{a_{D,t}Z_t} - \frac{W_t}{aZ_t}}{2}\right] \tag{17}$$

and

$$f_{X,t}(a) = \frac{1}{\gamma P^*_t}\left[\frac{\tau_t\frac{W_t}{a_{X,t}Z_t} - \frac{W_t}{aZ_t}\tau_t}{2}\right]. \tag{18}$$

As in the optimal prices, demand functions of the producers are bounded from above and determined by the cut-off productivity strategy.

3.3.2 Markups and Profits

The monopolistically competitive producers have excess capacity in which they operate on the downward sloping portion of their average total cost curve. Therefore, they produce less than the cost-minimizing output and have markup over marginal cost. The exogeneous markup is a common form in the IRBC models, because the good is aggregated using the constant elasticity of substitution (CES) technology. In this paper, the endogenous adjustment of markups of producers is generated from the variable elasticity of substitution (VES) technology of the final goods that aggregates a continuum of horizontally differentiated intermediate goods. Plugging the optimal pricing rules, $p_{D,t}(a)$ and $p_{X,t}(a)$ into the markup formula, the expressions for markup are as follow.

$$mu_{D,t}(a) = p_{D,t}(a) - \frac{W_t}{aZ_t} = \frac{\frac{W_t}{a_{D,t}Z_t} - \frac{W_t}{aZ_t}}{2} \tag{19}$$

$$mu_{X,t}(a) = p_{X,t}(a) - \frac{W_t}{aZ_t} = \frac{\tau_t \frac{W_t}{a_{X,t}Z_t} - \frac{W_t}{aZ_t}}{2} \tag{20}$$

Similarly, the profits of domestic sales $d_{D,t}(a)$ and exporting sales $d_{X,t}(a)$ are found by plugging in the optimal pricing rules $p_{D,t}(a)$ and $p_{X,t}(a)$ and the demand functions $f_{D,t}(a)$ and $f_{X,t}(a)$ into profits formula, the expression for profits are as follow.

$$d_{D,t}(a) = \left[p_{D,t}(a) - \frac{W_t}{aZ_t}\right] f_{D,t}(a) = \frac{1}{4\gamma P_t}\left[\frac{W_t}{a_{D,t}Z_t} - \frac{W_t}{aZ_t}\right]^2 \tag{21}$$

$$d_{X,t}(a) = \left[p_{X,t}(a) - \frac{W_t}{aZ_t}\tau_t\right] f_{X,t}(a) = \frac{1}{4\gamma P_t^*}\left[\tau_t \frac{W_t}{a_{X,t}Z_t} - \tau_t \frac{W_t}{aZ_t}\right]^2 \tag{22}$$

Note that the monopolistically competitive intermediate goods producers with higher productivity level, a, or lower marginal costs, $\frac{W_t}{aZ_t}$, are able to generate higher markups and profits.

3.4 Entry and Exit, Number of Producers

As in Ghironi & Melitz (2005), each producer knows its productivity only after entry. The mass of domestically producing and selling firms, $N_{D,t}$ and exporting firms to the foreign country, $N_{X,t}$ are written as the proportion of the mass of already operating firms, $N_{A,t}$. They are $N_{D,t} = (1 - \Phi(a_{D,t}))\, N_{A,t}$ and $N_{X,t} = (1 - \Phi(a_{X,t}))\, N_{A,t}$. The total mass of producers, N_t in the home economy are made of the sum of number of producers who domestically produce and sell, $N_{D,t}$, and number of foreign producers who export to the home market, $N_{X,t}^*$:

$$N_t = [1 - \Phi(a_{D,t})]\, N_{A,t} + \left[1 - \Phi(a_{X,t}^*)\right] N_{A,t}^*. \tag{23}$$

Similarly, the total mass of producers in the foreign economy is

$$N_t^* = \left[1 - \Phi(a_{D,t}^*)\right] N_{A,t}^* + \left[1 - \Phi(a_{X,t})\right] N_{A,t}. \tag{24}$$

As in Bilbiie et al. (2008) and Ghironi & Melitz (2005), the expected and discounted value of the future average total profits is characterized by $\tilde{v}_t = E_t \sum_{s=t+1}^{\infty} [\beta(1-\delta_d)]^{s-t} \left[\left(\frac{C_s}{C_t}\right)^{-\eta} \tilde{d}_s\right]$. This induces a free entry condition in which firms enter until $\tilde{v}_t$ is equal to the cost of entry that is proportional to marginal costs:

$$\tilde{v}_t = \frac{W_t f_{E,t}}{Z_t}. \tag{25}$$

3.5 Aggregation with Firm Averages

As in Melitz (2003) and Ghironi & Melitz (2005), a firm's individual productivity level a is Pareto distributed. The probability distribution function follows $\frac{\kappa a_{min}^{\kappa}}{a^{\kappa+1}}$ and the cumulative distribution function follows $1 - \Phi(a) = \left(\frac{a_{min}}{a}\right)^{\kappa}$ where $\kappa \geq 1$ is a shaping parameter (lower κ, higher heterogeneity[18]) and $a_{min} \in [0, a]$. Therefore, it can be said that $\tilde{a} \equiv \int_{a_{min}}^{\infty} a d\Phi(a)$, $\tilde{a}_{D,t} \equiv \frac{1}{1-\Phi(a)} \int_{a_{D,t}}^{\infty} a d\Phi(a)$, and $\tilde{a}_{X,t} \equiv \frac{1}{1-\Phi(a)} \int_{a_{X,t}}^{\infty} a d\Phi(a)$. Following closely with Ottaviano (2011), the parametrization of the average productivity and the variance of firm specific productivity are defined as $a = \frac{\kappa+1}{\kappa} \tilde{a}_{s,t}$, and $var(\tilde{a}_{s,t}) = \int_{a_{s,t}}^{\infty} \tilde{a}_{s,t}^2 d\Phi(a_{s,t}) - \left[\frac{1}{1-\Phi(a_{s,t})} \int_{a_{s,t}}^{\infty} \tilde{a}_{s,t} d\Phi(a_{s,t})\right]^2 = \frac{\kappa a^2}{(\kappa+1)^2(\kappa+2)}$ where $s = \{D, X\}$. Using the parametrization above, the model is written without variety notation. The average prices and average markups are $\tilde{p}_{D,t} = \left(\frac{2\kappa+1}{2\kappa+2}\right)\left(\frac{W_t}{Z_t \tilde{a}_{D,t}}\right)$, $\tilde{p}_{X,t} = \left(\frac{2\kappa+1}{2\kappa+2}\right)\left(\frac{W_t \tau_t}{Z_t \tilde{a}_{X,t}}\right)$, $\tilde{mu}_{D,t} = \left(\frac{1}{2\kappa+2}\right)\left(\frac{W_t}{Z_t \tilde{a}_{D,t}}\right)$, and $\tilde{mu}_{X,t} = \left(\frac{1}{2\kappa+2}\right)\left(\frac{W_t \tau_t}{Z_t \tilde{a}_{X,t}}\right)$. The average linear demands are found as $\tilde{f}_{D,t} = \left(\frac{1}{2\gamma P_t}\right)\left(\frac{1}{\kappa+1}\right)\left(\frac{W_t}{Z_t \tilde{a}_{D,t}}\right)$ and $\tilde{f}_{X,t} = \left(\frac{1}{2\gamma P_t^*}\right)\left(\frac{1}{\kappa+1}\right)\left(\frac{W_t \tau_t}{Z_t \tilde{a}_{X,t}}\right)$. The average total profits consist of the average profit from domestic sales and export sales: $\tilde{d}_t = \tilde{d}_{D,t} + \tilde{d}_{X,t}$. As in Ottaviano (2011) and Melitz & Ottaviano (2008), average prof-

[18]If κ=1, it is identical to uniform distribution over [0,a].

its are defined as: $\tilde{d}_t = \int_{a_{D,t}}^{\infty} d_{D,t}(a)d\Phi(a) + \int_{a_{X,t}}^{\infty} d_{X,t}(a)d\Phi(a)$. Now, the average profit from domestic sales and export sales is found using the definition of average productivities: $\tilde{d}_{D,t} = \left(\frac{1}{2\gamma P_t(\kappa+1)(\kappa+2)}\right)\left(\frac{a_{min}}{\tilde{a}_{D,t}}\right)^{\kappa}\left(\frac{W_t}{Z_t\tilde{a}_{D,t}}\right)^2$ and $\tilde{d}_{X,t} = \left(\frac{1}{2\gamma P_t^*(\kappa+1)(\kappa+2)}\right)\left(\frac{a_{min}}{\tilde{a}_{X,t}}\right)^{\kappa}\left(\frac{W_t\tau_t}{Z_t\tilde{a}_{X,t}}\right)^2$. Aggregating technology of the final goods, F_t yields:

$$\begin{aligned} F_t &= \alpha \int_{i\in\Omega} f_t(i)di - \frac{\gamma}{2}\int_{i\in\Omega}\left[f_t(i)\right]^2 di - \frac{\xi}{2}\left[\int_{i\in\Omega} f_t(i)di\right]^2 \\ &= \left(\frac{\alpha N_t}{2\gamma(\kappa+1)P_t}\right)\left(\frac{W_t}{Z_t\tilde{a}_{D,t}}\right) - \left(\frac{N_t}{4\gamma(\kappa+1)(\kappa+2)P_t^2}\right)\left(\frac{W_t}{Z_t\tilde{a}_{D,t}}\right)^2 \\ &- \frac{\xi}{2}\left(\frac{N_t}{2\gamma(\kappa+1)P_t}\right)^2\left(\frac{W_t}{Z_t\tilde{a}_{D,t}}\right)^2. \end{aligned} \tag{26}$$

3.6 Market Clearing Conditions and Equilibrium

The equilibrium for the benchmark model requires several market-clearing conditions. First, the final goods, F_t, are all consumed by households since consumption is the only source of demand for the final goods. Therefore, $F_t = C_t$. The model is closed by the bond market clearing conditions $B_{H,t+1} + B_{H,t+1}^* = 0$ and $B_{F,t+1}^* + B_{F,t+1} = 0$ as well as by the value of shares in a mutual fund market clearing condition $q_{t+1} = q_{t+1}^* = 1$. Subtracting foreign household's budget constraints (2) from the budget constraints of household in the home economy (1) and then applying the bond and mutual fund market clearing conditions gives the net foreign assets condition as follows.

$$\begin{aligned} P_tB_{H,t+1} + P_t^*B_{F,t+1} = P_t(1+i_t)B_{H,t} + P_t^*(1+i_t^*)B_{F,t} + \frac{1}{2}\left(W_tL - W_t^*L^*\right) \\ - \frac{1}{2}\left(P_tC_t - P_t^*C_t^*\right) + \frac{1}{2}\left(N_{A,t}\tilde{d}_t - N_{A,t}^*\tilde{d}_t^*\right) - \frac{1}{2}\left(N_{E,t}\tilde{v}_t - N_{E,t}^*\tilde{v}_t^*\right) \end{aligned} \tag{27}$$

Finally, the labor market clearing condition requires that labor employed in domestic production and exporting production, and labor employed to cover the entry costs equal the fixed labor supply L:

$$
\begin{aligned}
L =& \frac{\kappa}{W_t}\tilde{d}_{D,t}N_{D,t}\frac{1}{1-\Phi(a_{D,t})} + \frac{\kappa}{W_t}\tilde{d}_{X,t}N_{X,t}\frac{1}{1-\Phi(a_{X,t})} + \frac{N_{E,t}f_{E,t}}{Z_t} \\
=& \frac{\kappa}{2\gamma(\kappa+1)(\kappa+2)P_tW_t}\left(\frac{W_t}{\tilde{a}_{D,t}Z_t}\right)^2 N_{D,t} \\
&+ \frac{\kappa}{2\gamma(\kappa+1)(\kappa+2)P_t^*W_t}\left(\frac{W_t\tau_t}{\tilde{a}_{X,t}Z_t}\right)^2 N_{X,t} + \frac{N_{E,t}f_{E,t}}{Z_t}
\end{aligned} \tag{28}
$$

The benchmark model economy and its associated steady state system has 45 independent equations, so 45 variables must be solved for: 23 home variables ($\lambda_t, C_t, W_t, i_t, P_t, \tilde{d}_t, \tilde{v}_t, N_{A,t}, N_{D,t}, N_{X,t}, N_{E,t}, \tilde{p}_t, \tilde{p}_{D,t}, \tilde{p}_{X,t}, \tilde{mu}_{D,t}, \tilde{mu}_{X,t}, \tilde{a}_{D,t}, \tilde{a}_{X,t}, N_t, \tilde{d}_{D,t}, \tilde{d}_{X,t}$, $B_{H,t}, B_{F,t}$) and 22 foreign variables ($\lambda_t^*, C_t^*, i_t^*, \tilde{d}_t^*, \tilde{v}_t^*, N_{A,t}^*, N_{D,t}^*, N_{X,t}^*, N_{E,t}^*, \tilde{p}_{D,t}^*, \tilde{p}_{X,t}^*, \tilde{mu}_{D,t}^*$, $\tilde{mu}_{X,t}^*, \tilde{a}_{D,t}^*, \tilde{a}_{X,t}^*, N_t^*, \tilde{d}_{D,t}^*, \tilde{d}_{X,t}^*, W_t^*, \tilde{p}_t^*, B_{F,t}^*, B_{H,t}^*$). I have chosen foreign welfare-based price, P_t^* as the numeraire. It has 6 exogenous policy variables: $Z_t, Z_t^*, f_{E,t}, f_{E,t}^*, \tau_t, \tau_t^*$. The full summary of all 45 systems of equations are provided in the Appendix.

4 Quantitative Analysis

In this section, the properties of the model are examined by numerical experiments. I have two purposes for the quantitative analysis: a) analyzing the consequences of an economic depression and trade restriction dynamics, and b) studying properties of the international business cycle in the model. I start by presenting how the benchmark model is calibrated in order to fit the real world data. In order to capture the short-run effects of a recession and trade restrictions, the impulse responses for each scenario are thoroughly analyzed. Last, I compute the business cycle statistics produced when there is a stochastic productivity shock in the home economy. I solve the baseline model by log-linearizing the system of equations around the steady state and solve the resulting system of linear difference equations as described in King, Plosser & Rebelo (2002) and applying Uhlig (1995) techniques. Given the parameters that characterize behavior around the steady state and the law of motion of shocks, DYNARE with MATLAB[19] are used to solve and simulate a system of linear difference equations.

4.1 Benchmark Calibration

The benchmark values are chosen for the set of relevant parameters to match the features of the US economy. The intertemporal discount factor of households β is set equal to 0.99, a standard choice in the literature. The inverse of the intertemporal elasticity of substitution η is set equal to 2 as in Ghironi & Melitz (2005) and the quadratic adjustment cost of bond holdings is set equal to $n = \beta^2 * 0.01$ as in Boileau & Normandin (2008). Closely following Sakane (2011) and Rodriguez-Lopez (2011), I set the technology of the final goods parameters as α=9.5, γ=0.5, and ξ=1.1. Relying on Chaney (2008), the scaling parameter of the Pareto distribution κ condition holds in order to assure the standard deviation of the idiosyncratic shock is finite and positive. As documented by Bernard et al. (2003), this parameter also matches the standard deviation of the log of domestic US plant sales at 1.67 in a steady state. I set the probability of a death shock equal to 0.025, which implies that average annual death rate for US firms is 10%. As in Alessandria & Choi (2007) and Obstfeld & Rogoff (2000), I set the steady-state value of ice-berg transport costs equal to 1.4, and the steady-state value of the entry cost is 1 as in Ghironi & Melitz (2005). Labor endowments are normalized to 1 for both economies. The location parameter of the productivity, a_{min} is also set equal to 1, without loss of generality. The steady state cut-off productivity for produers who sell in domestic market, $\tilde{a}_D$ is found solving the symmetric steady-state equilibrium. Table 3 lists all calibrated parameters.

[19] I simulate the model using Dynare version 4.2.4. See Juillard (2001).

Table 3: Benchmark Parameter Values

Description	value
Strength of product differentiation coefficient	α=9.5
Product differentiation index	γ=0.5
Variety substitutability	ξ=1.1
Inverse of the intertemporal elasticity of substitution	η=2
Intertemporal discount factor	β=0.99
Probability of death shock	δ_d=0.025
Iceberg transport cost	τ=1.4
Sunk entry costs parameter	f_E=1
Quadratic adjustment cost of bond holdings	$n = \beta^2 * 0.01$
Cut-off productivity for domestic firms	a_D=1.793
Location parameter of productivity	a_{min}=1
Characterizing parameter of $\Phi(a)$	κ=3.4
Labor endowment	$L = L^* = 1$

4.2 Shocks Strategy

4.2.1 Productivity Shocks

I solve for the dynamics in response to deterministic and stochastic shocks by log-linearizing the model around the steady state. In order to analyze the consequences of the economic slump in the home economy, a deterministic and negative shock to aggregate productivity of 1 percent deviations from the steady-state value is considered. This deterministic shock is only allowed to be temporary (duration of the shock is one year), and the model eventually comes back to the steady state. The shock process is to study the impact of a change in regime, as the home economy falls into recession.

In order to analyze the business cycle statistics, stochastic shocks to aggregate productivities are introduced. The positive shocks hit unexpectedly. For this, I use a bivariate autoregressive process for percent deviations of home and foreign aggregate productivities from their steady state. The symmetric and exogenous process can be expressed as follows (in log-linearized form):

$$\begin{bmatrix} \tilde{z}_t \\ \tilde{z}_t^* \end{bmatrix} = \begin{bmatrix} \rho & \rho_{HF} \\ \rho_{FH} & \rho^* \end{bmatrix} \begin{bmatrix} \tilde{z_{t-1}} \\ \tilde{z_{t-1}^*} \end{bmatrix} + \begin{bmatrix} \varepsilon_t \\ \varepsilon_t^* \end{bmatrix} \textit{with} \begin{bmatrix} \varepsilon_t \\ \varepsilon_t^* \end{bmatrix} \sim N\left(\begin{bmatrix} 0 \\ 0 \end{bmatrix}, \begin{bmatrix} \sigma_\varepsilon^2 & \sigma_{\varepsilon\varepsilon^*} \\ \sigma_{\varepsilon\varepsilon^*} & \sigma_{\varepsilon_*}^2 \end{bmatrix} \right)$$

As in Backus et al. (1994), the persistence of the aggregate productivity shock (ρ, ρ^*) is set to 0.906. The spillover parameter ρ_{HF}, ρ_{FH} is set to 0.088. The standard deviation of the productivity innovations is 0.00852 and the correlation between productivity innovations is 0.258.

Under permanent productivity shocks, the model reaches a new steady state and shocks are entirely expected. To study the effects of permanent productivity shocks hitting the economy today, the initial and ending values are set so as to calculate the transition path of each key variable. Since the results of the deterministic and permanent productivity shocks are similar to the one from stochastic productivity shocks, the resulting impulse response functions are only illustrated in the Appendix.

4.2.2 Trade Shocks

In an open macroeconomic model, one important variable is the real interest rate chosen by the monetary authority (e.g. central bank). The typical interest rate is generated by the Taylor rule in a reaction function with consumer price index (CPI) inflation and output growth deviation from the steady-state values to formalize the monetary policy rule:

$$1 + i_t = i^{1-\rho_i}(1 + i_{t-1})^{\rho_i} E_t \left(\frac{\pi_{t+1}}{\pi}\right)^{(1-\rho_i)\eta_\pi} \left(\frac{Y_{t+1}}{Y}\right)^{(1-\rho_i)\eta_y}.$$

Motivated by this Taylor rule interest rate setting, goverments can determine their trade policy rule in response to economic recession of their trading partner. Following closely with

Larch & Lechthaler (2011), a simple trade restriction setting rule is generated as follow:

$$1 + \tau_t = (1 + \tau)\frac{Z^*}{Z_t^*} \tag{29}$$

and

$$1 + f_{E,t} = (1 + f_E)\frac{Z^*}{Z_t^*} \tag{30}$$

This trade shock process shows that as trade costs or entry costs decrease by 1 percent, aggregate productivity increases by 1 percent, and vice versa.

4.3 Macroeconomic Dynamics

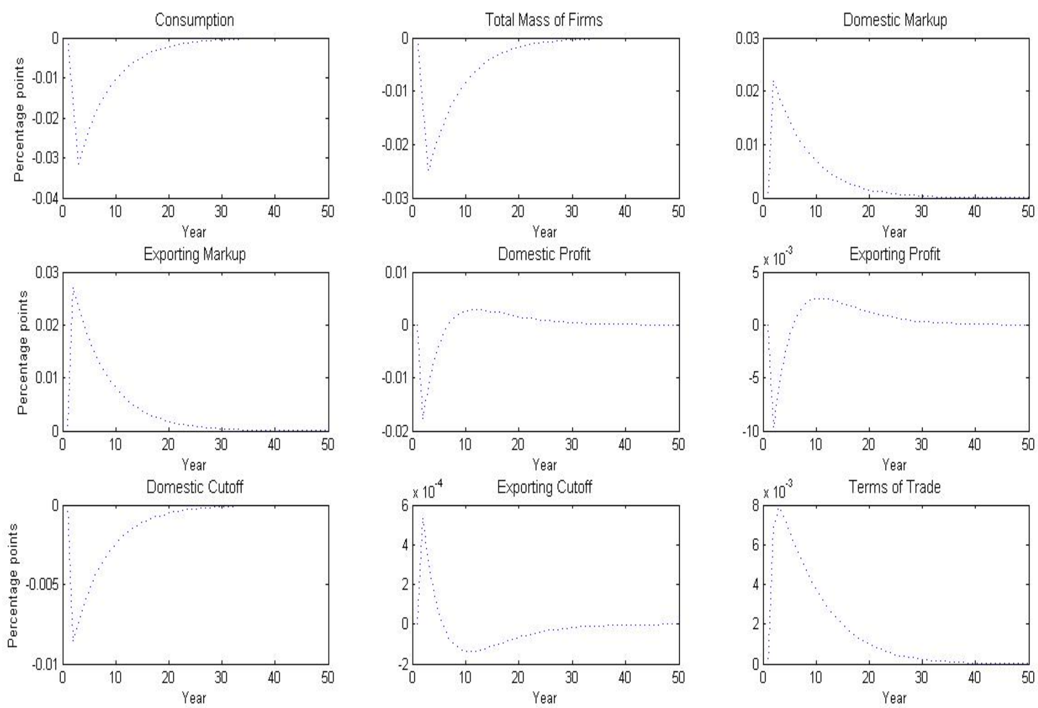
In this subsection, the dynamics of a recession and trade restrictions are thoroughly analyzed. First, I begin by analyzing the follow-up to a recession in the home country. After that, the subsequent introduction of trade restrictions in the foreign economy is investigated. The trade restrictions are imposed by the foreign economy to protect its domestic industries from the spillover of the home country's economic downturn through the interconnection of trade.

4.3.1 Economic Slump

The first case is that of an economic downturn in the home economy. The economy starts from the stationary steady-state and a 1 percent exogenous, asymmetric, temporary, and negative productivity shock hits the home economy. The dynamic responses of the main variables to this shock are illustrated in Figure 4 (home) and Figure 5 (foreign). The duration of the shock is one year and the horizontal axis is the number of years after shock. The negative shock leads to a depression in the home economy. Not surprisingly, the economic slowdown in the home economy is followed by a decrease in consumption ($C \downarrow$) and output ($GDP \downarrow$) due to the drop in the aggregate productivity. For all producers in the home economy, the cost of units of labor is higher than before ($\frac{W}{Z} \uparrow$) as aggregate productivity falls

($Z \downarrow$). The economic slump also matters to the number of producers. Now, the home market is relatively less competitive than before and the number of newly created firms has decreased ($N_E \downarrow$). This leads the total number of producers to fall as well ($N \downarrow$) in the home economy. As previously described, firms' markups are the avenue of 'toughness' of competition and more competitive firms lower their markups in the micro firm-level dynamics. The resulting macroeconomic dynamics show that producers' variable markups have substantial effect on aggregate fluctuations. Since the home market is less competitive than before, markups for home producers in domestic and exporting markets increase ($\tilde{mu}_D \uparrow$, $\tilde{mu}_X \uparrow$) during a recession. Note that the average profits of domestic and export production both go down as a consequence of the economic slump ($\tilde{d}_D \downarrow$, $\tilde{d}_X \downarrow$).

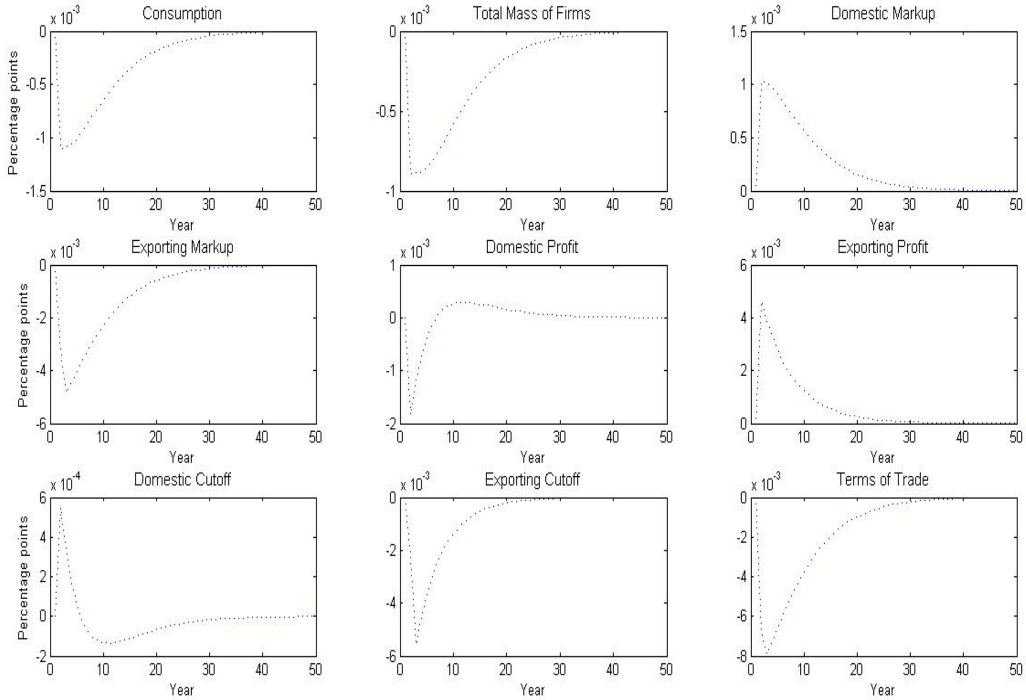
Figure 4: Economic Slump at Home: the Home Economy



The recession in the home country has an aftereffect on the foreign country through the interconnectedness of the trade between two countries. Consumption ($C^* \downarrow$) and output ($GDP^* \downarrow$) also decline in the foreign economy, although the magnitude of movement is much smaller than in the home economy. Because of the economic downturn in the home economy, fewer home producers export to the foreign country ($N_X \downarrow$) and this causes the total number of producers to fall ($N^* \downarrow$) as well in the foreign economy because $N^* = N_D^* + N_X$. Interestingly, due to the fact that the home market is less competitive, foreign producers exporting to the home economy become relatively more competitive and decrease their markups ($\tilde{mu}_X^* \downarrow$). Consequently, the average profit of foreign exporting firms increases during the shock ($\tilde{d}_X^* \uparrow$). The increase in exporting profit in the foreign country makes them relatively more productive than home exporting firms as their cut-off productivity decreases ($\tilde{a}_X^* \downarrow$). It means that relatively less productive foreign firms are able to export to the home economy since all exporters with their productivities above the cut-off productivity consider it worthwhile to export. In contrast, demand for varieties in the home economy decreases, exporting becomes harder for the home exporting firms, and consequently their cut-off productivity increases ($\tilde{a}_X \uparrow$). Due to recession, only relatively more productive home exporters consider it beneficial to continue exporting. With higher cut-off productivity, there are less home exporters and each exporter sell less.

Finally, the international relative prices depreciate ($RER, TOT \uparrow$) in the home economy and appreciate in the foreign ($RER^*, TOT^* \downarrow$) economy. As an indicator of competitiveness in the trade balance of a country, the terms of trade is defined as the ratio of the price of imports to the price of exports ($TOT = \frac{P_{IMP}}{P_{EXP}}$). The real exchange rate is defined as the ratio of the price indexes of the final goods between two countries ($RER = \varsigma \frac{P^*}{P}$). During a recession of the home economy, the price of home exports become cheaper and the terms of trade and real exchange rate depreciates. At the same time, it is relatively expensive to import goods for the home economy. The dynamic responses clearly show the depreciation of the terms of trade (Figure 4). I find that the terms of trade depreciation in the home economy occurs through the strong influence of the relative cut-off exporting productivity of both countries. In the benchmark model, the terms of trade can be written as $TOT = \frac{\tilde{a}_X}{\tilde{a}_X^*} \frac{\frac{W^*}{Z^*}}{\frac{W}{Z}}$. The first fraction is the relative cut-off productivity across countries ($\frac{\tilde{a}_X}{\tilde{a}_X^*}$) and the

Figure 5: Economic Slump at Home: the Foreign Economy



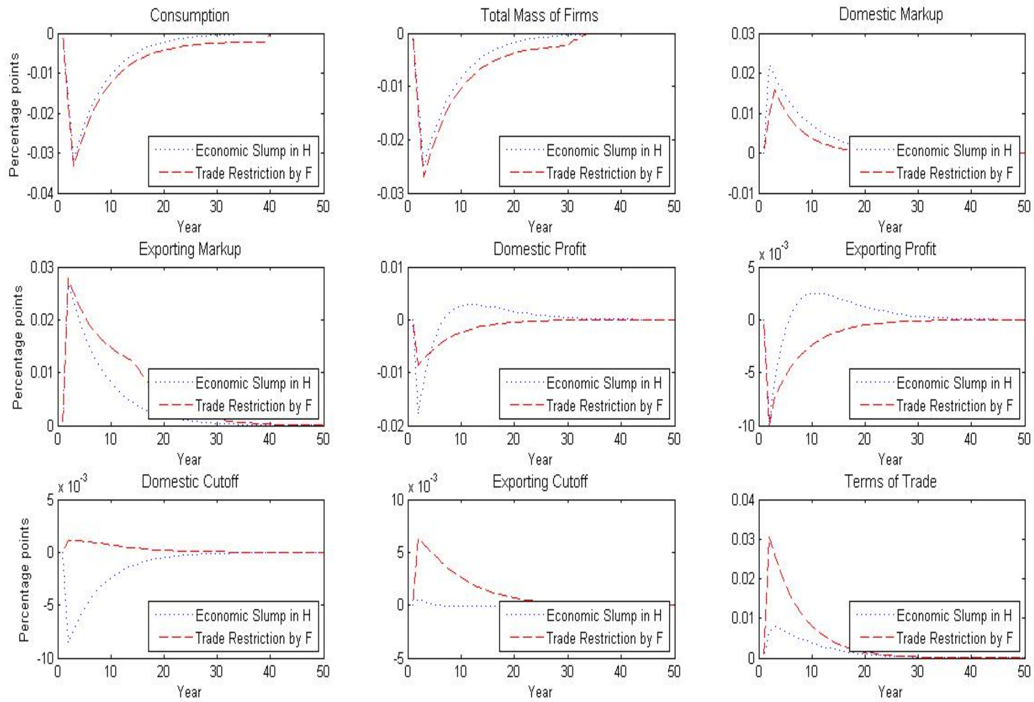
second fraction is the relative cost of units of labor $(\frac{\frac{W^*}{Z^*}}{\frac{W}{Z}})$. As previously found in the dynamics of the recession, home exporting firms' average individual specific productivity cut-off increases ($\tilde{a}_X \uparrow$), while foreign exporting firms' average productivity cut-off decreases ($\tilde{a}^*_X \downarrow$). Therefore, relative cut-off productivity increases. The relative cost of units of labor decrease as $\frac{W}{Z}$ increases. However, the effect of the relative cut-off productivity is stronger than the effect of the relative cost of labor, and so the international relative prices leads to depreciation with an economic slump in the home economy. In analyzing the outcome of the recession, an important point to note is that through international trade between two countries, the foreign country also suffers as a result of the economic slowdown in the home country, even though the effect is smaller than that felt in the home economy.

4.3.2 Trade Restrictions

In this subsection, I analyze the consequence of trade restrictions in the case where the foreign country raises its import restrictions in order to protect its domestic industries. As previously found, the exporting firms gain, but the average profit of the domestic production decreases in the foreign economy. Therefore the foreign country implements this trade policy to shield its domestic producers who get hurt mostly from the economic slowdown in the home economy. The result dynamics are illustrated in Figure 6 (home) and Figure 7 (foreign). The blue dotted line represents the case of the economic slump in the home economy and the red dashed line represents the case of the trade restrictions imposed by the foreign economy. The trade cost or entry cost of home exporting firms to the foreign economy only increase due to this change in trade policy. Since the home economy does not raise its trade restriction, the trade cost or entry cost for foreign exporting firms to the home economy does not change. Also, I assume that this trade restriction does not have any direct effect on foreign government revenue. Therefore, an increase in trade cost can be understood as any type of temporary non-tariff trade barriers (NTTBs) such as a voluntary export restraint (VER), 'Buy national' policy, safeguards, exchange controls, and countervailing duties. The NTTBs also are a close reality because many governments in the world had pursued protectionist measures in the form of NTTBs after the global economic crisis of 2008 and 2009.

Surprisingly, the increase in trade restrictions in the foreign economy is followed by a further decrease in consumption ($C, C^* \downarrow$) and income ($GDP, GDP^* \downarrow$) in both countries. As shown in the dynamic responses, consumption in the foreign economy dropped sharply while consumption in the home economy declined slightly. This change in policy harms both home and foreign consumers because of the increase in prices in the foreign country. Due to the trade limitation on home exports, the number of home exporting firms and their average profits further decrease ($N_X \downarrow$, $\tilde{d}_X \downarrow$). This clearly shows through the further increase in the cut-off productivity of home exporting firms ($\tilde{a}_X \uparrow$) since exporting become difficult for them due to the trade barrier. In the foreign country, the trade limiting-measures

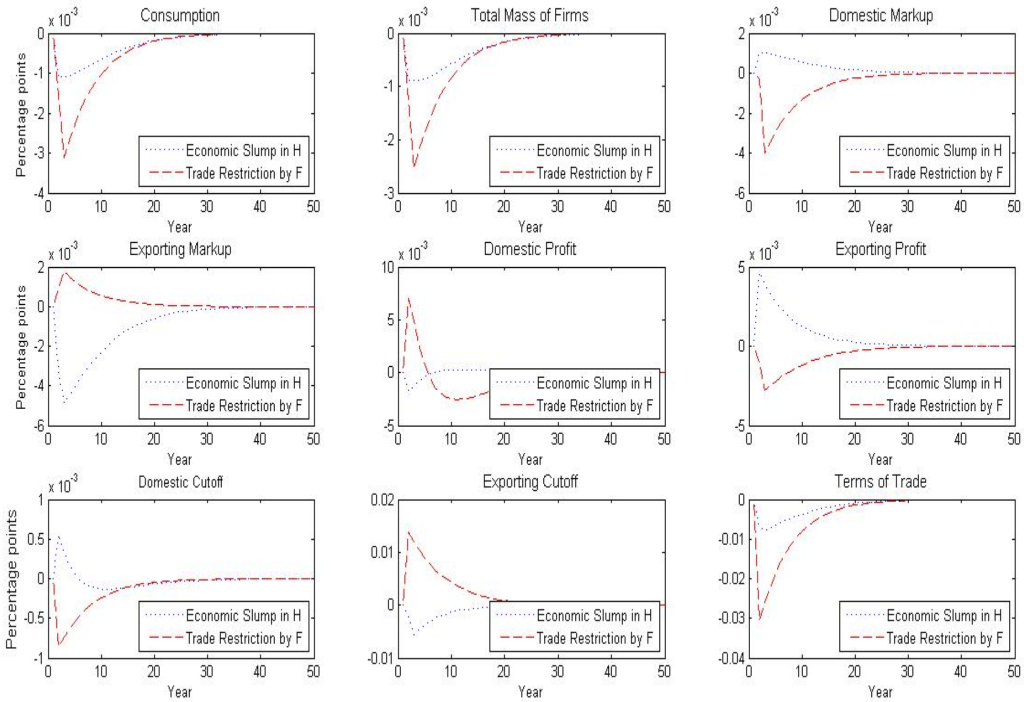
Figure 6: Trade Restrictions by Foreign: Home Economy



lead to diverse results for domestically selling firms and exporting firms. Since domestic industries are shielded from cheap imports, they become competitive and markups actually decrease ($\tilde{mu}_D^* \downarrow$). Consequently, domestic profits increase ($\tilde{d}_D^* \uparrow$). However, markups for the exporting industry go up ($\tilde{mu}_X^* \uparrow$) and this lead to a sharp decline in export profits ($\tilde{d}_X^* \downarrow$) along with an increase in the cut-off productivity ($\tilde{a}_X^* \uparrow$). Even though domestically selling producers generate positive profits, the strong decrease in the profits of the export-industry and losses to consumers dominate the profits of domestic industries and lead to a further decline in output of the country.

In the home country, demand for varieties further diminishes and exporting producers raise their markup ($\tilde{mu}_X \uparrow$) more than before. This leads to a further decrease in exporting profits ($\tilde{d}_X \downarrow$). This pushes their price level lower than before ($P \downarrow$) and its export price further declines ($P_{EXP} \downarrow$). It becomes relatively more expensive to import goods for the home country. This makes the real exchange rate and the terms of trade in home economy

Figure 7: Trade Restrictions by Foreign: Foreign Economy



depreciate more ($RER, TOT \uparrow$) with implementation of trade restrictions of the foreign economy. The markup for producers selling in the domestic market increases ($\tilde{mu}_D \uparrow$) and their average profits still decrease ($\tilde{d}_X \downarrow$), but with less magnitude than the original economic slump.

In the foreign country, lower GDP and consumption, further appreciation of the international relative prices, a sharp decrease in average export profits, and increasing an average markup for exporting industries all counteract the reduced markup and increased average profits of domestically selling firms. These effects clearly show that trade restrictions not only hurt the trading partner, but also the country imposing them damaging its market competitiveness even though its domestic industries are protected from lower prices of imports. In summary, foreign country impose trade restrictions to protect its domestic industries that got hurt mostly from the recession of its trading partner. The policy benefits domestically producing and selling producers, but harms consumers and exporting producers in the economy. The losses to the trade restrictions far outweigh the gains, and analyzed economy ending up worse off than they would have been otherwise during the economic downturn of the home economy.

4.4 International Real Business Cycle Moments

To further evaluate the properties of the simulated model, business cycle statistics of the simulated model are computed with a stochastic shock to the aggregate productivity in the home economy. I augment the benchmark model (as in section 3) with elastic labor. Here unconditional second moments are presented using the benchmark model and comparing this to what is observed in the economic data for the US and European countries (See section 2). I use the model to confront the observations on business cycle statistics. The Hodrick and Prescott (HP)[20] filter is applied to compute the model statistics by logging and filtering the models artificial time series. The data for the correlation between relative consumption and the terms of trade is taken from Corsetti et al. (2008) and the source of the data for the net exports is Backus et al. (1992). Table 4 summarizes the main statistics of the simulated model under the benchmark parameters at the business cycle frequency. The impulse response functions are illustrated in Appendix. I study the model's implications for (a) the standard deviations of a variable relative to that of the log of output, (b) the correlation between a variable and the log of output as a domestic co-movement, (c) the international correlations between home variables and foreign variables, and (d) the correlation between relative consumption and the terms of trade as an other correlation. I compare the benchmark model with data, the simulated model of the CES technology of the final goods (Moon (2012)), the financial autarky asset market, and the case of the inelastic labor in incomplete market. The detailed descriptions of the model with CES technology of final goods and financial autarky appear in section 5.

In the results of the benchmark model, although the volatility of the terms of trade in the

[20]The HP filter removes the cyclical component of a time series and is commonly used for macroeconomic data.

Table 4: Business Cycle Statistics: Baseline Parameters

	Data	CES	Inelastic Labor	Benchmark	
		IM	IM	IM	FA
Volatility					
% S.D. relative to GDP					
GDP	1	1	1	1	1
Consumption (C)	0.72	0.52	0.41	0.32	1
Employment (L)	0.58	0.58	_	0.18	0.25
Investment (X)	3.87	2.99	_	_	_
Net Export (NX/Y)	0.45 (BKK)	_	0.43	0.58	_
Terms of Trade (TOT)	1.44	0.32	0.38	0.38	0.08
Entry (N_E)	_	1.69	4.39	4.40	3.72
Domestic Comovement					
Correlations with GDP					
Consumption (C)	0.86	0.70	0.42	0.22	1
Employment (L)	0.79	0.61	_	0.68	0.68
Net Export (NX/Y)	-0.47 (BKK)	_	0.73	0.64	_
Terms of Trade (TOT)	-0.25	-0.53	-0.46	-0.48	0.58
Entry (N_E)	_	0.51	0.52	0.52	0.49
Mark-up ($\tilde{MU}$)	_	_	-0.90	-0.91	-0.89
Average Profits ($\tilde{d}$)	_	_	0.53	0.53	0.47
International Correlations					
GDP, GDP^*	0.55	-0.87	-0.23	-0.21	0.10
C, C^*	0.42	0.21	0.06	0.06	0.10
X, X^*	0.39	-0.89	_	_	_
L, L^*	0.28	-0.23	_	-0.91	0.65
N_E, N_E^*	_	-0.84	-0.92	-0.92	-0.81
Other Correlation					
Consumption ratio, TOT	-0.35 (CDL)	-0.93	-0.37	-0.39	0.18

model (0.38) is much less than the data (1.44), the patterns of aggregate volatilities observed in the model are similar to those in the actual data. Entry is the most volatile (4.40) among the six key variables. In the IRBC model without physical capital accumulation, entry provides a similar framework as investment because it is defined as new firm construction with a one period 'time to build' lag[21]. That is why the volatility of entry is the highest in the benchmark model where capital is omitted. In the model of CES technology with

[21]In the literature, physical capital accumulation evolves according to $K_{t+1} = X_t + (1 - \delta_k)K_t$ of one period time lag driven by depreciation, where K_t is the capital stock and X_t is the investment in capital accumulation.

capital stock, investment is the most volatile (2.99), and entry is the second most (1.69). As in the data, consumption (0.32), employment (0.18), and net exports (0.58) are less volatile than GDP. Regarding domestic co-movement, the key aggregate variables correctly predict cyclicity with GDP, except net exports. Consumption (0.22), employment (0.68), entry (0.52), and average profits (0.53) are positively correlated and terms of trade (-0.48) and average markup (-0.91) are negatively correlated. Pro-cyclical average profits and counter-cyclical markups are in line with empirical findings of Bilbiie et al. (2008). However, the benchmark model is not able to generate counter-cyclical net exports in the data.

International correlations of GDP (-0.21), labor (-0.91), and entry (-0.92) are negative in the benchmark model, due to the fact that production and the entry of firms transfer to more productive locations (international production shifting). These results share the failure of the standard IRBC models and adding entry and exit dynamics along with firm selection to the benchmark model does not help. The model also fails to predict the higher cross-country GDP correlations than consumption correlations (what Backus et al. (1992) call 'quantity anomaly') in the data. In the model, consumption is more closely correlated (0.06) across countries than GDP (-0.21). Note that the gap between the two cross correlations is smaller than what is found using the model with CES technology (-0.87 for GDP cross correlation, 0.21 for consumption cross correlation).

The model's prediction regarding co-movement between relative consumption and the terms of trade has novel. They are negatively correlated (-0.39) in the benchmark model just as in the data, solving the Backus-Smith puzzle (Backus & Smith (1993)). The Backus-Smith puzzle is an anomaly in which conventional IRBC models predict that the terms of trade is positively correlated with the relative consumption across countries, but they are negatively correlated in the data. Following a productivity shock in the home economy, GDP and consumption go up in the home country. Consumption also goes up in the foreign economy, but less so than in the home economy, so it results in an increase in relative consumption ($\frac{C}{C^*}$).

This is due to an incomplete financial market[22] that allows international risk sharing between home and foreign countries. Trading bonds internationally allows households dampen their demands for goods (wealth effect) as home exports become more expensive and the terms of trade appreciate.

5 Robustness Analysis

To understand the robustness of the main results under different assumptions, two additional cases are compared. In the first case, the final goods are aggregated using CES technology. In the second case, the model with financial autarky and endogeneous labor is considered. Table 4 reports the business cycle statistics of simulated models for these two cases.

5.1 Exogenous Markup (CES preference)

Based on the model of Bergin & Glick (2007) and Ghironi & Melitz (2005), Moon (2012) studies international relative prices and endogenous tradability, incorporating endogeneous labor and capital along the IRBC setting. The technology of the final goods is that combines home and foreign produced intermediate goods as in Armington (1969):

$$F_t = \left[\left\{ \int_{a \in \Lambda_{D,t}} f_{D,t}(a)^{\frac{\theta-1}{\theta}} da \right\}^{\frac{\theta}{\theta-1}\frac{\gamma-1}{\gamma}} + \left\{ \int_{a \in \Lambda^*_{X,t}} f^*_{X,t}(a)^{\frac{\theta-1}{\theta}} da \right\}^{\frac{\theta}{\theta-1}\frac{\gamma-1}{\gamma}} \right]^{\frac{\gamma}{\gamma-1}} \tag{31}$$

where γ is the elasticity of substitution between domestic and foreign varieties of intermediate goods, and θ is the elasticity of substitution among domestic varieties. Dixit & Stiglitz (1977) refer to θ as a 'love of variety' parameter in which, when more varieties are available, more goods are produced, and more consumers are satisfied.

[22] See Letendre (2000), Baxter & Crucini (1995), and Arvanitis & Mikkola (1996).

5.2 Financial Autarky

Endogenizing labor, the utility function of the representative household is characterized by:

$$E_0 \sum_{t=0}^{\infty} \beta^t \left[\frac{\{C_t^{\eta}(1-L_t)^{1-\eta}\}^{1-\psi}}{1-\psi} \right]$$

where C_t denotes consumption, and L_t represents hours worked. Here, the parameter β is the intertemporal discount factor, η is the consumption weight in utility, and ψ is the coefficient of relative risk aversion. In the case of the financial autarky, the budget constraint is as follows:

$$P_t C_t + P_t B_{t+1} + \tilde{v}_t (N_{A,t} + N_{E,t}) q_{t+1} = W_t L_t + (1+i_t) P_t B_t + N_{A,t}(\tilde{d}_t + \tilde{v}_t) q_t. \tag{32}$$

The Euler equation for bond holdings is

$$[C_t^{\eta}(1-L_t)^{1-\eta}]^{1-\psi} \frac{1}{C_t} = \beta(1+i_{t+1}) E_t \left[[C_{t+1}^{\eta}(1-L_{t+1})^{1-\eta}]^{1-\psi} \frac{1}{C_{t+1}} \right]. \tag{33}$$

The Euler equation for the shares in a mutual fund is

$$\tilde{v}_t = \beta(1-\delta) E_t \left[\left(\frac{P_t C_t}{P_{t+1} C_{t+1}} \right) \frac{[C_{t+1}^{\eta}(1-L_{t+1})^{1-\eta}]^{1-\psi}}{[C_t^{\eta}(1-L_t)^{1-\eta}]^{1-\psi}} (\tilde{d}_{t+1} + \tilde{v}_{t+1}) \right]. \tag{34}$$

The financial autarky model is closed by the bond market clearing condition $B_{t+1} = B_{t+1}^* = 0$ and the value of shares in a mutual fund market clearing condition $q_{t+1} = q_{t+1}^* = 1$. Applying these market clearing conditions to the budget constraint implies the following aggregate accounting identity: $P_t C_t + \tilde{v}_t N_{E,t} = W_t L_t + \tilde{d}_t N_{A,t}$. This equation is explained as financial autarky of income equal to spending. Spending on consumption and investment of new firms is equal to labor and investment income. Finally, the financial autarky assumption requires a balanced trading equation in which the value of home exports is equal to the value of imports from the foreign country. The balanced trading equation using firm averages is written as follows:

$$P_t N_{X,t} \left(\frac{W_t \tau_t}{Z_t \tilde{a}_{X,t}} \right)^2 = P_t^* N_{X,t}^* \left(\frac{W_t^* \tau_t^*}{Z_t^* \tilde{a}_{X,t}^*} \right)^2 \tag{35}$$

The system of equations and its associated steady state system have 41 independent equations, 41 of which must be solved for: 21 home variables $(C_t, W_t, L_t, P_t, \tilde{d}_t, \tilde{v}_t, N_{A,t}, N_{D,t}, N_{X,t}, N_{E,t}, \tilde{p}_t, \tilde{p}_{D,t}, \tilde{p}_{X,t}, \tilde{mu}_{D,t}, \tilde{mu}_{X,t}, \tilde{a}_{D,t}, \tilde{a}_{X,t}, N_t, \tilde{d}_{D,t}, \tilde{d}_{X,t}, i_t)$, 20 foreign variables $(C_t^*, W_t^*, L_t^*, \tilde{d}_t^*, \tilde{v}_t^*, N_{A,t}^*, N_{D,t}^*, N_{X,t}^*, N_{E,t}^*, \tilde{p}_{D,t}^*, \tilde{p}_{X,t}^*, \tilde{mu}_{D,t}^*, \tilde{mu}_{X,t}^*, \tilde{a}_{D,t}^*, \tilde{a}_{X,t}^*, N_t^*, \tilde{d}_{D,t}^*, \tilde{d}_{X,t}^*, i_t^*, \tilde{p}_t^*)$, and I chose foreign welfare-based price, P_t^* as the numeraire. It has 6 exogenous policy variables: $Z_t, Z_t^*, f_{E,t}, f_{E,t}^*, \tau_t, \tau_t^*$. The full summary of 41 system of equations and its log-linearized model are available upon request.

6 Concluding Remarks

This paper explores the aggregate effects of an economic slump and trade restrictions as a short-run response along international real business cycles. During the crisis of 2008 and 2009, world output, exports, and imports all collapsed tremendously. As a response to the global crisis, international trade-limiting measures emerged in several countries. In order to capture the recession and the change in trade policy along the IRBC, I proposed a DSGE model with firm entry and exit dynamics, non-homothetic preferences of the final goods technology with product differentiation, and heterogeneity in firm productivity. The variable adjustment of markups was generated from the non-homothetic, non-constant elasticity of substitution production function of the final goods. By analyzing the dynamics of an economic slump in the home economy and then an increase in trade restrictions in the foreign economy as part of a policy to protect itself from the diffusion of recession, I showed that both economies are in a worse position than during the economic downturn. The follow-ups to the recession and trade restrictions were analyzed through the variable markups, firms' individual specific productivity cut-off, and the movement of international relative prices such as real exchange rate and terms of trade. The foreign country suffered from the economic downturn of its trading partner and imposed trade restrictions on import goods from the home economy. There were winners and losers from the implementation of the import restrictions, but the losses far outweighed the gains, and both analyzed economies ended up worse off than they would have been in the absence of trade restrictions.

The simulated model replicated several U.S. business cycle statistics and emphasized the fact that the endogenous entry of heterogeneous firms with various adjustment of markup may have important effects for the interpretation of the international transmission of business cycles. The benchmark model can be extended in a number of ways. Possible extension will be to empirically estimate the responses of aggregate fluctuations on the trade restrictions. Another future work will be to augment the model with a banking sector, analyzing the effect of banking deregulation and to explore the ability of the model using quasilinear non-constant elasticity of substitution production functions and heterogeneous producers.

References

Alessandria, G. & Choi, H. (2007). Do sunk costs of exporting matter for net export dynamics? *The Quarterly Journal of Economics*, *122*(1), 289–336.

Alessandria, G. & Choi, H. (2011). Establishment heterogeneity, exporter dynamics, and the effects of trade liberalization. Working Papers 11-19, Federal Reserve Bank of Philadelphia.

Amiti, M. & Weinstein, D. E. (2009). Exports and financial shocks. NBER Working Papers 15556, National Bureau of Economic Research, Inc.

Antras, P. & Caballero, R. J. (2010). On the role of financial frictions and the saving rate during trade liberalizations. *Journal of the European Economic Association*, *8*, 442–455.

Armington, P. S. (1969). A theory of demand for products distinguished by place of production. *IMF Staff Papers*, *16*(1), 159–178.

Arvanitis, A. V. & Mikkola, A. (1996). Asset-market structure and international trade dynamics. *American Economic Review*, *86*(2), 67–70.

Aw, B. Y., Chung, S., & Roberts, M. J. (2000). Productivity and turnover in the export market: Micro-level evidence from the republic of korea and taiwan (china). *World Bank Economic Review*, *14*(1), 65–90.

Backus, D. K., Kehoe, P. J., & Kydland, F. E. (1992). International real business cycles. *Journal of Political Economy*, *100*(4), 745–75.

Backus, D. K., Kehoe, P. J., & Kydland, F. E. (1994). Dynamics of the trade balance and the terms of trade: The j-curve? *American Economic Review*, *84*(1), 84–103.

Backus, D. K. & Smith, G. W. (1993). Consumption and real exchange rates in dynamic economies with non-traded goods. *Journal of International Economics*, *35*(3-4), 297–316.

Baxter, M. & Crucini, M. J. (1995). Business cycles and the asset structure of foreign trade. *International Economic Review*, *36*, 821–54.

Bergin, P. R. & Corsetti, G. (2008). The extensive margin and monetary policy. *Journal of Monetary Economics*, *55*(7), 1222–1237.

Bergin, P. R. & Glick, R. (2007). Tradability, productivity, and international economic integration. *Journal of International Economics*, *73*(1), 128–151.

Bernard, A. B. & Bradford Jensen, J. (1999). Exceptional exporter performance: cause, effect, or both? *Journal of International Economics*, *47*(1), 1–25.

Bernard, A. B., Eaton, J., Jensen, J. B., & Kortum, S. (2003). Plants and productivity in international trade. *American Economic Review*, *93*(4), 1268–1290.

Bernard, A. B., Jensen, J. B., & Schott, P. K. (2006). Trade costs, firms and productivity. *Journal of Monetary Economics*, *53*(5), 917–937.

Bilbiie, F. O., Ghironi, F., & Melitz, M. J. (2008). Monetary policy and business cycles with endogenous entry and product variety. In *NBER Macroeconomics Annual 2007, Volume 22*, NBER Chapters (pp. 299–353). National Bureau of Economic Research, Inc.

Blanchard, O. (2009). The state of macro. *Annual Review of Economics*, *1*(1), 209–228.

Boileau, M. & Normandin, M. (2008). Closing international real business cycle models with restricted financial markets. *Journal of International Money and Finance*, *27*(5), 733–756.

Bown, C. P. & Crowley, M. A. (2013). Emerging economies, trade policy, and macroeconomic shocks. FRB of Chicago Working Paper No. 2012-18.

Bussire, M., Callegari, G., Ghironi, F., Sestieri, G., & Yamano, N. (2011). Estimating trade elasticities: Demand composition and the trade collapse of 2008-09. NBER Working Papers 17712, National Bureau of Economic Research, Inc.

Caballero, R. J. & Hammour, M. L. (1994). The cleansing effect of recessions. *American Economic Review*, *84*(5), 1350–68.

Campbell, J. R. & Hopenhayn, H. A. (2005). Market size matters. *Journal of Industrial Economics*, *53*(1), 1–25.

Chaney, T. (2008). Distorted gravity: The intensive and extensive margins of international trade. *American Economic Review*, *98*(4), 1707–21.

Chen, P. (2010). *Trade Volatility and Intermediate Goods*. PhD thesis, University of Minnesota.

Corsetti, G., Dedola, L., & Leduc, S. (2008). International risk sharing and the transmission of productivity shocks. *Review of Economic Studies*, *75*(2), 443–473.

Davis, S. & Huang, K. X. (2010). International real business cycles with endogenous markup variability. Globalization and Monetary Policy Institute Working Paper 60, Federal Reserve Bank of Dallas.

Dixit, A. K. & Stiglitz, J. E. (1977). Monopolistic competition and optimum product diversity. *American Economic Review*, *67*(3), 297–308.

Engel, C. & Wang, J. (2011). International trade in durable goods: Understanding volatility, cyclicality, and elasticities. *Journal of International Economics*, *83*(1), 37–52.

Evenett, S. J. (2009). *The collapse of global trade, murky protectionism, and the crisis: Recommendations for the G20*, chapter Crisis-era protectionism one year after the Washington G20 meeting. A VoxEU.org Publication.

Evenett, S. J. (2010). Tensions contained... for now: The 8th gta report, centre for economic policy research.

Foellmi, R., Hepenstrick, C., & Zweimller, J. (2011). Non-homothetic preferences, parallel imports and the extensive margin of international trade. Economics Working Paper Series 1122, University of St. Gallen, School of Economics and Political Science.

Gawande, K., Hoekman, B., & Cui, Y. (2011). Determinants of trade policy responses to the 2008 financial crisis. Technical report, World Bank Policy Research Working Paper Series.

Ghironi, F. & Melitz, M. J. (2005). International trade and macroeconomic dynamics with heterogeneous firms. *The Quarterly Journal of Economics*, *120*(3), 865–915.

Goksel, T. (2009). *Income, Trade Barriers, and International Trade*. PhD thesis, University of Minnesota.

Heathcote, J. & Perri, F. (2002). Financial autarky and international business cycles. *Journal of Monetary Economics*, *49*(3), 601–627.

Hodrick, R. J. & Prescott, E. C. (1997). Postwar u.s. business cycles: An empirical investigation. *Journal of Money, Credit and Banking*, *29*(1), 1–16.

Juillard, M. (2001). Dynare: A program for the simulation of rational expectation models. Computing in Economics and Finance 2001 213, Society for Computational Economics.

Kee, H. L., Neagu, C., & Nicita, A. (2010). Is protectionism on the rise ? assessing national trade policies during the crisis of 2008. Policy Research Working Paper Series 5274, The World Bank.

Kehoe, P. J. & Perri, F. (2002). International business cycles with endogenous incomplete markets. *Econometrica*, *70*(3), 907–928.

King, R. G., Plosser, C. I., & Rebelo, S. T. (2002). Production, growth and business cycles: Technical appendix. *Computational Economics*, *20*(1-2), 87–116.

King, R. G. & Rebelo, S. T. (1999). Resuscitating real business cycles. In J. B. Taylor & M. Woodford (Eds.), *Handbook of Macroeconomics*, volume 1 of *Handbook of Macroeconomics* chapter 14, (pp. 927–1007). Elsevier.

Larch, M. & Lechthaler, W. (2011). Why 'buy american' is a bad idea but politicians still like it. *Canadian Journal of Economics*, *44*(3), 838–858.

Letendre, M.-A. (2000). Linear approximation methods and international real business cycles with incomplete asset markets. Econometric Society World Congress 2000 Contributed Papers 1539, Econometric Society.

Markusen, J. R. (2010). Putting per-capita income back into trade theory. Working Paper 15903, National Bureau of Economic Research.

Melitz, M. (2007). *The Dynamics of Firm-Level Adjustment to Trade Liberalization*. Cambridge: Harvard University Press.

Melitz, M. J. (2003). The impact of trade on intra-industry reallocations and aggregate industry productivity. *Econometrica*, *71*(6), 1695–1725.

Melitz, M. J. & Ottaviano, G. I. P. (2008). Market size, trade, and productivity. *Review of Economic Studies*, *75*(1), 295–316.

Moon, S. (2012). *Endogenous Tradability, International Relative Prices, and the International Transmission of Business Cycles*. PhD thesis, University of Colorado at Boulder.

Obstfeld, M. & Rogoff, K. (2000). The six major puzzles in international macroeconomics: Is there a common cause? Technical Report 176, Center for International and Development Economics Research, Institute for Business and Economic Research, UC Berkeley.

Ottaviano, G., Tabuchi, T., & Thisse, J.-F. (2002). Agglomeration and trade revisited. *International Economic Review*, *43*(2), 409–436.

Ottaviano, G. I. P. (2011). Firm heterogeneity, endogenous entry, and the business cycle. In *NBER International Seminar on Macroeconomics 2011*, NBER Chapters. National Bureau of Economic Research, Inc.

Pavcnik, N. (2002). Trade liberalization, exit, and productivity improvement: Evidence from chilean plants. *Review of Economic Studies*, *69*(1), 245–76.

Rodriguez-Lopez, J. A. (2011). Prices and exchange rates: A theory of disconnect. *Review of Economic Studies*, *78*(3), 1135–1177.

Sakane, M. (2011). Product variety, firm entry, and terms of trade dynamics. Tokyo Center for Economic Research Working Paper Series.

Simonovska, I. (2010). Income differences and prices of tradables. NBER Working Papers 16233, National Bureau of Economic Research, Inc.

Stockman, A. C. & Tesar, L. L. (1995). Tastes and technology in a two-country model of the business cycle: Explaining international comovements. *American Economic Review*, *85*(1), 168–85.

Syverson, C. (2004). Product substitutability and productivity dispersion. *The Review of Economics and Statistics*, *86*(2), 534–550.

Uhlig, H. (1995). A toolkit for analyzing nonlinear dynamic stochastic models easily. Discussion Paper / Institute for Empirical Macroeconomics 101, Federal Reserve Bank of Minneapolis.

Yi, K.-M. (2009). *The collapse of global trade, murky protectionism, and the crisis: Recommendations for the G20*, chapter The Role of Vertical Specialization. A VoxEU.org Publication.

Appendix

A Data Sources

Data for most countries are from the International Financial Statistics (IFS) provided by the International Monetary Fund (http://elibrary-data.inf.org/). U.S. quarterly data (1973Q1-2009Q4) for GDP, consumption, and investment are extracted and all variables have been logged and detrended using the Hodrick-Prescott filter (smoothing parameter of 1600). U.S. labor data is obtained from the Bureau of Labor Statistics (http://www.bls.gov/) and the OECD.StatExtracts (http://stat.oecd.org). To calculate the international correlations, U.S. data and Europe aggregates are compared. The quarterly data (1973Q1-2008Q3) for GDP, consumption, investment, and civilian employment are from IFS. European countries include Austria, Finland, France, Germany, Italy, Sweden, Switzerland, and the U.K. Investment includes gross fixed capital formation and changes in inventories. Labor input per capita is calculated as hours per worker multiplied by civilian employment and then devided by population age 16 and over. I follow the tradition of the international business cycle literature in defining the terms of trade as the relative price of imports to exports.

B The Set of Equations

B.1 Benchmark Model - Incomplete Asset Market

Here I list a summary of the system of 45 equilibrium equations of the model.

♦ Optimal conditions for Consumption

$$\lambda_t P_t = C_t^{-\eta} \tag{B.1}$$

$$\lambda_t^* = C_t^{*-\eta} \tag{B.2}$$

♦ Euler Equations (Bonds)

$$\lambda_t P_t (1 + nB_{H,t+1}) = \beta(1 + i_{t+1}) E_t \left\{ P_{t+1} \lambda_{t+1} \right\} \tag{B.3}$$

$$\lambda_t (1 + nB_{F,t+1}) = \beta(1 + i_{t+1}^*) E_t \left\{ \lambda_{t+1} \right\} \tag{B.4}$$

$$\lambda_t^* (1 + nB_{F,t+1}^*) = \beta(1 + i_{t+1}^*) E_t \left\{ \lambda_{t+1}^* \right\} \tag{B.5}$$

$$\lambda_t^* P_t (1 + nB_{H,t+1}) = \beta(1 + i_{t+1}) E_t \left\{ P_{t+1} \lambda_{t+1}^* \right\} \tag{B.6}$$

♦ Euler Equations (Shares)

$$\tilde{v}_t \lambda_t = \beta(1 - \delta_d) E_t \left\{ \lambda_{t+1} (\tilde{d}_{t+1} + \tilde{v}_{t+1}) \right\} \tag{B.7}$$

$$\tilde{v}_t^* \lambda_t^* = \beta(1 - \delta_d) E_t \left\{ \lambda_{t+1}^* (\tilde{d}_{t+1}^* + \tilde{v}_{t+1}^*) \right\} \tag{B.8}$$

♦ Free Entry Conditions

$$\tilde{v}_t = f_{E,t} \frac{W_t}{Z_t} \tag{B.9}$$

$$\tilde{v}_t^* = f_{E,t}^* \frac{W_t^*}{Z_t^*} \tag{B.10}$$

♦ Number of Firms and New Firm Creation

$$N_t = N_{D,t} + N_{X,t}^* \tag{B.11}$$

$$N_t^* = N_{D,t}^* + N_{X,t} \tag{B.12}$$

$$N_{A,t+1} = (1 - \delta_d) \left(N_{A.t} + N_{E,t} \right) \tag{B.13}$$

$$N_{A,t+1}^* = (1 - \delta_d) \left(N_{A.t}^* + N_{E,t}^* \right) \tag{B.14}$$

$$N_{D,t} = \left(1 - \Phi(a_{D,t}) \right) N_{A,t} \tag{B.15}$$

$$N_{X,t} = \left(1 - \Phi(a_{X,t}) \right) N_{A,t} \tag{B.16}$$

$$N_{D,t}^* = \left(1 - \Phi(a_{D,t}^*) \right) N_{A,t}^* \tag{B.17}$$

$$N_{X,t}^* = \left(1 - \Phi(a_{X,t}^*) \right) N_{A,t}^* \tag{B.18}$$

♦ Total Average Profits

$$\tilde{d}_t = \tilde{d}_{D,t} + \tilde{d}_{X,t} \tag{B.19}$$

$$\tilde{d}_t^* = \tilde{d}_{D,t}^* + \tilde{d}_{X,t}^* \tag{B.20}$$

♦ Average Profits from Domestic Sales

$$\tilde{d}_{D,t} = \left(\frac{1}{2\gamma P_t(\kappa+1)(\kappa+2)}\right)\left(\frac{a_{min}}{\tilde{a}_{D,t}}\right)^{\kappa}\left(\frac{W_t}{Z_t\tilde{a}_{D,t}}\right)^2 \tag{B.21}$$

$$\tilde{d}^*_{D,t} = \left(\frac{1}{2\gamma(\kappa+1)(\kappa+2)}\right)\left(\frac{a_{min}}{\tilde{a}^*_{D,t}}\right)^{\kappa}\left(\frac{W^*_t}{Z^*_t\tilde{a}^*_{D,t}}\right)^2 \tag{B.22}$$

♦ Average Profits from Foreign Sales

$$\tilde{d}_{X,t} = \left(\frac{1}{2\gamma(\kappa+1)(\kappa+2)}\right)\left(\frac{a_{min}}{\tilde{a}_{X,t}}\right)^{\kappa}\left(\frac{W_t\tau_t}{Z_t\tilde{a}_{X,t}}\right)^2. \tag{B.23}$$

$$\tilde{d}^*_{X,t} = \left(\frac{1}{2\gamma P_t(\kappa+1)(\kappa+2)}\right)\left(\frac{a_{min}}{\tilde{a}^*_{X,t}}\right)^{\kappa}\left(\frac{W^*_t\tau^*_t}{Z^*_t\tilde{a}^*_{X,t}}\right)^2 \tag{B.24}$$

♦ Price Bounds/Cost Threshold

$$\frac{W_t}{Z_t\tilde{a}_{D,t}} = \frac{\alpha\gamma P_t + \xi N_t\tilde{p}_t}{\gamma + \xi N_t} \tag{B.25}$$

$$\frac{W_t\tau_t}{Z_t\tilde{a}_{X,t}} = \frac{\alpha\gamma + \xi N^*_t\tilde{p}^*_t}{\gamma + \xi N^*_t} \tag{B.26}$$

$$\frac{W^*_t}{Z^*_t\tilde{a}^*_{D,t}} = \frac{\alpha\gamma + \xi N^*_t\tilde{p}^*_t}{\gamma + \xi N^*_t} \tag{B.27}$$

$$\frac{W^*_t\tau^*_t}{Z^*_t\tilde{a}^*_{X,t}} = \frac{\alpha\gamma P_t + \xi N_t\tilde{p}_t}{\gamma + \xi N_t} \tag{B.28}$$

♦ Average Relative Prices

$$\tilde{p}_{D,t} = \left(\frac{2\kappa+1}{2\kappa+2}\right)\left(\frac{W_t}{Z_t\tilde{a}_{D,t}}\right) \tag{B.29}$$

$$\tilde{p}_{X,t} = \left(\frac{2\kappa+1}{2\kappa+2}\right)\left(\frac{W_t\tau_t}{Z_t\tilde{a}_{X,t}}\right) \tag{B.30}$$

$$\tilde{p}^*_{D,t} = \left(\frac{2\kappa+1}{2\kappa+2}\right)\left(\frac{W^*_t}{Z^*_t\tilde{a}^*_{D,t}}\right) \tag{B.31}$$

$$\tilde{p}^*_{X,t} = \left(\frac{2\kappa+1}{2\kappa+2}\right)\left(\frac{W^*_t\tau^*_t}{Z^*_t\tilde{a}^*_{X,t}}\right) \tag{B.32}$$

$$N_t\tilde{p}_t = N_{D,t}\tilde{p}_{D,t} + N^*_{X,t}\tilde{p}^*_{X,t} \tag{B.33}$$

$$N^*_t\tilde{p}^*_t = N^*_{D,t}\tilde{p}^*_{D,t} + N_{X,t}\tilde{p}_{X,t} \tag{B.34}$$

⧫ Variable Markups

$$\tilde{mu}_{D,t} = \left(\frac{1}{2\kappa+2}\right)\left(\frac{W_t}{Z_t \tilde{a}_{D,t}}\right) \tag{B.35}$$

$$\tilde{mu}_{X,t} = \left(\frac{1}{2\kappa+2}\right)\left(\frac{W_t \tau_t}{Z_t \tilde{a}_{X,t}}\right) \tag{B.36}$$

$$\tilde{mu}^*_{D,t} = \left(\frac{1}{2\kappa+2}\right)\left(\frac{W^*_t}{Z^*_t \tilde{a}^*_{D,t}}\right) \tag{B.37}$$

$$\tilde{mu}^*_{X,t} = \left(\frac{1}{2\kappa+2}\right)\left(\frac{W^*_t \tau^*_t}{Z^*_t \tilde{a}^*_{X,t}}\right) \tag{B.38}$$

⧫ Bond Market Equilibrium

$$B_{H,t+1} + B^*_{H,t+1} = 0 \tag{B.39}$$

$$B^*_{F,t+1} + B_{F,t+1} = 0 \tag{B.40}$$

⧫ Labor Market Equilibrium

$$\begin{aligned} L = & \frac{\kappa}{2\gamma(\kappa+1)(\kappa+2)P_t W_t}\left(\frac{W_t}{\tilde{a}_{D,t} Z_t}\right)^2 N_{D,t} + \frac{\kappa}{2\gamma(\kappa+1)(\kappa+2)W_t}\left(\frac{W_t \tau_t}{\tilde{a}_{X,t} Z_t}\right)^2 N_{X,t} \\ & + \frac{N_{E,t} f_{E,t}}{Z_t} = 1 \end{aligned} \tag{B.41}$$

$$\begin{aligned} L^* = & \frac{\kappa}{2\gamma(\kappa+1)(\kappa+2)W^*_t}\left(\frac{W^*_t}{\tilde{a}^*_{D,t} Z^*_t}\right)^2 N^*_{D,t} + \frac{\kappa}{2\gamma(\kappa+1)(\kappa+2)P_t W^*_t}\left(\frac{W^*_t \tau_t}{\tilde{a}^*_{X,t} Z^*_t}\right)^2 N^*_{X,t} \\ & + \frac{N^*_{E,t} f^*_{E,t}}{Z^*_t} = 1 \end{aligned} \tag{B.42}$$

⧫ Final Goods Technology

$$\begin{aligned} F_t = & \left(\frac{\alpha N_t}{2\gamma(\kappa+1)P_t}\right)\left(\frac{W_t}{Z_t \tilde{a}_{D,t}}\right) - \left(\frac{N_t}{4\gamma(\kappa+1)(\kappa+2)P_t^2}\right)\left(\frac{W_t}{Z_t \tilde{a}_{D,t}}\right)^2 \\ & - \frac{\xi}{2}\left(\frac{N_t}{2\gamma(\kappa+1)P_t}\right)^2\left(\frac{W_t}{Z_t \tilde{a}_{D,t}}\right)^2 = C_t \end{aligned} \tag{B.43}$$

$$\begin{aligned} F^*_t = & \left(\frac{\alpha N^*_t}{2\gamma(\kappa+1)}\right)\left(\frac{W^*_t}{Z^*_t \tilde{a}^*_{D,t}}\right) - \left(\frac{N^*_t}{4\gamma(\kappa+1)(\kappa+2)}\right)\left(\frac{W^*_t}{Z^*_t \tilde{a}^*_{D,t}}\right)^2 \\ & - \frac{\xi}{2}\left(\frac{N^*_t}{2\gamma(\kappa+1)}\right)^2\left(\frac{W^*_t}{Z^*_t \tilde{a}^*_{D,t}}\right)^2 = C^*_t \end{aligned} \tag{B.44}$$

♦ Net Foreign Assets

$$P_t B_{H,t+1} + B_{F,t+1} = (1+i_t)P_t B_{H,t} + (1+i_t^*)B_{F,t} + \frac{1}{2}\left(W_t L - W_t^* L^*\right) \\ - \frac{1}{2}\left(P_t C_t - C_t^*\right) + \frac{1}{2}\left(N_{A,t}\tilde{d}_t - N_{A,t}^*\tilde{d}_t^*\right) - \frac{1}{2}\left(N_{E,t}\tilde{v}_t - N_{E,t}^*\tilde{v}_t^*\right) \tag{B.45}$$

C Figures

Figure 8: U.S. data: HP filtered trend

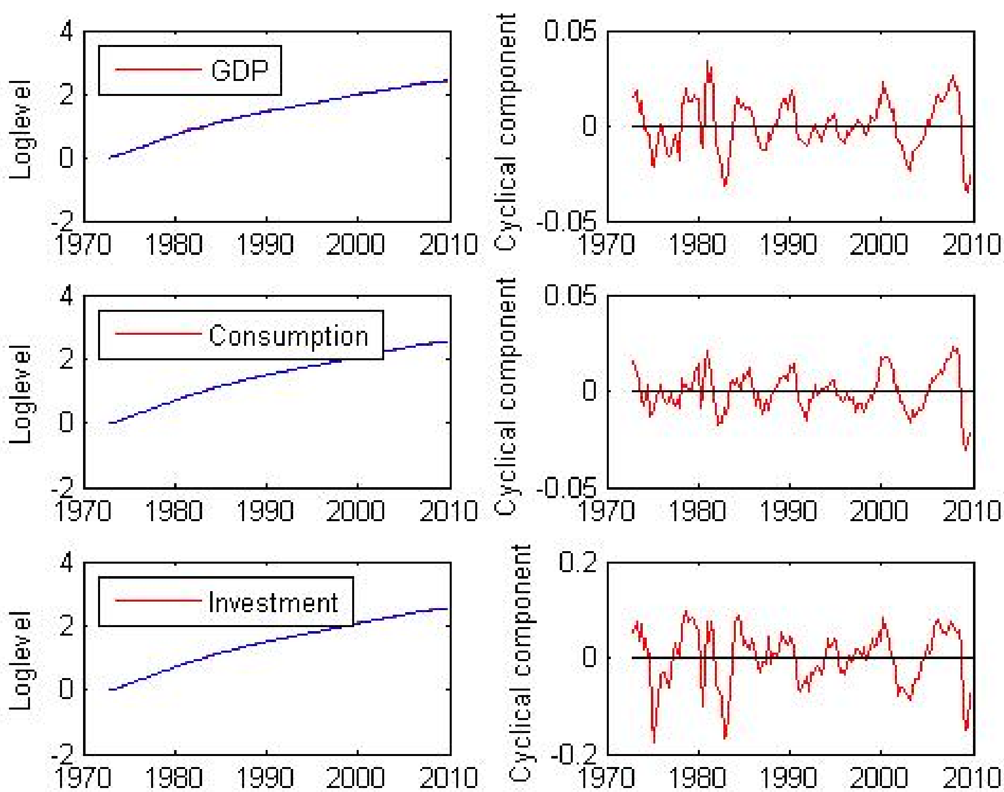


Figure 9: Dynamic Responses to Home Aggregate Productivity Shock

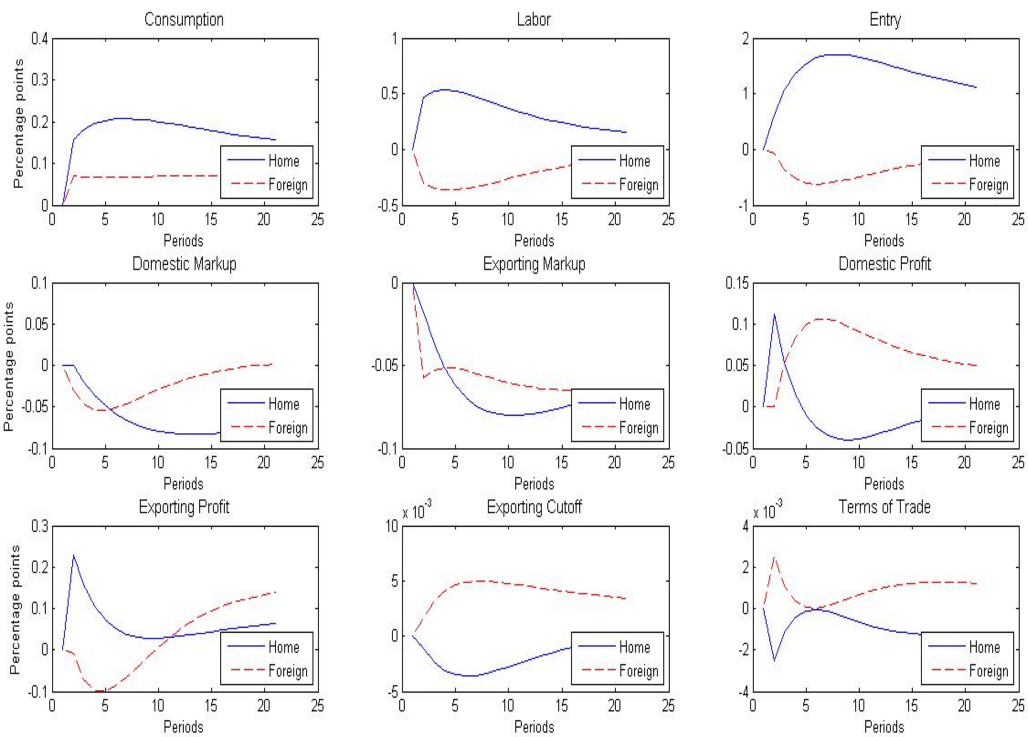


Figure 10: Dynamic Responses to Permanent Increase in Z_t

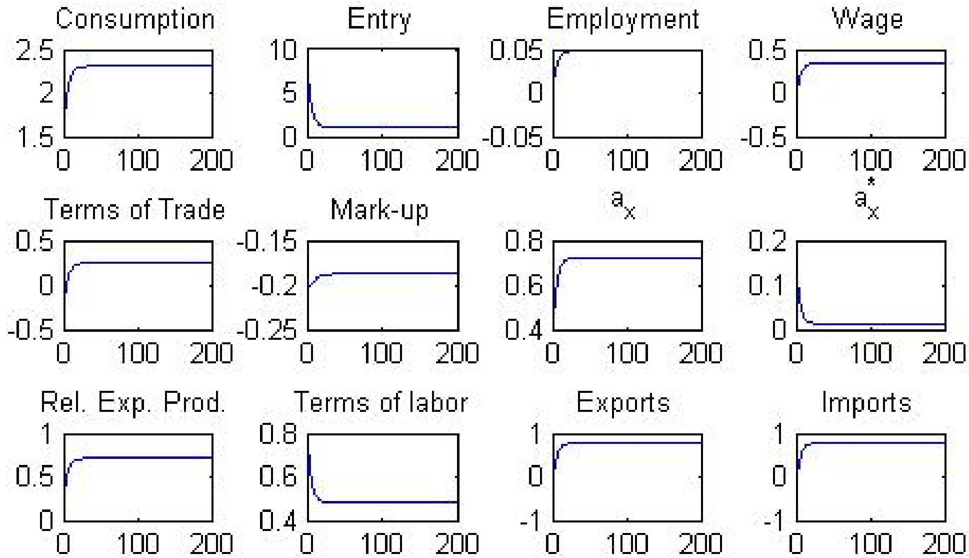


Figure 11: Dynamic Responses to Permanent Decrease in τ_t and f_E