Exposure to International Crises: Trade vs. Financial Contagion

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Abstract

I identify new patterns in country growth rates during the late 2000s based on proximity to the US subprime mortgage and Eurozone debt crises through distance, trade, and finance. I use a model of firm and sovereign default with international trade to study international crisis transmission. I model two transmission channels that can be shocked separately: cross-country trade and finance. I calibrate the model to the experiences of representative countries near and far from the crisis areas. Using these calibrations, disturbances on the order of those observed during the late 2000s are applied to each channel separately to study transmission through them. The model produces output declines brought on by contagion similar to those actually observed, without explicitly targeting them. The results support the observation of greater contagion for countries closer to the crisis areas and suggest credit disruption as the primary contagion driver, rather than the trade channel. Capital controls are found to be a useful tool for preventing similarly severe contagion in the future.

Keywords: Economic crises, contagion, endogenous costs of default, sovereign default, banking crisis, Great Recession, Eurozone debt crisis

JEL Codes: E32, F40, F41, F44, H63

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1 Introduction

Economic crises often spread across international borders, with a crisis in one country leading to significant economic disruptions for its trade and finance partners. Over the previous few decades the emerging world has experienced many such periods of crisis contagion, from the 1982 Latin American debt crisis, to the 1994 Tequila Crisis, 1997 Asian Flu, and 1998 Russian Virus. None of these periods of contagion, however, matched the magnitude of the late 2000s global crisis. In that case, issues originating in the US sub-prime mortgage and Eurozone debt markets spread globally with world real GDP growth slowing from 5.44% in 2007 to 2.81% in 2008 before contracting by 0.59% in 2009.[1]

The late 2000s highlighted the importance of understanding how economic crises propagate between nations, given the greater impact that these crises had when they originated in the world's two largest economies and then spread globally. The purpose of this paper is to study the transmission of crises between countries, and separately identify how they are passed through the two primary economic transmission channels: cross-country trade and financial linkages. First, I find empirical evidence that in the 2009-2012 period, countries farther from the Eurozone and United States crisis areas on average performed better relative to their trend levels of real GDP per-capita than those nearer. Second, I create a model that extends the classic small open economy framework to allow for separate trade and financial transmission channels from the rest of the world to the home economy to study how economic disturbances flow through each one. The model is calibrated to fit both representative near and far countries in the pre-crisis world. When the trade and financial shocks measured in the data for each region over the 2008-2012 period hit, contagion causes GDP declines in my model for representative near and far countries at levels similar to those suffered by corresponding country groups in the data — without having explicitly targeted the magnitudes of these declines. Third, I run counterfactual scenarios wherein only one of the trade or financial shocks occurs for the representative near and far countries. The results of this exercise indicate that: the trade channel was responsible for a minor portion of the crisis transmission, with similar magnitudes for near and far countries; financial transmission was minimal for far countries; and the finance channel was the primary contagion channel for near countries. Finally, I model implementing capital controls and find that they would have been a useful policy for near countries to mitigate

[1] Data from the International Monetary Fund's *World Economic Outlook Database April 2013*.

contagion.

There exists a large empirical literature on the factors driving cross-country crisis contagion, in particular the importance of bilateral trade and financial relationships in this transmission. Kaminsky & Reinhart (2000)'s contagion definition is the one generally applied in the empirical literature: "a case where knowing that there is a crisis elsewhere increases the probability of a crisis at home," with the crisis incidence found to increase with greater trade and financial relationships with a crisis area. Using this definition their paper — along with others such as Kaminsky & Reinhart (1999), Hernandez & Valdes (2001), De Gregorio & Valdes (2001), Kali & Reyes (2010), Forbes (2012), and Forbes & Warnock (2012) — finds empirical evidence of cross-country trade and finance as significant contagion channels for several types of economic crises during the 1980s-2000s.

Given the results of this literature, it was thus a puzzle when Rose & Spiegel (2010) performed similar analysis for the 2008 global financial crisis and found that greater exposure to the United States did not increase the crisis incidence of other countries. In fact, they found that if anything greater exposure to the United States led to increased growth.[2]

I extend the focus of this research beyond the initial 2008 crisis year to find that, while the experiences of nations near to and far from the Eurozone and United States crisis zone were similarly severe in that year, there was significant variation across countries as the crises developed from 2009-2012. As is shown in Section **??**, proximity to the crisis areas was negatively related to countries' outcomes over this period. With proximity measured by either distance, trade or financial linkages with the crisis areas, countries closer to the crisis zone by each measure fared worse than those farther from it. From 2010-2012, countries that were near to the crisis zone had real GDP per-capita that was on average below trend by a statistically significant amount, whereas countries farther from the crisis zone did not. In fact, countries that were farther from the crisis zone had on average risen above their trend real GDP per-capita levels by 2012, while those nearer to the crisis area continued to see declines versus their previous trends. These results imply that after the initial crisis year cross-country trade and financial relationships regained their significance as crisis transmission channels.

To study the importance of contagion through these two transmission channels, I use a

[2]Bacchetta et al (2012), Bacchetta & van Wincoop (2013), and Kamin & DeMarco (2012) suggest a global financial panic as the cause of the high cross-country growth correlations over this period.

model of international trade and finance that augments the standard small open economy setup and allows for separate disturbances to the trade and finance channels. My model is closely related to those in two strands of literature: papers such as Paasche (2001) that extend the small open economy setup to examine transmission theoretically through both trade and credit; and research into international borrowing following Eaton & Gersovitz (1981) analyzing the costs and motivation for country default and the effects of financial disruptions on the real economy. In particular, my model builds on the work of Sosa-Padilla (2012), and Mendoza & Yue (2012).[3]

Rather than a standard small home economy trading a single good with a rest of the world that has infinite demand for that good at a fixed price, there is a foreign endowment economy with endogenous demand for a set of heterogeneous home goods, market prices, and terms of trade. The home country is affected through the trade channel when changes in the foreign endowment alter these quantities. The degree of these effects will vary across countries, with increased potency as trade costs with the foreign economy decline and the countries become more integrated through trade.

With regard to finance, instead of the home economy facing a single world interest rate permitting infinite borrowing or investment at that same rate, there is a local banking sector facilitating home lending and investment with the rest of the world at endogenously determined rates. A novel aspect of my model is that the home firms and government will borrow and make default decisions independent of one another, with their default probabilities reflected in the prices of their debt. Further, these agents will indirectly interact with one another through the banking sector, as greater borrowing or a default by borrowers will increase credit tightness for all others. This dynamic can produce endogenous crowding out and output declines during default periods, and is the deterrent for sovereign default. The state of the foreign financial system will be transferred to the home economy by changes in the international interest rates and bank capital inflows faced by the domestic banking sector.

The model is calibrated for two representative countries, one near and one far from the crisis zone. Average data for groups of countries near and far from the crisis zone is used for

[3]Sosa-Padilla (2012)'s model is similar to mine in that bank balance sheet issues lead to an externality for firm borrowing when there is government default. The model of Mendoza & Yue (2012) is also similar, with firms relying on working capital to pay for a portion of production, which is tied to government default decisions through financing.

the associated representative countries. To model the trade channel, I match the changes in the foreign endowment to the changes in the aggregate crisis zone detrended GDP, altering the foreign demand for home goods. To model the financial channel, the interest rates and bank capital endowments in my model are matched to US dollar treasury and AAA corporate yields, and Bank for International Settlements (BIS) international banking claims data. The sizes of the shocks to the transmission channels are replicated by taking these averages separately over historical boom, recession, and crisis periods. Doing so produces crisis contagion with output declines for both representative near and far countries similar in magnitude to those observed, without explicitly targeting the contagion effects.

The separation of the trade and financial transmission channels is important for the purpose of evaluating their relative importance for crisis transmission over the 2008-2012 period. Given the high correlations between trade and finance in the data, the roles of the two cannot be reliably linearly decomposed using empirical methods.[4] In standard models, the trade and finance channels are normally closely tied together. For example, a negative production shock adversely affects trade while also decreasing asset prices and bank balances sheets, causing an adverse financial shock.

The separation of the parameters governing shocks to these channels does not mean that there is no interaction between these two aspects of the economy. The important feature is that the model parameters for each channel can be independently matched to the data and adjusted to see the effects from a lone shock to each (e.g., the foreign endowment state space can be changed to simulate a trade shock without altering the parameters governing the financial channel). The ability to individually include these shocks enables the study of whether the late 2000s global crisis was: primarily a crisis area output and demand shock that transferred globally through the trade channel; a financial shock arising from the worldwide tightening of credit; or a precise combination of the two that led to such poor outcomes.

To gauge the relative importance of the trade and financial transmission channels, I run four counterfactual experiments wherein I separately include the trade and financial channel disturbances experienced during the late 2000s for the representative near and far countries. For the representative near country, employing both the financial and trade shocks produces a GDP decline of 12.1%, compared to the 11.3% average decline across

[4]See Kaminsky & Reinhart (2000) for a discussion of this issue.

this group in the data. Including only the credit shock results in a 10.5% output reduction and only the trade shock in a 1.7% drop. Likewise, for the representative far country, replicating both shocks produces a 0.7% output increase — compared to the 0.1% average change — while separately simulating the credit and trade shocks produce -1.9% and 0.9% changes.

These results indicate the decline in capital from abroad caused a credit crunch in the near economies, which drove the contagion there. The far countries had lower initial levels of international banking claims and saw smaller declines in them during the crisis period, making these countries less susceptible to such a credit crunch. With the decline in interests rates, the financial channel was a net positive for the far countries. These results match the observation of greater contagion for countries closer to the crisis area. Further, they suggest credit disruption as the primary contagion driver for the near countries, those most affected by crisis transmission.

I then study the effectiveness of various levels of capital controls for the near countries due to the importance of the financial transmission channel for them. The results of counterfactual analysis across a spectrum from complete capital openness to capital immobility suggest that the limited use of capital controls would be effective at mitigating financial contagion in both the short and long runs. On the other hand, very tight capital controls — or total banking capital immobility — will induce government default by easing the credit tightness experienced during default periods. This policy leads to less long run financial contagion, but at the cost of greater short run contagion and decreased output in non-crisis periods. These results are in agreement with much of the recent literature on capital controls — such as Korinek (2011), Korinek & Sandri (2014), and Magud et al (2011) — in finding that capital controls can help reduce crisis transmission, though the particulars of their implementation and the circumstances of an economy may alter their efficacy.

The paper is organized as follow: Section **??** provides an empirical analysis of international contagion during the late 2000s global crisis; Section **??** outlines the model; Section **??** reviews the model solution; Section **??** details the model calibration; Section **??** details how contagion occurs in the model; Section **??** discusses the results; and Section **??** concludes.

2 Crisis Area Proximity & Contagion: Distance, Trade & Banking

The 2007-2008 United States financial crisis and 2010-2013 European sovereign debt crisis triggered a period of weak global economic activity.[5] [6] From 2008-2009 the global economy experienced a world-wide recession followed by several years of anemic growth. Looking beyond the aggregate global impact of these crises, there were large differences in country level outcomes for nations outside of the US and Eurozone crisis areas. In particular, those countries nearer to the crisis zone performed worse on average over the subsequent half decade than those that were farther from it.

To add more precision to this observation, I collected population weighted bilateral country distance data from CEPII and real GDP per-capita (Constant 2005 USD) data from the World Bank. To remove extremely small, undeveloped countries, only countries with real GDP per-capita of at least $500 or total GDP of at least $5 billion were kept, leaving 150 countries. The average annual growth by country from 2001-2007 was calculated and used to forecast trend levels of real GDP per-capita for each country for the 2008-2012 period based on the 2007 pre-crisis level. To normalize across countries, the levels relative to trend were calculated by taking each year's real GDP per-capita as a percentage of the country's trend forecast. Individual country average annual growth was used for the trends to counter the fact that countries farther from the crisis zone — especially those in eastern Asia — had high levels of growth entering the crisis period that could be said to amplify the growth-distance relationship. Not detrending the data by individual country growth, or following the Kehoe & Prescott (2002) practice of detrending all countries by 2% — or any other single rate — would strengthen the findings below that countries farther from the crisis zone performed better than those nearer it.[7]

[5]The crisis area is defined as the US and Eurozone entering 2007 (Austria, Belgium, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain).

[6]The timing of the United States led global financial crisis is defined as the period of abnormally high TED credit spreads of 1% and above. The European sovereign debt crisis is defined as the continuous period when 10 year bond interest rates for at least one Eurozone country other than Estonia and Greece were over 6%. Estonia is excluded because it is not in my crisis area, and Greece is excluded because of its material fiscal issues contributing to high yields over a longer time period. The data used for the calculations is from the US Federal Reserve and European Central Bank, respectively.

[7]The results are also robust to: not detrending the data; using different windows to calculate average

The first column of Table ?? presents the results of regressing 2012 detrended real GDP per-capita on each country's minimum distance to the nearest crisis area country. As expected, there is a positive relationship between distance from the crisis area and output, which is statistically significant. The regression suggests that a thousand miles of extra distance from the crisis area is associated with 1.77% greater 2012 detrended real GDP per-capita.

While this result is interesting in and of itself, it likely holds because inter-country economic linkages through trade and finance have been shown to adhere to gravity relationships, with greater bilateral linkages for country pairs that are physically closer to one another. To examine how international trade and financial connections mattered for propagating the late 2000s crises, I collected bilateral country data on each of these channels. The trade channel is measured as the sum of a nation's bilateral imports and exports across all crisis area countries from the UN Comtrade database. The finance data is measured as total banking claims of the crisis area on a country. The banking claims were gathered from the Bank for International Settlements' international banking statistics database.[8] To evaluate each country's closeness to the crisis area, the 2007 levels of these measures as a percentage of GDP were used; the levels during the crisis period itself were not used to avoid endogeneity issues.

The second and third columns of Table ?? show the results of regressing 2012 detrended real GDP per-capita on these variables individually, similar to what was done for distance. The fourth column then presents the results when controlling for both of these measures of economic proximity together. In all cases, the signs of the estimated coefficients match the contagion theory with greater crisis area proximity associated with poorer outcomes, and in all cases the results are statistically significant. The final regression's estimates in particular suggest the importance of both the trade and finance channels in transmitting the crisis, as the estimated coefficient for each channel is negative and statistically significant even accounting for the effects of the other one. From column 4, one percent declines in 2007 trade and finance with the crisis zone are consistent with 0.298% and 0.0152% greater detrended growth, respectively.

country growth rates; using total local currency or USD GDP; several redefinitions of the crisis zone and the sample of non-crisis countries; using 2005 or 2006 as the base year; and looking at GDP for any year from 2009 to 2014 rather than 2012.

[8]Note that banking data for Luxembourg was not available so it was excluded.

An obvious follow up question to the results of Table **??** is how much exports to China might have propped up the economies of its trading partners given its large size and relatively high growth over this period. In other words, do these proximity relationships hold because countries farther from the crisis zone are often closer to China? Table **??** repeats the analysis of Table **??** with 2007 exports to China as a percentage of GDP included in the regressions. The results of these regressions suggest pretty convincingly that this theory of Chinese driven growth divergence does not hold. While exports to China were generally positively related with country growth outcomes, they were not so at a statistically significantly level. Additionally, including Chinese exports changes the coefficients of the distance, trade and finance variables, but the coefficients remain at similar levels and retain their statistical significance.

As another form of robustness, Table **??** has the average and median 2012 detrended real GDP per-capita broken out by distance, trade, and finance proximity quartiles. These are arranged so that lower ranked quartiles are always more connected to the crisis area. The generally increasing average and median output levels as the quartile numbers increase supports the idea that countries closer to the crisis zone by these measures performed worse, and that there was contagion.

To get a clearer understanding of the magnitudes and economic significance of these relationships — and to act as the basis for later modeling countries near and far from the crisis zone — I use each of these measures of crisis zone proximity to group countries into those within, near to and far from the crisis zone. To classify countries into the near and far groups, I apply a κ-clustering algorithm to each measure of crisis area proximity for the non-crisis area countries.[9] To get the average annual detrended real GDP per-capita for each country group, the following regression was run individually for the crisis area and each group of near and far countries:

$$rGDPpc\ Pct\ Trend_{ct} = \alpha + \sum_{t} \beta_t * YearDV_t + \epsilon_{ct}.$$

where $rGDPpc\ Pct\ Trend_{ct}$ is country c's real GDP per-capita in year t as a percentage of

[9]All clustering was performed using the STATA "cluster kmedian" command on the pertinent variable with two groups. To begin the iterative clustering process, each observation is assigned to the group whose median is closest according to L2 (Euclidian) distance. Based on that categorization, new group medians are determined. These steps continue until no observations change groups.

the trend level as described above, and the $YearDV_t$ are dummy variables equal to one in year t. The estimates by year for each country group along with 95% confidence intervals were gathered to get the average annual real GDP per-capita relative to trend by group. As Figure **??** shows, countries that were geographically closer to the United States and Eurozone crisis areas performed significantly worse than those farther away as the crises unfolded. On average, countries in the group closer to the crisis area had fallen 11.3% below trend by 2012 and were continuing to see declines in real GDP per-capita relative to trend. Countries in the more distant group had on average climbed 0.1% back above trend levels. In fact, there was only one year for the far country group where the trend level was not within its 95% confidence interval.

These results were not driven by countries in the immediate proximity of the Eurozone crisis area, either. Figure **??** plots these same three sets of countries with a third group added: countries within 1,000 miles of the Eurozone crisis area. There are two things that stand out from this figure. The first is that the relationships in Figure **??** are only marginally changed. The second is how closely the countries in the immediate Eurozone periphery followed what occurred within the crisis zone.

Similar relationships hold when closeness to the crisis area is measured by trade or financial linkages with the crisis area rather than raw distance from it. To isolate the differences between countries near and far from the crisis zone by distance, trade and finance, Figure **??** plots the average yearly differences between each set of country groups closer to and farther from the crisis zone by these three measures, along with 95% confidence intervals. Lower values mean the group that was more connected to the crisis area did on average worse than the less connected group. While the differences are small during the peak of the global financial crisis in 2008, through the later years the average in each group nearer the crisis area is worse than the associated far group by about 8.3-11.4%, levels that are economically and statistically significant.

In addition to the differences in how real GDP per-capita evolved for countries near and far from the crisis area, there were also differences in how trade, finance, and government yields evolved. Figure **??** plots the changes in countries' aggregate world trade over the crisis period by country distance groups. To normalize the values across countries they are divided by each country's trend GDP. The figure shows that both the near and far country averages had large 2009 declines; however, the far group quickly returned to its

initial level while the near continued to decline. Figure **??** plots similar results for annual average banking claims of the rest of the world on a nation divided by trend GDP. The near group of countries averaged declines in banking claims, while the far countries experienced growth by 2.8% of trend GDP by 2012.

Figure **??** plots average government bond credit spreads over US 10 year bonds. The average credit spread for both country groups increased through 2009, though the far country average declined thereafter. The near countries had greater increases in government credit risk priced in during the crisis. Initially, the average near country credit spread was below that of the average far one, 1.12% to 1.82%. By 2012, however, the credit risk priced into the near countries' bonds increased enough to bring the average rate for that group to 4.08%, which was 1.40% above the far country average. These results suggest that investors perceived significantly different credit risks for sovereign bonds in the two country groups, with the far country ones seen as relatively safer investments.

These regressions and plots show how distance, trade and financial connections were related to country outcomes during the late 2000s global crisis. The results suggest that there was contagion from the crisis zone to the rest of the world, leading to differential country growth rates. Further, both the trade and finance channels were significantly related to output in the data. It is the divergence in growth across countries and driving of that variation that I intend to replicate and explain with my model in the following sections. I use the near and far distance groups as the basis for calibrating my model. First, I replicate contagion through the trade and finance channels as measured in the data. Second, to determine whether trade or finance served as a greater crisis transmission channel I run counterfactuals wherein only the trade or financial shock occurred to better understand the drivers of the contagion.

3 Model

In the model there are five groups of agents across two countries, Home and Foreign, acting under discrete time. The agents in Home include: households; firms; the Home government; and international bankers. The Foreign economy contains a continuum of identical consumers who receive an exogenous endowment each period; it can be thought

of as the crisis area.[10] In the following sections we will review the problems facing each set of agents. For reference, Figure **??** presents the interaction between agents within and between time periods.

3.1 Home and Foreign Households

In each country there is a unit continuum of identical households that must decide on a quantity of labor to supply to domestic firms at the start of a period and make consumption decisions at the end of the period, after exogenous shocks to Home and Foreign are realized during production. A household's utility in each period is a function of labor supplied (n_j), as well as the consumption of a set of Home goods ($\{c_{ji}\}$) and a single Foreign good (f_j) where i indexes the unit continuum of Home firms and $j \in \{H, F\}$ is the country of the household. The Home households save using the domestic equity market; however, since the households are all identical and the initial allocation is assumed equal across them, there will not be any net trade in equities. Therefore, I exclude the purchase and sale of domestic equities from the household problem, though I do include the profit returned to households each period from firm dividends.

In addition to being a consumption good, the Foreign good also acts as the unit of account for both Home goods and borrowing.[11] To remove the wealth effect on labor supply I follow Greenwood, Hercowitz, and Huffman (1988) by stating period utility as a function of consumption net of the disutility of labor. Removing the wealth effect on labor supply is important to prevent increases in labor supply in states with low consumption, the reverse of what is seen in the data. The period utility function for a household has a standard constant relative risk aversion kernel:

$$U_j(\{c_{ji}\}, f_j, n_j) \equiv \frac{\left(C_j(\{c_{ji}\}, f_j) - \frac{n_j^\omega}{\omega}\right)^{1-\rho}}{1-\rho}; \rho > 0, \omega > 0$$

where

[10] Similar results to what I find can be obtained with a model of two countries fully specified as the Home economy is by adjusting the Foreign country's model parameters to match what occurred in the real world crisis area; however, the current setup better allows for focusing on how aggregate conditions in the Foreign economy are transmitted to the Home country.

[11] Foreign currency borrowing is consistent with the liability dollarization (Krugman, 1999) of many countries.

$$C_j(\{c_{ji}\}, f_j) = \left(\int_0^1 (c_{ji})^{\frac{\sigma-1}{\sigma}} di + \alpha_j f_j^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}}; \sigma > 1, \alpha_j > 0.$$

The household relative risk aversion is ρ, ω is the curvature of labor disutility, σ is the elasticity of substitution across Home goods, and α_j is a weighting factor between the Home and Foreign goods' benefits.[12] Note that the Frisch elasticity of labor supply is then $\frac{1}{\omega-1}$. The period utility functions for Home and Foreign households are identical except for the α_j term.

Each household maximizes the present discounted value of its period utility function:

$$\max_{\{\{c_{jits}\},\{f_{jts}\},n_{jts}\}_0^\infty} E_0 \sum_{t=0}^{\infty} \beta^t U_j(\{c_{jits}\}, f_{jts}, n_{jts}), \tag{1}$$

where $0 < \beta < 1$ is the household discount factor, t the time period, and s the state of the world. Consumption is limited in each period by a household's budget constraint, which is different for Home and Foreign households.

The expenditures of a Home household are constrained by the amount it receives in after-tax wages, a transfer it receives from the government, and its share of the profits of Home firms. Every Home household is paid at the competitive market wage rate, w_t, which it takes as given, and must choose the amount of labor that it will supply before production occurs. The government taxes Home households a share of their wages, T_t, that it selects at the beginning of each period and is known to the Home households. The government also transfers the fixed amount G to all Home households. In addition, consumers own equal amounts of all Home firms so that the aggregate profits from firms, Π_{ts}, are shared across — and taken as given by — Home consumers. Let $s \equiv \{Z, W\}$ be the post-production state of the exogenous shocks, and Ω be the set of all such possible states. The Home consumers' budget constraint in period t given a final state s is:

$$B_{Hts} \equiv (1 - T_t) n_{Ht} w_t + G + \Pi_{ts} = \int_0^1 c_{Hits} p_{its} di + f_{Hts}, \tag{2}$$

where p_{its} is the price of the product produced by firm i.

[12]The preferences of the $C_j(\{c_{ji}\}, f_j)$ function are similar to what one would find if the Foreign good were replaced by a continuum of goods that entered a CES function along with the Home goods; however, in order to abstract from the Foreign wage determination, firm problems, government, and banking sector the Foreign market is assumed to produce one good exogenously.

Foreign households share their endowment equally and have the following budget:

$$W_{ts} = \int_0^1 c_{Fits} \tau p_{its} di + f_{Fts}, \tag{3}$$

where W_t is the endowment of the Foreign good in state s and τ is the iceberg transaction cost associated with international trade.[13] The size of the endowment follows an exogenous random process, with the realization revealed during the production process. This setup enables me to focus on how the Foreign country's output level passes through to the Home country as the trade channel. By modeling the Foreign country as an endowment economy I create an export destination for Home goods with endogenous terms of trade and product demands, while abstracting from the unnecessary details of the Foreign economy.

3.2 Home Firms

Home has a unit continuum of firms, indexed by i, producing differentiated goods under monopolistic competition. The variation in firms allows me to model sectors with differing foreign market exposures, including tradable versus non-tradable sectors. This is important given the variation in firm outcomes during crises.[14]

Each period before production occurs, Home firms choose the amount of labor to employ, how much working capital to borrow, and whether to export to Foreign. After production, each firm individually decides whether to default on its debt, the price it will charge for its good, and the allocation of sales across Home and Foreign.

Firms utilize labor as the single input into their production process, and the production function for firm i is:

$$Q_{its} \leq \frac{Z_{ts}}{a_i} N_{it}^{\alpha}$$

where N_{it} is the labor employed, Z_{ts} is an economy-wide productivity shock realized during the production process in period t, and a_i is the productivity factor of firm i. There is no

[13] For one unit of a good to arrive abroad $\tau > 1$ units must be sent. The iceberg costs are only on Home goods, but adding trade costs on the Foreign good would not materially alter the solution or model dynamics given that there is balanced trade. Since the Foreign good is the unit of payment it does not make sense to send it abroad unless it is in exchange for Home goods, so there is balanced trade, save for the loss of Home goods during transit.

[14] See for example Durbin & Ng (2005), Chor & Manova (2012) and Manova (2013) for studies of variation in firm outcomes during crises.

entry or exit for firms and firms are not able to draw new a_i, so there is a fixed distribution of firm productivities. The economy-wide productivity shock follows an exogenous random process.

While labor is the sole input to production, following Fuerst (1992)'s pay in advance setup, firms require within period working capital because workers demand a fraction (λ) of their wages in advance of production. Home firms face a fixed cost to export and iceberg trade costs similar to the Melitz (2003) model, though there is no firm entry or exit.[15] The reliance of international trade on financing is replicated by requiring that firms pay the fixed export cost (γ) upfront before production occurs to gain access to the Foreign market if they plan to export in the current period.[16] Additionally, across the continuum of heterogeneous firms which endogenously choose each period whether to export or not, changes in both the intensive and extensive margins of trade can be modeled, the importance of which have been demonstrated in papers such as Melitz (2003) and Ruhl (2008).

All profit or loss is transferred to the households at the end of each period in the form of a dividend, π_{its}. Since firms do not have any resources on hand they must take out intra-period working capital loans to pay their pre-production costs. Firm i sells zero coupon commercial paper to the bank at a price of h_{its}, and the amount of commercial paper that it sells is κ_{its}. Since firms independently choose whether to default or not there will be firm specific commercial paper price schedules dependent on the amount a firm wishes to borrow, its a_i, and the aggregate state of the world. A firm's working capital constraint is then:

$$h_{its}\kappa_{its} \geq \begin{cases} \lambda w_{ts} N_{its} & \text{if do not choose to export} \\ \lambda w_{ts} N_{its} + \gamma & \text{if choose to export} \end{cases}.$$

Firms are expected to pay back their borrowing after production is completed; however, each firm has the option to default and be penalized the fraction μ of its output.[17] [18]

[15]The fixed cost is in terms of the Foreign good; however, the solution and model dynamics would not materially change if it were instead a fixed labor cost or in terms of the Home goods.

[16]For analysis of the dependence of firm exports on external financing and trade credit during crises see Chor & Manova (2012) and Manova (2013).

[17]Because firms' commercial paper prices will be less than one — due to default risk and the return of the short term risk free asset being > 1 — and firms have no need for working capital beyond their up-front down payments, the working capital constraint will hold with equality.

[18]Defaulting firms losing a fraction of output is supported by the theory of Mendoza & Yue (2012),

The problem of a firm maximizing the present discounted value of its profits can be reduced to a static profit maximization problem, with firms not accumulating precautionary inter-period asset holdings, assuming that they begin with zero long-term assets (See Appendix I for proof). This is true whether the owner of a firm is a Home household discounting at its stochastic discount factor, or if a fixed world required return is used to discount the cash flows. For this reason, the firms will not take part in the long-term bond market, and I approach the firms' problem as a static one.

The above facets of the firm problem can be combined to yield the profit function. Let:

$$d_{its} = \begin{cases} 0 & \text{if pay off debt} \\ 1 & \text{if default} \end{cases}$$

and

$$x_{its} = \begin{cases} 0 & \text{if do not choose to export} \\ 1 & \text{if choose to export} \end{cases} .$$

Since the decisions that a firm makes today will not influence its state in future periods, each firm maximizes expected current period profit taking the market aggregates as given:

$$\begin{aligned} E_s\left(\pi_{its}\right) = \max_{\{\Theta_{its}\}} E_s\left[p_{its}Q_{its}(1-\mu d_{its}) - w_t N_{it} + h_{it}\kappa_{it} - \kappa_{it}(1-d_{its}) - \gamma x_{it}\right] \\ s.t. \quad \tfrac{z_{ts}}{a_i} N_{it}^{\alpha} \geq Q_{its} \\ Q_{its}(1-\mu d_{its}) \geq m_{Hits} + \tau m_{Fits} \\ \text{On consumer demand curves: } \begin{matrix} m_{Hits} \geq c_{Hits} \\ m_{Fits} \geq c_{Fits} \end{matrix} \quad , \qquad (4) \\ h_{it}\kappa_{it} \geq \lambda w_t N_{it} + \gamma x_{it} \\ m_{Fits} \begin{cases} = 0 & \text{if } x_{it} = 0 \\ \geq 0 & \text{if } x_{it} = 1 \end{cases} \end{aligned}$$

where m_{Hit} and m_{Fit} are the quantities allocated for Home and Foreign consumption and $\Theta_{its} \equiv \{N_{it}, \kappa_{it}, x_{it}, \{Q_{its}\}, \{m_{Hits}\}, \{m_{Fits}\}, \{p_{its}\}, \{d_{its}\}\}$ is the choice set.[19] The firms'

where restricted capital access reduces firm productivity. Alternately, one could think of this lost fraction of output as litigation costs associated with default or a reputation cost that diminishes the perceived quality of a firm's goods.

[19] Agents can arbitrage Home goods if the price of a good in Foreign does not equal τ times its price at Home. This price relationship then holds with equality and firms cannot price discriminate between the two markets.

total payment to Home households can then be derived as:

$$\Pi_{its} \equiv \int_0^1 \pi_{its} di.$$

3.3 Banking Sector

The competitive Home banking sector is modeled using a representative banker. The goal of the bankers is to maximize the net present value of their end of period cash flows, I_{ts}. With these preferences the bankers are then risk neutral as they are maximizing a linear function of their cash flows. Entering each period, the bankers' only assets are government bond holdings from the previous period. At the start of the period the government pays the bankers or defaults, and the bankers receive endowment income of A_t. This endowment can be thought of as an inflow from a foreign parent bank, or revenue from other ongoing business activities. With the former interpretation, the Home economy is assumed to not be small in the sense that it can borrow or invest an infinite amount at a single international rate. It is, however, small in the sense that regardless of the amount that the banking sector profits today, the endowment income for the banking sector in future periods will not be affected, as it is determined externally. The size of the A_t banking endowment can vary between countries, with greater levels of the endowment corresponding to greater international financial integration.

The bankers are the only ones in the Home economy with access to international capital markets, so firm and government borrowing must occur through them.[20] Credit instruments available to the bankers are in one of two tenures: short-term instruments that are repaid in the same period after production occurs; and long-term securities that are repaid at the start of the following period. As explained earlier, the firms choose not take part in the inter-period lending market. The government, however, does issue one period bonds to the bankers that will be repaid at the start of the following period. The firms do take part in the intra-period lending market, though the government is assumed not to do so.[21] The

[20]Having international borrowing funneled through the banking system fits the experiences of many countries. As an example, in a sample of 3,312 international corporate bonds from Euromoney, Durbin & Ng (2005) finds that half of them are from the Banking and Finance sector.

[21]The bankers would not loan short-term to the government because post-production the government does not have any cash on hand to repay such debts. Therefore, this assumption comes down to assuming that the government would not seek short-term profit from investments in the banking sector.

prices for these securities are determined endogenously by their respective default risks, with individual firms and the government able to independently default on their debts.

In addition to the commercial paper from firms and government bonds, there are three other investment securities that the bankers can use. They can invest an unlimited quantity in a risk free international security, borrow by using government bond holdings as collateral in a repurchase agreement, or borrow an unlimited amount with uncollateralized debt. All three of these investment options are short term, which means that they will be agreed to at the start of a period pre-production and paid at the end of the same period post-production. The interest rates on these investments are taken as given by the bankers. K_t is the amount that a bank invests in the international risk free asset returning r^f, and L_t is the amount of uncollateralized bank borrowing at a rate of r^H. R_t is the amount that a bank borrows via bond repurchase agreements at a rate of r^R. Given the nature of the repurchase agreements, the quantity used must be positive and is limited by the market value of a banker's bond holdings, $p_B B'$. The risk free investment and bank borrowing rates are determined exogenously in the rest of the world based on the state entering the period and are taken as given by the bankers. Also, it is assumed that $r^f < r^R < r^H$, with the risk free asset requiring the lowest return, and the collateralized repurchase agreement borrowing rate being lower than the uncollateralized one, as participation in the uncollateralized lending market is a signal that a bank is leveraged beyond its assets on hand.

This capital market structure closely follows the options available to real world banks. Further, modeling the banking sector in this manner fits the interest rate dynamics that occurred during the late 2000s global crisis period better than a single international rate would. Figure **??** shows the three month US Treasury bill versus Aaa and Baa corporate bond yields, and the spreads between the treasury rate and these yields. The US Treasury rate and corporate yields align with the risk free rate that my banking sector can invest at and the collaterlized borrowing rate, respectively. As can be seen in the diagram, the credit spreads — the difference between the treasury rate and each relevant corporate borrowing rate — are significant in magnitude and countercyclical. For low levels of these spreads, it would be reasonable to use a standard model with one world interest rate that the banking sector can both borrow and invest at; however, that is not what is reflected in the data. During the global crisis, the US treasury rate was near zero while the credit spreads were at or near their twenty year highs.

The pre-production lending constraint for a banker at the beginning of the period is:

$$A_t + B_t + L_t + R_t \geq \int_0^1 h_{it}\kappa_{it}di + K_t + p_{Bt}B_{t+1}, \tag{5}$$

where p_{Bt} is the price of one period zero coupon government bonds. The pre-production constraint specifies that net investment in government bonds, firm borrowing and the risk free asset must be less than or equal to a bank's capital plus the amount it borrows short term.

The post-production investment constraint for a bank in final state s is:

$$r^f K_t + \int_0^1 \kappa_{it}(1 - d_{its})di \geq I_{ts} + r^H L_t + r^R R_t. \tag{6}$$

The post-production constraint states that a banker's end of period investment cash flow is less than or equal to his net profit from the short term lending market, inclusive of firms' defaults.

There are effectively two cases for the bankers, depending on the default choice of the government. If the government defaults then it will be excluded from borrowing in the bond market for the given period and enter the following period with only ϕB_t of its debt remaining, where $0 < \phi < 1$. Therefore, depending on the government's default behavior there either will or will not be bonds available for the bankers to invest in, and if the government defaults the banks' funds today will be only A_t rather than $A_t + B_t$. Further, a government default will cause an interruption that closes the bond repurchase agreement market for the current period.

If the government does not default in the current period then the problem facing a bank is:

$$\begin{aligned}
\Psi(B, Z_{-1}, W_{-1}) \mid_{D=0} = \max_{\{B',K,L,R,\{I_s\},\{\kappa_i\}\}} & E_s\left\{I_s + \delta\Psi(B', Z_s, W_s)\right\} \\
s.t.\ & A + B + L + R \geq \textstyle\int_0^1 h_i\kappa_i di + K + p_B B' \\
& r^f K + \textstyle\int_0^1 \kappa_i(1 - d_{is})di \geq I_s + r^H L + r^R R \ \ \forall s \\
& p_B B' \geq R \geq 0 \\
& K \geq 0;\ \ L \geq 0.
\end{aligned}$$

The first constraint is the pre-production lending constraint, and the second is the post-production investment constraint. The next constraint requires that the money borrowed

in a repurchase agreement be between zero and the market value of the new held bond position. The final two constraints restrict the bankers to borrow and invest risk free at different interest rates. If the government defaults this period then the problem for a bank is:

$$\begin{aligned}\Psi(B, Z_{-1}, W_{-1}) \mid_{D=1} = \quad & \max_{\{K,L,\{I_s\},\{\kappa_i\}\}} E\left\{I_s + \delta\Psi(\phi B, Z_s, W_s)\right\} \\ & s.t.\ A + L \geq \textstyle\int_0^1 h_i \kappa_i di + K \\ & \quad r^f K + \textstyle\int_0^1 \kappa_i (1 - d_{is}) di \geq I_s + r^H L \ \ \forall s \\ & \quad K \geq 0;\ \ L \geq 0.\end{aligned}$$

A government default closes the bond market, and with it the repurchase agreement borrowing market.

3.4 Home Government

The Home government seeks to maximize the discounted present value of its households' utilities; however, to support government debt levels seen in the data I follow Grossman & Van Huyck (1988) and Rieth (2014) with a myopic government. The government has the same period utility function as its households but a lower discount factor, seeking to maximize:

$$\max_{\{\{c_{Hits}\}, f_{Hts}, n_{Ht}\}_0^\infty} E_0 \sum_{t=0}^{\infty} (\xi\beta)^t U_H(\{c_{Hits}\}, f_{Hts}, n_{Ht})$$

where $0 < \xi \leq 1$ is the degree of government myopia.[22] Note that other than that constant this is the same as the Households' target utility given in Equation **??**.

The government makes three choices each period before production occurs to achieve its goal: whether to default or repay the bankers at the start of the period (D_t); the tax rate on wages (T_t); and the amount to borrow into the next day via bonds (B_{t+1}).[23] Greater values of B_{t+1} mean greater government indebtedness. If the government chooses to default then it is excluded from the debt market for the current period and reduces its debt by a

[22]The term $h = \frac{1}{1-\xi}$ can be interpreted as the expected planning horizon of the government in years.

[23]The government being the actor to borrow from the banking sector to smooth household consumption matches extant programs by which the government does much of this smoothing (e.g., social security, unemployment insurance).

factor of $(1-\phi)$. Government spending, G, is exogenously fixed. The government budget constraint is:

$$T_t n_{Ht} w_t + p_{Bt} B_{t+1}(1-D_t) \geq G + B_t(1-D_t)$$

where

$$D_t = \begin{cases} 0 & \text{if pay off debt} \\ 1 & \text{if default} \end{cases} .$$

4 Model Equilibrium

In this section I outline the solution to the model and define the equilibrium. The problems of the households, firms, and bankers within a period given the government's choices will be examined first, followed by a determination of the government's optimal policies knowing the effects it will have on the other agents.

4.1 Solution to the Home and Foreign Households' Problems

The households make their labor supply decisions before production occurs, and their consumption decisions after production occurs taking the pre-production labor choices, the shocks, taxes, firm profits, firm default choices, firm export choices, and prices as given. To write their equilibrium conditions that govern these choices it is helpful to provide some notation:

1) Price index for Home goods in Home $\quad P_{Hts} \equiv \left(\int_0^1 (p_{its})^{1-\sigma} di\right)^{\frac{1}{1-\sigma}}$

2) Price index for all goods in Home $\quad \Phi_{Hts} \equiv \left(P_{Hts}^{1-\sigma} + \alpha_H^{\sigma}\right)^{\frac{1}{1-\sigma}}$

3) Price index for Home goods in Foreign $\quad P_{Fts} \equiv \tau\left(\int_{\chi_t} (p_{its})^{1-\sigma} di\right)^{\frac{1}{1-\sigma}}$

4) Price index for all goods in Foreign $\quad \Phi_{Fts} \equiv \left(P_{Fts}^{1-\sigma} + \alpha_F^{\sigma}\right)^{\frac{1}{1-\sigma}}$

where χ_t is the set of Home goods exported to Foreign. The first order conditions for the Home households are then:

$$f_{Hts}\ FOC:\ f_{Hts} = \left(\frac{B_{Hts}}{\Phi_{Hts}}\right)(\alpha_H \Phi_{Hts})^{\sigma} = C_{Hts}\,(\alpha_H \Phi_{Hts})^{\sigma} = B_{Hts}\Phi_{Hts}^{\sigma-1}\alpha_H^{\sigma}, \tag{7}$$

$$c_{Hits}\ FOC:\ p_{its} c_{Hits} = B_{Hts}\Phi_{Hts}^{\sigma-1} p_{its}^{1-\sigma}\ \ \forall\, i, \tag{8}$$

$$n_{Ht}\ FOC:\ n_{Ht}^{\omega-1} = \frac{(1-T_t)w_t E_s\left(U_{Hts}^{\frac{\rho}{\rho-1}}\Phi_{Hts}^{-1}\right)}{E_s\left(U_{Hts}^{\frac{\rho}{\rho-1}}\right)}. \tag{9}$$

Similarly, the first order conditions for the Foreign households are:

$$f_{Fts}\ FOC:\ f_{Fts} = \left(\frac{B_{Fts}}{\Phi_{Fts}}\right)(\alpha_F\Phi_{Fts})^{\sigma} = C_{Fts}\left(\alpha_F\Phi_{Fts}\right)^{\sigma} = B_{Fts}\Phi_{Fts}^{\sigma-1}\alpha_F^{\sigma}, \tag{10}$$

$$c_{Fits}\ FOC:\ \tau p_{its}c_{Fits} = B_{Fts}\Phi_{Fts}^{\sigma-1}\tau^{1-\sigma}p_{its}^{1-\sigma}\ \ \forall \text{ exported } i, \tag{11}$$

$$n_{Ft}\ FOC:\ n_{Ft} = 0. \tag{12}$$

Since households in Foreign receive their endowment regardless of the labor effort they exert, the households there will choose to not provide any labor. Additionally, it can be found that — as in the standard Dixit-Stiglitz (1977) model that consumer preferences in my model are based on — both the Home and Foreign households' budget constraints will hold strictly, and that given prices household consumption is a linear function of wealth. That is:

$$C_{Hts} = \frac{B_{Hts}}{\Phi_{Hts}}$$

and

$$C_{Fts} = \frac{B_{Fts}}{\Phi_{Fts}}.$$

4.2 Solution to the Home Firms' Problem

The firms know the optimal demand choices of the Home consumers given prices and will utilize these reaction functions when calculating their prices and allocations across Home and Foreign after production occurs. Let

$$\psi_{sExporter} \equiv B_{Hts}\Phi_{Hts}^{\sigma-1} + B_{Fts}\Phi_{Fts}^{\sigma-1}\tau^{1-\sigma}$$

and

$$\psi_{sNonexporter} \equiv B_{Hts}\Phi_{Hts}^{\sigma-1}$$

be the pricing indices for firms that do and do not export to Foreign, respectively, and

$$d_{its} = \begin{cases} 0 & \text{if pay off debt in state } s \\ 1 & \text{if default in state } s \end{cases}$$

and

$$x_{it} = \begin{cases} 0 & \text{if do not choose to export} \\ 1 & \text{if choose to export} \end{cases}$$

be firm i's default and export decisions. The consumers' problems then give use the following pricing rule for all firms:

$$\psi_{sx_{it}} = Q_{its}(1 - \mu d_{its}) p_{its}^{\sigma}.$$

It is shown in the Appendix that the price indices have an unique positive solution given the state, pre-production labor choices, export and tax decisions, and current firm default choices that are the solution to the following two equation system:

$$\psi_{sX}\alpha_H^{\sigma} = (\lambda - T_t) w_t n_{Ht} + G - \int_0^1 (1 - d_{its})\kappa_{it} di + (\psi_{sX} - \psi_{sH}) \left(\psi_{sX}^{\frac{1-\sigma}{\sigma}} k_{ts} + \alpha_H^{\sigma} \right)$$

$$\frac{W_{ts}}{\psi_{sX}^{\frac{1-\sigma}{\sigma}} k_{ts} + \tau^{\sigma-1}\alpha_F^{\sigma}} = (\psi_{sX} - \psi_{sH})$$

where

$$k_{ts} = \int_{\chi_t} \left(\frac{Z_{ts}}{a_i} N_{it}^{\alpha} (1 - \mu d_{its}) \right)^{\frac{\sigma-1}{\sigma}} di.$$

Upon substitution of the pricing rule and all strictly binding constraints into the problem for firm i the problem becomes:

$$E_s(\pi_{its}) = \max_{\{N_{it}, x_{it}, \{d_{its}\}\}} w_t N_{it}(\lambda - 1) + E_s \begin{bmatrix} \psi_{sx_{it}}^{\frac{1}{\sigma}} \left(\frac{Z_{ts}}{a_i} N_{it}^{\alpha}(1 - \mu d_{its}) \right)^{\frac{\sigma-1}{\sigma}} \\ -(1 - d_{its}) \frac{(\lambda w_t N_{it} + \gamma x_{it})}{h_{it}} \end{bmatrix}.$$

The first order condition for labor demand is

$$w_t \left[(1 - \lambda) + \lambda \frac{E_s(1 - d_{its})}{h_{it}} \right] = N_{it}^{\frac{\alpha(\sigma-1)}{\sigma} - 1} a_i^{\frac{1-\sigma}{\sigma}} \frac{\alpha(\sigma - 1)}{\sigma} E_s \left[\psi_{sx_{it}}^{\frac{1}{\sigma}} \left(Z_{ts}(1 - \mu d_{its}) \right)^{\frac{\sigma-1}{\sigma}} \right], \tag{13}$$

where the left hand side can be shown from the banker's problem to be constant for all producing firms (i.e., all firms that do not default in all post-production states and therefore

are able to acquire funds in the short term capital market). Firms will maximize their expected profits over this choice and the discrete choices of whether to export and default. Note that the default threshold for a firm is based on its output and the aggregate price index that will prevail after production. Specifically, a firm will repay its debt if and only if the extra revenue received when not defaulting is greater than the amount of short term commercial paper due:

$$\psi_{sx_{it}}^{\frac{1}{\sigma}} Q_{its}^{\frac{\sigma-1}{\sigma}} \left(1-(1-\mu)^{\frac{\sigma-1}{\sigma}}\right) \geq \kappa_{it}.$$

The export choice is based on whether moving to the greater price index facing exporters is worth the fixed cost of exporting.

4.3 Solution to the Bankers' Problem

The solutions to the bankers' problem in the cases where the Home government does and does not default produce similar equilibrium conditions (See the Appendix for detailed solutions). The primary difference is that when the government defaults it shuts down the bond and repurchase markets, such that the equilibrium conditions for the problem under default are a subset of those that exist with repayment.

These conditions state that within a period the short term required returns of investments in firms and the government are the same. Γ is used to denote this required short term return. The specific pricing formulas for firm commercial paper and government bonds are then:

$$h_i = \frac{E_s(1-d_{is})}{\Gamma} \ \ \forall \ \ i, \tag{14}$$

and

$$p_B = \frac{\delta E_s\left(\Gamma'_s(1-D'_s)\right)}{\Gamma-\Lambda}, \tag{15}$$

with the latter not applying if the government defaulted in the current period, closing the bond market. The Λ in the denominator of the latter equation is the shadow cost of the constraint limiting the amount borrowed via repurchase agreements to the value of the held bond position. In both cases the price of firm debt is discounted by the short term required return in the current period and the chance of default. For government debt, which spans two periods, there are also price adjustments for the bankers' inter-period discount rate, and the short term required return that will prevail in the following period. If the full bond position is not borrowed against then Λ will be zero, and the current period discount

for bonds is simply Γ, the required return. On the other hand, if the full bond position is borrowed against then Λ will adjust such that $\Gamma - \Lambda = r^R$, the bond financing cost.

In both the cases where the Home government does and does not default it can be shown that the pre-production lending constraint and post-production investment constraint will hold strictly. This means a banker's end of period investment decision is trivially to select I_{ts} to make up the shortfall of his short term investments or to set aside his short term profits.

The level of Γ will be influenced by the bankers' opportunity cost of funds. This opportunity cost comes from the bankers' outside investment opportunity in K_t, or their marginal cost of funds through either uncollateralized borrowing or borrowing with their held government bond positions as collateral. I define Home Borrowing as being the total borrowing by Home firms and the government (If the Home government defaults then this is just the total Home firm borrowing):

$$\text{Home Borrowing } \equiv \int_0^1 h_{it}\kappa_{it}di + p_{Bt}B_{t+1}.$$

I also define the Bank Cash as $A_t + (1 - D_t)B_t$, the capital endowment from abroad added to the amount that the government repays on its bonds. There are then five potential cases for the required return, Γ, when the government honors its debt and three when it does not based on the total desired amount of Home borrowing as demonstrated in Figure **??**. To be clear, the B bond positions in the figure are those that the bank holds entering the period, and the B' bond positions are those that the bank invests in pre-production that pay off in the following period.

The aggregate interest rate schedule for Home Borrowing when the government repays is given in the left panel of the figure. If the amount of Home Borrowing is less than a banker's cash on hand, $A_t + B_t$, then the opportunity cost of funds for the banker will be the return on the risk free investment of r^f, so $\Gamma = r^f$. In the case where the amount of Home Borrowing is greater than a banker's cash assets on hand by an amount less than the value of its new bond positions, $p_B B'$, then the short term required rate is the repurchase agreement rate that it will borrow marginal funds at, so $\Gamma = r^R$. Similarly, if the aggregate amount of Home Borrowing is greater than a banker's total assets on hand of $A_t + B_t + p_B B'$ then the opportunity cost of funds is the rate of r^H at which the banker borrows the marginal dollar it is investing, so $\Gamma = r^H$. The spread between r^R and r^H is

the premium charged on uncollateralized lending to high leverage banks. The other two cases are the edge cases between these three zones. If the level of Home Borrowing equals a banker's cash on hand then the equilibrium conditions stipulate that $\Gamma \in [r^f, r^R]$, and if it is equal to $A_t + B_t + p_B B'$ then $\Gamma \in [r^R, r^H]$.

In the right panel of Figure **??** is the case if there is a government default. With a default the government bond and repurchase markets are closed and the bankers do not receive the payment B_t at the start of the period, but firms will not be crowded out by the government. This reduces the bankers' cash on hand and shifts the threshold for the highest rate down to A_t. Below that level the required return is r^f, and at the edge case where total firm borrowing is A_t, it is the case that $\Gamma \in [r^f, r^H]$.

This framework for the domestic bankers has important consequences for the indirect interaction of Home borrowers. As the total amount borrowed by the Home firms and government increases, the opportunity cost of funds for the bankers increases. As the bankers leverage themselves to support greater loans to the firms and government, the required return for lending increases endogenously from the risk free investment rate to the higher rates at which the banks themselves borrow. Therefore, when there is increased borrowing in the home economy the cost of borrowing endogenously increases, without making the common assumptions that there is a strict collateral requirement facing the banking sector that cuts off borrowing when exceeded, or an infinite amount of borrowing at a fixed rate before an exogenous cessation of all lending to a country when there is a government default.[24] Also, firms and the government indirectly affect each other with their default risk altering asset pricing and credit tightness.

4.4 Solution to the Government's Problem

For the solution to the Home government's problem I focus on Markov perfect equilibria where the government's policies are functions of the state variables entering the period, $\{B, Z_{-1}, W_{-1}\}$. The Home government's default, borrowing and taxation decisions will have

[24]These alternate assumptions are explained in the sudden stop literature introduced by Calvo (1998). Korinek & Mendoza (2013) gives a good summary of the sudden stop literature. Other good models of sudden stops and their implications for optimal policy include Benigno et al (2010), Benigno et al (2013a), Benigno et al (2013b), Bianchi & Mendoza (2011), Chakraborty (2009), Jeanne & Korinek (2010), Mendoza (2002) and Young (2012).

consequences for the other agents in the model. Therefore, we can think of Home period utility for a given post-production state s, U_{Hts}, as being a function of the government's decisions and existing debt, specifically $U_{Hts}(T, D, B)$. If the government chooses to default then its tax revenue must cover its fixed expenditure and its level of bonds tomorrow are set at $B' = \phi B$. These requirements yield the following value function in the case of default:

$$V(B, Z_{-1}, W_{-1}) \mid_{D=1} = E_s \left\{ U_{Hs} \left(T_G, 1, 0 \right) + (\xi\beta) V(\phi B, Z_s, W_s) \right\}, \tag{16}$$

where T_G is the level of taxation such that the government's tax revenue equals G. The general form of the government problem can then be written as:

$$V(B, Z_{-1}, W_{-1}) = \max_{\{D\}} \begin{cases} \max\limits_{\{T, B'\}} E_s \left\{ U_{Hs}(T, 0, B) + (\xi\beta) V(B', Z_s, W_s) \right\} & \text{if pay off debt} \\ \qquad s.t.\ T_t n_{Ht} w_t + p_B B' \geq G + B & \\ V(B, Z_{-1}, W_{-1}) \mid_{D=1} & \text{if default.} \end{cases} \tag{17}$$

4.5 Definitions of Model Equilibria

In this section I provide definitions for the model's equilibria. The first is for the competitive equilibrium given the Home government's actions, and the second is for the government's policies knowing the effects it will have on the other agents in the model.

Definition 1. *Recursive Competitive Equilibrium Given Government Policies*
A competitive equilibrium given government policies is sequences of:

- *Allocations* $\begin{array}{c} \{\{c_{jits}\}, \{f_{jts}\}, K_t, L_t, R_t, \{I_{ts}\}, B_{t+1}^{supply}, \{\kappa_{it}^{supply}\}, \\ \{m_{jits}\}, \{Q_{its}\}, \{\kappa_{it}^{demand}\}, \{N_{it}\}, \{n_{jt}\}\}_{t=0}^{\infty} \end{array}$
- *Firm default* $\{\{d_{its}\}\}_{t=0}^{\infty}$ *and export* $\{\{x_{it}\}\}_{t=0}^{\infty}$ *choices*
- *And prices* $\{\{p_{its}\}, \{h_{it}\}, w_t, \{\pi_{its}\}, \{\Pi_{ts}\}\}_{t=0}^{\infty}$

such that given sovereign bond prices $\{p_{Bt}\}_{t=0}^{\infty}$*, government policies* $\left\{D_t, T_t, B_t^{demand}\right\}_{t=0}^{\infty}$*, and shocks* $\{Z_{t-1}, W_{t-1}\}_{t=0}^{\infty}$ *the following hold:*

- $\{\{c_{jits}\}, \{f_{jts}\}, \{n_{jt}\}\}_{t=0}^{\infty}$ *solve the households' problems in* **??**-**??** *subject to the budget constraints* **??**-**??**

- $\{\{m_{jits}\}, \{Q_{its}\}, \{\kappa_{it}^{demand}\}, \{N_{it}\}, \{p_{its}\}, \{d_{its}\}, \{x_{it}\}\}_{t=0}^{\infty}$ *solve the firms' problems in* **??** *and discrete export and default decision rules, subject to the constraints described in its full problem in* **??**

- $\{K_t, L_t, R_t, \{I_{ts}\}, B_{t+1}^{supply}, \{\kappa_{it}^{supply}\}\}_{t=0}^{\infty}$ *solve the banker's problem* **??-??**, *meet its budget constraints* **??-??**, *and its* Γ *rule given leverage.*

- *And markets clear:*

$$B_{t+1}^{supply} = B_{t+1}^{demand}; \qquad \kappa_{tt}^{supply} = \kappa_{tt}^{demand}; \qquad n_{Ht} = \int_0^1 N_{it} di;$$

$$n_{Ft} = 0; \qquad m_{jits} = c_{jits}; \qquad \& \quad \Pi_{ts} = \int_0^1 \pi_{it} di$$

for all $j \in \{H, F\}$, $i \in [0, 1]$ *and states* $s \equiv \{Z, W\} \in \Omega$.

Definition 2. *Markov Perfect Equilibrium*
The Markov perfect equilibrium for this economy is government borrowing, default and taxation rules $(B'(B, Z_{-1}, W_{-1}), D(B, Z_{-1}, W_{-1}), T(B, Z_{-1}, W_{-1}))$ *with associated value functions* $V(B, Z_{-1}, W_{-1})$ *and* $V(B, Z_{-1}, W_{-1})\,|_{D=1}$, *consumption and labor plans* $\{\{c_{His}(B, Z_{-1}, W_{-1})\}, \{f_{Hs}(B, Z_{-1}, W_{-1})\}, \{n_H(B, Z_{-1}, W_{-1})\}\}$, *and an equilibrium government bond pricing function* $p_B(B'; B, Z_{-1}, W_{-1})$ *such that:*

- *Given the price* $p_B(B'; B, Z_{-1}, W_{-1})$, *the borrowing and default rules solve the government's maximization problem* **??-??**

- *Given the price* $p_B(B'; B, Z_{-1}, W_{-1})$ *and the borrowing and default rules, the consumption and labor plans* $\{\{c_{His}(B, Z_{-1}, W_{-1})\}, \{f_{Hs}(B, Z_{-1}, W_{-1})\}, \ \{n_H(B, Z_{-1}, W_{-1})\}\}$ *are consistent with the competitive equilibrium defined above*

- *Given the prices* $p_B(B'; B, Z_{-1}, W_{-1})$ *and the borrowing and default rules, the taxation rule* $T(B, Z_{-1}, W_{-1})$ *satisfies the government's budget constraint*

- *The government bond price equilibrium function* $p_B(B'; B, Z_{-1}, W_{-1})$ *satisfies the banker's bond pricing condition in equation* **??**

for all $i \in [0, 1]$ *and states* $s \equiv \{Z, W\} \in \Omega$.

5 Model Calibration

Since my model is run for several different scenarios — countries both near and far from the crisis area in both normal and crisis times — there are multiple types of parameters that must be set. First, the parameters that remain the same across all of the scenarios and are drawn from common values in the literature or are selected to match specific moments in the data. Second, there are trade and financial parameters that differ based on whether a country is near or far from the crisis zone. Third, there are parameters that change between crisis and non-crisis times. Finally, there are those that are simultaneously determined to match data moments. The subsections below review the logic for setting each group of parameters in turn.

5.1 Common Parameters

In this section I describe the calculation of parameters that are the same across all scenarios and are taken from standard values in the literature or individually matched to specific moments in the data. A summary of these parameters is given in Table **??**. To start, the banker's (δ) and households' (β) discount rates are set to 0.95. The consumers' inter-variety elasticity of substitution (σ) is 5 and their risk aversion (ρ) is 2, both standard values in the literature. In a brief survey of estimates of the Frisch wage elasticity from macroeconomic data, Reichling & Whalen (2012) find the range of estimates to be from 2 to 4. I use the midpoint of this estimate range, 3, which results in a curvature of labor disutility (ω) of 1.33.

For the continuum of firms' distribution, I assume that there are two types based on their productivity factors. This distribution is chosen to simulate tradable and non-tradable sectors of the economy. A fraction $\mathcal{H}$ of firms are high cost and the remainder low cost, with the difference being in the productivity factor of firm i where $a_i \in \{a_L, a_H\}$; $a_L < a_H$. The fraction of firms that have a high cost parameter is selected to match the portion of US manufacturing firms that do not export from Bernard et al (2012), 0.82. The low cost parameter (a_L) is given a normalized value of 1.00, and the high cost parameter (a_H) is selected to match the average productivity ratio of the top 18% of firms to the bottom 82% using estimates of the distribution of firm productivities from Del Gatto, Mion & Ottaviano (2007). See the Appendix for specific details of these calculations. It is assumed

that the fraction of wages that must be paid before production occurs (λ) is 100%, since wages are normally given the highest creditor priority and repaid even during defaults. The fraction of production lost when a firm defaults (μ) is set to a level such that when there are the highest draws for both the Home productivity factor and Foreign endowment the low cost firms do not default; there are many such levels that satisfy this condition and the results are not qualitatively changed by marginally adjusting this value.[25] The labor share in output (α) of 0.64 is taken from Hansen (1997).

Government spending (G) is set to 15 to match the median of government revenue as a percentage of GDP for the non-crisis area countries in 2007. The myopic government discount factor (ξ) is calculated as 0.80 assuming an expected government planning horizon of 5 years. Finally, the fraction of government debt remaining after a default (ϕ) is chosen as 60% after reviewing historical creditor losses during country defaults in Sturzenegger & Zettelmeyer (2008).

5.2 Trade Costs & Financial Flows

Countries near and far from the crisis zone are modeled using varying levels of iceberg trade costs and inflows of capital via the bank endowment, A_t. The fixed costs of trade are assumed constant, and the financial inflows are assumed to exogenously shift with the Foreign state.

The target total trade cost for near countries is chosen to match the estimates for US-Canadian trade. For $\sigma = 5$, Anderson & van Wincoop (2004) estimate total US-Canadian trade costs to be 91% of the goods' value and Head & Ries (2001) estimate it to be 97%. That is, the total price of goods abroad is about 190% of the domestic price. I choose to round these levels off to 90%.

The trade costs for far country goods are found in two ways. The first is by using the distance elasticity of trade costs found in Hummels (2001) of 0.27. Using this value, and the fact that countries in the far group are on average about 2.75 times as far from the crisis area as those in the near group, the far group's iceberg costs can be computed as $190\% * 2.75^{0.27} = 250\%$, giving trade costs of 150%. Alternately, using Eaton & Kortum (2002)'s analysis of 19 OECD countries 750-1500 miles apart, one finds that for $\sigma = 5$ trade costs are 174%. The 150% from the distance elasticity calculation is similar and is used in

[25] With the level chosen, my model does not produce firm defaults in any state.

the calibration.

These target trade costs are used to determine τ and γ by selecting a fixed trade cost great enough that the high cost firms do not export, and then choosing the iceberg cost such that total trade costs as calculated in the following formula match the targets above during normal, non-crisis times:

$$\text{Trade cost} = E_s\left[\frac{(\tau-1)p_{Lts}c_{FLts}+\gamma}{p_{Lts}c_{FLts}}\right] = \tau - 1 + E_s\left[\frac{\gamma}{p_{Lts}c_{FLts}}\right]$$
$$\implies \tau = (1+\text{Trade cost}) - E_s\left[\frac{\gamma}{p_{Lts}c_{FLts}}\right].$$

Only the low cost firms' goods are considered here because of the choice of γ to suppress high cost firm exports. The values produced by this procedure, as well as the calculated trade costs for both near and far countries, can be seen in Table **??** with the other simultaneously matched parameters.

The bank endowment levels are chosen to match the BIS banking claims data. The average banking claims of the crisis area as a percentage of trend GDP on countries in the near and far groups for 2007 were used for the normal times levels, and for 2008-2012 for the crisis levels. These levels — along with the changes between normal and crisis times — are provided in Table **??**. As can be seen, the near countries had greater banking claims before the crisis occurred, but then had their average banking claims decline by over 10% as much as did the level for the far countries.

5.3 Aggregate Shocks and Interest Rates

This section describes how the parameters defining the states of the world are determined. These include the good and bad Z levels, the good and bad W levels, the interest rates, and the transition probabilities between these. The Z and W production shocks follow two and four state random Markov processes independent of one another. The Z states represent high and low productivity shocks for the Home economy. The W states represent high and low output levels during normal times, as well as two potential crisis situations. The first crisis state is targeted to match what occurred during the Great Depression, and the second to match what occurred over the late 2000s crisis period.

The interest rates are assumed to be determined in the Foreign country so their values depend on the Foreign state. This setup is inspired by risk tolerances in the major financial

centers of the US and Eurozone connecting the state of the economy there with interest rates.

5.3.1 Z Levels and Transitions

To determine the good and bad levels and transition matrix for Z, I use the Barro & Ursua (2008) real GDP per-capita data from 1870-2007 for the available countries in my two non-crisis area regions.[26] I calculate the annual growth for each country in each year and aggregate the results across all countries. The sample average is taken as the trend level of growth and is subtracted from all observations to get detrended values. Whether each year's growth was above or below trend and the status in the following period is tracked to create the transition matrix between these states. As a check, I confirmed that the limiting transition matrix produced from the probabilities in Table **??** mirrored the fractions of good and bad states observed in the data.

The relative levels of Z_G and Z_B are selected such that the following relationship holds

$$Z_B = Z_G \frac{1 + \text{Avg Detrended Growth in Below Trend Years}}{1 + \text{Avg Detrended Growth in Above Trend Years}},$$

and the expected value of Home production is 100 when the crisis area has a good endowment draw, as would have been the case in 2007. The calibration to 100 is performed separately for near and far countries, as the differences in parameterizations mentioned in the previous section mean that the two areas cannot both have the same expected value of Home production for a given set of Z_G and Z_B values and transition probabilities. These values are presented with the other simultaneously determined values below.

5.3.2 Non-Crisis Foreign Economy: W Levels, Interest Rates, & Transitions

The normal times W states and transition matrix are determined in a manner similar to that for Z. The difference is that rather than look at the results across many countries, I examine the results of the aggregated crisis area from 1870-2007. The crisis area data is aggregated across countries by using a weighted average of the Barro & Ursua (2008)

[26]The available countries far from the crisis area were: Argentina, Australia, Brazil, Chile, China, India, Indonesia, Japan, Korea, Malaysia, New Zealand, Peru, Philippines, South Africa, Singapore, Sri Lanka, and Uruguay. The available countries near to the crisis area were: Canada, Colombia, Egypt, Greece, Iceland, Mexico, Norway, Russia, Sweden, Switzerland, Turkey, and Venezuela.

real GDP per-capita data based on 1960-2012 World Bank GDP (Constant 2005 US$). These weights changed little over this period, supporting the use of the average country weights over this period for all years. The growth in this time series is used to get normal times good and bad endowment levels similarly to the individual countries in the previous section. The primary difference is that the mid-value for the Foreign endowment is set to 100*(2007 aggregate crisis area GDP) / (Average 2007 non-crisis area country GDP) to get the proper relative sizes for the Home and Foreign economies. These results can be seen in Table **??**. Again, I confirmed that the limiting transition matrix for the Foreign state mirrored the fractions of good and bad states observed in the data.

The interest rates are calculated using real 3-month US Treasury bill rates and US dollar corporate Aaa credit spreads over them for 1990-2007. The average levels of each of these are calculated separately for periods when there was above and below trend growth in the countries that became the late 2000s crisis area to get values for the good and bad states. The interest rates from the US treasury bills are used for r^f and these rates plus the associated credit spreads are used for r^R. The levered borrowing rate is set to 30% to match data on yields observed during defaults.[27] Table **??** provides the rates used.

5.3.3 Crisis Foreign Economy: W Levels, Interest Rates, & Transitions

The method for determining the good and bad W levels and their transition probabilities is quite different for the crisis scenarios. In this case the worst case scenario is taken to be experiencing 1929-1934 Great Depression growth, and the best case is taken as what occurred in the 5 year period from 2008-2012. The probability of ending up in each state is determined by taking the average initial crisis area detrended growth during each real world crisis period, and the April 2008 IMF advanced country growth expectations detrended to -5.85%.[28] This growth expectation is between the detrended growth rates of the two alternative crisis scenarios, so it is easy to impute the expectations of entering each one to derive the transition matrix. The two crisis state W levels are the normal times mid-value adjusted down by the average growth in each crisis period.

The transition matrix given in Table **??** is taken by using the Foreign endowment

[27] Durbin & Ng (2005) and Neumeyer & Perri (2005) find bond yields spiking to 25-40% during government defaults. To support my results I only need a levered borrowing rate of 19%, well below this range.

[28] http://www.imf.org/external/pubs/ft/weo/2009/01/pdf/text.pdf

probabilities from this and the previous section, as well as the Z transition probabilities. It is important to reiterate that the Home productivity parameter follows the same Markov process independent of whether there is a crisis or not. Additionally, it is assumed that there is a 2% chance of entering a crisis period from a non-crisis one — reflecting the two crises that were entered in the last hundred years — and crises are expected to continue into another crisis period with an 80% chance — to give a five year expected duration to match the two actual crises.

The interest rates are derived from the same rates as for normal times. The average real 3-month US Treasury bill and Aaa corporate rates are used for the risk free and bond repurchase agreement rates over each corresponding real-world crisis period. Again, the levered rate of return is set to 30% to match data on yields observed during defaults.

5.4 Parameters Concurrently Determined to Match Data Moments

Finally, there are three other sets of parameters that are simultaneously determined to match specific moments in the data. The iceberg trade costs and Z levels for the representative near and far countries were already mentioned above. Additionally, there are the Home consumers' utility coefficient on the Foreign good (α_H) and the Foreign consumers' utility coefficient on the Foreign good (α_F). For symmetry, the Home and Foreign coefficients on the Foreign good are assumed to be multiplicative inverses. They then are chosen to match the levels of Home exports seen in the data. The values selected for these parameters and the model moments versus their targets can be seen in Table **??**.

6 Modeling Contagion

In this section I describe how the trade and financial channels transmit the state abroad to the Home economy in my model. The structure of the model allows separation of shocks via the trade and financial channels, as each of these two channels is governed by a separate set of model parameters. The separation of the parameters governing shocks to these channels does not mean that there is no interaction between the two. In fact, it is quite the opposite, with changes in the credit market substantially affecting trade and vice-versa. The important feature is that the model parameters for each channel can be independently

adjusted to see the effects from a lone shock to each (e.g., the Foreign endowment state space can be changed without altering the financial parameters).

6.1 Contagion through Trade

In the model there are three specific parameters that affect the trade channel: the fixed export cost; the Foreign endowment; and the iceberg trade cost. The fixed export cost will govern the fraction of Home firms that choose to export; however, this cost is assumed to be constant for all countries in all states, so it is not significant for the dynamics of trade channel contagion. The other two parameters are important for transmission through the trade channel and cross-country variation.

The Foreign endowment is the driver of trade shocks. A trade shock occurs when changes in the Foreign endowment alter the export demand facing Home firms and the terms of trade. For example, a negative Foreign endowment draw will have a number of consequences for the Home economy. First, there is the direct effect of diminished demand from abroad for Home goods, reducing the prices at which exporting firms can sell their goods and the terms of trade. Second, the reduced profitability of Home exporters will decrease income to the Home households. There will then be a negative demand shock for all Home goods, not just the exported ones. Third, if the reduction in a firm's profitability from these former effects is great enough, they can lead the firm to default on its debt at a cost of a fraction of its output. Through this mechanism negative shocks in the Foreign economy can produce large real decreases in Home output.

The above effects are the result of a realized poor draw of the Foreign endowment; however, lower endowment expectations can also be harmful for the Home economy, even if the realized endowment level does not change. A lower expected endowment decreases the demand for labor of exporters, and with that household income and output. Additionally, the export decisions of home firms may change resulting in less trade profit entering the Home economy.

The iceberg transaction costs influence the degree of trade integration between the Home economy and the rest of the world by making exporting more or less profitable for firms. The degree of trade directly affects Home's susceptibility to trade contagion. The variation in the degree of trade contagion with the level of trade costs can be seen in Figure **??** for a representative set of model parameters. The figure plots aggregate Home firm

profit on the y-axis — which is used as a measure of the health of the Home economy — against the iceberg trade cost, τ, along the x-axis. The four upper solid and dashed lines are for each of four post-production states, the cross product of good and bad draws of the Home productivity factor and the Foreign endowment. The lines with the same color are for the same Home productivity draw, and the dashed lines are for the bad Foreign draw. As the iceberg trade costs decline to the left, the world becomes more integrated through trade and the profits of the Home firms increase for a given final state.

As the lower two dotted lines in the plot show, though, there is a cost to greater integration. The dotted lines present the differences in aggregate firm profit between a good and a bad Foreign endowment draw, taking Home productivity as given. As the variable trade cost decreases and trade increases, the amount of contagion from abroad rises as evidenced by larger differences in Home profits between the good and bad Foreign states.

6.2 Contagion through Finance

Financial channel transmission from the rest of the world to Home flows through borrowing by the Home firms and government from domestic banks. The local bankers' interactions with the rest of the world include the receipt of a capital endowment each period from their Foreign parent banks, as well as the three interest rates mentioned earlier: risk free investment; bond repurchase agreement; and uncollateralized loan rates. The levels of these factors will depend on the state entering a period. The capital flows may vary by country, though the domestic bankers in all countries will face the same interest rates.

The transmission of a financial shock occurs as a response to changes in these quantities. As the capital endowment decreases, or the interest rates increase, credit in the domestic economy will tighten, which can endogenously increase the required return on borrowing. The amount of cash on hand that the bankers have is very important for the response of the Home economy. For example, if r^f decreases and r^R increases as in 2009, then countries with low levels of bank cash relative to their domestic financing demands would be forced to borrow from abroad at a higher rate, increasing the required return. On the other hand, a well-funded economy with excess bank cash relative to domestic borrowing demands would actually benefit, as the opportunity cost for funds would decrease with the risk free investment rate. Changes in the bank endowment would also affect credit

tightness. Similar to what Forbes & Warnock (2012) find relating booms and busts with capital inflows and declines, capital flows to a country are positively related to output due to easing credit conditions.

An increased required return on borrowing would adversely affect firms, by making it more costly to finance the fraction of wages paid up-front and the fixed cost of exporting. The former leads to decreased output for firms as the marginal cost of labor increases, and the latter makes firms less likely to choose to export. On the government side, the increased borrowing costs make borrowing more costly for the government and make issuing debt less attractive.

In addition to these direct effects, a higher required return would make default more attractive for Home firms and the government. If the required return is high enough, then firms may choose to default, with real effects on output when a fraction of production is lost by doing so. Since both sets of agents are competing for the same funds, each group's risk of default will affect the other through banks, with the potential to endogenously increase the required return for all borrowers. As each firm is only one of a continuum, they will assume that their default choices have no ramifications for the lending market; however, in aggregate their choices will be major drivers of this market.

On the other hand, given its size, the government is able to materially affect Home credit markets with its borrowing and default. Higher levels of government borrowing will crowd out Home firms, making it more costly for firms to produce and lower output. The interaction between these two sides, however, goes beyond this simple crowding out effect. When selling more bonds to the bankers, the government increases the leeway for collateralized borrowing this period, and the cash on hand that the bankers will have in the following period, assuming that the government does not default. In other words, by increasing the amount of safe bonds issued the government is able to increase the assets retained in the Home banking sector, at the cost of increased crowding out and repaying more in the following period. The Home government and economy are, however, small in the sense that regardless of the amount that the domestic banks profit today, the endowment income for the banking sector in future periods will not be affected, as it is determined by external factors.

When the government defaults, there is a significant reduction in bank balance sheets and a closing of the bond repurchase agreement market, with credit tightening effects anal-

ogous to a reduction in the capital endowment. This dynamic produces endogenous output declines during default periods, and is the deterrent for sovereign default.[29] Additionally, a government default can increase credit tightness to such a degree that it induces firms to default, with real output costs.

7 Results

In this section I examine the causes of contagion in my model and then review its implications. I do this in three steps. First, I describe the results of the model calibrated to fit the average outcomes of countries near and far from the crisis zone during the period before the late 2000s crises. To model the trade channel, I match the changes in the foreign endowment to the changes in the aggregate crisis zone detrended GDP during the crisis period. To model the financial channel, I match the interest rates and foreign banking claims to those observed in the data. I apply the crisis period changes in both of these channels to the initial calibration and am able to replicate the output declines brought on by crisis contagion for representative near and far countries similar in magnitudes to those observed, without explicitly targeting the levels of output decline. Specifically, my model matches the fact that countries nearer to the crisis zone were more susceptible to contagion from it. Second, I review a series of counterfactual scenarios wherein only the trade or finance channel shock is applied to representative near and far countries. I perform this analysis to determine how the crises were transmitted through each channel. These results suggest that finance was the primary contagion channel over this period, and that it was much more deleterious for the near countries than for the far ones. Finally, I examine the effectiveness of capital controls for the near countries to mitigate the high degree of financial contagion they experienced.

[29] The combination of firm reliance on working capital and government borrowing through the banking sector is likely to produce twin sovereign default and GDP crises, as is often seen in the data. See Levy-Yeyati & Panizza (2011) for a historical discussion of this relationship.

7.1 Modeling Near & Far Countries during the Late 2000s Crisis Period

The results of applying the late 2000s trade and financial shocks experienced by representative near and far countries are presented in two stages. The steady-states for the normal and crisis periods are compared to the data for both of the representative countries, followed by an explanation of the model's dynamics using transition paths from 5 periods before a crisis commences to 5 periods afterwards.

A comparison of the steady-state values for the normal and crisis periods can be found in Table **??**. The results for the near country are provided on the left, and those for the far country on the right. For each country the values are presented in three sections: the normal times steady-state; the crisis period steady-state; and the differences between the two. The normal times columns provide information on the steady-state when there is a high productivity draw at Home and the best draw of the Foreign endowment.[30] The data for the crisis period is taken from the steady-state for a good Home draw and the late 2000s equivalent crisis state abroad. Choosing this set of states as the point of comparison isolates the effects of the crisis, without conflating it with the consequences of a negative Home productivity draw. The corresponding real world values are provided for several fields in bold in the margins next to each of the columns. If an item in the margin is underlined then it was explicitly targeted in the calibration, otherwise it is a result of the model. Finally, in the third column for each of the near and far countries is the difference between the normal and crisis period steady-states. For fields measured in percentages this is the difference between the two steady-states, otherwise it is the growth rate between them.

The first row contains information on the expected levels of Home production and is the benchmark for measuring contagion.[31] The means of the near and far Home productivity shocks were calibrated so that the normal times output in each case would be 100, and the resulting values are 99.7 for the representative near country and 98.9 for the far one. The crisis period output levels were not explicitly targeted, but the model was able to produce

[30] This was selected as the basis of comparison because 86% of non-crisis countries had above trend growth in 2007, as did the region that became the crisis zone.

[31] The Home production levels are expectations over the Home productivity draw conditional on remaining in the same Foreign state at the end of the current period.

declines in output for both the near and far countries similar to what was measured in the data. For the representative near country, the model's contagion from abroad results in a 12.1% decline in output against an 11.3% decline in the data. For the far countries, production increases by 0.7%, which is similar to the 0.1% increase in average output for the far country group by the end of the crisis period in Figure **??**. These results reflect greater contagion for those countries closer to the crisis zone, a prominent feature of the data.

While the aggregate Home output levels are replicated well by the model, the declines in trade for the two countries are too small. For the near country, the model has trade falling from 13.9 to 13.0, as opposed to the decline from 14.0 to 10.6 seen in the data. For the far country, trade drops from 7.5 to 7.2 as opposed to the 8.0 to 7.0 decline in the data. The model does, however, have trade declining by about twice the rate for the near countries as the far ones, as actually occurred.

Another shortcoming is that the government debt levels produced by my model are significantly lower than the levels of debt that actual governments held both before and during the crisis period. This is an issue endemic to models such as this in the literature.[32] The differences between the debt levels in the near and far countries do, however, align well with two features of the data: the nearly static levels of near country debt; and greater borrowing by far countries during both normal and crisis periods.

The differences in crisis output between the two representative countries are closely tied with the governments' decisions. For the near country, the government chooses to leave the level of debt largely unaltered, while the far country government chooses to pay off a fraction of its debt to reduce its debt financing burden and crowding out of firm borrowing. To help explain these decisions and study the dynamics around a crisis period, Figures **??** and **??** provide graphs of several measures around crisis events in the representative near and far countries.

Each of the panels in Figures **??** and **??** plots eleven periods: the five years before and the five years after a crisis that commences during the production stage of T=0.[33] The

[32] See, for example, Mendoza & Yue (2012) and Aguiar & Gopinath (2006).

[33] The state entering period zero is assumed to be high output draws of both the Home productivity factor and Foreign state, at the corresponding steady-state government debt level. For the five preceding periods, the Foreign state draw is assumed to be a high one, and the average value across the Home productivity states and associated government debt levels is taken conditional on there being a high Home productivity

conditional expected values over the level of Home productivity and associated government debt levels are plotted. The dotted lines are two standard deviation confidence intervals. The plots provide an overview of the initial transition from the normal times steady-states in Table **??** to the crisis ones. The left column of each figure lists the field being plotted, the center contains plots for the near country and the right for the far one.

The plots in the first row of Figure **??** show the expected values of aggregate Home production. The near country shows an initial decline towards the crisis steady-state of 88, then levels off close to that point and remains there. The far country also shows an initial decline and — similar to 2008 — there is little difference between the near and far country averages in the first year of the crisis. Further, as in the data, in the first year of the crisis there is virtually no decline in output for the non-crisis countries, and only in the second full year of the crisis is the initial level of output for the far country not within that year's confidence interval. The second year decline in output of 13% overshoots the average decline experienced by the far countries in that same year, but the levels in the subsequent years are similar.

The output declines are closely associated with decreases in the after tax real wages. Between the normal times and crisis period steady-states, the nominal wage in the near economy actually increased slightly, but hours worked still declines by 17.7% because of the increased tax burden. As can be seen in the bottom row of the figure, the tax rate for the near country increased by 4.6%, driving a 6.2% decline in the after tax real wage. There was also a shift of labor into the low cost, exporting industry as Home income declined.

Alternately, the far country saw a decline in wages of 3.3%, but this was offset by a decrease in the tax rate after an initial spike as the government chose to pay down a fraction of its debt. For the far country, there was also a shift between labor utilization in the high and low cost industries; however, this time the shift was into the domestic, non-tradable sector as Home income increased while the Foreign endowment decreased.

Figure **??** presents some graphs to help explain the choice of the far country to pay off its debt to reduce its debt financing burden and crowding out, while the near country increased its tax rate to keep its debt level unchanged. The first row shows the debt levels for the two countries, and the second row the level of bank cash at the start of each period.

realization entering period zero. Beginning during production in period zero and continuing through the subsequent five periods, it is assumed that there is a draw of the Foreign state corresponding to the late 2000s crisis period.

Both the near and the far countries experience declines in the bank endowments received once the crisis begins. The level of bank cash in the far economy falls one for one with the 16% decrease in the bank endowment because the level of government debt changes little, while the bank cash for the far country falls by more than the 5% decline in the bank endowment.

The third row provides some insight into why this is. The two plots in that row show the aggregate amount of firm borrowing in each economy minus the level of bank cash.[34] In both economies, prior to the crisis the amount that the bank had to borrow to support the Home economy's financing was less than the amount of government debt, placing the economies on the central, flat portion of Figure **??**. This position corresponds to a required return on borrowing equal to the government bond repurchase agreement rate, which was 4.13% before the crisis.

After the beginning of a crisis at T=0 in each figure, credit conditions tightened and both of the economies were shifted to the right hand vertical edge of the aggregate interest rate schedule between the government bond repurchase and uncollateralized borrowing rates. This situation can be recognized by the fact that aggregate firm borrowing is equal to the level of bank cash for the latter few periods in each plot. The level of credit tightness was greater in the representative near economy, pushing rates up to 11.10%, whereas in the far economy the required return declines when entering the crisis period with lower real world interest rates. This left the near economy in a position where it did not want to deleverage and lead the banking sector to do so as well. Conversely, the far country was able to pay off part of its debt to reduce its debt financing burden and crowding out without causing significant deleveraging. In neither case did the government wish to default and accept the resultant destruction of bank wealth, which would have caused a greater contraction in the real economy by further increasing the required return on firm borrowing and potentially induced the firms themselves to default with real output losses.

[34]The level of bank cash will be the A_t endowment that the bank receives plus the B_t that the government repays to the bank.

7.2 Separating Trade & Financial Contagion: Counterfactual Scenarios

To determine the relative importance of the trade and financial channels for transmission of the 2008-2012 crises, I ran several counterfactual simulations. In these simulations, I included the shocks to the trade and financial channels separately. For the case with only a trade channel shock, I left the bank endowment and interest rates on international investments fixed at the normal period levels and only had the Foreign endowment change. In the latter case, I did the reverse and matched the crisis period's finance channel changes while leaving the Foreign endowment at non-crisis levels. I then analyzed the normal times steady-state against that for each partial crisis period, similar to the analysis discussed in the previous section.

The results from the counterfactual analysis are given in Table **??**. There are six columns of data presented in the table, those being pairs of data for representative near and far countries when exposed to contagion through: both transmission channels; only the trade channel; and only the financial channel. Each column lists the changes between the normal and crisis period steady-states. The first two columns — containing information on contagion through both channels simultaneously — are identical to the difference columns in Table **??** and are here to serve as baselines for the other scenarios.

The data in the first row demonstrates that applying the trade shock individually resulted in small declines in output on the order of less than 2%. The decline in the Foreign endowment flowed through the trade channel to decrease trade for the near and far countries. Additionally, the exporting, low cost firms saw greater declines in labor utilization than did the non-trading firms, corresponding to a labor shift into the non-tradable sector. These changes are not surprising, given that the lower demand from abroad would flow to the Home economy through the decreased export demand faced by the low cost firms. The government borrowing levels and tax rates remained largely unchanged. The changes in labor utilization (-1.4% for the near country and -1.6% for the far one) and wages (-0.3% for both countries) were minor enough that the steady-state levels of firm borrowing were relatively constant, leaving the required return on borrowing unchanged in each case.

Figure **??** provides transition plots of the expected Home output for each of the six cases of near and far countries crossed with the three combinations of international shocks. The first row corresponds to the two cases already discussed with both the trade and

financial shocks. The second row shows the results for only the trade shock. From these two plots, it is clear that the effects of a trade shock alone were relatively minor and nearly indistinguishable between the near and far countries.

The final two columns of Table **??** show the results of only applying the financial shock. Doing so results in a 10.5% output decline for the near country, and a 0.9% output increase for the far one. The results, and the associated dynamics, are similar to what occurred when both the trade and financial shocks were applied, but with the economic contraction slightly muted without the decline in the Foreign endowment. Looking at the plots in the first column of Figure **??**, one can see that the results were extremely similar between the cases with only the credit shock and with both shocks for the near country. For the far country, the results towards the end of the period were similar between the two cases, but the initial decline in output was significantly less without the exacerbating effects of the trade shock leading the far government to cut its debt to reduce its debt financing burden and crowding out.

Examining the results in Table **??**, it is evident that the trade shock was less impactful than the credit shock for both the near and far countries, with similar magnitudes for each. In fact, the lower interest rate environment during the crisis period, combined with the small change in the average bank endowment faced by far countries, made the credit shock alone a net positive for far countries. These results suggest that the worst transmission of the late 2000s crises was driven by financial contagion rather than the trade channel. This result has important implications for policy makers looking to combat contagion in the future.

7.3 Capital Controls & Contagion Mitigation

Given the substantial degree of financial contagion experienced by the represenative near country, an obvious follow up is to examine what policies the near countries might have used to attenuate it. Since the decline in interest rates during the recent crisis in and of itself would have been expansionary for the near country, it must have been the reduction in banking flows that caused the contagion. Therefore, implementing capital controls to prevent the loss of banking funds appears to be a suitable policy to consider for the near countries.

To evaluate the efficacy of capital controls, the representative near country case is

repeated while varying only the level of the crisis A_t value. To consider different degrees of capital controls that could be implemented, values ranging from the near countries' average crisis A_t level of 24 up through their non-crisis average of 40 are considered. The former would be equivalent to no capital controls, and the latter to complete capital immobility. Note that this exercise does not account for the fact that implementing capital controls might make foreign investors less willing to invest in the Home economy, reducing the non-crisis level of A_t. Therefore, the results of this exercise can be thought of as the best case scenario for capital controls.

Figure **??** plots the percentage decline in aggregate Home country output during a crisis on the y-axis versus the crisis level of A_t on the x-axis. The "SS to SS contagion" line plots the non-crisis steady-state to crisis steady-state level of contagion. The "1st crisis period contagion" line plots the decline in output from the non-crisis steady-state through the first period of a crisis. In both cases, one unit on the y-axis is equivalent to a 1% decline in output from the non-crisis steady-state.

From the "SS to SS contagion" line, it is evident that the degree of steady-state to steady-state contagion decreases as the crisis A_t increases. This relationship suggests that capital controls are an effective tool for fighting financial contagion in the long run. The "1st crisis period contagion" line, however, suggests a more complicated relationship between capital controls and immediate financial contagion. At the left of the plot, as capital controls are first introduced the short run contagion is monotonically reduced with more restrictive controls. In these cases, the greater levels of the crisis bank endowment enforced by capital controls lead to less credit tightness and improved crisis period aggregate output.

As stricter capital controls are implemented, the short run results improve to such a degree that they exceed the long run level of contagion, with a peak of only 0.97% short run contagion at a crisis A_t of 34. Over this range, the government pays down its debt over time, incrementally increasing credit tightness and shifting the economy towards the greater long run contagion level.

As the crisis A_t level increases to 37 or above — approaching the normal times level — there is a steep increase in the short run contagion. The bank funding that the government is able to ensure with capital controls is high enough to support an acceptable short run level of output under default relative to the future benefit of lower government debt levels. In other words, the destruction of bank assets caused by a default is no longer enough to

incite a severe banking crisis and deter the government from defaulting because the capital controls enable the government to guarantee adequate bank reserves. This is the region over which the assumption that the non-crisis A_t remains constant must be kept in mind, since this is where it is most likely to fail. Additionally, as can be seen in Figure **??**, the non-crisis steady-state output starts to decline when defaults are realized with high A_t. That effect is the primary reason why the stead-state contagion is reduced over the right hand range of Figure **??**, not that the crisis steady-state is improved.

Taken together, these results suggest that capital controls can be effective at mitigating financial contagion in both the short and long run. It is important, however, to consider whether they restrict the flow of capital so much as to induce the Home government to default on its debt during crises. If that is the case, then lower capital controls and the correspondingly more severe crises may be worth it in order achieve higher non-crisis steady-state output, given that foreign crises are expected only 10% of the time.

8 Conclusion

Episodes of cross-country economic crisis contagion have occured numerous times over the past century. These events can have severe consequences for large blocks of countries, or even the global economy as evidenced by the late 2000s crisis period.

In this paper, I identified new patterns in country growth rates during the late 2000s based on proximity to the US subprime mortgage and Eurozone debt crises through distance, trade, and finance. Economic growth in the countries near the crisis zone remained stalled years after the crises commenced, costing on average 11.3% of real GDP per-capita. Countries that were farther from the crisis zone still had poor short term outcomes, but on average they had returned back above their trend growth levels by 2012.

Using a model of firm and sovereign default with international trade, I find that the primary cause of the differences in country outcomes was varied exposure through the finance channel. To arrive at this result, I model two transmission channels that can be separately perturbed: cross-country trade and finance. I calibrate the model to the experiences of representative countries near and far from the crisis areas. Using these calibrations, disturbances on the order of those observed during the late 2000s are applied to each channel to study transmission through them. For the representative near country,

applying both the financial and trade shocks produces a GDP decline of 12.1%, compared to the 11.3% average decline in the data. Applying only the credit shock results in a 10.5% output reduction and only the trade shock in a 1.7% drop. For the representative far country, replicating both shocks produces 0.7% growth — compared to the 0.1% average change — while separately simulating the credit and trade shocks produce 0.9% and -1.9% changes.

For both representative countries, the model produces output declines similar to those actually observed, without explicitly targeting them. The results support the observation of greater contagion for countries closer to the crisis areas and suggest credit disruption as the primary contagion driver, rather than the trade channel. Finally, I find that the contagion experienced by near countries could have been significantly diminished by the use of capital controls on bank assets.

This paper offers several avenues for future research and possible extensions. In this paper I analyze the near and far countries independent of one another, and an obvious first extension would be to add more countries to the model to study the third party network effects of contagion. Perhaps the reason that the countries farther from the crisis zone performed better over this period was because of greater levels of trade and banking with other non-crisis countries, rather than only lower ties with the crisis area. Additionally, having multiple countries borrowing from the same banking sector would allow for a better study of the interactions between governments' default decisions, as evidenced by the apparent coordination of government defaults in Reinhart & Rogoff (2009).

Over the late 2000s crisis period, many countries utilized monetary easing to combat the global recession. Also, many governments increased their debt levels beyond what my model produces. Adding a monetary authority could help analyze these decisions. Additionally, having endogenous levels of government spending rather than a fixed level could help evaluate expansionary fiscal policy versus a program of government austerity during the crises.

Finally, higher levels of government reserves and improved exchange rate policies have been proposed as reasons why the developing world weathered the late 2000s crises better than previous ones. Adding currencies to the model would help analyze these propositions. Additionally, this expansion of my model could shed light on the optimal local/foreign currency mix for government debt.

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Table 1: 2012 real GDP per-capita detrended by individual country growth vs 2007 Crisis Area proximity

	(1)	(2)	(3)	(4)
	Distance	Trade	Bank	Bank and Trade
Distance	0.00177***			
	(0.000400)			
Trade PctGDP		-0.327***		-0.298***
		(0.0800)		(0.0841)
Bank PctGDP			-0.0312***	-0.0152*
			(0.0112)	(0.00774)
Constant	84.61***	99.99***	93.14***	100.1***
	(2.054)	(2.423)	(1.482)	(2.467)
Observations	131	128	128	125
R-squared	0.118	0.120	0.024	0.116

Note: Robust standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Distance is population weighted bilateral country distance from the nearest crisis area country from CEPII. Trade is measured as 2007 bilateral imports and exports across the entire crisis area as a percentage of GDP. Banking is measured as 2007 banking claims of the crisis area on a country as a percentage of GDP.

Table 2: 2012 real GDP per-capita detrended by individual country growth vs 2007 Crisis Area proximity controling for Chinese exports

	(1) CHN Exp	(2) Distance and CHN Exp	(3) Trade and CHN Exp	(4) Bank and CHN Exp	(5) Bank, Trade and CHN Exp
Distance		0.00169***			
		(0.000461)			
Trade PctGDP			-0.212***		-0.196**
			(0.0732)		(0.0754)
Bank PctGDP				-0.0271***	-0.0180***
				(0.00947)	(0.00665)
CHN Exp PctGDP	0.121	-0.0506	0.121	0.106	0.109
	(0.130)	(0.104)	(0.141)	(0.121)	(0.134)
Constant	91.06***	85.43***	96.48***	92.16***	96.87***
	(1.599)	(2.103)	(2.718)	(1.745)	(2.791)
Observations	105	104	105	104	104
R-squared	0.007	0.128	0.069	0.032	0.082

Note: Robust standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Distance is population weighted bilateral country distance from the nearest crisis area country from CEPII. Trade is measured as 2007 bilateral imports and exports across the entire crisis area as a percentage of GDP. Banking is measured as 2007 banking claims of the crisis area on a country as a percentage of GDP. CHN Exp are the 2007 exports to China as a percentage of GDP.

Table 3: Crisis Area proximity quartile mean and median 2012 real GDP per-capita detrended by individual country growth

Measure	Quartile	N	Mean	Median
Distance to EUR/US	1	33	84.96	84.82
	2	33	89.23	89.47
	3	33	93.25	96.61
	4	32	99.74	95.18
2007 Trade with EUR/US PctGDP	1	32	84.48	88.74
	2	32	89.80	89.45
	3	32	94.25	93.61
	4	32	98.74	95.95
2007 Fin with EUR/US PctGDP	1	32	88.55	88.74
	2	32	93.87	93.06
	3	32	91.64	93.18
	4	32	94.63	97.01

Note: Quartiles arranged so lower numbers are always more connected to the crisis area.

Table 4: Model Calibration — Common Parameters

Type	Parameter	Description	Value	Reasoning
Bank	δ	Banker's discount rate	0.95	Standard value from literature
Utility	β	Household's discount rate	0.95	Standard value from literature
Utility	σ	Inter-variety elasticity of substitution	5	Standard value from literature
Utility	ω	Curvature of labor disutility	1.3	Match Frisch wage elasticity of 3.
Utility	ρ	Household risk aversion	2	Standard value from literature
Firms	$\mathcal{H}$	Fraction of high cost firms	0.82	Fraction of US manufacturing firms that do not export from Bernard et al (2012)
Firms	a_L	Low cost productivity parameter	1	Normalized value
Firms	a_H	High cost productivity parameter	2.65	Match average productivity ratio between top 18% of firms and bottom 82% using Del Gatto et al (2007)'s firm productivity distribution estimates.
Firms	λ	Fraction of wages paid before production	1	Assume wages completely paid up front.
Firms	α	Labor share in output	0.64	From Hansen (1997).
Firms	γ	Fixed export cost	6	High cost firms do not export.
Firms	μ	Fraction of production lost when a firm defaults	0.7	Firms repay debts when both have their best draws.
Govt	G	Government spending	15	Match government spending / GDP for non-crisis countries.
Govt	ξ	Government discount factor	0.8	For a myopic government with a time horizon of 5 years.
Govt	ϕ	Fraction of debt remaining after default	0.6	Sturzenegger & Zettelmeyer (2008) country default data

Table 5: Model Calibration — Average BIS Banking Claims as a Fraction of GDP

Country Group	2007	2008-2012	Difference
Near to Crisis Area	40%	24%	-16%
Far from Crisis Area	35%	30%	-5%

Note: The Bahamas and Bermuda were excluded from the near country group because, as major international banking sectors with small economies, their banking claims to GDP ratios were not representative of the larger group.

Table 6: Model Calibration — State Transition Matrix

			Next Period State							
		Z Draw	High				Low			
	Z Draw	W Draw	19,726	18,859	18,343	17,144	19,726	18,859	18,343	17,144
		19,726	0.3965	0.1942	0.0065	0.0056	0.2614	0.128	0.0043	0.0037
	High	18,859	0.225	0.3656	0.0065	0.0056	0.1483	0.241	0.0043	0.0037
Current		18,343	0.0459	0.0746	0.2598	0.2223	0.0303	0.0492	0.1713	0.1466
Period		17,144	0.0459	0.0746	0.2598	0.2223	0.0303	0.0492	0.1713	0.1466
State		19,726	0.2946	0.1443	0.0048	0.0041	0.3632	0.1779	0.006	0.0051
	Low	18,859	0.1672	0.2717	0.0048	0.0041	0.2061	0.335	0.006	0.0051
		18,343	0.0341	0.0554	0.1931	0.1652	0.0421	0.0684	0.2381	0.2037
		17,144	0.0341	0.0554	0.1931	0.1652	0.0421	0.0684	0.2381	0.2037

Table 7: Model Calibration — Gross Interest Rates

Parameter	Description	Normal Times Good Draw	Normal Times Bad Draw	Late 2000s Crisis	Depression
r^f	Risk free investment rate	1.0136	1.0084	0.9834	1.0536
r^R	Repo rate	1.0413	1.0380	1.0276	1.0843
r^H	Uncollateralized borrowing rate	1.3000	1.3000	1.3000	1.3000

Table 8: Model Calibration — Parameters Simultaneously Determined to Match Data Moments

Type	Parameter	Description	Value	Reasoning
Consumer utility	α_F	Foreign consumer's utility coefficient on the foreign good	1.60	Adjust to match trade level.
Consumer utility	α_H	Home consumer's utility coefficient on the foreign good	0.63	$= \frac{1}{\alpha_F}$
Firms	τ	Iceberg trade costs	1.81 near; 2.34 far	Target total trade costs
Home Productivity	Z_G	Home high productivity draw	30.63 near; 33.91 far	Aggregate Home expected revenue equal to 100.
Home Productivity	Z_B	Home low productivity draw	28.00 near; 31.00 far	Aggregate Home expected revenue equal to 100.

Targeted Quantity	Target Value	Model Value
Near country trade	14.0	13.9
Far country trade	8.0	7.5
Near country total trade costs	0.90	0.89
Far country total trade costs	1.50	1.49
Near country expected output	100	99.7
Far country expected output	100	98.9

Table 9: Model Results — Near & Far Normal Times vs Crisis Period Steady-States

	Both Trade and Financial Shocks									
	Near					Far				
Description	Normal Times		Crisis Period		Diff	Normal Times		Crisis Period		Diff
Expected Home production	99.7	**100.0**	87.7	**88.7**	-12.1%	98.9	**100.0**	99.6	**100.1**	0.7%
Expected trade	13.9	**14.0**	13.0	**10.6**	-6.7%	7.5	**8.0**	7.2	**7.0**	-3.5%
Government Debt	17.4	**37.8**	17.4	**37.5**	0.0%	27.0	**46.3**	19.1	**52.7**	-29.2%
Tax rate	32.4%		37.0%		4.6%	34.3%		31.9%		-2.3%
Wage	4.13		4.13		0.2%	3.83		3.71		-3.3%
After tax wage	2.79		2.61		-6.6%	2.52		2.52		0.1%
After tax real wage	2.26		2.12		-6.2%	2.31		2.32		0.8%
Labor supply	11.86		9.75		-17.7%	12.65		12.96		2.4%
Low cost firm labor	38.10		31.57		-17.1%	39.29		40.11		2.1%
High cost firm labor	6.10		4.97		-18.6%	6.80		7.00		2.8%
Required effective return	4.13%		11.10%		6.97%	4.13%		5.94%		1.81%

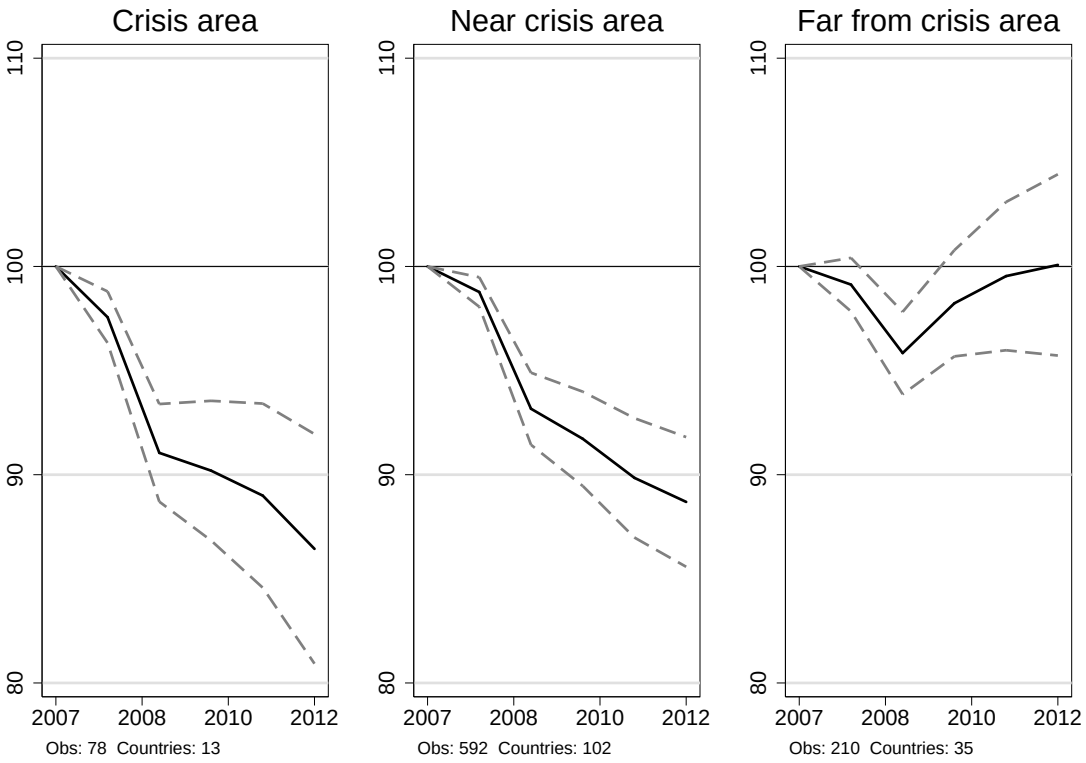
Note: Real world values provided in bold next to relevant items. Underlined real world values were explicitly targeted for model calibration. The Diff columns show percentage changes between normal and crisis times for items measured in quantity terms and differences for items measured as percentages.

Table 10: Model Results — Normal Times vs Crisis Period Steady-State Scenario Analysis

	Both Shocks		Only Trade Shock		Only Credit Shock	
Description	Near	Far	Near	Far	Near	Far
Expected Home production	-12.1%	0.7%	-1.7%	-1.9%	-10.5%	0.9%
Expected trade	-6.7%	-3.5%	-3.6%	-3.6%	-3.2%	0.0%
Government Debt	0.0%	-29.2%	0.0%	0.0%	0.0%	-21.7%
Tax rate	4.6%	-2.3%	0.5%	0.7%	3.9%	-1.6%
Wage	0.2%	-3.3%	-0.3%	-0.3%	0.2%	-2.0%
After tax wage	-6.6%	0.1%	-1.1%	-1.2%	-5.6%	0.4%
After tax real wage	-6.2%	0.8%	-0.5%	-0.5%	-5.8%	0.4%
Labor supply	-17.7%	2.4%	-1.4%	-1.6%	-16.5%	1.4%
Low cost firm labor	-17.1%	2.1%	-1.7%	-1.7%	-15.7%	1.3%
High cost firm labor	-18.6%	2.8%	-1.1%	-1.4%	-17.6%	1.5%
Required effective return	6.97%	1.81%	0.00%	0.00%	7.15%	1.48%

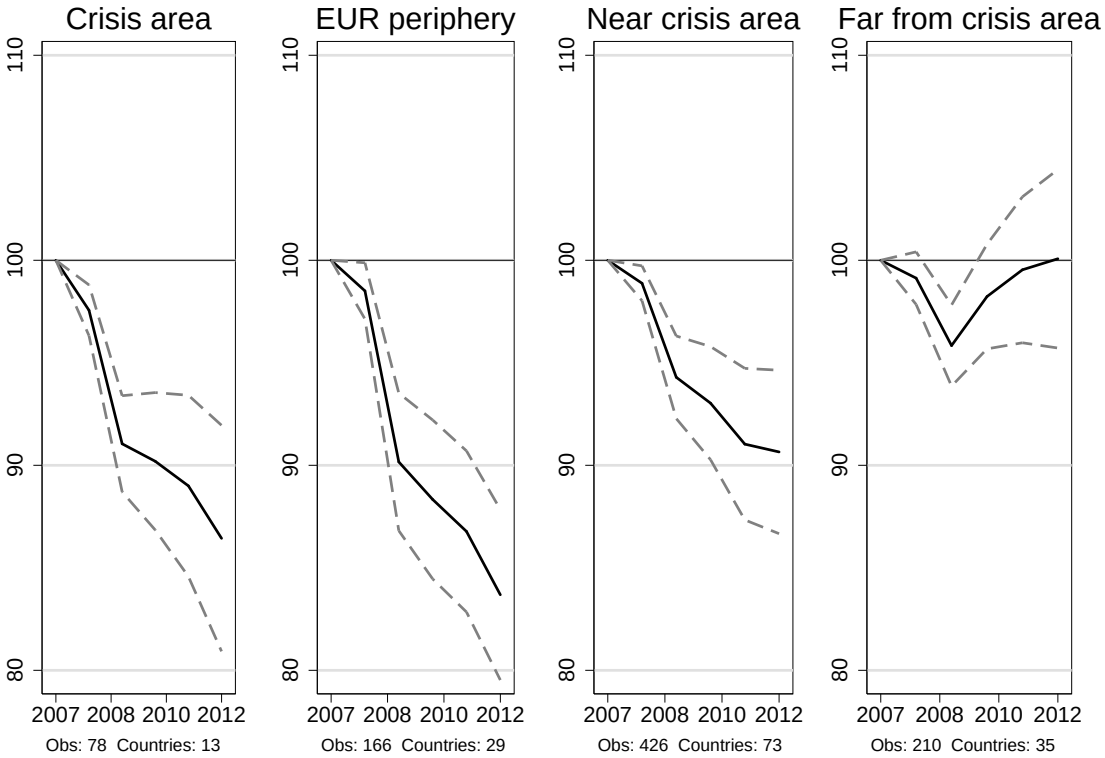
Note: The columns show changes between normal and crisis times, measured as percentage changes for items measured in quantity terms and in differences for items measured as percentages.

Figure 1: Average real GDP per capita index by country group: Distance



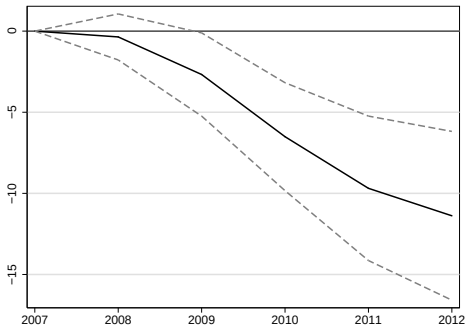
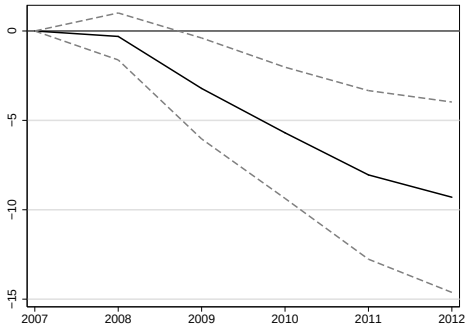
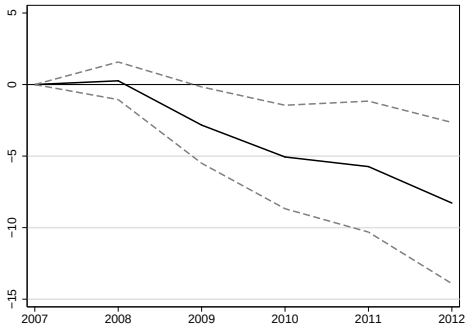
Note: Base year of 2007 is 100. Detrended by individual country growth from 2001 to 2007. The dotted lines are 95% confidence intervals. The crisis area is the US and Eurozone entering 2007 (Austria, Belgium, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain). κ-clustering based on minimum distance to a crisis area country was used to determine the near and far country groups.

Figure 2: Average real GDP per capita index by country group: Distance Ex-European periphery



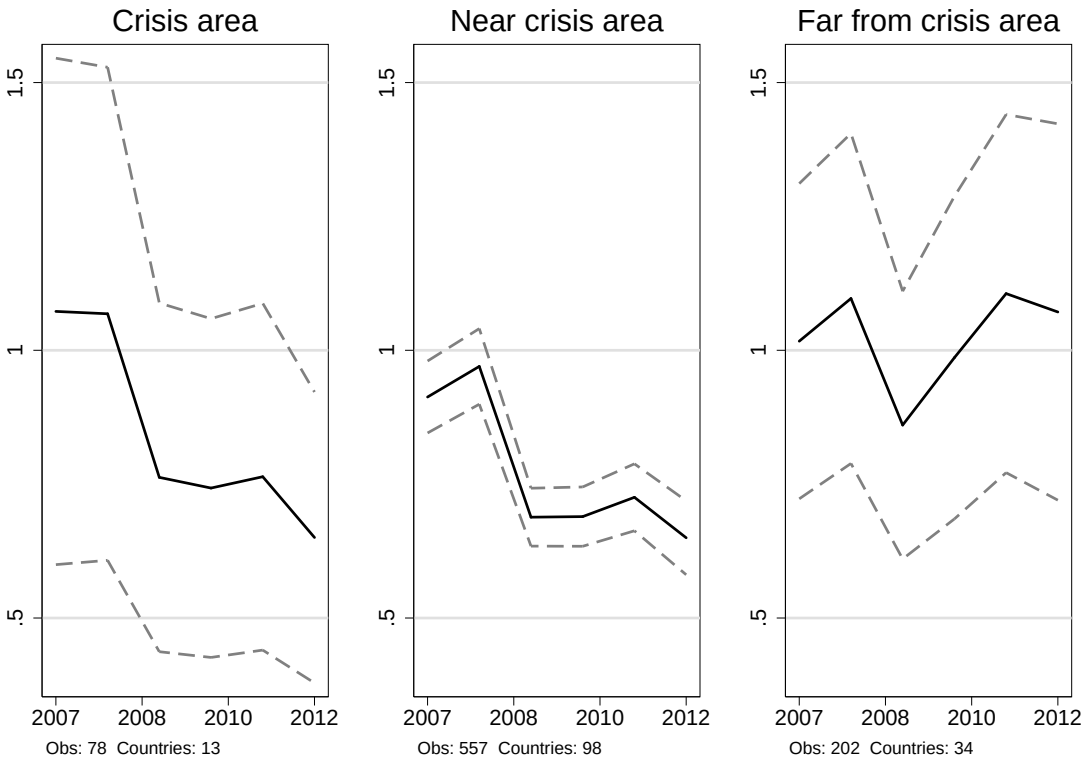
Note: Base year of 2007 is 100. Detrended by individual country growth from 2001 to 2007. Countries within 1,000 miles of the Eurozone are separated into the EUR periphery group. The dotted lines are 95% confidence intervals. The crisis area is the US and Eurozone entering 2007 (Austria, Belgium, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain). κ-clustering based on minimum distance to a crisis area country was used to determine the near and far country groups.

Figure 3: Average differences between close & far country groups by year

Country Group Delineation	**Plot**
Distance to the crisis area	
2007 Trade with the crisis area / GDP	
2007 Banking with the crisis area / GDP	

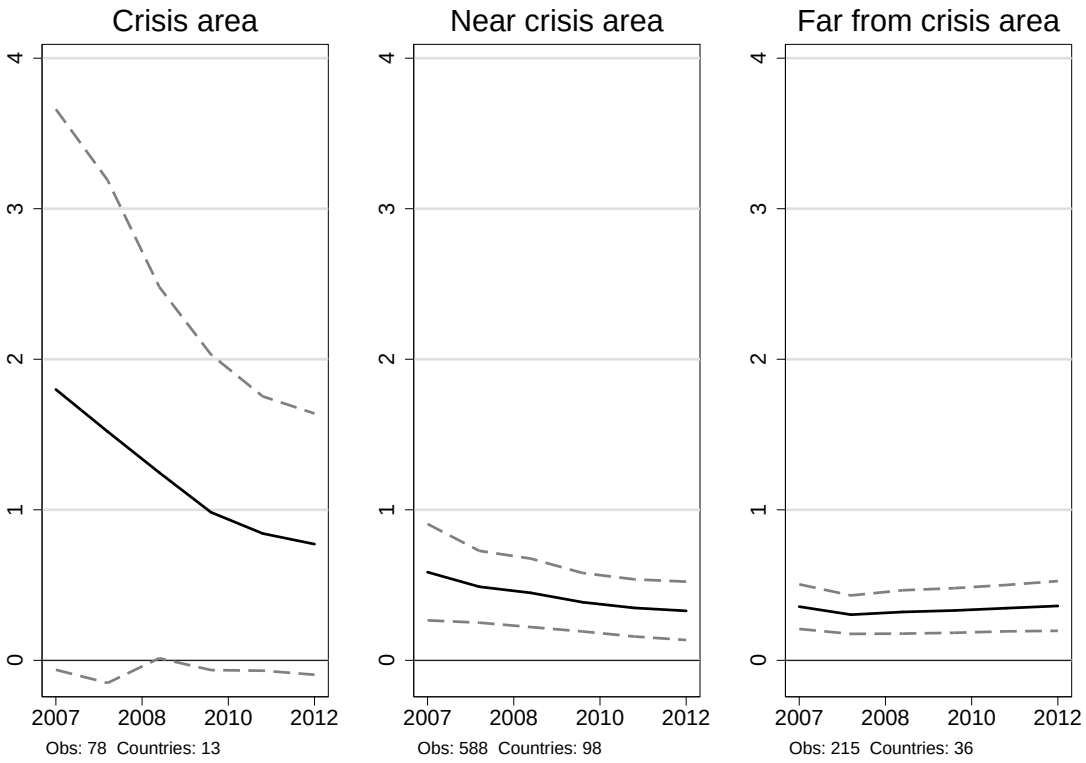
Note: Base year of 2007 is 100. Detrended by individual country growth from 2001 to 2007. Plots of yearly dummy variables of differences between the two non-crisis groups. Lower values mean the group that was more connected to the crisis area did on average worse than the less connected group. The dotted lines are 95% confidence intervals.

Figure 4: Average trade with the rest of the world by country group: Distance



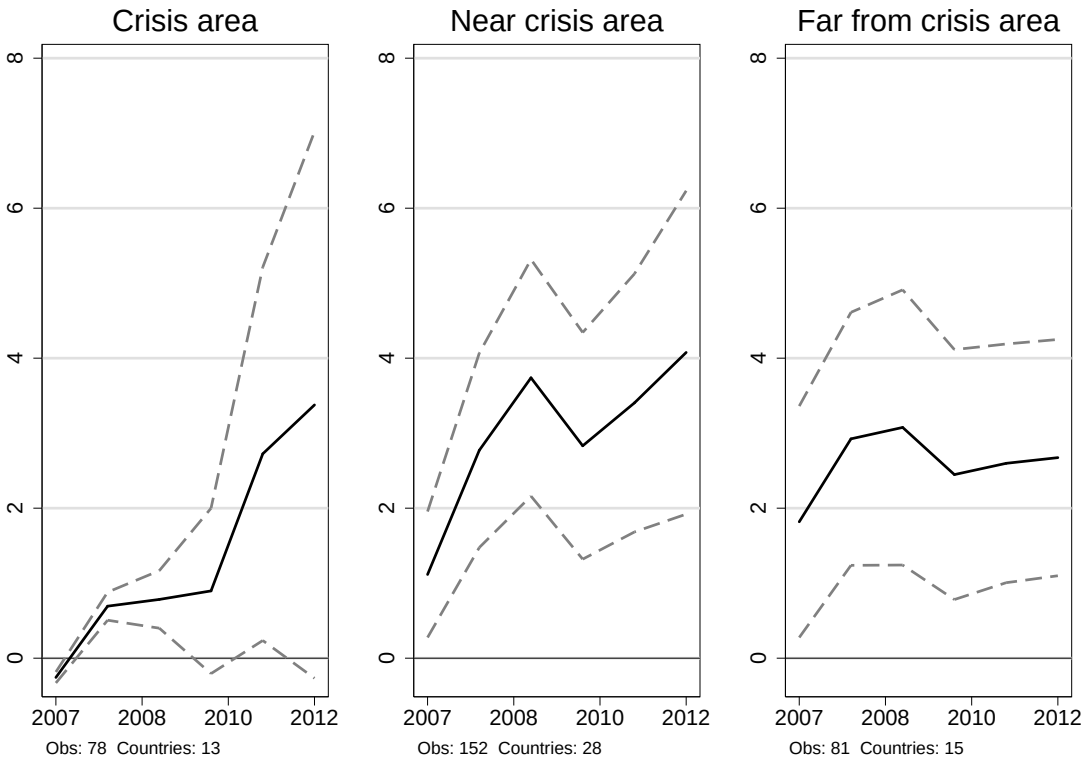
Note: The dotted lines are 95% confidence intervals. The crisis area is the US and Eurozone entering 2007 (Austria, Belgium, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain). κ-clustering based on minimum distance to a crisis area country was used to determine the near and far country groups. Divided by trend GDP extrapolated from 2007 using individual country growth from 2001 to 2007.

Figure 5: Average banking claims of the rest of the world by country group: Distance



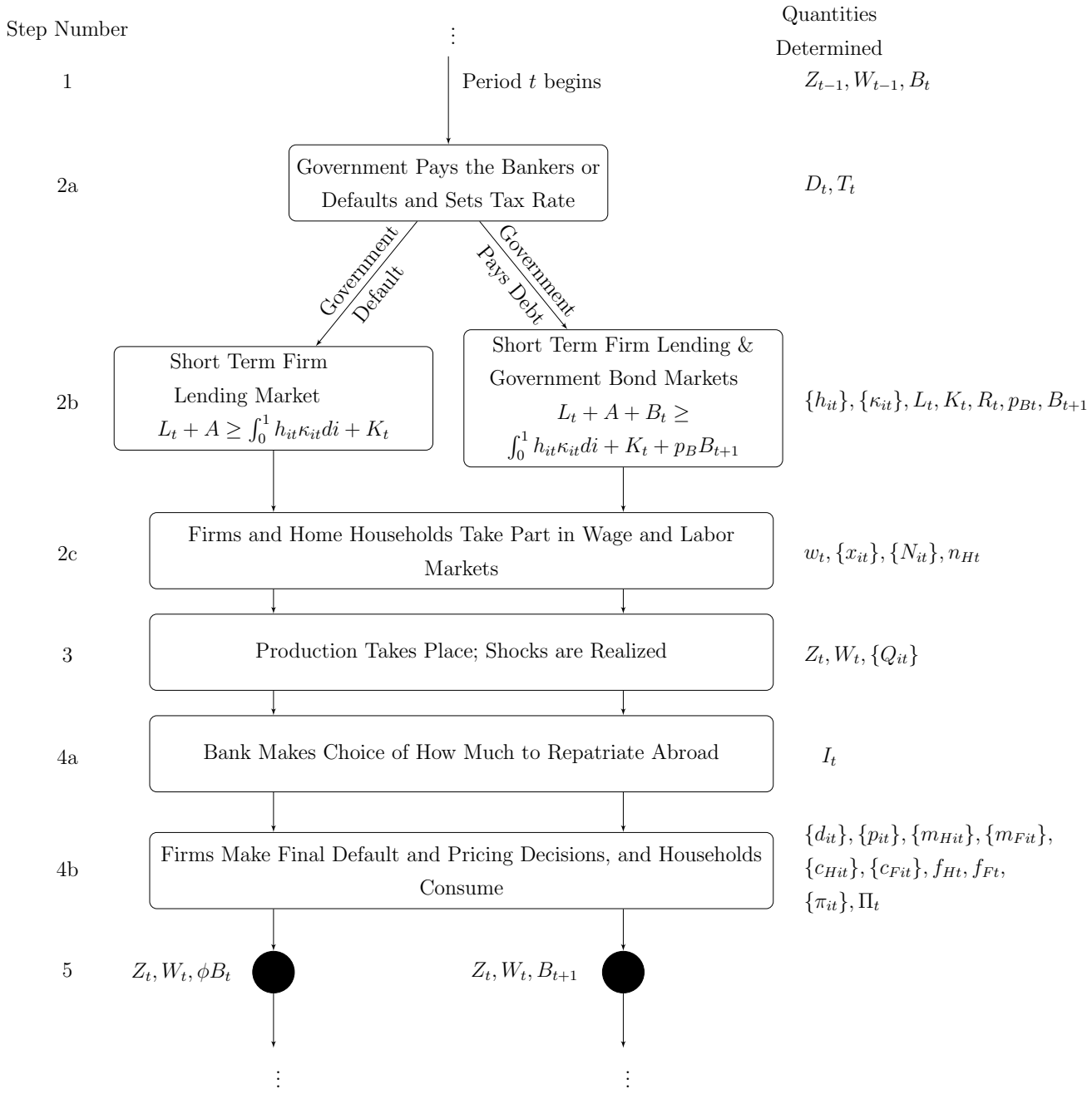
Note: The dotted lines are 95% confidence intervals. The crisis area is the US and Eurozone entering 2007 (Austria, Belgium, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain). κ-clustering based on minimum distance to a crisis area country was used to determine the near and far country groups. Divided by trend GDP extrapolated from 2007 using individual country growth from 2001 to 2007.

Figure 6: Average government bond spread vs US 10 bonds by country group: Distance



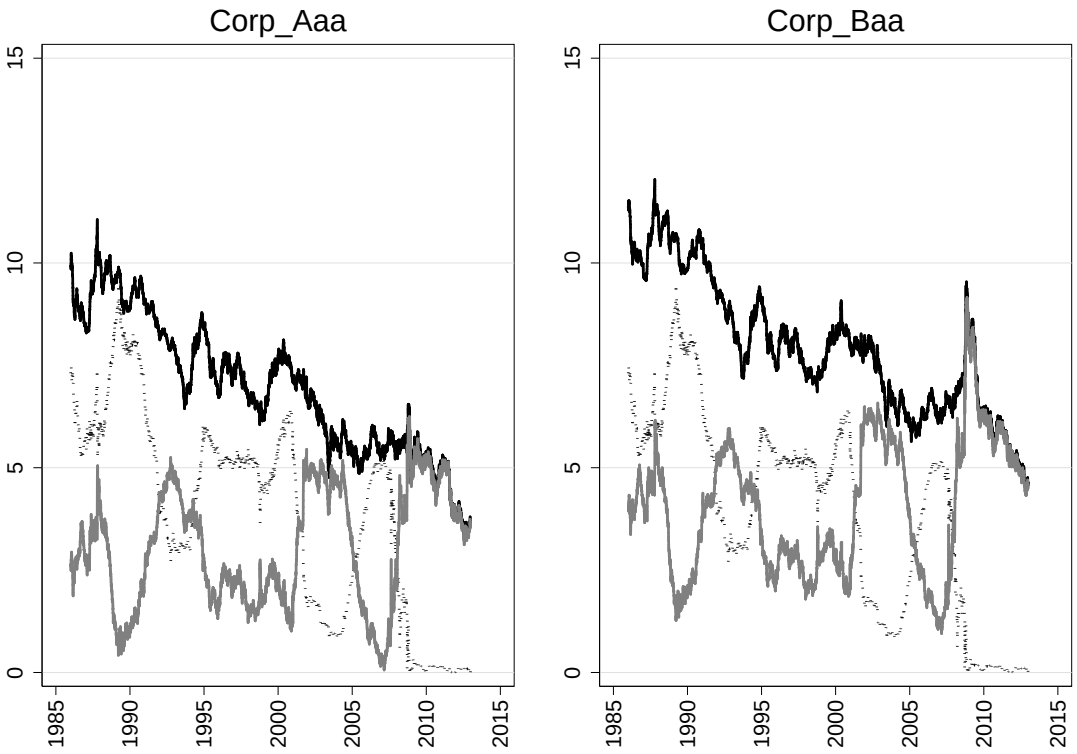
Note: The dotted lines are 95% confidence intervals. The crisis area is the US and Eurozone entering 2007 (Austria, Belgium, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain). κ-clustering based on minimum distance to a crisis area country was used to determine the near and far country groups. The plots show each group's annual average government bond yield spread over the US 10 year bond.

Figure 7: Period Timeline



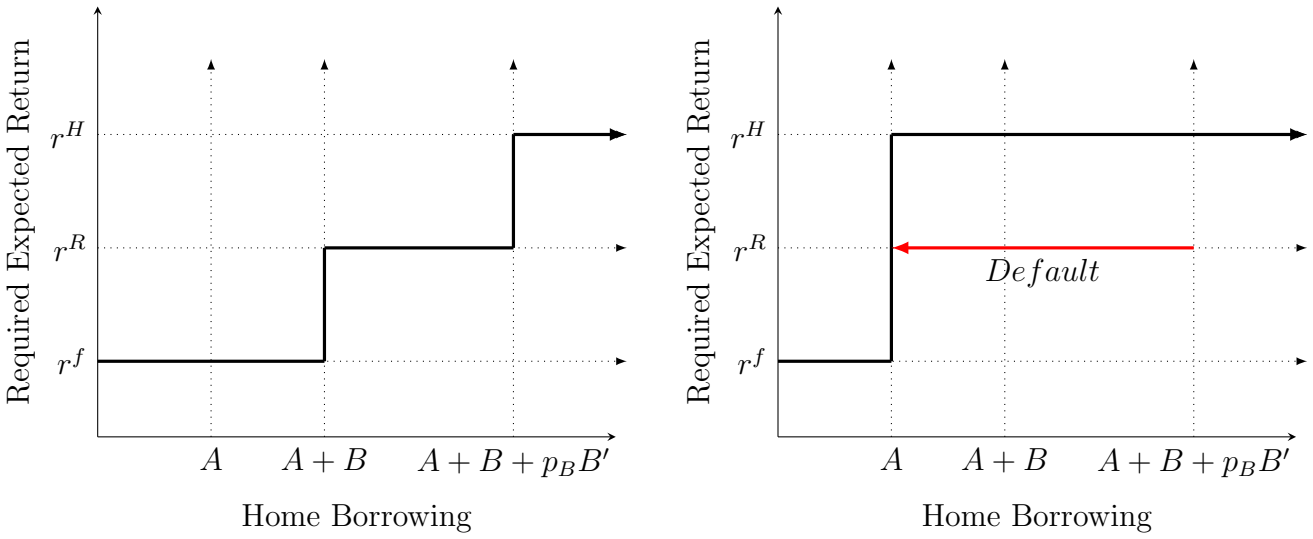
Note: All steps with the same number occur simultaneously.

Figure 8: US dollar interest rates



Note: The black line is the yield for the credit quality given in each subtitle. The dotted line is for the 3 month US Treasury rate. The grey line is the credit spread between the two. Source: US Federal Reserve and author's calculations.

Figure 9: Aggregate Interest Rate Schedule

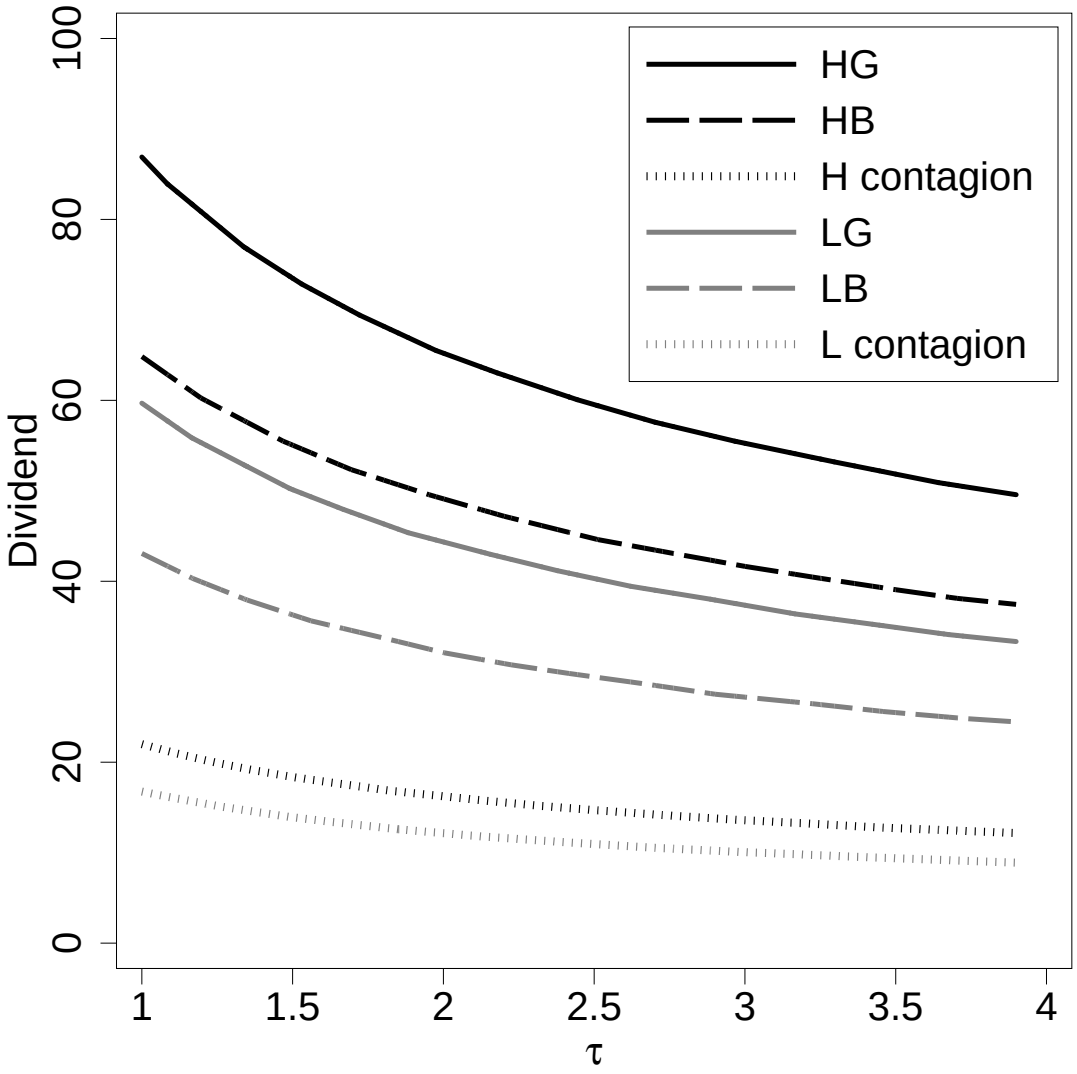


With Government Repayment

With Government Default

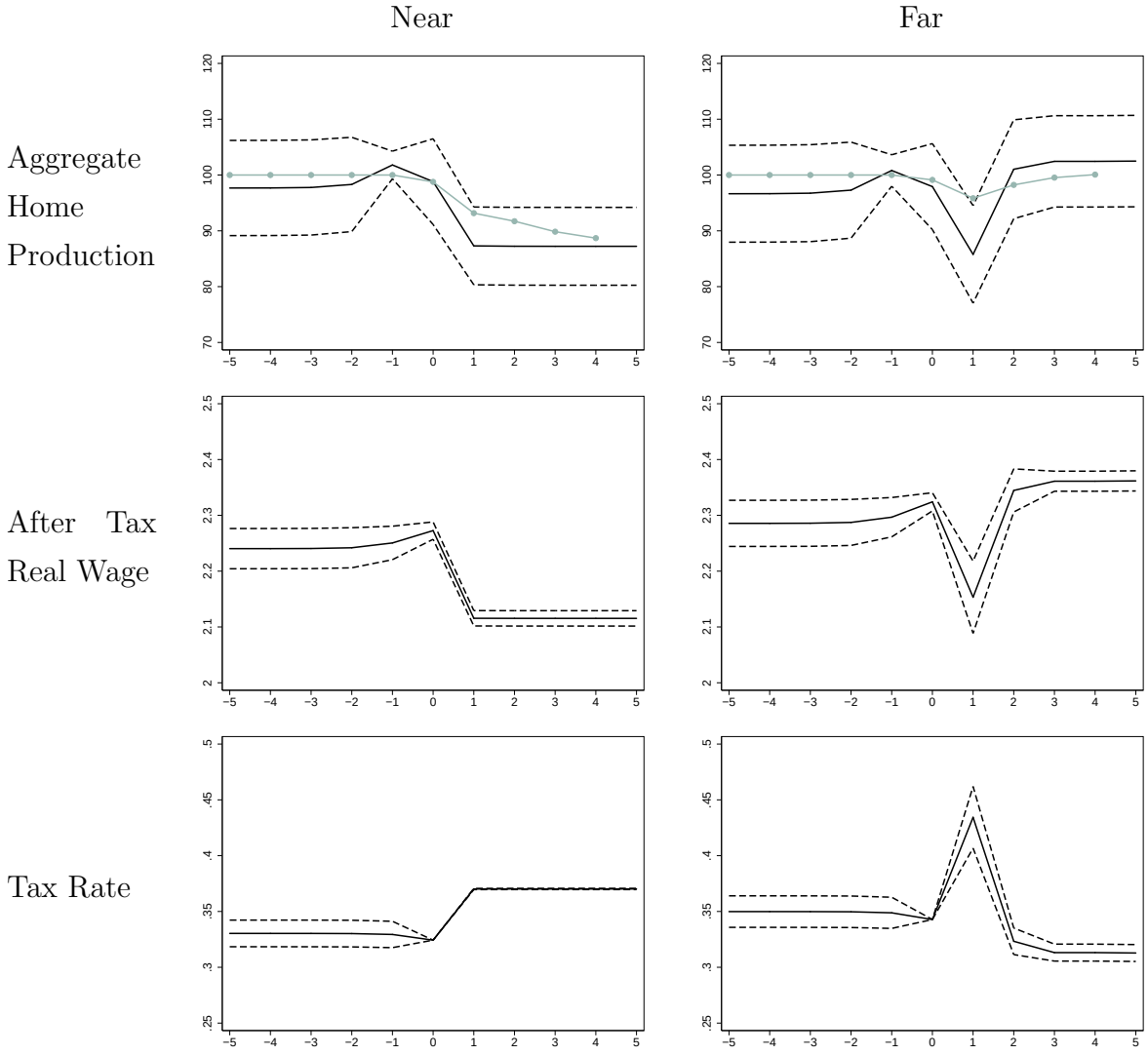
Note: Required expected return for Home firm and government borrowing vs. the aggregate amount of money these two groups wish to borrow. Home Borrowing is total borrowing by Home firms and the government. r^H is the rate that the bank can borrow at uncollateralized, r^R is the rate that the bank can borrow at with collateral, and r^f is the return on the risk free asset it can invest in.

Figure 10: Aggregate Home firm dividend vs. iceberg trade costs



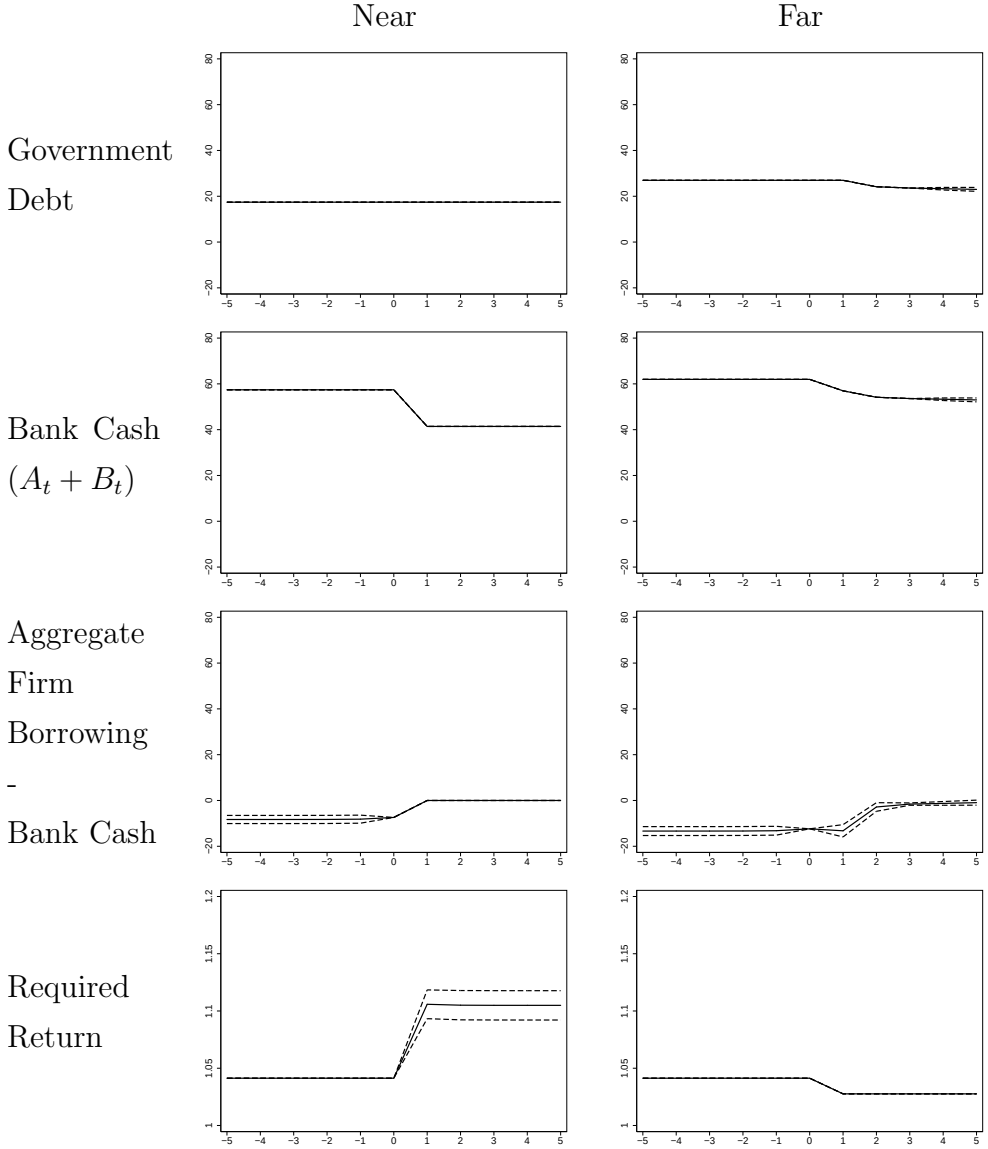
Note: Plot of the aggregate dividend across all Home firms in each of four states: the cross product of good and bad Z draws at Home and good and bad W draws in Foreign. The black lines are for high draws of Z and the grey for low draws. The solid lines are for good draws of W and the dashed ones for bad ones. The bottom two dotted lines are the differences between the results with good and bad Foreign draws keeping the Home state static to isolate the contagion effect: the higher the line the greater the contagion level.

Figure 11: Transition around a crisis at T=0 — Home production and wages



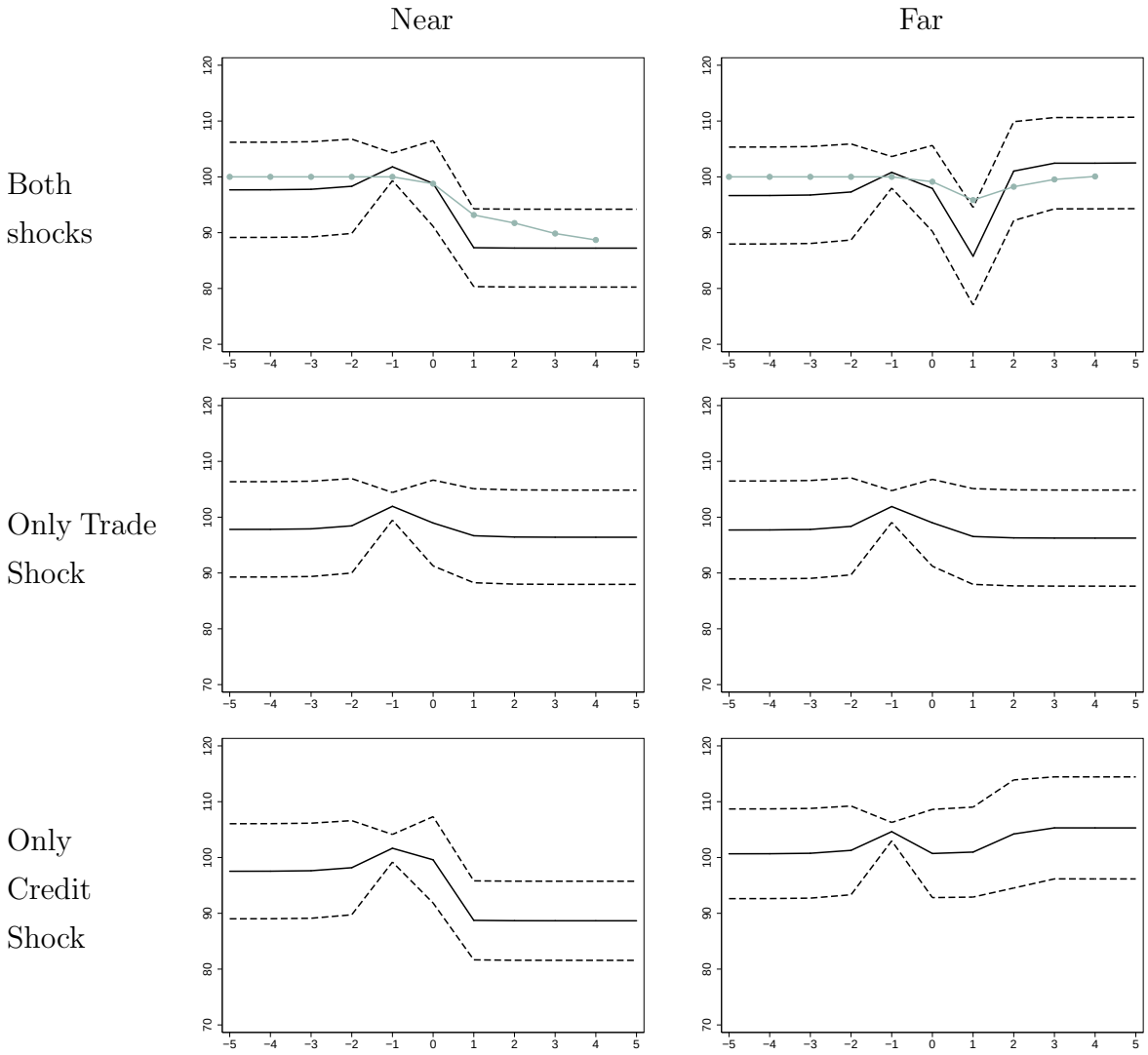
Note: Each panel plots eleven periods: 5 years before to 5 years after a crisis that commences during production at T=0. The state entering T=0 is assumed to be high output draws of both the Home productivity factor and Foreign state, at the corresponding steady-state government debt level. For the 5 preceding periods, the Foreign state draw is assumed to be a high one, and the average value across the Home productivity states and associated government debt levels is taken conditional on there being a high Home productivity realization entering period zero. Beginning during production in period zero and continuing through the subsequent 5 periods, it is assumed that there is a draw of the Foreign state corresponding to the late 2000s crisis period. The conditional expected values over the level of Home productivity and associated government debt levels are plotted. The dashed lines are two standard deviation confidence intervals, and the dotted ones are actual data.

Figure 12: Transition around a crisis at T=0 — Home assets



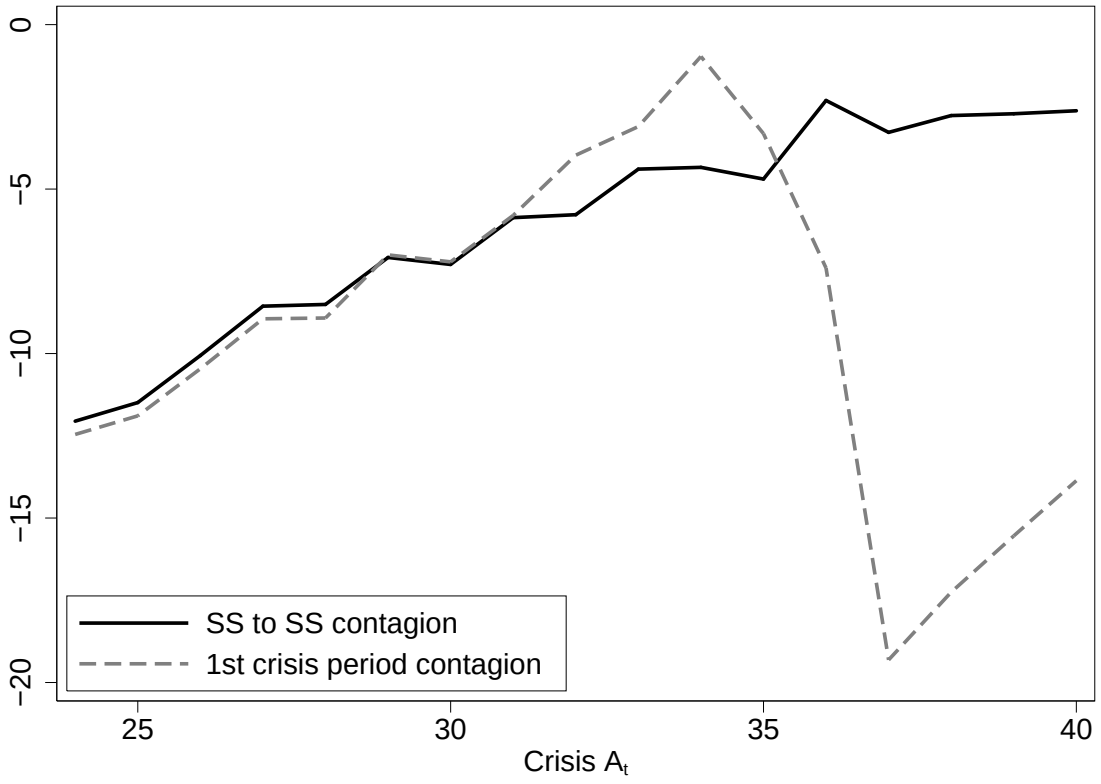
Note: Each panel plots eleven periods: 5 years before to 5 years after a crisis that commences during production at T=0. The state entering T=0 is assumed to be high output draws of both the Home productivity factor and Foreign state, at the corresponding steady-state government debt level. For the 5 preceding periods, the Foreign state draw is assumed to be a high one, and the average value across the Home productivity states and associated government debt levels is taken conditional on there being a high Home productivity realization entering period zero. Beginning during production in period zero and continuing through the subsequent 5 periods, it is assumed that there is a draw of the Foreign state corresponding to the late 2000s crisis period. The conditional expected values over the level of Home productivity and associated government debt levels are plotted. The dashed lines are two standard deviation confidence intervals.

Figure 13: Transition around a crisis at T=0 — Aggregate home production for counterfactual scenarios



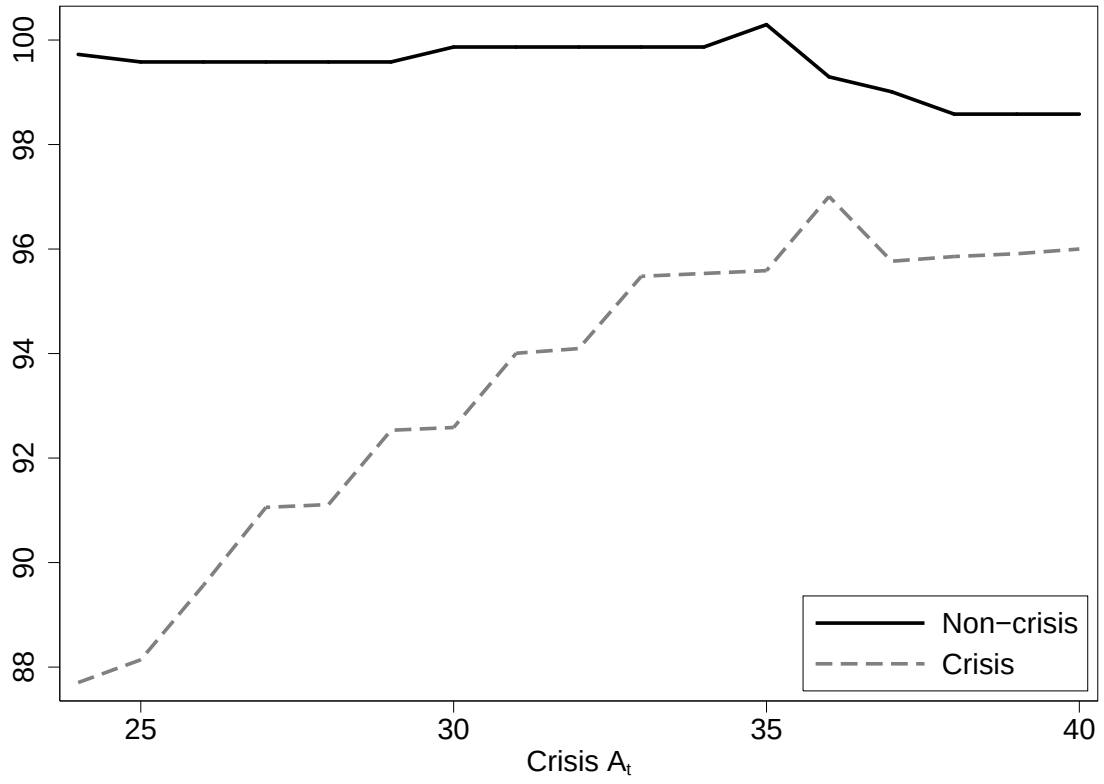
Note: Each panel plots eleven periods: 5 years before to 5 years after a crisis that commences during production at T=0. The state entering T=0 is assumed to be high output draws of both the Home productivity factor and Foreign state, at the corresponding steady-state government debt level. For the 5 preceding periods, the Foreign state draw is assumed to be a high one, and the average value across the Home productivity states and associated government debt levels is taken conditional on there being a high Home productivity realization entering period zero. Beginning during production in period zero and continuing through the subsequent 5 periods, it is assumed that there is a draw of the Foreign state corresponding to the late 2000s crisis period. The conditional expected values over the level of Home productivity and associated government debt levels are plotted. The dashed lines are two standard deviation confidence intervals, and the dotted ones are actual data.

Figure 14: Near country contagion with varying levels of capital controls



Note: the x-axis measures the crisis level of A_t, ranging from the near countries' average crisis level of 24 up through their non-crisis average of 40. The "SS to SS contagion" line plots the non-crisis steady-state to crisis state-steady level of contagion. The "1st crisis period contagion" line plots the decline in output from the non-crisis steady-state through the first period of a crisis.

Figure 15: Near country output with varying levels of capital controls



Note: the x-axis measures the crisis level of A_t, ranging from the near countries' average crisis level of 24 up through their non-crisis average of 40. The non-crisis line plots the normal times steady-state aggregate Home output, and the other line the crisis state-steady level.