The Great Recession: A Self-Fulfilling Global Panic[1]

Philippe Bacchetta
University of Lausanne
Swiss Finance Institute
CEPR

Eric van Wincoop
University of Virginia
NBER

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Abstract

While the 2008-2009 financial crisis originated in the United States, we witnessed steep declines in output, consumption and investment of similar magnitudes around the globe. This raises two questions. First, given the observed strong home bias in goods and financial markets, what can account for the remarkable global business cycle synchronicity during this period? Second, what can explain the difference relative to previous recessions, where we witnessed far weaker co-movement? To address these questions, we develop a two-country model that allows for self-fulfilling business cycle panics. We show that a business cycle panic will necessarily be synchronized across countries as long as there is a minimum level of economic integration. Moreover, we show that several factors generated particular vulnerability to such a global panic in 2008: tight credit, the zero lower bound, unresponsive fiscal policy and increased economic integration.

1 Introduction

The 2008-2009 Great Recession clearly had its origins in the United States, where an historic drop in house prices had a deep impact on financial institutions and markets. It is remarkable then, as illustrated in Figure 1, that the steep decline in output, consumption and investment during the second half of 2008 and beginning of 2009 was about the same in the rest of the world as in the United States.[1] This is surprising both in the context of existing theory and historical experience. Transmission channels in existing models depend critically on trade and financial linkages and on the type of shocks. A recent literature has shown that it is possible to have one-to-one transmission of shocks if goods and financial markets are perfectly integrated and there are credit rather than technology shocks.[2] But in reality goods and financial markets are far from perfectly integrated and there is significant home bias in both goods and asset trade. As illustrated in van Wincoop (2013), a model with credit shocks that captures the observed financial home bias will have partial transmission at best. Consistent with this, Rose and Spiegel (2010) and Kamin and Pounder (2012) find that there is little relation between financial linkages that countries have with the U.S. and the decline in their GDP growth and asset prices during 2008-2009.[3]

The close co-movement of business cycles illustrated in Figure 1 is also unusual from an historical perspective. Figure 2 shows that during the Great Depression the decline in output in the rest of the world was much smaller then in the United States. Perri and Quadrini (2012) show that business cycle co-movement during the 2008-2009 recession stands out significantly relative to previous recessions since 1965. Hirata, Kose and Otrok (2013) find that over the past 25 years the global

[1] Even outside of Europe, which had by far the largest foreign exposure to U.S. asset backed securities, the business cycle decline was of similar magnitude.

[2] Examples are Devereux and Sutherland (2011), Kollmann, Enders and Muller (2011) and Perri and Quadrini (2012). It is well known that with technology shocks output tends to be negatively correlated across countries even in models with perfect goods and financial market integration.

[3] Kalemli-Ozcan et al. (2013) find that financial integration has a negative effect on business cycle synchronization outside of crisis times and a zero effect during crisis times. They also find that the bulk of the increase in synchronization during the 2008-2009 crisis is associated with an undetermined common shock. The same conclusions are also drawn in the October 2013 World Economic Outlook by the IMF, which in addition concludes that trade links also cannot explain the close co-movement during the crisis.

component of business cycles has actually declined relative to local components (region and country-specific). This then leads to two questions that we aim to address in this paper. First, given the limited extent of goods and financial integration, how can we explain that the sharp decline in business cycles was similar in the rest of the world as in the United States during the Great Recession? Second, what can explain the difference relative to previous recessions?

To answer these questions we develop a two-country model that explains the recession as resulting from a self-fulfilling shock to expectations (or panic) as opposed to an exogenous shock to fundamentals. This by itself is not the key contribution of the paper as there exists a significant literature on self-fulfilling business cycles already.[4] Moreover, the view that the Great Recession should be viewed as a result of a self-fulfilling expectation shock has already gained significant traction in the literature.[5] When defining the Great Recession as the sharp decline in output over the three quarters from Q3, 2008 to Q1, 2009, this view is quite natural.[6] Alternative explanations based on credit or wealth shocks do not hold up. There was a much smaller decline in credit in the rest of the world than in the U.S., while even in the U.S. the decline was spread out over many years rather than concentrated during th three quarters of steep output decline (see Figure 4).[7] An increasing body of research indeed points against a credit shock as an explanation for the recession.[8] Household wealth did decline sharply in the United States, but

[4]See Schmitt-Grohe (1997) for a review of the earlier models. Apart from models of self-fulfilling beliefs listed in the next footnote that relate specifically to the Great Recession, other recent contributions include Farmer (2012b), Benhabib, Wang and Wen (2012) and Angelatos and La'O (2013).

[5]Examples include Aruoba and Schorfheide (2013), Bacchetta, Tille and van Wincoop (2012), Farmer (2012a), Heathcote and Perri (2012), Perri and Quadrini (2012) and Mertens and Ravn (2013).

[6]The speed of recovery since the steep and synchronized decline in business cycles during this period varies substantially across countries. This can be explained by focusing on more standard differences in fundamentals, such as the sharp decline in house prices in the U.S. not experienced by most other countries, and is not the focus of this paper.

[7]Figure 4 is based on BIS data on total credit to the private sector for the U.S. and non-U.S. G-7 countries. In the non-U.S. G7 we see a continued increase in private credit during and after the crisis. In the U.S. there was a gradual decline in private credit through 2012. This was largely the result of the gradual deleveraging of U.S. households and was not concentrated during the 3 quarters of the sharp decline in output.

[8]Chari, Christiano and Kehoe (2008) document that bank credit actually increased in the U.S. during the second half of 2008 (both consumer and industrial bank credit). Adrian, Colla and

the rest of the world did not experience a similar drop in wealth.[9] More generally, as discussed above, pure fundamental shocks in the United States would only be partially transmitted to the rest of the world under partial economic integration.[10]

The core of our contribution lies in explaining the synchronization of business cycles. In particular, in the context of a self-fulfilling expectation shock, we explain why it is necessarily synchronized across countries even if economic integration is limited.[11] This result is related to a large literature showing that the very existence of multiple equilibria depends on the value of fundamentals. Generally, there is only a good equilibrium when fundamentals are very strong, only a bad equilibrium when fundamentals are very weak and multiple equilibria for intermediate values of fundamentals. While such fundamentals are usually exogenous, here the endogenous state of the foreign economy is a key fundamental that affects the existence of multiple equilibria in the domestic economy. If the foreign economy is strong, the domestic economy may not be vulnerable to a self-fulfilling bad equilibrium, and the other way around. Similarly, if the foreign economy is really weak, only a bad equilibrium may be feasible in the domestic country. Their interconnectedness makes it impossible for one country to have self-fulfilling favorable beliefs about

Shin (2013) find that a decline in bank credit to firms in 2009 was replaced by an equal increase in bond financing. Also consistent with the absence of a large credit shock, Kahle and Stulz (2013) use firm level data to show that there was no relationship between the drop in investment by firms and their bank dependence. Helbling, Huidrom, Kose and Otrok (2011) estimate a global VAR to find that a global credit shock accounts for only 10% of the global drop in GDP in 2008-2009. Nguyen and Qiuan (2013) use firm level survey data to argue that the impact of the crisis on Eastern European firms took the form of a demand shock rather than a credit crunch.

[9] With the exceptions of some smaller countries like Ireland and Spain, the rest of the world did not experience a collapse of housing wealth. While the stock market did decline significantly everywhere, it accounts for a smaller fraction of financial wealth in the rest of the world than in the United States.

[10] The view that the Great Recession was the result of an expectation shock is also consistent with the language used in the press and among policy makers at the time, which was consistent with panicked beliefs about the future. On September 18, 2008, U.S. Treasury Secretary Henry Paulson famously announced that if Congress did not pass the $700 bln. TARP bailout, "we won't have an economy on Monday".

[11] The literature on self-fulfilling business cycles mentioned above consists of closed economy models and therefore does not address this question. Perri and Quadrini (2012) is an exception in that they have a two-country model with self-fulfilling credit shocks. But they assume that goods and financial markets are perfectly integrated, generating perfect co-movement of business cycles even if credit shocks are exogenous.

the future while the other country has very negative beliefs about the future. Limited interconnectedness implies that their fate will be common. A self-fulfilling business cycle panic, if it happens, will then necessarily be global. We show that the threshold level of economic integration to make sure that this is the case does not need to be high. It is therefore possible to still have significant home bias in trade and asset holdings as seen in the data.

This argument for synchronization is quite general and should be valid under a wide range of models with self-fulfilling beliefs when applied to a two-country framework. The particular model of self-fulfilling beliefs that we adopt here is also aimed at addressing the second question, of why the extent of business cycle synchronization during the Great Recession was unusual from an historical perspective. We argue that this was the case because of series of factors that generated particular vulnerability to a global panic in 2008: tight credit, the zero lower bound and constraints on fiscal policy. In order to capture these elements, we adopt a simple two-period New Keynesian model in which firms are borrowing constrained.

The self-fulfilling beliefs are a result of several inter-linkages between the present (period 1) and the future (period 2). The future affects the present as beliefs of lower and riskier second-period income lead to higher first period saving. As consumption falls, output and firm profits decline.[12] The present also affects the future as lower profits lead to an expectation of lower future economic activity and greater sensitivity of firms to future shocks. This lowers expected future output and increases uncertainty about future output. Figure 3, which is based on survey data, shows that there was indeed a large drop in expected GDP growth and an increase in its perceived variance. Moreover, these changes in beliefs were of similar magnitude in the rest of the world as in the United States.[13]

The model implies particular vulnerability to a global panic at the end of 2008.

[12] This relates to the classic Paradox of Thrift, where higher saving implies lower demand, which reduces output and may actually end up lowering saving. We will discuss the Paradox of Thrift in the context of our model in Section 5. For recent contributions, see Eggertsson and Krugman (2012), Eggertsson (2010) and Christiano (2004).

[13] The data comes from Consensus Economics, who survey about 250 "prominent financial and economic" forecasters. Each January, forecasters are asked to give probabilities for GDP growth rate intervals for the current year. We compute the average and the variance for each country, as explained in more detail in Appendix A. For the non-US data line, we use the average across the 17 other countries in the sample.

First, we show that when credit conditions are easier, self-fulfilling panics are not feasible in equilibrium. Tight credit makes firms more susceptible to default when hit by a drop in demand that lowers profits. Second, the fact that we were close to the zero lower bound at the start of the Great Recession reduced the potential stabilizing role of monetary policy. We show that self-fulfilling panics are not possible when the central bank can conduct significant countercyclical policy. Third, there were constraints on countercyclical fiscal policy, especially due to historically high debt levels. We show that with significant countercyclical fiscal policy self-fulfilling panics would again be ruled out. Finally, consistent with the discussion about synchronization above, the significant increase in both trade and financial integration over the past two decades generated particular vulnerability to a panic that is global in nature.

To present the basic mechanism, we analyze a benchmark model without investment, financial asset trade or uncertainty. In that context, it is possible to derive theoretically the conditions under which global panics occur. Our main result, stated in Proposition 2, is that partial integration is sufficient to guarantee that business cycles are perfectly synchronized during a panic. We show numerically that the extent of integration required is relatively small. A panic limited to one country is not possible with sufficient integration. When we extend the model to include investment, financial asset trade and uncertainty, the results are similar but can only be derived numerically.

The remainder of the paper is organized as follows. Section 2 describes the benchmark model. Section 3 analyzes the equilibria and determines when business cycle panics are global. Section 4 shows that countries are more vulnerable to global panics with tight credit, low interest rates or rigid fiscal policies. Section 5 considers various extensions and Section 6 concludes.

2 The Model

In this section we describe the benchmark model. There are two countries, Home and Foreign, and two periods, 1 and 2. The basic two-period New Keynesian structure is similar to closed economy models found in the literature, starting with

Krugman (1998).[14] Prices are pre-set, while wages are flexible. There is partial integration of goods markets through trade. Countries are in financial autarky, with financial assets (claims on firms, a bond, and money) only held domestically. Goods are only used for consumption, abstracting from investment. There are households, firms, a government and a central bank. There is no uncertainty about the future (period 2). The only potential shock in the model is a sunspot shock in period 1 that can generate self-fulfilling shifts in expectations. In Section 5 we examine several extensions, including investment, uncertainty and financial integration.

2.1 Households

Households make consumption and leisure decisions in both periods. Households in the Home country maximize

$$\frac{1}{1-\gamma}c_1^{1-\gamma} + \lambda l_1 + \beta\left(\frac{1}{1-\gamma}c_2^{1-\gamma} + \lambda l_2\right) \tag{1}$$

where l_t is the fraction of time devoted to leisure in period t and c_t is the period-t consumption index of Home and Foreign goods:

$$c_t = \left(\frac{c_{H,t}}{\psi}\right)^{\psi}\left(\frac{c_{F,t}}{1-\psi}\right)^{1-\psi} \tag{2}$$

where

$$c_{H,t} = \left(\int_0^{n_{H,t}} c_{H,t}(j)^{\frac{\mu-1}{\mu}}dj\right)^{\frac{\mu}{\mu-1}} \tag{3}$$

$$c_{F,t} = \left(\int_0^{n_{F,t}} c_{F,t}(j)^{\frac{\mu-1}{\mu}}dj\right)^{\frac{\mu}{\mu-1}} \tag{4}$$

Here $c_{H,t}$ is the consumption index of Home goods and $c_{F,t}$ the consumption index of Foreign goods. Consumption of respectively the Home and Foreign good j is $c_{H,t}(j)$ and $c_{F,t}(j)$. The number of Home and Foreign goods in period t is $n_{H,t}$ and $n_{F,t}$, which are equal to the number of Home and Foreign firms. The elasticity of substitution among goods of the same country is $\mu > 1$, while the elasticity of substitution between Home and Foreign goods is 1 (we examine non-unitary

[14] See Mankiw and Weinzierl (2011) or Fernandez-Villaverde et al. (2012) for recent contributions. Aghion, Bacchetta and Banerjee (2000) analyze a small open economy.

elasticities in Section 5). There is a preference home bias towards domestic goods as we assume $\psi > 0.5$. The specification is symmetric for the Foreign country, with the overall consumption index denoted as c_t^* and $c_{H,t}^*(j)$, $c_{F,t}^*(j)$ denoting the consumption of individual Home and Foreign goods consumption by Foreign households.

The parameter ψ captures the degree of goods market integration. A value of $\psi > 0.5$ implies a positive preference for domestic goods, which is well-known to be indistinguishable from introducing positive trade costs without a preference home bias.[15] The limit $\psi = 0.5$ implies perfect goods market integration. As we will see, $\psi = 0.5$ also implies that in equilibrium $c_t = c_t^*$, so that financial markets are effectively complete even though there is no asset trade.[16] This is a feature that results specifically from the Cobb-Douglas specification and is familiar from Cole and Obstfeld (1991). We can then think of $\psi = 0.5$ as perfect economic integration across the two countries.

In period 1 Home households earn labor income $W_1(1 - l_1)$, where W_1 is the nominal wage rate. They also earn a dividend Π_1^C and receive a transfer of $\bar{M}_1$ in money balances from the central bank. They use these resources to consume, pay a tax T_1 to the government, buy Home nominal bonds with interest rate i and hold money balances:

$$\int_0^{n_{H,1}} P_{H,1}(j)c_{H,1}(j)dj + \int_0^{n_{F,1}} S_1 P_{F,1}(j)c_{F,1}(j)dj + T_1 + B + M_1 = W_1(1 - l_1) + \Pi_1^C + \bar{M}_1 \tag{5}$$

where $P_{H,t}(j)$ and $P_{F,t}(j)$ are the price of respectively Home and Foreign good j in the Home and Foreign currency. S_t is the nominal exchange rate in period t (Home currency per unit of Foreign currency).

In period 2 Home households earn labor income $W_2(1 - l_2)$, earn a dividend Π_2^C, receive $(1 + i)B$ from bond holdings, carry over M_1 in money balances from period 1, and receive an additional money transfer of $\bar{M}_2 - \bar{M}_1$ from the central bank. These resources are then used to consume, pay a tax T_2 to the government

[15] See for example Anderson and van Wincoop (2003).

[16] Financial markets are complete when the ratio of marginal utilities of consumption across the two countries is equal to the real exchange rate, which is 1 when $\psi = 0.5$.

and hold money balances M_2:[17]

$$\int_0^{n_{H,2}} P_{H,2}(j)c_{H,2}(j)dj + \int_0^{n_{F,2}} S_2 P_{F,2}(j)c_{F,2}(j)dj + T_2 + M_2 =$$
$$W_2(1-l_2) + \Pi_2^C + (1+i)B + M_1 + (\bar{M}_2 - \bar{M}_1) \tag{6}$$

We assume a cash-in-advance constraint, with the buyer's currency being used for payment:

$$\int_0^{n_{H,t}} P_{H,t}(j)c_{H,t}(j)dj + \int_0^{n_{F,t}} S_t P_{F,t}(j)c_{F,t}(j)dj \leq M_t \tag{7}$$

The constraint will always bind in period 2. It will bind in period 1 when the nominal interest rate i is positive. When $i = 0$, the constraint will generally not bind in period 1.

Households choose consumption and leisure to maximize (1). The first-order conditions are

$$c_1^{-\gamma} = \beta(1+i)\frac{P_1}{P_2}c_2^{-\gamma} \tag{8}$$

$$c_{H,t}(j) = \left(\frac{P_{H,t}(j)}{P_{H,t}}\right)^{-\mu} c_{H,t} \tag{9}$$

$$c_{F,t}(j) = \left(\frac{P_{F,t}(j)}{P_{F,t}}\right)^{-\mu} c_{F,t} \tag{10}$$

$$c_{H,t} = \psi\frac{P_t}{P_{H,t}}c_t \tag{11}$$

$$c_{F,t} = (1-\psi)\frac{P_t}{S_t P_{F,t}}c_t \tag{12}$$

$$\frac{W_t}{P_t} = \lambda c_t^{\gamma} \tag{13}$$

where

$$P_{H,t} = \left(\int_0^{n_{H,t}} P_{H,t}(j)^{1-\mu}dj\right)^{\frac{1}{1-\mu}}$$
$$P_{F,t} = \left(\int_0^{n_{F,t}} P_{F,t}(j)^{1-\mu}dj\right)^{\frac{1}{1-\mu}}$$
$$P_t = P_{H,t}^{\psi}[S_t P_{F,t}]^{1-\psi}$$

[17] As usual in finite-time models, there is an implicit assumption on the final use of money, e.g., agents need to return the money stock to the central bank.

$P_{H,t}$ and $P_{F,t}$ are price indices of Home and Foreign goods that are denominated in respectively Home and Foreign currencies. P_t is the overall price index, denominated in the Home currency.

Equation (8) is a standard intertemporal consumption Euler equation. (9)-(10) represent the optimal consumption allocation across goods within each country. (11)-(12) represent the optimal consumption allocation across the two countries. (13) represents the consumption-leisure trade-off. As usual, the inverse of γ measures the intertemporal rate of substitution. However, in equation (13) γ also measures the wage elasticity to consumption.

There is an analogous set of first-order conditions for Foreign households. Other than for Home and Foreign prices and price indices, we only need to add * superscripts to the variables and exchange ψ and $1-\psi$. The Foreign price index is $P_t^* = (P_{H,t}/S_t)^{1-\psi} P_{F,t}^{\psi}$.

2.2 The Government and the Central Bank

The government and central bank policies are analogous in the two countries. We therefore again only describe the Home country. The Home government only buys Home goods. The total government consumption index is analogous to the CES index for private Home consumption:

$$g_t = \left(\int_0^{n_{H,t}} g_t(j)^{\frac{\mu-1}{\mu}} dj \right)^{\frac{\mu}{\mu-1}} \tag{14}$$

In the benchmark case we will simply set $g_t = 0$. But we will also consider a positive constant level of government spending, where $g_t = \bar{g}$. Moreover, in Section 4 we consider the role of countercyclical fiscal policy, where $g_1 = \bar{g} - \Theta(c_1 - \bar{c})$, with $\bar{c}$ consumption in the non-panic equilibrium of the model and $\Theta \geq 0$.

Optimal allocation of government spending across the different goods implies

$$g_t(j) = \left(\frac{P_{H,t}(j)}{P_{H,t}} \right)^{-\mu} g_t \tag{15}$$

We have $\int_0^{n_{H,t}} P_{H,t}(j) g_t(j) dj = P_{H,t} g_t$. Since the timing of taxation across the two periods does not matter due to Ricardian equivalence, we simply impose the balanced budget condition

$$T_t = P_{H,t} g_t \tag{16}$$

The central bank's behavior is modeled as in other two-period models (e.g., Krugman, 1998, or Mankiw and Weinzierl, 2001). The central bank credibly sets second-period money supply to stabilize second-period prices. We assume that the central bank has a zero inflation target from period 1 to period 2, so that $P_2 = P_1$. Since the cash-in-advance constraint is binding in period 2, we have $\bar{M}_2 = P_2 c_2$, and the second-period price level can be controlled through the second period money supply.

In the first period the central bank sets the nominal interest rate i. For now we will assume that the central bank sets the interest rate such that $(1+i)\beta = 1$. This corresponds to the interest rate in the flexible price equilibrium of the model. We will see that the non-panic equilibrium of the model then corresponds to the flexible price equilibrium. In Section 4 we consider what happens when during a panic the central bank lowers the interest rate to stimulate demand. Such a policy will not avert a panic when we are close to the zero-lower bound. The central bank then has limited ability to counter a business cycle decline and the equilibrium will be similar to that without any countercyclical central bank action.

2.3 Firms

The number of firms operating in period 1 is based on prior decisions and therefore taken as given. We normalize it at 1 for both countries, so $n_{H,1} = n_{F,1} = 1$. At the end of period 1 firms decide whether to continue to operate in period 2. We denote the number of period-2 firms by $n_{H,2} = n$ and $n_{F,2} = n^*$. We do not allow new firms to enter.[18]

We focus our description mainly on Home firms. Results are analogous for Foreign firms. Output of Home firm j in period t is

$$y_t(j) = (AL_t(j))^\alpha \tag{17}$$

where $L_t(j)$ is labor input, A a constant labor productivity parameter and α is between 0 and 1.

Firms set prices at the start of each period. This Keynesian assumption only bites for period 1 as no unexpected shocks happen after firms set prices at the start

[18] We could allow for entry under a fixed cost. If the fixed cost is large enough we revert to our current setup. Lower fixed costs that leads to limited entry, only partially replacing exiting firms, will only affect results quantitatively, not qualitatively.

of period 2. As we will see in Section 4, in period 1 there may be multiple equilibria, with consumption lower when a panic equilibrium occurs. This occurs with some exogenous probability as it is driven by a sunspot whose arrival is unknown in advance. Firms need to set prices at the start of period 1 before knowing whether the panic will occur. Production will then adjust to demand. Lower consumption during a panic lowers demand for goods and therefore production. Labor demand is then adjusted to satisfy the demand for goods. This Keynesian aspect is critical to the self-fulfilling business cycle panic in the model.

Since prices in period 1 are preset, and their level does not matter for what follows, we simply assume that all Home firms set the same price of P_{H1}, so that $P_{H1}(j) = P_{H1}$. Similarly, for the Foreign firms $P_{F1}(j) = P_{H1}$. In period 2 Home firm j sets its price $P_{H,2}(j)$ to maximize profits

$$\Pi_2(j) = P_{H,2}(j)y_2(j) - \frac{W_2}{A}y_2(j)^{1/\alpha} \tag{18}$$

subject to

$$y_2(j) = c_{H,2}(j) + g_2(j) + c^*_{H,2}(j) = \left(\frac{P_{H,2}(j)}{P_{H,2}}\right)^{-\mu}\left[\psi\frac{P_2}{P_{H,2}}c_2 + g_2 + (1-\psi)\frac{S_2P^*_2}{P_{H,2}}c^*_2\right] \tag{19}$$

The optimal price is a markup $\mu/(\mu-1)$ over the marginal cost:

$$P_{H,2}(j) = \frac{\mu}{\mu-1}\frac{W_2}{\alpha A}y_2(j)^{\frac{1-\alpha}{\alpha}} \tag{20}$$

Second-period profits are then

$$\Pi_2(j) = \kappa\frac{1}{A}W_2y_2(j)^{1/\alpha} \tag{21}$$

where $\kappa = [\mu(1-\alpha)+\alpha]/[(\mu-1)\alpha]$. Since all firms face the same demand and the same wage, they set the same price. From the definition of the Home price index we have $P_{H,2} = P_{H,2}(j)n^{1/(1-\mu)}$.

We now turn to period 1. An important ingredient of the model is that lower profits of firms in period 1 can reduce economic activity, and therefore income, in period 2. Together with the negative effect of period 2 income on consumption, and therefore profits, in period 1, this leads to a circular relationship that can give rise self-fulfilling expectations. We model the negative impact of period 1 profits on period 2 economic activity through borrowing constraints that can give

rise to bankruptcy of firms. When period 1 losses are too large and firms are unable to fill the gap through borrowing, they will cease operations in period 2. Bankruptcy should more generally be seen as a methaphor for a much broader range of ways that period 1 firm losses can impact future economic activity. One could alternatively assume that firms continue to operate at a smaller scale by for example reducing branches or departments, reducing investment, or reducing worker training. All of these generate additional funds that may avoid bankruptcy, but nonetheless have the same effect of reducing period 2 production.[19]

We assume some heterogeneity of firms in order to avoid the extreme that either all or none of the firms go bankrupt at the end of period 1. The only difference across firms in period 1 is a fixed cost. A fraction $1-\overline{n}$ of firms face an additional real cost z in period 1. This cost captures business costs other than wages.[20] As discussed further at the end of Section 3.4, the binomial distribution of the cost across firms is assumed only for analytical convenience and is not critical to the results.

Total profits of Home firm j in period 1, $\widetilde{\Pi}_1(j)$, are equal to

$$\widetilde{\Pi}_1(j) = \Pi_1 - P_1 z(j) = P_{H,1} y_1 - W_1 L_1 - P_1 z(j) \tag{22}$$

where $z(j) = 0$ for a fraction $\bar{n}$ of firms and $z(j) = z$ for a fraction $1-\bar{n}$ of firms. It is also useful to define Π_1 as period-1 profits before paying this cost. When firm j is unable to fully pay the fixed cost, it is declared bankrupt and cannot produce in period 2. We assume that $z(j)$ does not affect aggregate resources and is paid to an agency. In case of bankruptcy, the agency seizes Π_1. The agency operates at no cost and transfers its income to households.

Since $\Pi_1 > 0$, the $\bar{n}$ firms for which $z(j)$ is zero always have positive profits in period 1 and therefore do not need to borrow to continue their operation into period 2. The other $1-\bar{n}$ firms may need to borrow when their first-period profits are negative. But they face a maximum limit on their borrowing capacity. Let $D(j)$ be borrowing by firm j at the end of period 1. The firm then owes $(1+i)D(j)$

[19] Even if we take the bankruptcy in the model literally, we show in an extension in Section 5.4 that self-fulfilling panics can happen in the model without any firms actually going bankrupt. Just the belief that Great Depression style widescale bankruptcies might occur is sufficient, even if it does not actually materialize.

[20] We choose to do so through an additive term in profits only because it simplifies the algebra. Results would not change fundamentally if instead we introduced differences in firm productivity, which interacts multiplicatively with $W_1 L_1$.

in period 2. It is assumed that this can be no larger than a fraction ϕ of second period profits:

$$(1+i)D(j) \leq \phi \Pi_2(j) \tag{23}$$

This standard borrowing constraint reflects that lenders can seize at most a fraction ϕ of second period profits in case of non-payment. Second-period profits are positive and known at the end of period 1.

The $1-\bar{n}$ firms facing the cost z are fragile in that they will go bankrupt if their debt limit is insufficient to cover negative profits in period 1. This is the case when

$$\Pi_1 + \phi \frac{\Pi_2}{1+i} < P_1 z \tag{24}$$

Another way to look at the bankruptcy condition is to define the real quantity of funds π available to pay for the fixed cost:

$$\pi \equiv \pi_1 + \phi \frac{\pi_2}{1+i} \tag{25}$$

where $\pi_1 = \Pi_1/P_1$ and $\pi_2 = \Pi_2/P_2$. From (24), the $1-\bar{n}$ fragile firms will go bankrupt when

$$\pi < z \tag{26}$$

Therefore the number of firms in period 2 is either 1 or $\overline{n}$, depending on whether $\pi \geq z$ or $\pi < z$.

Let D denote aggregate borrowing by firms. The total dividends received by households include dividends from firms and from the service agency. Dividends received in periods 1 and 2 are

$$\Pi_1^C = \Pi_1 + D \tag{27}$$

$$\Pi_2^C = n\Pi_2 - (1+i)D \tag{28}$$

While we have discussed production in period 2, a brief comment is in order about production in period 1. As mentioned, this is based on a prior decision as firms need to commit in advance to produce. But of course it only makes sense to produce if a positive profit is anticipated. If the only equilibrium in the model is such that no firms will default ($\pi > z$), then it is clearly always optimal to produce as $\pi > z$ implies that the present value of profits will be positive even for firms that face a positive z.[21] But we will see that there may be multiple equilibria, with

[21] Note that the present value is $\pi_1 + \pi_2/(1+i) - z > \pi - z > 0$.

either no defaults ($\pi > z$) or positive defaults ($\pi < z$). In the latter case the firms that default at the end of period 1 earn only first period profits $\pi_1 - z$, which will be negative. Which of these outcomes occurs depends on a period 1 sunspot that has some probability. But as long as this probability is not too big, it will always be optimal for firms to commit to produce because the present value of profits will be positive in the no-default equilibrium.[22]

2.4 Market Clearing

For the Home country the market clearing conditions are

$$y_t(j) = c_{H,t}(j) + g_t(j) + c^*_{H,t}(j) \quad t = 1, 2 \tag{29}$$

$$n_{H,t} L_t = 1 - l_t \quad t = 1, 2 \tag{30}$$

$$M_t = \overline{M}_t \quad t = 1, 2 \tag{31}$$

$$B = D \tag{32}$$

These represent respectively the goods markets clearing conditions, the labor market clearing condition, the money market clearing condition and the bond market clearing condition. There is an analogous set of market clearing conditions for the Foreign country.

If we substitute into the household budget constraints (5)-(6) the bond, money and labor market clearing conditions, along with the dividend expressions (27)-(28), we get

$$P_{H,t} c_{H,t} + P_{H,t} g_t + S_t P_{F,t} c_{F,t} = \int_0^{n_{H,t}} P_{H,t}(j) y_t(j) dj \tag{33}$$

This says that national consumption is equal to GDP. The trade balance is therefore zero. Indeed, multiplying the goods market clearing condition (29) by $P_{H,t}(j)$ and aggregating and substituting into the right hand side of (33), gives the balanced trade condition

$$S_t P_{F,t} c_{F,t} = P_{H,t} c^*_{H,t} \tag{34}$$

Using the expressions for $c_{F,t}$ and $c^*_{H,t}$, this can also be written as

$$P_t c_t = S_t P^*_t c^*_t \tag{35}$$

[22] More generally, even firms with a positive z will choose to produce when $(1-p)E[u_{c_1}(\pi_1 + \pi_2/(1+i) - z)|no\ sunspot] + pE[u_{c_1}(\pi_1 - z)|sunspot] > 0$, where p is the probability of the sunspot arrival and $u_{c_1} = c_1^{-\gamma}$ is the marginal utility from period 1 consumption.

The nominal value of consumption is equal across the two countries. This does not imply that real consumption is equal as the real exchange rate $S_t P_t^*/P_t$ is not necessarily equal to 1 when $\psi > 0.5$. Only when markets are perfectly integrated ($\psi = 0.5$) is the real exchange rate equal to 1 and $c_t = c_t^*$.

Together with the definitions of the price indices, (35) also gives an expression for relative prices that we will use below:

$$\frac{P_{H,t}}{P_t} = \left(\frac{c_t^*}{c_t}\right)^{\frac{1-\psi}{2\psi-1}} \tag{36}$$

The Foreign relative prices are the reciprocal: $P_{F,t}/P_t^* = P_t/P_{H,t}$.

2.5 Equilibrium

Appendix B provides a description of the main equilibrium conditions. Assuming $(1+i)\beta = 1$ and $g_t = 0$, the equilibrium can be reduced to a set of 6 equations in c_1, c_1^*, π, π^*, n and n^*:

$$c_1 = \frac{1}{\theta} n^{(1-\delta)\zeta} (n^*)^{\delta\zeta} \tag{37}$$

$$c_1^* = \frac{1}{\theta} n^{\delta\zeta} (n^*)^{(1-\delta)\zeta} \tag{38}$$

$$\pi = c_1 - \frac{\lambda}{A} c_1^{\gamma+1/\alpha} \left(\frac{P_1}{P_{H,1}}\right)^{1/\alpha} + \frac{\phi\beta\kappa\lambda}{A} (c_1)^{\gamma+1/\alpha} \left(\frac{P_1}{P_{H,1}}\right)^{1/\alpha} n^{-\frac{\mu}{(\mu-1)\alpha}} \tag{39}$$

$$\pi^* = c_1^* - \frac{\lambda}{A} (c_1^*)^{\gamma+1/\alpha} \left(\frac{P_1^*}{P_{F,1}}\right)^{1/\alpha} + \frac{\phi\beta\kappa\lambda}{A} (c_1^*)^{\gamma+1/\alpha} \left(\frac{P_1^*}{P_{F,1}}\right)^{1/\alpha} (n^*)^{-\frac{\mu}{(\mu-1)\alpha}} \tag{40}$$

$$n = \begin{matrix} \overline{n} & \text{if } \pi < z \\ 1 & \text{if } \pi \geq z \end{matrix} \tag{41}$$

$$n^* = \begin{matrix} \overline{n} & \text{if } \pi^* < z \\ 1 & \text{if } \pi^* \geq z \end{matrix} \tag{42}$$

where

$$\theta = \left(\frac{\lambda\mu}{(\mu-1)\alpha A}\right)^{\alpha/(1-\alpha+\alpha\gamma)}$$

$$\zeta = \frac{\alpha + \mu(1-\alpha)}{(\mu-1)(1-\alpha+\alpha\gamma)}$$

$$\delta = (1-\psi)/[(1-\alpha+\alpha\gamma)(2\psi-1) + 2(1-\psi)]$$

and the relative prices depend on c_1/c_1^* as in (36).

Appendix B provides algebraic details behind these equations. Equations (37)-(38) are derived by combining the Home and Foreign counterpart of the optimal second period price setting equation (20), the labor supply schedule $W_2/P_2 = \lambda c_2^{\gamma}$, $P_{H,2}(j)/P_{H,2} = n^{1/(\mu-1)}$, the consumption Euler equations and the assumed monetary policy. Note that the relationship between the number of firms and consumption depends on the parameter ζ. If it is zero, the number of firms has no impact on income and consumption. This would be the case when $\alpha = 1$ and $\mu = \infty$. In that case production is linear and goods are perfect substitutes. The number of firms is then irrelevant. A smaller number of firms reduces real income and consumption when either the production function is concave ($\alpha < 1$) or goods are imperfect substitutes ($\mu < \infty$). In the former case it essentially reduces aggregate productivity, while in the latter case it raises the cost of living.

Equation (39) is the expression for available funds $\pi = \pi_1 + \phi\pi_2/(1+i)$, using $W_t/P_t = \lambda c_t^{\gamma}$, (35) and the fact $c_2 = c_1$ from the consumption Euler equations. Equation (40) is the Foreign counterpart for available funds. After substituting the expression (36) for the relative price, available funds depend on c_1, c_1^*, n and n^*. Finally, (41)-(42) follow from the description of default in Section 2.3.

Before turning to the solution of the model, some brief comments are in order about the flexible price equilibrium, where first-period prices are perfectly flexible. We show in Appendix B that the equilibrium is then unique. This results from the absence of a Keynesian demand effect. Independent of parameters, first-period consumption is $c_1 = c_1^* = 1/\theta$, while first-period profits are $\pi_1 = \pi_1^* = [\mu(1-\alpha) + \alpha]/(\mu\theta)$. We will assume that in the flexible price equilibrium first-period profits of all firms are positive:

Assumption 1 $z < [\mu(1-\alpha) + \alpha]/(\mu\theta)$

The right hand side of the expression in Assumption 1 is equal to $\pi_1 = \pi_1^*$ in the flexible price equilibrium. We then also have $z < \pi$ since $\pi_2 > 0$, so that no firms go bankrupt ($n = n^* = 1$). Finally, we find that the equilibrium interest rates are given by $(1+i)\beta = (1+i^*)\beta = 1$. As mentioned above, this corresponds to the policy we assume in our benchmark model. The global non-panic equilibrium in the benchmark Keynesian model will then correspond exactly to the flexible price equilibrium.

3 Multiple Equilibria and Global Panics

The model can generate multiple equilibria with either $n = 1$ (no bankruptcies) or $n = \overline{n}$ (with bankruptcies). When both equilibria exist, we call the equilibrium with bankruptcies the *panic* equilibrium as it is simply generated by low expectations. There are potentially four equilibria, characterized by the values of n and n^*. We refer to equilibria where $n = n^*$ as symmetric equilibria. The case where $n = n^* = 1$ is a global non-panic equilibrium. If in addition there is an equilibrium where $n = n^* = \bar{n}$ we refer to it as a *global panic*. But there may also be asymmetric equilibria, where only one country panics and the other does not. There are potentially two asymmetric equilibria, with either $n = \bar{n}$ and $n^* = 1$ or $n = 1$ and $n^* = \bar{n}$.

In this section we first focus on symmetric equilibria in which $n = n^*$. In that case first-period consumption, output and profits are also equal across the two countries. Then we look at equilibria when countries are in autarky, where $\psi = 1$. Finally, we consider all equilibria for any value of ψ between 0.5 and 1. We will show that when economies are in autarky ($\psi = 1$), asymmetric equilibria always exist. However, when countries are somewhat integrated, i.e., ψ is below some cutoff, there are only symmetric equilibria and a panic is necessarily global.

3.1 Symmetric Equilibria

Considering symmetric equilibria allows us to clearly illustrate the mechanism behind a global panic. Moreover, considering global panics first is natural as in the absence of a global panic equilibrium the model does not feature any type of panic equilibrium, including asymmetric panics.

It is immediate from (37)-(42) that $n = n^*$ implies $c_1 = c_1^*$ and $\pi = \pi^*$. The equilibria are then characterized by (c_1, π, n) that satisfy

$$c_1 = \frac{n^\zeta}{\theta} \tag{43}$$

$$\pi = c_1 - \frac{\lambda}{A} c_1^{\gamma+1/\alpha} + \phi\beta \frac{\mu(1-\alpha)+\alpha}{\mu\theta} n^{\zeta-1} \tag{44}$$

$$n = \begin{cases} \overline{n} & \text{if } \pi < z \\ 1 & \text{if } \pi \geq z \end{cases} \tag{45}$$

Substituting (43) into (44) we can write available funds π as a function of only

n. Let $\pi(1)$ and $\pi(\overline{n})$ represent available funds without and with bankruptcies in the symmetric equilibrium. We will assume that parameters are such that available funds are higher without bankruptcies:

Assumption 2 $\pi(1) > \pi(\bar{n})$

This can be written in terms of a condition on the various parameters in the model.[23] A sufficient, but not necessary, condition for this to hold is that $\zeta \geq 1$, which implies $\alpha\gamma(\mu - 1) \leq 1$.

Together with Assumption 1, which implies that $z < \pi(1)$, the equilibria follow directly from (43)-(45) and are summarized in the following proposition.

Proposition 1 *When Assumptions 1 and 2 hold, there are one or two symmetric equilibria. They are characterized by:*

1. $(n, c_1) = (1, 1/\theta)$ *if* $\pi(\overline{n}) \geq z$
2. $(n, c_1) = (1, 1/\theta)$ *or* $(n, c_1) = (\bar{n}, \overline{n}^{\zeta}/\theta)$ *if* $\pi(\overline{n}) < z < \pi(1)$

For the case where $\phi = 0$, so that $\pi = \pi_1$, Figure 5 illustrates the multiple equilibria in Proposition 1. The hump-shaped curve represents the first-period profits function (44). The vertical lines represent (43) for the two levels of n and the cut-off point is determined by the level of z. When $\zeta > 1$, both vertical lines cross the profit schedule when it is upward sloping. When z is in the intermediate range ($\pi(\overline{n}) < z < \pi(1)$), there are two equilibria, A and B. Equilibrium A is a good one, which we refer to as the non-panic equilibrium. First-period consumption and profits are high and no firms go bankrupt ($n = 1$). Equilibrium B is the bad one, which we refer to as the panic equilibrium. First-period consumption and profits are low and $1 - \overline{n}$ firms go bankrupt.

The presence of two equilibria is a result of the possibility of self-fulfilling business cycle panics. This occurs due to reinforcing linkages between periods 1 and 2. The link from period 2 to period 1 is standard as low expected period 2 income leads to low period 1 consumption. The link from period 1 to period 2 operates through profits and bankruptcies. Low period 1 consumption leads to

[23] The condition is $\left(\bar{n}^{-\zeta} - 1\right) + \frac{1}{\kappa}\left(\bar{n}^{\kappa} - 1\right) + \phi\beta\left(\bar{n}^{-\zeta} - \frac{1}{\bar{n}}\right) > 0$. The condition is not satisfied for a high γ as real wages then decline significantly during a panic, which raises profits. We will return to this issue in Section 3.5.

low period 1 firm profits, which leads to bankruptcies and therefore a low number of firms in period 2. This implies low period 2 income, making the belief of low period 2 income self-fulfilling.

It is useful to emphasize that this is by no means the only possible way to model the link from the present to the future. One can think of many alternatives that would deliver similar results. Low current demand may affect future output through inventory buildup, lower current investment or production chains. In addition, as discussed previously in Section 2.3, rather than through bankruptcy low current profits may lower future output through cost-cutting measures such as reduced R&D, less training of labor, closing some departments or branches or less investment. Finally, lower output today may reduce future output when a reduction in productive capacity is combined with sunk costs. Together with the standard link from the future to the present through expected income, these alternative mechanisms for linking the present to the future will also generate self-fulfilling beliefs.

3.2 Autarky

When $\psi = 1$ the two economies are in autarky. They only consume their own goods, so that the relative prices $P_t/P_{H,t}$ and $P_t^*/P_{F,t}$ are equal to 1 in both periods. It then follows from (37)-(42) that for each country the equilibria correspond exactly to the symmetric equilibria described above. But in autarky the equilibrium in one country has no impact on the equilibrium of another country. When $\pi(\overline{n}) < z < \pi(1)$ there are then four possible outcomes. Either country may be in the panic equilibrium B or the non-panic equilibrium A, independent of the other country. Therefore it is possible for both countries to experience a panic together, but it is also possible for just one of the two countries to experience a panic (asymmetric equilibria).

There is no a priori reason why the two countries would panic simultaneously. There may be arguments outside of the model why a panic would be global. For example, if the trigger that sets off the panic is particularly frightening, the two countries may react together. But if this trigger event takes place in the Home country[24], it would seem odd that the Foreign country would react to it in the

[24] An example is the bankruptcy of Lehman Brothers or more generally events surrounding U.S. financial markets in the Fall of 2008.

absence of any integration between the two countries.

3.3 When Are Panics Global?

In this section we examine all equilibria for values of ψ between 0.5 and 1. We have already described the symmetric equilibria, where $(n, n^*) = (1, 1)$ or $(n, n^*) = (\bar{n}, \bar{n})$. We now need to consider asymmetric equilibria as well, where either $(n, n^*) = (\bar{n}, 1)$ or $(n, n^*) = (1, \bar{n})$. We are particularly interested in circumstances where only the two symmetric equilibria exist. When a panic occurs, it will then necessarily be global.

We will assume that symmetric multiple equilibria exist, i.e., $\pi(\overline{n}) < z < \pi(1)$ from Proposition 1. As discussed in Section 3.2, this implies that multiple equilibria also exist in individual countries in autarky. This means that asymmetric equilibria exist when $\psi = 1$. However, as we move away from autarky, i.e., as we lower ψ, the asymmetric equilibria will no longer exist, so that panics can only be global. This is stated in the following proposition.

Proposition 2 *Assume $\pi(\overline{n}) < z < \pi(1)$, so that there are multiple equilibria. There is a threshold $\psi(z) > 0.5$ such that only the symmetric equilibria exist when $\psi < \psi(z)$.*

Proof. See Appendix C. ■

Using (37), Figure 6 illustrates Proposition 2 by plotting all equilibrium Home consumption levels as a function of ψ. Symmetric equilibria give perfectly horizontal schedules as consumption is $c_1 = n^{\zeta}/\theta$, which is unaffected by the level of integration. This is not the case in the asymmetric equilibria. For example, a Foreign panic affects Home consumption more the greater the extent of integration (the lower ψ).

When ψ is below the threshold $\psi(z)$, only the two symmetric equilibria exist. In that case panics are necessarily global. In other words, when the level of trade is sufficiently high, or home bias sufficiently low, a panic will be perfectly coordinated across the two countries. However, the two countries do not need to be perfectly integrated. A panic will be necessarily global for all values of ψ larger than 0.5 and less than $\psi(z)$. A sufficient degree of integration, not perfect integration, is needed to guarantee that panics will be global. As we show in Section 3.5, the cutoff for ψ will generally be far above 0.5, so that we do not need to be anywhere

close to full integration to assure that panics will be perfectly coordinated across countries.

Before we turn to the intuition behind this key result, it is useful to first draw out some of the implications. First, Proposition 2 implies that when the two countries are sufficiently integrated ($\psi > \psi(z)$) a panic leads to a drop in consumption that is common across countries. Consumption in both countries drops from $1/\theta$ to $\bar{n}^{\zeta}/\theta$. Second, output drops equally in both countries and the same as consumption.[25] Third, future output is expected to drop in both countries by the same amount as well. All these pieces of evidence are consistent with the business cycle and survey data reported in Figures 1 and 3. Also consistent with the model, we can observe a worldwide decline in profits. Figure 7 shows substantial and similar declines in corporate profits for the U.S. and other G7 countries.[26]

3.4 Intuition Behind Global Panics

Unless countries are perfectly integrated, business cycle shocks are only partially transmitted across countries in standard models. This is the case in our model as well in the sense that an asymmetric panic in one country is only partially transmitted to the other country. But the key to perfect business cycle co-movement here is that limited transmission impacts the range of feasible equilibria. In particular, under sufficient integration we can rule out asymmetric equilibria, so that a panic is necessarily global.

The intuition for this is quite general and goes beyond the specifics of our model. We will therefore start off with a broad discussion about the impact of economic integration on the existence of equilibria before illustrating this in the context of our specific model. It is well known that in models with multiple equilibria the nature of equilibria depends on the value of the "fundamentals". What exactly those fundamentals are depends on the model. In general there are three possibilities.

[25] The real value of Home output in period 1 is $P_1 c_1 / P_{H,1}$ from (33), while $P_1/P_{H,1}$ depends on c_1/c_1^* from (36) and therefore stays equal to 1. The drop in Home real GDP in period 1 is therefore the same as the drop in Home consumption. The same is the case for the Foreign country.

[26] There is no cross-country database on aggregate corporate profits that we are aware of. The numbers in Figure 7 have been derived by aggregating profits from firms listed in the Worldscope database. We selected continuing firms over the interval and windsorized the top and bottom tails at 1 percent. The resulting profit series are divided by the GDP deflator.

When the fundamentals are very strong, only the good equilibrium is possible. When the fundamentals are very weak, only the bad equilibrium is possible. For an intermediate range of the fundamentals, either the good or the bad equilibria are possible. The economy is then vulnerable to multiple equilibria.

In the next section we discuss some of these fundamentals in the context of our model, such as the tightness of credit and the nature of fiscal and monetary policy. We will see that when these fundamentals are favorable, only the good (no-panic) equilibrium is feasible. When the fundamentals are weaker, both the panic and no-panic equilibria are feasible. In principle it would also be possible to have only a panic equilibrium when fundamentals are sufficiently bad, although here this is ruled out for the symmetric equilibria because of Assumption 1.

Now consider a two country setup and assume that we are in the intermediate range of fundamentals, so that both the good and bad equilibria are possible when restricting ourselves to symmetric equilibria. From the perspective of an individual country there is now one additional fundamental, associated with the state of the other economy. If the Foreign economy is strong, this will favorably affect the Home country (e.g. through exports). In the context of our model we can simply measure the strength or weakness of the Foreign economy by whether it experiences a panic or not ($n^* = \bar{n}$ or $n^* = 1$).

Assume that the Foreign economy is strong (no panic). This additional strong fundamental may or may not be enough for the bad (panic) equilibrium to disappear for the Home country. So in general there are now two possibilities. Either the Home country is still in the intermediate range where both the panic or non-panic equilibria are feasible or only the non-panic equilibrium is possible. In the latter case the additional favorable fundamental (strong Foreign economy) is sufficient to pull the Home economy out of the intermediate multiplicity range.

Now assume instead that the Foreign economy is weak (experiences a panic). This additional weak fundamental may or may not be enough for the good (non-panic) equilibrium to disappear for the Home country. So in general there are now two possibilities. Either the Home country is still in the intermediate range where both the panic or non-panic equilibria are feasible or only the panic equilibrium is possible. In the latter case the additional bad fundamental (weak Foreign economy) is sufficient to pull the Home economy out of the intermediate multiplicity range and into a unique bad equilibrium.

Similarly, the equilibria in the Foreign country depend on the state of the

Home economy (panic or no panic). Because of symmetry, there are then four possible outcomes. The first possibility is that for both economies there may or may not be a panic, independent of the state of the other economy. This is the case when the level of integration is very limited (ψ close to 1). Then the additional fundamental (state of the other economy) does not matter much. The other three cases assume that the countries are more significantly integrated, so that the additional fundamental is more important. One possibility is that when the Foreign economy is strong (no panic), only the no-panic equilibrium in Home is possible, while a weak Foreign economy (panic) leaves the Home economy in the intermediate range of either a panic or non-panic equilibrium. In this scenario the only possibilities are that either both countries panic or neither panics. It is not possible for the Home country to experience a panic and the Foreign country no panic. The strong Foreign economy will then imply that only the no-panic equilibrium is possible in Home.

Another possibility is that when the Foreign economy is weak (panic), only the panic equilibrium in Home is possible, while a strong Foreign economy (no panic) leaves the Home economy in the intermediate range of either a panic or non-panic equilibrium. The only possibilities are again that either both countries panic or neither panics. It is not again not possible for one country, say Foreign, to experience a panic and the other country, Home, no panic. The weak Foreign economy will then imply that only the panic equilibrium is possible in Home.

The final possibility is that when the Foreign economy is weak (panic), only the panic equilibrium in Home is possible, while a strong Foreign economy (no panic) implies that only the no panic equilibrium is feasible in Home. In that case obviously the only possibilities are again that either both countries panic or neither panics.

The overall conclusion is therefore that when countries are sufficiently integrated, either both countries panic or neither country panics. A panic is necessarily synchronized across countries. By sufficiently integrated we mean that the state of one economy has an impact on the equilibria that are feasible in the other economy. We now turn to the specifics of our model to illustrate how the state of one economy can impact the equilibria in the other economy.

It is useful to start with (37)-(38), which are repeated here for convenience:

$$c_1 = \frac{1}{\theta} n^{(1-\delta)\zeta} (n^*)^{\delta\zeta} \tag{46}$$

$$c_1^* = \frac{1}{\theta} n^{\delta\zeta} (n^*)^{(1-\delta)\zeta} \tag{47}$$

Since δ is between 0 and 0.5 when ψ is between 0.5 and 1, one implication immediately follows. Assume that there is a panic in just one country, say Foreign ($n = 1$ and $n^* = \bar{n}$). The panic in the Foreign economy has a negative impact on Home consumption as it drops from $1/\theta$ (without a Foreign panic) to $\bar{n}^{\delta\zeta}/\theta$. Transmission across countries is therefore positive. But it is also partial when economic integration is partial ($0.5 < \psi < 1$). Foreign consumption is $\bar{n}^{(1-\delta)\zeta}$, which is lower than Home consumption $\bar{n}^{\delta\zeta}/\theta$ as $\delta > 0.5$. This partial transmission is standard in open economy models with partial integration. However, in our framework transmission plays the additional role of impacting the very existence of equilibra. This is the key to Proposition 2.

Consider equilibria in the Home country. As before, there are two schedules. Conditional on the state n^* (1 or $\bar{n}$) in the Foreign economy, these are given by

$$c_1 = \frac{1}{\theta} n^{(1-\delta)\zeta} (n^*)^{\delta\zeta} \tag{48}$$

$$\pi = c_1 - \frac{\lambda}{A} c_1^{\gamma+1/\alpha} \left(\frac{\theta c_1}{(n^*)^\zeta} \right)^{\frac{\kappa}{\zeta}\frac{\delta}{1-\delta}} \tag{49}$$

$$n = \begin{cases} \overline{n} & \text{if } \pi < z \\ 1 & \text{if } \pi \geq z \end{cases} \tag{50}$$

(48) is the same as (46). For a given state of the Foreign economy, n^* is 1 or $\bar{n}$, it gives two possible values of c_1 corresponding to the two possible values of n. This is analogous to the two vertical lines in Figure 5. (49) is the humped shaped profit schedule, where we have assumed for simplicity that $\phi = 0$. It corresponds to (39), substituting the expression for the relative price as a function of relative consumption. Using (46)-(47) the latter can be written as $c_1/c_1^* = (\theta c_1/(n^*)^\zeta)^{(1-2\delta)/(1-\delta)}$.

When $\psi = 1$, so that $\delta = 0$ (the case of autarky), these schedules are the same as in the case of symmetric equilibria. Figures 8 and 9 show how Home equilibria are affected when economies are partially integrated, depending on the state of the Foreign economy, panic and no panic respectively in Figures 8 and 9. First

consider Figure 8, which is conditional on a Foreign panic ($n^* = \bar{n}$). The left vertical schedule (for $n = \bar{n}$) remains unaffected by integration as $c_1 = \bar{n}^\zeta/\theta$ when both countries are in a panic. But the right vertical schedule shifts to the left as a panic in the Foreign country has a negative effect on Home consumption even when there is no panic in the Home country. This is a regular negative transmission effect. Similarly, the profit schedule shifts down for values of c_1 above the global panic level ($c_1 > \bar{n}^\zeta/\theta$). Home profits are dragged down by the Foreign panic.

There are now two possibilities. When the two schedules do not move a lot (economic integration is limited), there remain two equilibria in the Home country. But when economic integration is sufficient, the good equilibrium no longer exists, as shown in Figure 8. In that case the additional bad fundamental (Foreign panic) pushes the Home economy into a singular bad equilibrium (panic). This precludes asymmetric equilibria as it is not possible to have a panic in only one country.

Next consider Figure 9, which is conditional on no Foreign panic ($n^* = 1$). The right vertical schedule (for $n = 1$) remains unaffected by economic integration as $c_1 = 1/\theta$ when neither country panics. But the left vertical schedule shifts to the right as the strong Foreign economy has a positive effect on Home consumption when there is a Home panic. The profit schedule now shifts up for values of c_1 below $1/\theta$, the global non-panic level. Home profits are raised by the strong Foreign economy.

There are again two possibilities. When the two schedules do not move a lot (economic integration is limited), there remain two equilibria in the Home country. But when economic integration is sufficient, the bad equilibrium no longer exists, as shown in Figure 9. In that case the additional good fundamental (strong Foreign economy) implies that the Home economy is no longer vulnerable to a panic. Only the non-panic equilibrium is feasible. This again precludes asymmetric equilibria as it is not possible to have a panic in the Home country when there is no panic in the Foreign country.

In order to rule out the existence of asymmetric equilibria it is sufficient that either in Figure 8 or 9 the schedules shift enough such that one of the equilibria goes away. How can we be sure that this is the case, and for values of ψ above 0.5 (partial integration)? It must be the case that either $\pi(n = 1|n^* = \bar{n}) < z$ or $\pi(n = \bar{n}|n^* = 1) > z$. Proposition 2 implies that one of these conditions will be satisfied for ψ less than a cutoff $\psi(z) > 0.5$. From Figures 8 and 9 it is immediate that very little integration is needed when z is close to either the panic or the

no-panic profit levels. But more generally, it can be shown that at least one of these conditions must be satisfied with sufficient integration, independent of the value of z. A sufficient condition for this to be the case is that $\pi(n = 1|n^* = \bar{n}) < \pi(n = \bar{n}|n^* = 1)$. The proof of Proposition 2 in Appendix C shows that this is the case for all values ψ below a cutoff $\bar{\psi} > 0.5$ that does not depend on z. More generally, the cutoff $\psi(z)$ in Proposition 2 lies somewhere between $\bar{\psi}$ and 1.

We should finally point out that Proposition 2 is not an artifact of the specific way that we have modeled the cost z that defaulting firms face. Instead of the binary assumption that some firms face the cost z and some do not, in a previous draft of the paper we assumed that there is a cross-sectional distribution of the cost across firms that is uniform over an interval $[a, b]$.[27] The fraction of firms that goes bankrupt then becomes endogenous. That version of the model is more complicated and requires a numerical solution. The numerical results are nonetheless consistent with Proposition 2. There are in general again two symmetric equilibria, while the asymmetric equilibria disappear when ψ drops below a cutoff that is above 0.5. As follows from our discussion at the start of this subsection, the logic behind this result is more general than the specifics of our particular model.

3.5 Numerical Illustration

While the model is obviously highly stylized, it is still useful to provide a numerical illustration for reasonable levels of parameters to see what level of integration is sufficient to guarantee that a panic is synchronized across countries. We will set the elasticity μ equal to 3. Broda and Weinstein (2006) estimate this elasticity using 8-digit, 5-digit and 3-digit industry levels. In all cases they find that the median elasticity across industries is just below 3. We set $\alpha = 0.75$. This delivers a labor share of $\alpha(\mu - 1)/\mu = 0.5$, which is consistent with 2010 data for the U.S., Japan and the Euro zone on the ratio of employee compensation to GDP. We normalize private consumption in the non-panic state to be 1 by setting λ/A such that $\theta = 1$. We re-introduce government spending, which was only suppressed in the previous subsections for analytic tractability. We set $g_t = \bar{g} = 0.3$ in both periods, implying that government consumption as a fraction of GDP is 0.3/1.3=0.23. This is consistent with recent data from industrialized countries for government spending (consumption plus investment) relative to GDP. For now we

[27] See http://people.virginia.edu/∼ev4n/papers/panic2012.pdf.

set $\phi = 0$, so that the borrowing constraint is very tight: firms cannot borrow at all. We will investigate the role of borrowing constraints further in the next section.

The only parameter left is γ. It is hard to calibrate as it plays three roles in the model: rate of risk aversion, inverse of intertemporal elasticity of substitution and real wage cyclicality. The real wage is λc^{γ}. Based on estimates of risk-aversion and the intertemporal elasticity of substitution γ should be larger than 1. But this is inconsistent with the evidence that the average real wage rate is not very cyclical. Moreover, given realistic choices for the other parameters the model implies counterintuitively that $\pi(1) < \pi(\bar{n})$ when γ is set at 1 or larger. The reason is that in the panic state the real wage is much lower, which raises firm profits. In order to avoid this strong cyclicality of the wage rate, we consider results both for the case where γ is well below 1 and the extension where nominal or real wages are rigid (preset at the start of each period). This extension is straightforward and described in Appendix D.

When we set $\gamma = 0.2$, so that the real wage rate is not very cyclical, we find $\bar{\psi} = 0.9$, independent of the level of $\bar{n}$. The actual cutoff $\psi(z)$ then lies somewhere between 0.9 and 1, dependent on the value of z. Only limited trade is then sufficient to guarantee a global panic. When 10% of private consumption goods are imported a panic is necessarily global and therefore business cycles will be perfectly synchronized during the panic. $\bar{\psi}$ will be only slightly lower, at 0.88, when we set γ infinitesimally close to 0, so that the real wage rate is not cyclical at all.

As discussed further in Appendix D, under both nominal and real wage rigidity wages are set at the start of each period under the assumption that there will be no panic.[28] Results will be very similar when setting the probability of a panic at a small positive number. This does not affect period 2 as there are no further unexpected shocks during period 2. When the real wage is negotiated at the start of period 1, it will then be set at its equilibrium non-panic level. When instead the nominal wage rate is agreed to in advance, the real wage will be equal to the non-panic real wage rate times $\bar{P}_1/P_1$, where $\bar{P}_1$ is the price index without a panic. We now set γ at 3, which is a standard value when measuring risk aversion or the inverse of the intertemporal elasticity of substitution.

[28] Even though firms preset their prices, there is a difference between nominal and real wage rigidity due to the exchange rate impact on the price level.

Under real wage rigidity we find that $\bar{\psi}$ is 0.89. Note that this is not the same model as under flexible real wages with γ very small since the second period equilibrium does depend on γ. Nonetheless the result is virtually identical and it again does not depend on $\bar{n}$. Under nominal wage rigidity $\bar{\psi}$ is a bit lower at 0.77, so that $\psi(z)$ is in the range of 0.77 to 1. But it is still the case that limited trade is needed to guarantee perfect synchronization of panics across countries. It is sufficient that 23% of private consumption goods are imported. This number may be even less depending on the precise value of z.

We can also numerically evaluate the extent of traditional business cycle transmission associated with asymmetric shocks. Since there are no exogenous asymmetric shocks in the model, we consider transmission associated with an asymmetric panic. Take the example of real wage rigidity where $\bar{\psi} = 0.89$. Assume that $\psi(z) = \bar{\psi}$ and that $\psi = 0.9 > \bar{\psi}$. We are then in the region where asymmetric panics are possible. Using the parameter values discussed above, the drop in log Foreign consumption is then only a fraction 0.05 of the drop in log Home consumption. Transmission is positive but small. But only slightly more trade integration (ψ equal to 0.89 or less) guarantees that panics are global, allowing us to explain the perfect business cycle synchronization while retaining significant home bias as seen in the data.

4 Vulnerabilities

We now consider factors that make countries vulnerable to self-fulfilling panics. We focus on symmetric equilibria. If symmetric panics do not exist, no type of panic, including asymmetric ones, exist in the model. The question is therefore under what conditions of the fundamentals of the model we are in the intermediate range where there are multiple equilibria, as opposed to only the non-panic equilibrium. We consider a version of the model that is general enough to focus on the role of credit, monetary policy and fiscal policy. These are captured by respectively ϕ, i and g_t. At the same time we will simplify by setting $\zeta = \alpha = 1$. This leads to a cleaner set of equilibrium equations, but is not critical to the results. As shown in

Appendix B, the schedules that determine the symmetric equilibrium are then

$$c_1 = [\beta(1+i)]^{-1/\gamma}\frac{n}{\theta} \tag{51}$$

$$\pi = c_1 + g_1 - \frac{\lambda}{A}c_1^{\gamma}(c_1+g_1) + \frac{\phi}{(1+i)\mu\theta}\left(1+\frac{g_2\theta}{n}\right) \tag{52}$$

$$n = \begin{array}{ll} \overline{n} & \text{if } \pi < z \\ 1 & \text{if } \pi \geq z \end{array} \tag{53}$$

We consider different versions of this set of equilibrium equations, dependent on the vulnerability of interest. We can think of $\phi = 0$, $g_t = 0$ and $(1+i)\beta = 1$ as a benchmark that we deviate from one parameter at a time.

4.1 Credit

In order to consider the role of credit we focus on the impact of the parameter ϕ, while setting $\beta(1+i) = 1$ and $g_t = 0$. Equilibrium is then characterized by two schedules:

$$c_1 = \frac{n}{\theta} \quad \text{with } n = \bar{n} \text{ if } \pi < z \text{ and } n = 1 \text{ if } \pi \geq z \tag{54}$$

$$\pi = c_1 - \frac{\lambda}{A}c_1^{1+\gamma} + \frac{\phi\beta}{\mu\theta} \tag{55}$$

These schedules are shown in Figure 10 for two values of ϕ. The vertical lines represent the consumption schedule while the humped shaped line reflects the available fund schedule. A higher ϕ raises the available fund schedule. Figure 10 shows that when ϕ is low, so that credit is tight, there may be two equilibria, so that self-fulfilling panics are possible. But when credit is loose, so that ϕ is high, only the non-panic equilibrium exists. The more firms are able to borrow, the less fragile they are. They are then better able to withstand a drop in demand that lowers first-period profits. This in turn can make a self-fulfilling panic impossible. While it remains the case that conditions in period 2 affect consumption in period 1, the linkage in the other direction is broken under loose credit conditions. Even with low consumption in period 1, leading to low profits, firms can avoid bankruptcy by borrowing.

4.2 Monetary Policy

So far we have assumed that monetary policy is a zero inflation policy and $(1+i)\beta = 1$, so that the non-panic equilibrium corresponds to the flexible price equilibrium. But it is sensible for the central bank to lower the interest rate when faced with a panic that reduces output and consumption. However, the central bank may be constrained by the zero lower bound. We will now assume that $\phi = 0$ and $g_t = 0$, but we no longer restrict monetary policy to be $(1+i)\beta = 1$. The symmetric equilibrium is then determined by

$$c_1 = [\beta(1+i)]^{-1/\gamma}\frac{n}{\theta} \quad \text{with } n = \bar{n} \text{ if } \pi < z \text{ and } n = 1 \text{ if } \pi \geq z \tag{56}$$

$$\pi = c_1 - \frac{\lambda}{A}c_1^{1+\gamma} \tag{57}$$

The interest rate only enters the consumption schedule. Lowering the interest rate raises consumption and therefore shifts the consumption schedule to the right.

Now consider the following policy. In the absence of a panic the central bank keeps $(1+i)\beta = 1$, so that we achieve the flexible price equilibrium. But when a panic occurs the central bank lowers the interest rate. The chart on the left-hand side of Figure 11 considers the case where the central bank lowers the interest rate all the way to zero during a panic. When β is only slightly below 1, so that the non-panic interest rate $i = \bar{\imath} = 1 - 1/\beta$ is already close to zero, this involves only a small rightward shift of the left vertical line of the consumption schedule. We see that in that case the central bank cannot avoid a panic due to the zero lower bound. There is a panic equilibrium at B' that is quite close to the panic equilibrium B under the passive policy $(1+i)\beta = 1$. The reason for this is that the central bank does not have much room to maneuver when the interest rate is already close to 0.

When instead β is well below 1, so that we are far from the zero lower bound without a panic, the interest rate can be lowered much more during a panic. This leads to a larger rightward shift of the left vertical line of the consumption schedule. When the central bank follows this policy, it is clear from Figure 11 that a panic can be avoided altogether. A large drop in the interest rate leads to a significant rise in first period consumption, which dampens the decline in firm profits and thus avoids defaults. Only the non-panic equilibrium A exists.

The chart on the right hand side of Figure 11 illustrates this point as well. We can think of (56) as a downward sloping IS curve in the space of (i, c_1). A panic

lowers n, which shifts the IS curve to the left. When policy is passive, so that $i = 1 - 1/\beta$, the panic leads to a significant drop in first-period consumption. We shift from point A to point B, corresponding to the same points in the chart on the left. If instead the central bank lowers the interest rate to zero during the panic, we move to point B'. The chart is drawn for the case where β is only slightly below zero, so that the interest is already close to zero without a panic. Lowering the interest further, all the way to zero, will then not raise consumption very much. Profits will then remain very weak and we are unable to escape bankruptcies and therefore the panic.

There is another policy option that theoretically exists and allows the central bank to avoid a panic even when close to the zero lower bound. Instead of a zero inflation policy it could adopt a high inflation policy during a panic. The consumption schedule is then

$$c_1 = [\beta(1+i)\frac{P_1}{P_2}]^{-1/\gamma}\frac{n}{\theta} \quad \text{with } n = \bar{n} \text{ if } \pi < z \text{ and } n = 1 \text{ if } \pi \geq z \tag{58}$$

High inflation expectations can significantly lower the real interest rate, which can lead to a large rightward shift of the left vertical line of the consumption schedule in the left chart of Figure 11 even when we are at the zero lower bound. The panic equilibrium would then no longer exist. This policy has been widely discussed but suffers from a credibility problem as ex-post the central bank has little incentive to generate the promised inflation.[29]

4.3 Fiscal Policy

Figure 12 illustrates the role of fiscal policy. In this case we set $\phi = 0$ and $(1+i)\beta = 1$, so that the two schedules become

$$c_1 = \frac{n}{\theta} \quad \text{with } n = \bar{n} \text{ if } \pi < z \text{ and } n = 1 \text{ if } \pi \geq z \tag{59}$$

$$\pi = c_1 + g_1 - \frac{\lambda}{A}c_1^{\gamma}(c_1 + g_1) \tag{60}$$

First consider the case where fiscal policy takes the form $g_1 = \bar{g}$, which is illustrated in the left chart of Figure 12. A higher level of $\bar{g}$ then shifts upward the

[29] Such credibility issues cannot be properly analyzed in our model as we have not modeled the cost of inflation.

available funds schedule.[30] The chart illustrates that when government consumption is sufficiently high, the panic equilibrium is ruled out. Only the non-panic equilibrium without bankruptcies exists. With a very high level of government consumption, it is impossible to have a self-fulfilling business cycle panic because government spending is not affected by expectations. Even if private consumption were to decline substantially, period 1 profits would remain relatively strong because of the stable government spending. This precludes the fragile firms from going bankrupt, thus avoiding a self-fulfilling panic.

The chart on the right hand side considers the role of countercyclical fiscal policy. The broken humped shaped schedule assumes that fiscal policy takes the form $g_1 = \bar{g} - \Theta(c_1 - 1/\theta)$. In that case government consumption is the same as under the $g_1 = \bar{g}$ policy in the absence of a panic. But when a panic occurs, which lowers first period consumption, government spending is higher. When fiscal policy is sufficiently countercyclical, as measured by the parameter Θ, the chart shows that the panic equilibrium no longer exists. When the drop in private consumption during a panic is sufficiently offset by an increase in government consumption, firm profits remain relatively strong and bankruptcies are avoided.[31]

4.4 Vulnerabilities during the 2008 Crisis

There are three ways in which the world economy was particularly vulnerable to a self-fulfilling panic in 2008. First, credit was known to be tight due to large losses experienced by banks and other financial institutions since early 2007, leading to deleveraging in the financial system. Second, interest rates around the world were close to zero even prior to the Fall of 2008, leaving central banks little room to maneuver. Third, the Great Recession took place against the backdrop of high levels of government debt, which limited the ability of fiscal authorities to

[30] The derivative of π with respect to $\bar{g}$ is $1 - (\lambda/A)c_1^{\gamma}$. When $c_1 = 1/\theta$, as in the non-panic equilibrium, this derivative is $1/\mu$, which is positive. Only for first-period consumption values well above that can the derivative be negative, but those are not of interest to us as first period consumption can be no larger than $1/\theta$.

[31] Another type of countercyclical fiscal policy that will avoid the panic equilibrium is a policy along the lines of that adopted towards GM. If the government recapitalizes firms during a panic, bankruptcy can be avoided. More specifically, the government would need to transfer real resources to vulnerable firms equal to $z - \pi$ conditional on a panic. This would preclude the panic equilibrium altogether.

respond with strong countercyclical policies.[32] Moreover, several countries had adopted fiscal rules, also limiting the flexibility of fiscal policy. These three factors were combined with increased global economic integration in recent decades, which made the world particularly vulnerable to a globally synchronized rather than a local panic.

4.5 Asymmetries

So far we have assumed that the parameters, including the policy parameters, are all exactly the same across the two countries. This means that the exogenous fundamentals faced by both countries are the same. It is natural to ask what would happen if these parameters differ. For example, what would happen if one country is further from the zero lower bound than the other or one country is less constrained to conduct countercyclical fiscal policy than the other?

In order to answer this, we consider two types of asymmetries. The first is a difference across countries in credit constraints, measured by different values of the parameter ϕ. Results will be analogous if instead we consider differences in the ability to conduct countercyclical fiscal or monetary policy. The other asymmetry is a difference in country size.

First consider credit constraints. Let ϕ be equal to ϕ_H in the Home country and ϕ_F in the Foreign country. Without loss of generality, assume that credit is less constrained in the Foreign country, so that $\phi_F > \phi_H$. Under Assumption 1, the symmetric non-panic equilibrium always exists. The first question is under what conditions a symmetric panic equilibrium exists. Symmetric equilibria are still given by the schedules (43)-(45). The only difference is that π and π^* are no longer equal. The weaker credit constraint in the Foreign country shifts up its available fund schedule. In order for the global panic equilibrium to exist we therefore must make sure that the panic equilibrium exists in the Foreign country when $n = n^* = \bar{n}$. This is the case when $\pi^*(\bar{n}) < z$. In terms of Figure 10, it means that the available funds schedule crosses the vertical line below $\pi^* = z$.

More generally, if the exogenous fundamentals are "too strong" in the Foreign

[32] Even before fiscal debt around the globe rose significantly as a result of the recession itself, gross public debt as a percent of GDP stood close to 80% among advanced economies (see for example the World Economic Outlook, International Monetary Fund, October 2012). With the exception of the end of World War II, this is the highest level in over a century.

country, a panic equilibrium in the Foreign country does not exist, independent of conditions in the Home country. In that case a global panic is not possible. For a global panic equilibrium to exist it must be the case that a panic equilibrium exists for both countries if they were in autarky. While conditions do not need to be equally bad, fundamentals in both countries must be sufficiently weak that both are vulnerable to a panic in autarky.

Assuming that a global panic exists, in general it remains the case that for sufficient integration either both countries panic or neither panics (Proposition 2 still holds). As shown in Appendix C, a sufficient condition for this to be the case is that

$$\kappa\beta(\phi_F - \phi_H) < (1 - \bar{n}^\kappa) + \left(\frac{1}{\bar{n}} - 1\right)\kappa\beta\phi_H \tag{61}$$

This will hold as long as either the difference in fundamentals is not too big or the magnitude of the panic is sufficiently large. If this condition is not satisfied, it may be possible (dependent on the value of z) for the Foreign country not to have a panic while the Home country does experience a panic, independent of the degree of economic integration.

To summarize, even when fundamentals differ across countries, a panic equilibrium that is necessarily global in nature may still exist. This requires that countries are sufficiently integrated and that in both countries fundamentals overall are sufficiently weak. This may for example be the case even if credit is less tight in one of the countries, but it still faces significant constraints on monetary and fiscal policy.

We finally briefly discuss asymmetry through a difference in country size. Consider the extreme where the Foreign country is infinitesimal in size relative to the Home country. In that case the Home country is essentially in autarky as the other country has an infinitesimal effect on its economy. When fundamentals are sufficiently weak in the Home country, both a panic and non-panic equilibrium are possible. With sufficient integration, the conditions in the Foreign country will be almost entirely determined by those in the Home country because of its large relative size.[33] This implies that when the Home country panics, the Foreign country

[33] Generalizing the symmetric case, one can define $2\psi - 1$ as home bias, equal to 1 minus the fraction spent on foreign goods relative to the share of the foreign country in world output. Doing so yields a ratio of the fraction spent on Foreign goods by Home agents relative to Foreign agents, times the relative size of the Home country, of $2(1-\psi)/(2\psi - 1)$ when the Foreign country is infinitesimal. This approaches infinity when $\psi \to 0.5$.

panics as well. Similarly, when the Home country does not panic, neither does the Foreign country. A panic will again necessarily be global for sufficient integration. In this case even less integration is needed to guarantee that a Home panic leads to a Foreign panic as now the Foreign country is even more dependent on the Home country than in the benchmark model where both countries are of equal size.

5 Extensions

In this section we consider four extensions to the benchmark model. While these extensions make the model more realistic, they do not alter the main results derived in the benchmark case. The first extension introduces international risk sharing, which leads to further integration across the two countries. The second extension allows for a non-unitary elasticity of substitution between Home and Foreign goods. The third extension adds investment and is able to explain a synchronized drop in investment as observed during the Great Recession. The last extension adds uncertainty about z. A panic then also leads to an increase in uncertainty about future output that is common across countries, consistent with what we saw during the Great Recession as documented in Figure 3.

5.1 Financial Integration

In the model so far the two countries trade goods but are in financial autarky. We have seen that a limited degree of goods market integration is sufficient to guarantee that a business cycle panic is global. We now add to this financial integration. We only consider the extreme case of full risk sharing.[34]

There is room for risk sharing as business cycle panics are a result of sunspot shocks that may affect only one country. Under complete markets the ratio of marginal utilities of consumption is equal to the real exchange rate:

$$\frac{c_t^{-\gamma}}{(c_t^*)^{-\gamma}} = \frac{P_t}{S_t P_t^*} \tag{62}$$

This replaces the condition $P_t c_t = S_t P_t^* c_t^*$ under financial autarky. As long as γ is

[34] Intermediate cases with partial financial integration can be accomplished in many ways and this is not necessarily captured well through one parameter in a way that is analogous to ψ for goods market integration.

different from 1 these two conditions will differ.[35] The expression (36) for relative prices no longer holds and is replaced by (62). This is the only change to the model. The equations (66)-(73) in Appendix B that summarize the equilibrium all remain the same, but the relative prices $P_{H,t}/P_t$ and $P_{F,t}/P_t^*$ that enter these equations are now based on (62).[36]

We find numerically that risk sharing tends to further increase the cutoff level of ψ below which a panic is necessarily global. With financial integration, less trade integration is then needed to assure a global panic. For example, in the numerical exercise in Section 3.5 we found that $\bar{\psi}$ was 0.89 under real wage rigidities and 0.77 under nominal wage rigidities.[37] With risk sharing these numbers increase to respectively 0.95 and 0.84.

To understand the role of risk sharing, consider for example Figure 8. We saw that trade integration makes it less likely that there is an equilibrium where there is no panic in the Home country if there is a panic in the Foreign country. The Foreign panic transmits negatively to the Home country, reducing both consumption and profits. With sufficient integration the good, non-panic, equilibrium then no longer exists in the Home country. This is reinforced with financial integration. If there is a panic only in the Foreign country, there will be a transfer of resources from Home to Foreign. This lowers Home consumption (shifting the right vertical line further to the left). The transfer also lowers relative demand for Home goods, which lowers the relative price of Home goods, which further lowers Home profits. The non-panic equilibrium is therefore even less likely to exist in the Home country. A similar argument can be made for Figure 9.

5.2 Elasticity of Substitution

Throughout the paper so far we have assumed a unitary elasticity of substitution between Home and Foreign goods. We now relax this assumption by adopting a CES specification with an elasticity of substitution of ν between Home and Foreign

[35] We assume that only households share risk. Firms do not have access to risksharing because of standard principal agents problems that also lead to borrowing constraints.

[36] We have $P_t/P_{H,t} = (c_t/c_t^*)^{\gamma(1-\psi)/(2\psi-1)}$ and $P_t^*/P_{F,t} = P_{H,t}/P_t$.

[37] As explained, without wage rigidities we needed to set γ close to zero to avoid excessive wage cyclicality, which is particularly unrealistic in the present context of risksharing where γ plays a role as the rate of relative risk-aversion. With wage rigidities we set $\gamma = 3$.

goods:

$$c_t = \left[\psi^{1/\nu} c_{H,t}^{\frac{\nu-1}{\nu}} + (1-\psi)^{1/\nu} c_{F,t}^{\frac{\nu-1}{\nu}}\right]^{\frac{\nu}{\nu-1}} \tag{63}$$

The specification for c_t^* is analogous, with the weights ψ and $1-\psi$ switched.

As was the case for risk sharing, equations (66)-(73) in Appendix B that describe the equilibrium of the model remain unchanged. The only change again applies to the expression for relative prices that enter these equations. Relative prices are derived from the balanced trade condition $S_t P_{F,t} c_{F,t} = P_{H,t} c_{H,t}^*$. With a unitary elasticity this implies $P_t c_t = S_t P_t^* c_t^*$. With an elasticity ν this generalizes to

$$\left(\frac{S_t P_{F,t}}{P_{H,t}}\right)^{\nu-1} \left(\frac{S_t P_t^*}{P_t}\right)^{\nu} = \frac{c_t}{c_t^*} \tag{64}$$

The left hand side is a function of the relative price $S_t P_{F,t}/P_{H,t}$, so this gives an implicit solution of the relative price as a function of c_t/c_t^*.[38]

We find numerically that the cutoff $\psi(z)$ rises when we lower ν below 1 and falls when we raise ν above 1. There is evidence that ν is in fact lower than 1. For example, Hooper, Johnson and Marquez (2000) estimate import price elasticities to be well below 1 for the G-7 countries. Using the parameter assumptions from Section 2.5 we find that lowering ν from 1 to 0.7 raises $\bar{\psi}$ from 0.91 to 0.95 for the flexible wage case, from 0.9 to 0.95 for the rigid real wage case and from 0.77 to 0.89 for the case of rigid nominal wages. These results imply that with trade elasticities less than 1 even less trade is needed to guarantee that panics will be global in nature.

The elasticity of substitution plays a role by affecting transmission, which we saw has in turn an effect on the very existence of equilibria. Consider an asymmetric equilibrium with a Foreign panic but no Home panic. While we have seen that a Foreign panic has a negative effect on the Home profit schedule (see (49)), there is one factor that weakens this negative transmission by operating in the opposite direction. The lower relative supply of Foreign goods raises the relative price of Foreign goods. This in turn leads to a substitution towards Home goods, raising demand for Home goods and Home profits. This factor is weakened for a lower elasticity of substitution. The negative transmission of a Foreign panic to Home

[38] It is well known that for sufficiently low elasticities of substitution (in our case below 0.5), this balanced trade condition has more than one solution for the relative price. This is an entirely separate form of multiplicity, discussed for example by Bodenstein (2010).

profits is then stronger and makes it less likely that the no-panic equilibrium in the Home country exists (Figure 8).

5.3 Investment

As shown in Figure 1, investment also declined sharply during the Great Recession. And the decline was again of similar magnitude in the rest of the world as in the United States. To capture this, we now consider a simple extension that allows for investment.

We assume that firms that do not go bankrupt need to invest in period 1 in order to operate in period 2. To simplify, we assume a given level of required investment per firm of $\bar{k}$. This investment is measured as the same index of Home and Foreign goods as for consumption. Investment demand for individual goods therefore takes the same form as for consumption, with c_1 replaced by I_1 and c_1^* by I_1^*. Aggregate investment is $I_1 = n\bar{k}$ and $I_1^* = n^*\bar{k}$.

The equilibrium conditions (66)-(73) listed in Appendix B remain the same with two exceptions that affect the available funds schedule. First, investment $\bar{k}$ needs to be subtracted from first period profits. Second, c_1 and c_1^* need to be replaced by $c_1 + I_1$ and $c_1^* + I_1^*$ (with the exception of wages, which only depend on consumption as in (13)). The only other change is to the expression for the relative price in period 1. It is derived from the balanced trade condition. Without investment we showed that it can be written as $P_1 c_1 = S_1 P_1^* c_1^*$. With investment it becomes $P_1(c_1 + I_1) = S_1 P_1^*(c_1^* + I_1^*)$. Correspondingly, in the expression (36) for the period-1 relative price we again need to replace c_1 and c_1^* with $c_1 + I_1$ and $c_1^* + I_1^*$.

The change in the expression for the relative price makes it more difficult to derive analytical results, but the numerical results are consistent with Propositions 1 and 2. If we set $\bar{k}$ such that the ratio of investment to GDP is 0.15 without a panic (the average for the U.S. since 1990), and set the other parameters the same as in Section 3.5, the values of $\bar{\psi}$ remain virtually the same. Therefore it is again the case that limited integration is sufficient to assure that a panic is global. The only difference is that now during a global panic there is also a synchronized drop in investment in both countries.

Another interesting point relates to the Paradox of Thrift. All agents in the economy attempt to save more because of an anticipated drop in future income.

But in the end equilibrium saving will be lower around the world. This occurs because the increase in desired saving leads to a drop in demand in period 1, which lowers output and income in period 1. For intertemporal smoothing reasons this reduces period 1 saving. In the model without investment equilibrium saving remains at zero during a global panic. But since we now have an endogenous decline in investment during the panic, global saving must have declined as well. This is consistent with the data, which show a decline in global saving and investment during the 2008-2009 crisis.

5.4 Uncertainty

A simple way to introduce uncertainty is to assume that the level of the fixed cost z is not known in advance. Let us assume that z can take the values z_L or z_H, with $z_H > z_L > 0$. The probability of either value is 0.5 and the draw is uncorrelated across countries. As we will see, this generates business cycle uncertainty only when there is a panic, consistent with the evidence of a significant spike in GDP uncertainty during the Great Recession, documented in Figure 3.

Of the equilibrium conditions (66)-(73) listed in Appendix B, only the consumption Euler equations will change. Previously period 2 consumption was known in period 1, while now it may be uncertain. Assuming $\phi = 0$, the Home fragile firms default when $\pi_1 < z$. This depends on the level of z. We assume that the fixed cost is paid at the end of period 1 and is unknown when consumption decisions are made.

Let p_D be the probability of default. We have $p_D = 0$ when $\pi_1 \geq z_H$, $p_D = 1$ when $\pi_1 < z_L$ and $p_D = 0.5$ when $z_L \leq \pi_1 < z_H$. In the latter case, default will depend on whether the draw of z is z_L or z_H. The probability of default p_D^* in the Foreign country depends similarly on π_1^*.

Let $c_2(n, n^*)$ and $c_2^*(n, n^*)$ be second-period consumption in both countries as a function of the number of firms. This takes the form, $c_2 = \frac{1}{\theta} n^{(1-\delta)\zeta} (n^*)^{\delta\zeta}$ when $g_2 = 0$ but more generally is derived from (66)-(67) in Appendix B. There are now 4 possible outcomes, dependent on whether or not there is default in Home and Foreign. This leads to the following consumption Euler equation for Home (assuming $(1+i)\beta = 1$):

$$\begin{aligned} c_1^{-\gamma} &= p_D p_D^* c_2(\bar{n}, \bar{n})^{-\gamma} + (1-p_D)(1-p_D) c_2(1,1)^{-\gamma} + \\ &\quad p_D(1-p_D^*) c_2(\bar{n}, 1)^{-\gamma} + (1-p_D) p_D^* c_2(1, \bar{n})^{-\gamma} \end{aligned} \tag{65}$$

The Foreign consumption Euler equation is analogous.

We can numerically verify the equilibria by considering all 9 possible values of the pair (p_D, p_D^*). Given a set of values for these default probabilities, we can compute first-period consumption from the consumption Euler equations. This gives us expressions for first-period profits in both countries, which maps into values of p_D and p_D^* as described above. When the latter are consistent with their assumed values, there is an equilibrium.

To provide an illustration of the type of equilibria that this can generate, consider again the parameter values in Section 3.5. Let $z_L = 0.5$ and $z_H = 0.58$. In the case of rigid real wages we find that for $\psi < 0.92$ there are two equilibria. In one equilibrium there is no panic in either country. Consumption and profits are high and the probability of default is zero. In the second equilibrium there is a panic. Consumption and profits are weak. The probability of default is 0.5 as there will not be default when $z = z_L$. The panic is synchronized across the two countries. When $\psi > 0.92$ these same two equilibria still exist. In addition there are now mixed equilibria where only one country panics, with a 0.5 probability of default, and the other does not.

The basic difference relative to the previous equilibria is that in a panic equilibrium there is now a positive probability of default rather than certain default. The main result of the paper still holds in that a limited extent of trade integration ($\psi < 0.92$) is sufficient to guarantee that panics are global. The same equilibria also apply to nominal wage rigidities, with the cutoff for ψ being 0.83, as well as flexible wages.[39]

Business cycle uncertainty is now endogenous and only spikes during a panic. Without a panic, consumption and profits are strong. No firms default, whether $z = z_L$ or $z = z_H$, assuming that Assumption 1 holds for $z = z_H$. The exogenous uncertainty about z therefore does not generate output uncertainty. In a panic, however, consumption and profits are weak. In that case the value of z does matter. When $z = z_L$ defaults can still be avoided even though profits are weak. But when $z = z_H$ the fragile firms will default. Therefore the uncertainty about z translates into output and consumption uncertainty only during a panic.

The endogenous uncertainty also contributes to the self-fulfilling mechanism itself. Without uncertainty we saw that the self-fulfilling beliefs operate through

[39] In the case of flexible wages we need to set different values for z_L and z_H. For example, if we set them at 0.4 and 0.54 the same types of equilibria occur, with the cutoff for ψ being 0.92.

the expected level of second period income. Lower expected income leads to lower consumption, which causes lower profits that generates bankruptcies that are consistent with the belief of lower expected future income. With uncertainty the second moment plays a role as well.[40] Higher income uncertainty leads to lower consumption as a result of precautionary saving. This in turn lowers profits, which makes the fragile firms more sensitive to fixed cost shocks. This generates uncertainty about defaults, making the belief of income uncertainty self-fulfilling.

It is also useful to note that panics do not necessarily imply bankruptcies in this extension. When $z_L \leq \pi_1 < z_H$ in a panic, bankruptcies only occur when $z = z_H$. It is the increased expectation of bankruptcies and uncertainty about bankruptcies that drives the panic. But dependent on z, these bankruptcies may not necessarily materialize. Moreover, since z and z^* are uncorrelated, bankruptcies may occur in only one country, even when the panic is global. In other words, perfect co-movement may only occur in a global panic and not in subsequent periods.

6 Conclusion

The paper is motivated by evidence of close business cycle co-movement during the Great Recession. Even though the housing and financial shock originated in the United States, business cycles in the rest of the world were impacted to a similar extent. Given limited trade and financial integration across countries this is surprising as standard models with exogenous shocks and limited integration generate only partial transmission. It is also surprising given the much lower co-movement of business cycles during prior recessions.

To explain this we have developed a two-country model with self-fulfilling business cycle panics. The self-fulfilling mechanism is a result of a circular relationship between present and future macroeconomic conditions. The link from the future to the present is standard in almost any intertemporal model as lower expected future income lowers consumption today. We have modeled the link from the present to the future through profits and bankruptcies, with lower demand today leading to weaker profits, which increases bankruptcies and lowers future output. But many other possible mechanisms may generate such a link from the present to the future.

[40] See Basu and Bundick (2012) for an analysis of the the impact of exogenous uncertainty in a sticky-price model. Ravn and Sterk (2012) focus on the impact of job uncertainty.

We have shown that the model is consistent with high international co-movement observed during the Great Recession. We find that limited economic integration is sufficient to assure that a panic, when it occurs, is necessarily perfectly synchronized across countries. In a panic, consumption, investment, and output collapse similarly across countries. Moreover, perceived uncertainty increases equally across countries.

At the same time we shed light on the fact that such strong business cycle co-movement as seen during the Great Recession is historically unusual. We have argued that several factors made the 2008 episode particularly vulnerable to such a global panic: tight credit, very low interest rates, rigid fiscal policy, combined with increased economic integration across countries. And of course there was an unusually strong trigger event for a panic in the form of U.S. financial market turmoil. The combination of these conditions separates the 2008 episode from previous recessions.

Appendix

A. GDP Forecast Expectation and Variance

This Appendix describes in some more detail how the numbers in Figure 3 are computed. The data has been purchased from Consensus Economics. In their January newsletter of "Consensus Forecast" and "Asia Pacific Consensus Forecasts" they publish one-year-ahead GDP forecast probabilities since 1999 for the countries listed in the Figure. More specifically, for every country and year there are seven intervals of growth forecasts (e.g. 1-2%, 2-3%). The precise intervals may change from year to year. The data reports probabilities of each interval as the percentage of forecasts that lie in that interval. We compute the expectation and variance of the forecasts by using the midpoint of each interval, together with the probabilities of the intervals.

One issue is that the intervals at both ends of the range are not bounded (e.g., an interval can be "< -1%"). In that case we adopt two scenarios to choose a midpoint for the interval. In the first scenario, we choose a midpoint by assuming that the interval width is the same as that for the other intervals. In the second scenario we choose a midpoint by assuming that the interval width is twice that for the other intervals. This leads to almost identical results. Figure 3 shows the results for the first scenario.

B. Model Equilibrium

In this Appendix we show how the model can be described a set of eight equations. Throughout the paper we use these equations to look at various special

cases. These equations are:

$$\frac{\mu}{\mu-1}\frac{\lambda}{\alpha A}c_2^{\gamma}\frac{P_2}{P_{H,2}}\left(\frac{P_2}{P_{H,2}}c_2+g_2\right)^{\frac{1-\alpha}{\alpha}}=n^{\kappa} \tag{66}$$

$$\frac{\mu}{\mu-1}\frac{\lambda}{\alpha A}(c_2^*)^{\gamma}\frac{P_2^*}{P_{F,2}}\left(\frac{P_2^*}{P_{F,2}}c_2^*+g_2^*\right)^{\frac{1-\alpha}{\alpha}}=(n^*)^{\kappa} \tag{67}$$

$$c_1^{-\gamma}=\beta(1+i)c_2^{-\gamma} \tag{68}$$

$$[c_1^*]^{-\gamma}=\beta(1+i^*)[c_2^*]^{-\gamma} \tag{69}$$

$$\begin{aligned}\pi = c_1+\frac{P_{H,1}}{P_1}g_1-\frac{\lambda}{A}c_1^{\gamma}\left(\frac{P_1}{P_{H,1}}c_1+g_1\right)^{1/\alpha} \\ +\frac{\phi}{1+i}\frac{\kappa\lambda}{A}c_2^{\gamma}n^{-\frac{\mu}{(\mu-1)\alpha}}\left[\frac{P_2}{P_{H,2}}c_2+g_2\right]^{1/\alpha}\end{aligned} \tag{70}$$

$$\begin{aligned}\pi^* = c_1^*+\frac{P_{F,1}}{P_1^*}g_1^*-\frac{\lambda}{A}(c_1^*)^{\gamma}\left(\frac{P_1^*}{P_{F,1}}c_1^*+g_1^*\right)^{1/\alpha} \\ +\frac{\phi}{1+i^*}\frac{\kappa\lambda}{A}(c_2^*)^{\gamma}(n^*)^{-\frac{\mu}{(\mu-1)\alpha}}\left[\frac{P_2^*}{P_{F,2}}c_2^*+g_2^*\right]^{1/\alpha}\end{aligned} \tag{71}$$

$$n=\begin{array}{ll}\overline{n} & \text{if } \pi<z\\ 1 & \text{if } \pi\geq z\end{array} \tag{72}$$

$$n^*=\begin{array}{ll}\overline{n} & \text{if } \pi^*<z\\ 1 & \text{if } \pi^*\geq z\end{array} \tag{73}$$

With relative prices as in (36), these are 8 equations in c_1, c_1^*, c_2, c_2^*, n, n^*, π and π^*. They are derived as follows. (66) follows by substituting the labor supply schedule $W_2/P_2=\lambda c_2^{\gamma}$ and $P_{H,2}(j)/P_{H,2}=n^{1/(\mu-1)}$ into the optimal price setting equation (20). It also uses the expression (19) for $y_2(j)$ that enters into the optimal price setting equation (20), after substituting (35) into the expression for $y_2(j)$. (67) is the Foreign counterpart of (66). (68) follows from the intertemporal consumption Euler equation (8) after substituting the zero inflation monetary policy ($P_2=P_1$). (69) is the Foreign counterpart.

(70) is an expression for available funds $\pi=\pi_1+\phi\pi_2/(1+i)$. It is derived as follows. First, we derive π_1, which is on the first line of the right hand side of (70). It is equal to

$$\pi_1=\frac{P_{H,1}}{P_1}y_1(j)-\frac{W_1}{P_1}\frac{1}{A}y_1(j)^{1/\alpha} \tag{74}$$

Using that $P_{H,1}(j)=P_{H,1}$, we have from (29) that $y_1(j)=c_{H,1}+c_{H,1}^*+g_1$. Substituting $c_{H,1}=\psi(P_1/P_{H,1})c_1$ and $c_{H,1}^*=(1-\psi)(S_1P_1^*/P_{H,1})c_1^*$, and also using

$P_1 c_1 = S_1 P_1^* c_1^*$ from (35), we have $y_1(j) = (P_1/P_{H,1})c_1 + g_1$. When we substitute this into (74), together with $W_1/P_1 = \lambda c_1^\gamma$, we get the first line on the right hand side of (70). The second line is $\phi\pi_2/(1+i)$. We derive an expression for π_2 as follows. From (21) it is equal to $\pi_2(j) = \kappa \frac{1}{A}(W_2/P_2)y_2(j)^{1/\alpha}$. We substitute $W_2/P_2 = \lambda c_2^\gamma$ and the expression (19) for $y_2(j)$. In the expression for $y_2(j)$ we also substitute (35) and $P_{H,2}(j)/P_{H,2} = n^{1/(\mu-1)}$. This then delivers the second line on the right hand side of (70). (71) is the Foreign counterpart. Finally, (72) follows from the bankruptcy condition (26) and (73) is its Foreign counterpart.

The paper considers two special cases of this system of equations. In sections 2.5 and 3.1-3.4 we assume $g_t = 0$ and in the vulnerability section 4 we assume $\zeta = \alpha = 1$. We will now show that $g_t = 0$ allows us to summarize the equilibrium in the form of the 6 equations (37)-(42) and that $\zeta = \alpha = 1$ implies the symmetric equilibrium given by (51)-(53) in the vulnerability section.

Setting $g_2 = g_2^* = 0$ and taking (66)-(67) to the power $\alpha/(1-\alpha+\alpha\gamma)$, these two equations can be written as

$$\theta \left(\frac{P_2}{P_{H,2}} \right)^{\frac{1}{1-\alpha+\alpha\gamma}} c_2 = n^\zeta \tag{75}$$

$$\theta \left(\frac{P_2^*}{P_{F,2}} \right)^{\frac{1}{1-\alpha+\alpha\gamma}} c_2^* = n^{*\zeta} \tag{76}$$

with θ and ζ defined in Section 2.5. Substituting the expressions for relative prices from (36), this gives two equations in c_2 and c_2^* that can be solved as a function of n and n^*. Using that $c_1 = [\beta(1+i)]^{-1/\gamma} c_2$ and $c_1^* = [\beta(1+i^*)]^{-1/\gamma} c_2^*$ from the consumption Euler equations (68)-(69), we then have

$$c_1 = \frac{[\beta(1+i)]^{-1/\gamma}}{\theta} n^{(1-\delta)\zeta} (n^*)^{\delta\zeta} \tag{77}$$

$$c_1^* = \frac{[\beta(1+i^*)]^{-1/\gamma}}{\theta} n^{\delta\zeta} (n^*)^{(1-\delta)\zeta} \tag{78}$$

This corresponds to the equilibrium equations (37)-(38) in Section 2.5 for the case where monetary policy is $(1+i)\beta = (1+i^*)\beta = 1$. (39)-(40) follow directly from (70)-(71) after again setting $(1+i)\beta = (1+i^*)\beta = 1$ and $g_t = g_t^* = 0$. This monetary policy also implies $c_2 = c_1$ and $c_2^* = c_1^*$. We therefore replace second period with first-period consumption on the second lines of (70)-(71). We also use that the second period relative prices are equal to the first period relative prices.

This follows from (36), together with $c_2 = c_1$ and $c_2^* = c_1^*$. Finally, (41)-(42) correspond exactly to (72)-(73).

In the vulnerability section 4 we only consider symmetric equilibria, under the assumption that $\alpha = \zeta = 1$. All relative prices are then equal to 1. It then follows immediately from (66) that $c_2 = n/\theta$. Together with the consumption Euler equation (68) this gives (51). (52) follows from (70) after substituting $c_2 = n/\theta$, setting $\alpha = \zeta = 1$ and setting all relative prices equal to 1.

Finally, a couple of brief comments are in order about the flexible price equilibrium for the case where $g_t = 0$, discussed at the end of Section 2.5. In that case there are two additional variables to solve for, the nominal interest rates i and i^*. There are also two additional equations, which are the period-1 analogues of (66)-(67), which follow from optimal price setting in period 1. Solving these equations for period 1, using the expression (36) for the relative price and the fact that the number of firms is 1 in period 1, gives $c_1 = c_1^* = 1/\theta$. This in turn implies that $\pi_1 = \pi_1^* = [\mu(1-\alpha)+\alpha]/(\mu\theta)$. Under Assumption 1, it follows that $\pi_1 > z$, so that also $\pi > z$ as $\pi_2 > 0$. Therefore no firms go bankrupt and $n = 1$. Similarly we also have $n^* = 1$. Solving for (66)-(67) with $g_2 = 0$ we then also have $c_2 = c_2^* = 1/\theta$. First and second period consumption are therefore equal and it follows from the consumption Euler equations (68)-(69) that $(1+i)\beta = (1+i^*)\beta = 1$.

C. Proof of Proposition 2

We already know that both symmetric equilibria exist when $\pi(\bar{n}) < z < \pi(1)$. We therefore focus on the existence of asymmetric equilibria. We will only consider the asymmetric equilibrium $(n, n^*) = (\bar{n}, 1)$ as the other asymmetric equilibrium, $(n, n^*) = (1, \bar{n})$, exists if and only if the first one exists.

From (37)-(38), setting $n = \bar{n}$ and $n^* = 1$ gives $c_1 = (1/\theta)\bar{n}^{(1-\delta)\zeta}$ and $c_1^* = (1/\theta)\bar{n}^{\delta\zeta}$. Substituting these values for c_1 and c_1^* into (39)-(40) gives

$$\hat{\pi}(\psi) = \frac{1}{\theta}\bar{n}^{(1-\delta)\zeta}\left(1 - \frac{(\mu-1)\alpha}{\mu}\bar{n}^{\kappa}\right) + \phi\beta\frac{\mu(1-\alpha)+\alpha}{\mu\theta}\bar{n}^{\zeta(1-\delta)-1}$$

$$\hat{\pi}^*(\psi) = (1+\phi\beta)\frac{\mu(1-\alpha)+\alpha}{\mu\theta}\bar{n}^{\zeta\delta}$$

where $\hat{\pi}(\psi)$ and $\hat{\pi}^*(\psi)$ are the values of π and π^* when $(n, n^*) = (\bar{n}, 1)$ and $\delta = (1-\psi)/[(1-\alpha+\alpha\gamma)(2\psi-1)+2(1-\psi)]$. We will consider values of ψ between 0.5 and 1. The asymmetric equilibrium $(n, n^*) = (\bar{n}, 1)$ exists when $\hat{\pi}(\psi) < z \leq \hat{\pi}^*(\psi)$. This is clearly the case for $\psi = 1$ as $\hat{\pi}(1) = \pi(\bar{n})$ and $\hat{\pi}^*(1) = \pi(1)$.

Using the negative relationship between ψ and δ, it follows immediately from the expressions for $\hat{\pi}$ and $\hat{\pi}^*$ above that the derivative of $\hat{\pi}$ with respect to ψ is negative and the derivative of $\hat{\pi}^*$ with respect to ψ is positive for ψ between 0.5 and 1. We will also show that there is a value $\bar{\psi} > 0.5$ for which $\hat{\pi}(\bar{\psi}) = \hat{\pi}^*(\bar{\psi})$. These two results together imply the proposition. As we lower ψ below 1, $\hat{\pi}$ rises and $\hat{\pi}^*$ falls, until we reach a level $\psi(z) > 0.5$ so that either $\hat{\pi}(\psi(z)) = z$ or $\hat{\pi}^*(\psi(z)) = z$. If this were not the case, then $\hat{\pi}(\psi) < \hat{\pi}^*(\psi)$ for all ψ between 0.5 and 1, which is inconsistent with the finding that they are equal for $\psi = \bar{\psi} > 0.5$. For values of ψ above $\psi(z)$ we have $\hat{\pi} < z$ and $\hat{\pi}^* > z$, so that $(n, n^*) = (\bar{n}, 1)$ is an equilibrium. For values of ψ below $\psi(z)$ we either have $\hat{\pi} > z$ or $\hat{\pi}^* < z$, so that $(n, n^*) = (\bar{n}, 1)$ is not an equilibrium.

We finally need to show that there is a value $\bar{\psi} > 0.5$ for which $\hat{\pi}(\bar{\psi}) = \hat{\pi}^*(\bar{\psi})$. Let the corresponding value of δ be $\bar{\delta}$. Equating the expressions above for $\hat{\pi}$ and $\hat{\pi}^*$ gives

$$\overline{n}^{(1-2\bar{\delta})\zeta} = \frac{(\alpha + \mu(1-\alpha))(1+\phi\beta)}{\mu - (\mu-1)\alpha\overline{n}^{\kappa} + \frac{\phi\beta(\mu(1-\alpha)+\alpha)}{\overline{n}}} \tag{79}$$

It follows from $\bar{n} < 1$ that the term on the right hand side is less than 1. Therefore it must be the case that $\bar{\delta} < 0.5$, from which it follows that $\bar{\psi} > 0.5$. It follows that there is a value $\psi = \bar{\psi} > 0.5$ for which $\hat{\pi}(\psi) = \hat{\pi}^*(\psi)$, which completes the proof of Proposition 2.

In Section 4.5 we discussed an extension where ϕ differs across countries, with $\phi_F > \phi_H$. In order to evaluate whether an asymmetric equilibrium exists where there is only a panic in the Home country, we must replace ϕ with ϕ_F and ϕ_H respectively in the expressions for $\hat{\pi}^*(\psi)$ and $\hat{\pi}(\psi)$. We can again find $\bar{\psi}$ by setting $\hat{\pi}^*(\psi) = \hat{\pi}(\psi)$. This still yields (79), with the ϕ in the numerator and denominator replaced by respectively ϕ_F and ϕ_H. $\bar{\psi}$ will be larger than 0.5 ($\bar{\delta} < 0.5$) when the term on the right hand side is less than 1. This can be rewritten as (61). This is a sufficient condition to assure that the asymetric equilibrium with $n = \bar{n}$ and $n^* = 1$ does not exist for sufficient integration. It is not a necessary condition as either $\hat{\pi}^*(\psi) < z$ or $\hat{\pi}(\psi) > z$ may hold for sufficient integration even when (61) is not satisfied.

D. Introducing Wage Rigidities

In order to introduce wage rigidities we first introduce labor heterogeneity. Labor L_t in the production function is now a CES index of labor supply by all

households:

$$L_t = \left(\int_0^1 L_t(j)^{\frac{\omega-1}{\omega}} dj \right)^{\frac{\omega}{\omega-1}} \tag{80}$$

where $L_t(j)$ is labor by agent j. Given L_t, this specification leads to the following demand for individual labor:

$$L_t(j) = \left(\frac{W_t(j)}{W_t} \right)^{-\omega} L_t \tag{81}$$

where $W_t(j)$ is the wage rate for labor supplied by agent j and

$$W_t = \left(\int_0^1 W_t(j)^{1-\omega} dj \right)^{\frac{1}{1-\omega}} \tag{82}$$

Aggregate labor demand in period t in the Home country is $n_{H,t}L_t$. Demand for labor supplied by agent j is then

$$1 - l_t(j) = \left(\frac{W_t(j)}{W_t} \right)^{-\omega} n_{H,t} L_t \tag{83}$$

We can now maximize agent j utility with respect to $W_t(j)$. All households choose the same optimal $W_t(j)$, which will then be equal to W_t. We will replace the λl_t in the utility function with $\tilde{\lambda} l_t$. Dropping the j, maximization of utility with respect to the individual wage rate gives

$$\frac{W_t}{P_t} = \lambda c_t^{\gamma} \tag{84}$$

where $\lambda = \tilde{\lambda}\omega/(\omega - 1)$. With the redefined λ this is the same as (13). Nothing else in the model changes.

When wages are rigid, they are set at the start of each period. This makes no difference for period 2 as there are no shocks during period 2. For period 1 the only shock is a self-fulfilling panic. We assume that the probability of a panic is infinitesimal. Then the right hand side of (84) needs to include the expectation of c_1^{γ} at the start of period 1 giving infinitesimal weight to a panic occurrence. The expectation is therefore based on $c_1 = 1/\theta$, its value in the absence of a panic. When the real wage is set at the start of period t, it will then be set at λ/θ^{γ}. If instead the nominal wage is set, it will be equal to $\bar{P}\lambda/\theta^{\gamma}$, where $\bar{P}$ is the price index in the non-panic state. This is equal to P_{H1}, the price set at the start of period 1 by all firms. The real wage will then be $(P_{H,1}/P_1)(\lambda/\theta^{\gamma})$, where $P_{H,1}/P_1$ depends on c_1^*/c_1 as in (36).

References

[1] Adrian, Tobias, Paolo Colla and Hyun S. Shin. 2013. "Which Financial Frictions? Parsing the Evidence from the Financial Crisis of 2007-09." in Daron Acemoglu, Jonathan Parker and Michael Woodford (eds), *NBER Macroeconomics Annual* 27, 159 – 214.

[2] Aghion, Philippe, Philippe Bacchetta, Abhijit Banerjee. 2000. "A simple model of monetary policy and currency crises." *European Econonomic Review* 44, 728–738.

[3] Anderson, James E. and Eric van Wincoop. 2003. "Gravity with Gravitas: A Solution to the Border Puzzle." *American Economic Review* 93, 170-192.

[4] Angelatos, George-Marios and Jennifer La'O. 2013. "Sentiments." *Econometrica* 81(2), 739-779.

[5] Aruoba, S. Boragan and Frank Schorfheide. 2013. "Macroeconomic Dynamics Near the ZLB: A Tale of Two Equilibria." NBER Working paper 19248.

[6] Bacchetta, Philippe, Cedric Tille and Eric van Wincoop. 2012. "Self-Fulfilling Risk Panics." *American Economic Review* 102, 3674–3700.

[7] Basu, Susanto and Brent Bundick. 2012. "Uncertainty Shocks in a Model of Effective Demand." mimeo.

[8] Benhabib, Jess, Pengfei Wang and Yi Wen. 2012. "Sentiments and Aggregate Demand Fluctuations." NBER Working Paper 18413.

[9] Bodenstein, Martin. 2010. "Trade Elasticity of Substitution and Equilibrium Dynamics." *Journal of Economic Theory* 145, 1033-1059.

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

[11] Chari V.V., Christiano, Lawrence J., Kehoe, Patrick J. 2008. "Facts and Myths about the Financial Crisis of 2008." Working paper. Federal Reserve Bank of Minneapolis.

[12] Christiano, Lawrence J. 2004. "The Zero-Bound, Low Inflation, and Output Collapse." Working paper.

[13] Cole, Harold L. and Maurice Obstfeld. 1991. "Commodity Trade and International risk sharing: How much do Financial Markets Matter?" *Journal of Monetary Economics* 28, 3-24.

[14] Dedola, Luca and Giovanni Lombardo. 2012. "Financial Frictions, Financial Integration and the International Propagation of Shocks." *Economic Policy* 27(70): 319-359.

[15] Devereux, Michael B. and Alan Sutherland. 2011. "Evaluating International Integration under Leverage Constraints." *European Economic Review* 55(3): 427-442.

[16] Eggertsson, Gauti B. 2010. "The Paradox of Toil." Federeal Reserve Bank of New York, Staff Report 433.

[17] Eggertsson, Gauti B. and Paul Krugman. 2012. "Debt, Deleveraging, and the Liquidity Trap: A Fisher-Minsky-Koo Approach." *The Quarterly Journal of Economics* 127(3), 1469-1513.

[18] Farmer, Roger E.A. 2012a. "The Stock Market Crash of 2008 Caused the Great Recession: Theory and Evidence" *Journal of Economic Dynamics and Control* 36, 693-707.

[19] Farmer, Roger E.A. 2012b. "Confidence, Crashes and Animal Spirits" *The Economic Journal* 122 (559), 155-172.

[20] Fernández-Villaverde, Jesús, Pablo Guerrón-Quintana, and Juan F. Rubio-Ramírez. 2012. "Supply-Side Policies and the Zero Lower Bound." mimeo.

[21] Heathcote, Jonathan and Fabrizzio Perri. 2012. "Wealth and Volatility." working paper, University of Minnesota.

[22] Helbling, Thomas, Raju Huidrom, Ayhan Kose and Christopher Otrok. 2011. "Do Credit Shocks Matter? A Global Perspective." *European Economic Review* 55, 340-353.

[23] Hirata, Hideaki, M. Ayhan Kose and Christopher. 2013. "Regionalization versus Globalization." IMF Working paper 13/19.

[24] Hooper, Peter, Karen Johnson, and Jaime Marquez. 2000. "Trade Elasticities for the G-7 Countries." *Princeton Studies in International Economics* 87.

[25] Kahle, Kathleen M. and René M. Stulz. 2013. "Access to Capital, Investment, and the Financial Crisis," *Journal of Financial Economics*, forthcoming.

[26] Kalemli-Ozcan, Sebnem, Elias Papaioannou and Fabrizio Perri. 2013. "Global Banks and Crisis Transmission." *Journal of International Economics*, forthcoming.

[27] Kamin, Steven B. and Laurie Pounder DeMarco. 2012. "How Did a Domestic Slump Turn into a Global Financial Crisis?" *Journal of International Money and Finance* 31, 10-41.

[28] Kollmann, Robert, Zeno Enders and Gernot Muller. 2011. "Global Banking and International Business Cycles." *European Economic Review* 55, 407-426.

[29] Krugman, Paul. 1998. "It's Baaack: Japan's Slump and the Return of the Liquidity Trap." *Brookings Papers on Economic Activity* 2:1998, 137-205.

[30] Mankiw, N. Gregory and Matthew Weinzierl. 2011. "An Exploration of Optimal Stabilization Policy." *Brookings Papers on Economic Activity, Spring,* 209-249.

[31] Mertens, Karel and Morten O. Ravn. 2013. "Fiscal Policy in an Expectations Driven Liquidity Trap." working paper.

[32] Nguyen, Ha and Rong Qiuan. 2013. "Demand Collapse or Credit Crunch to Firms? Evidence from the World Bank's Financial Crisis Survey in Eastern Europe." working paper.

[33] Perri, Fabrizio and Vincenzeo Quadrini. 2012. "International Recessions." working paper.

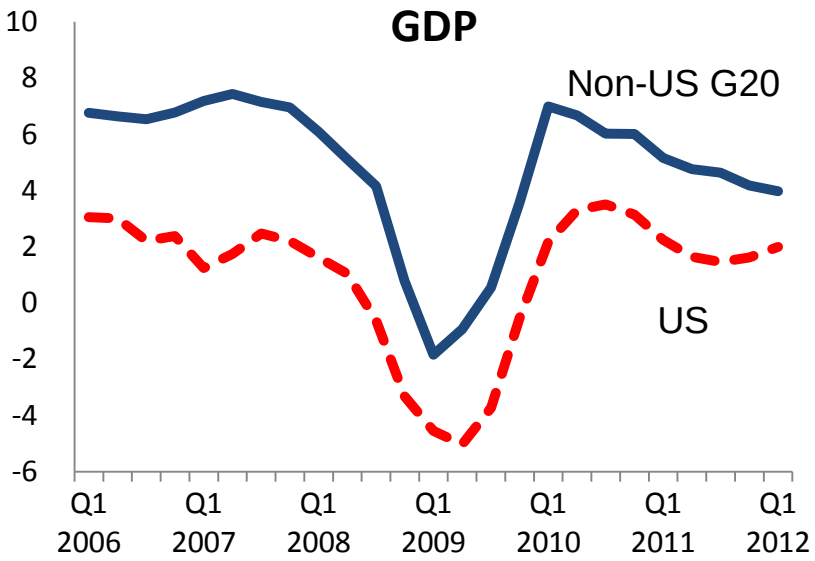
[34] Ravn, Morten and Vincent Sterk. 2012. "Job Uncertainty and Deep Recessions." working paper.

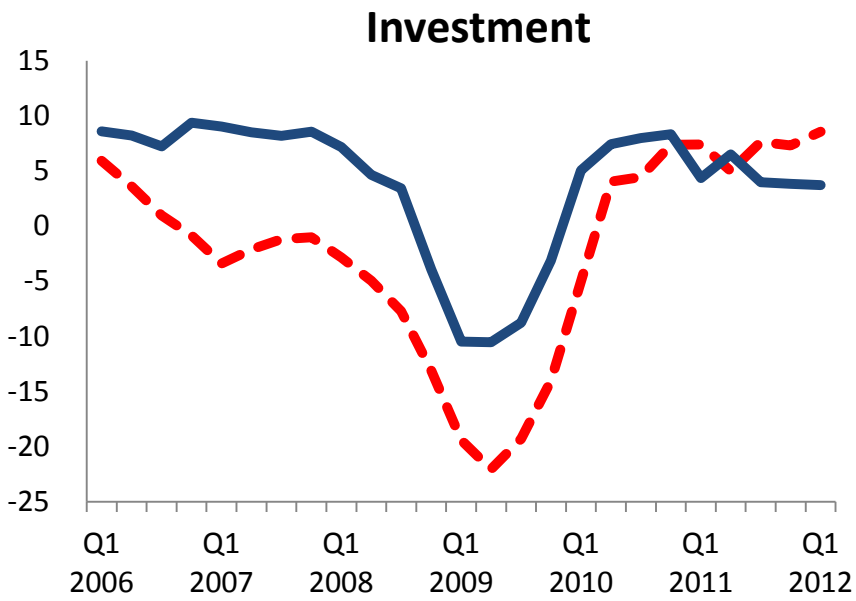
[35] Rose, Andrew and Mark Spiegel. 2010. "The Causes and Consequences of the 2008 Crisis: International Linkages and American Exposure." *Pacific Economic Review* 15: 340-363.

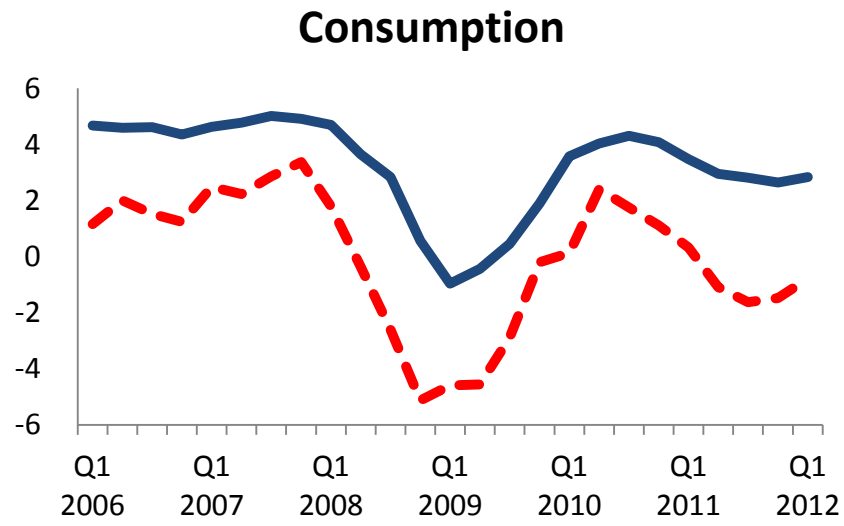
[36] Schmitt-Grohé, Stephanie. 1997. "Comparing Four Models of Aggregate Fluctuations due to Self-Fulfilling Expectations." *Journal of Economic Theory* 72, 96-147.

[37] van Wincoop, Eric. 2013. "International Contagion through Leveraged Financial Institutions." *American Economic Journal: Macroeconomics* 5(3): 152-189.

Figure 1 Global Growth (Percent; Annual; Real)*

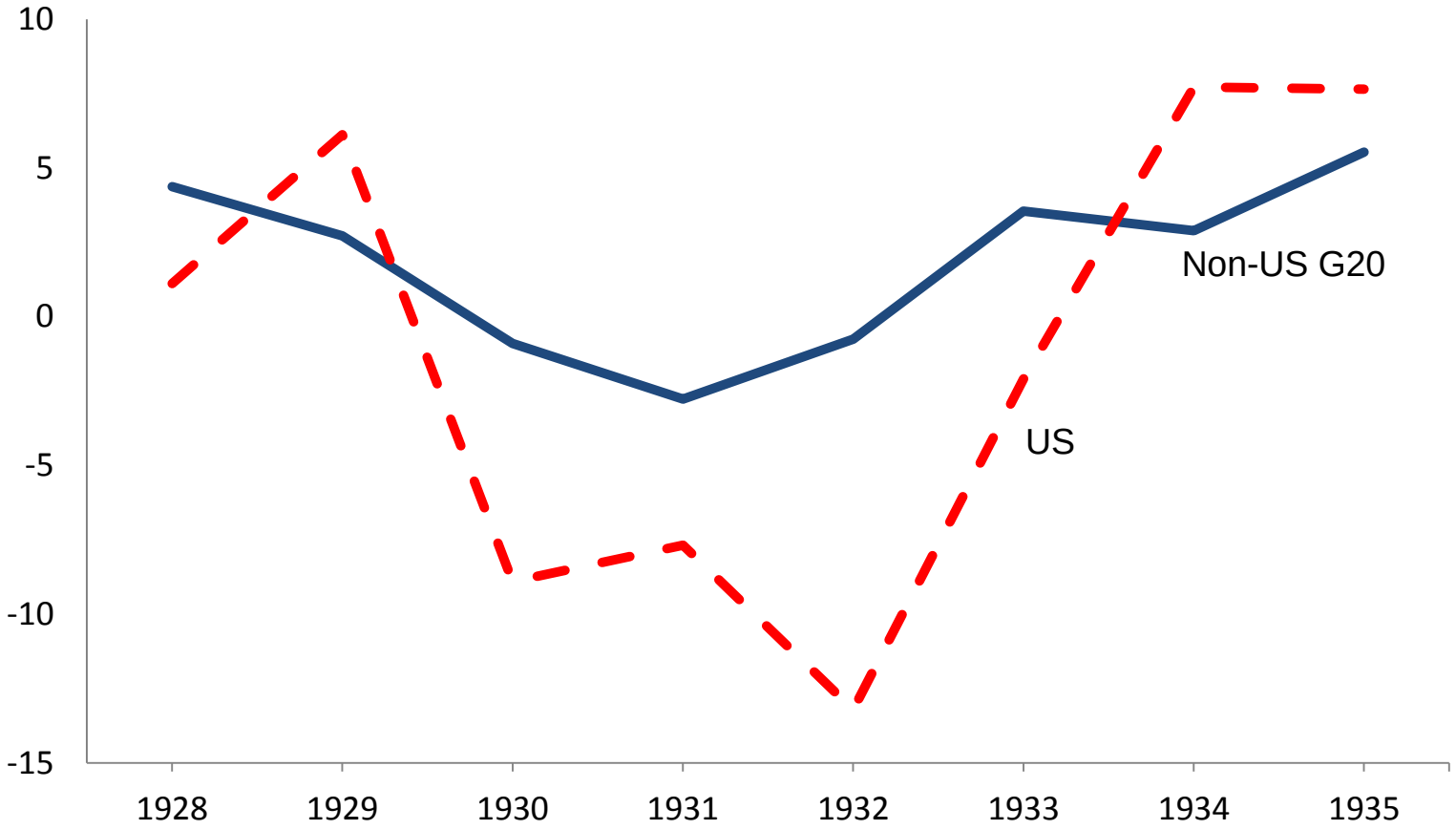






* Source: Datastream. Growth over past 4 quarters. Broken line is the U.S.; solid line is the non-U.S. G20 minus Saudi Arabia. Consumption and investment also do not include China.

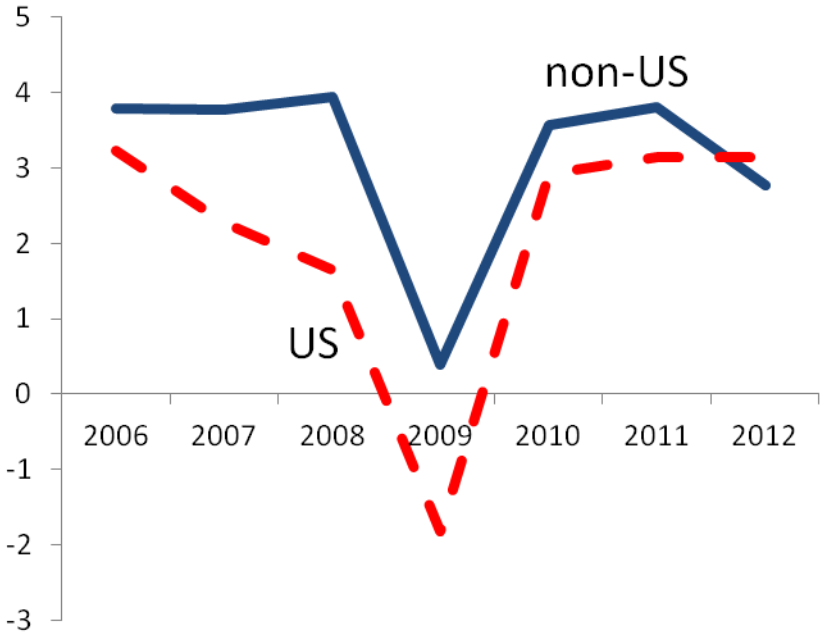
Figure 2 Real GDP Growth During the Great Depression



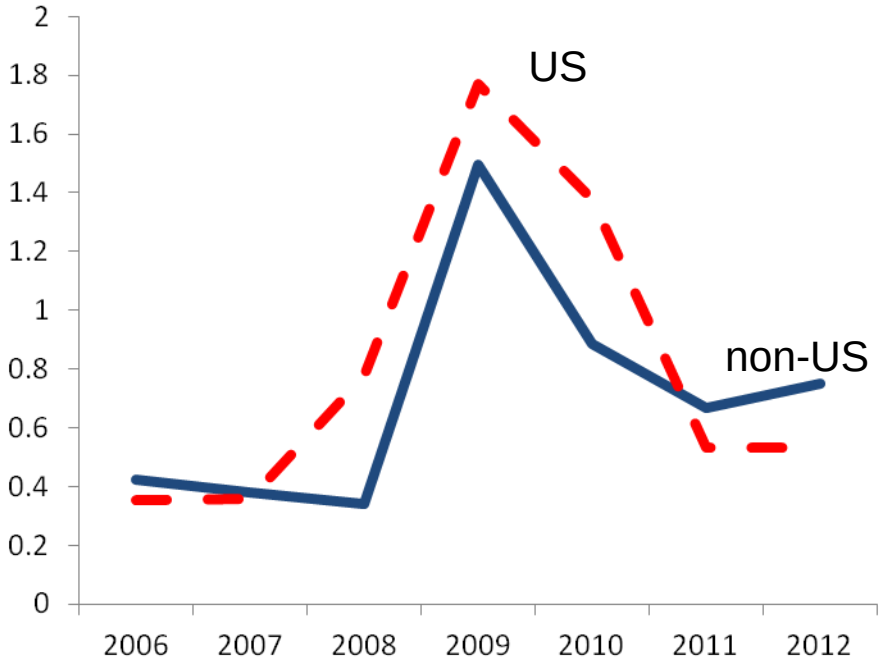
*Source: Angus Maddison. Broken line is the U.S.; solid line is the non-U.S. G20 minus Saudi Arabia minus South Africa.

Figure 3 GDP Growth Forecasts Probabilities: Expectation and Variance*

Average Expectation

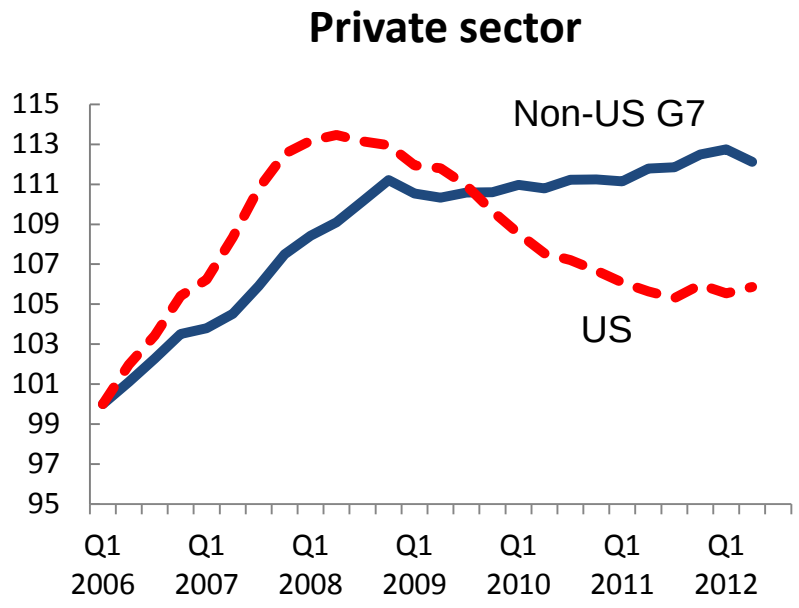


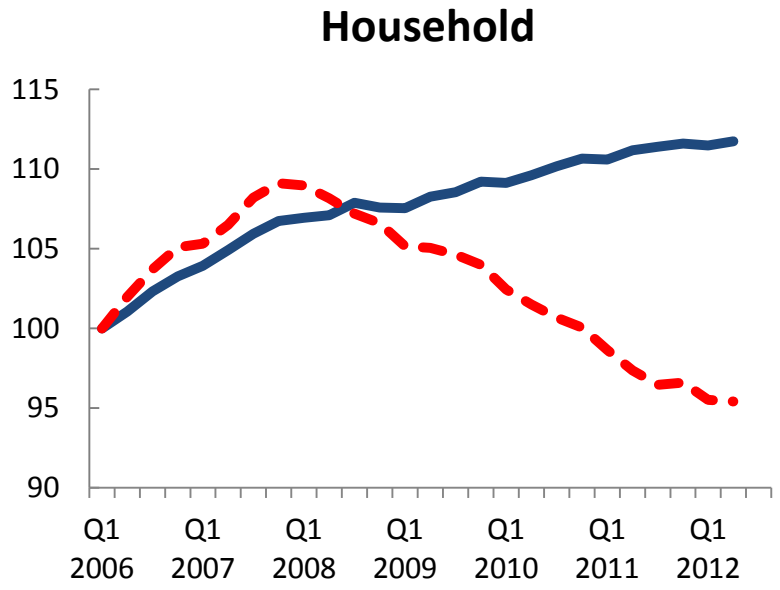
Average Variance

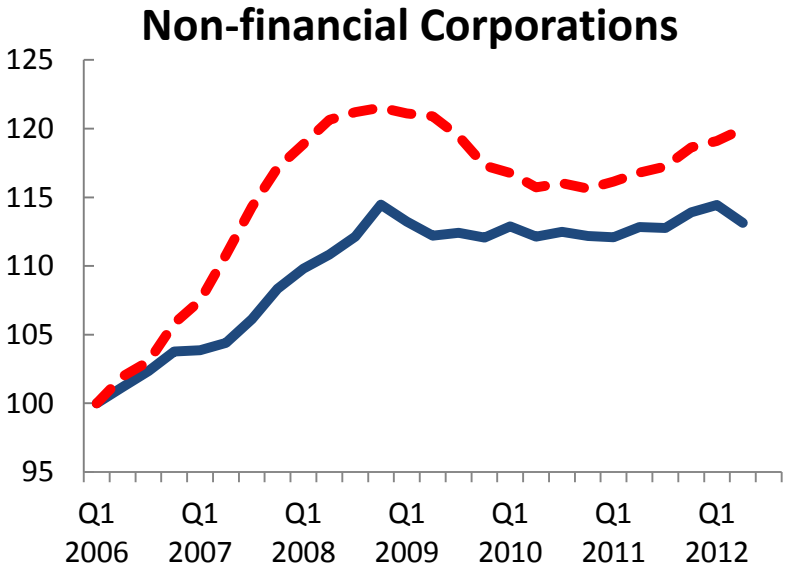


*Data from Consensus Forecasts, based on one-year ahead forecast probabilities. See Appendix A for a description. Non-US: Australia, China, Hong Kong, India, Indonesia, Malaysia, New Zealand, Singapore, South Africa, Taiwan, Thailand, Japan, Germany, France, U.K., Italy, Canada

Figure 4 Total Credit







Source: Bank for International Settlements, *Long series on credit to private non-financial sectors*. The credit series are divided by the GDP deflator and normalized at 100 in 2006:Q1. The non-US G7 series is computed using relative PPP-adjusted GDP weights.

Figure 5 Symmetric Equilibria*

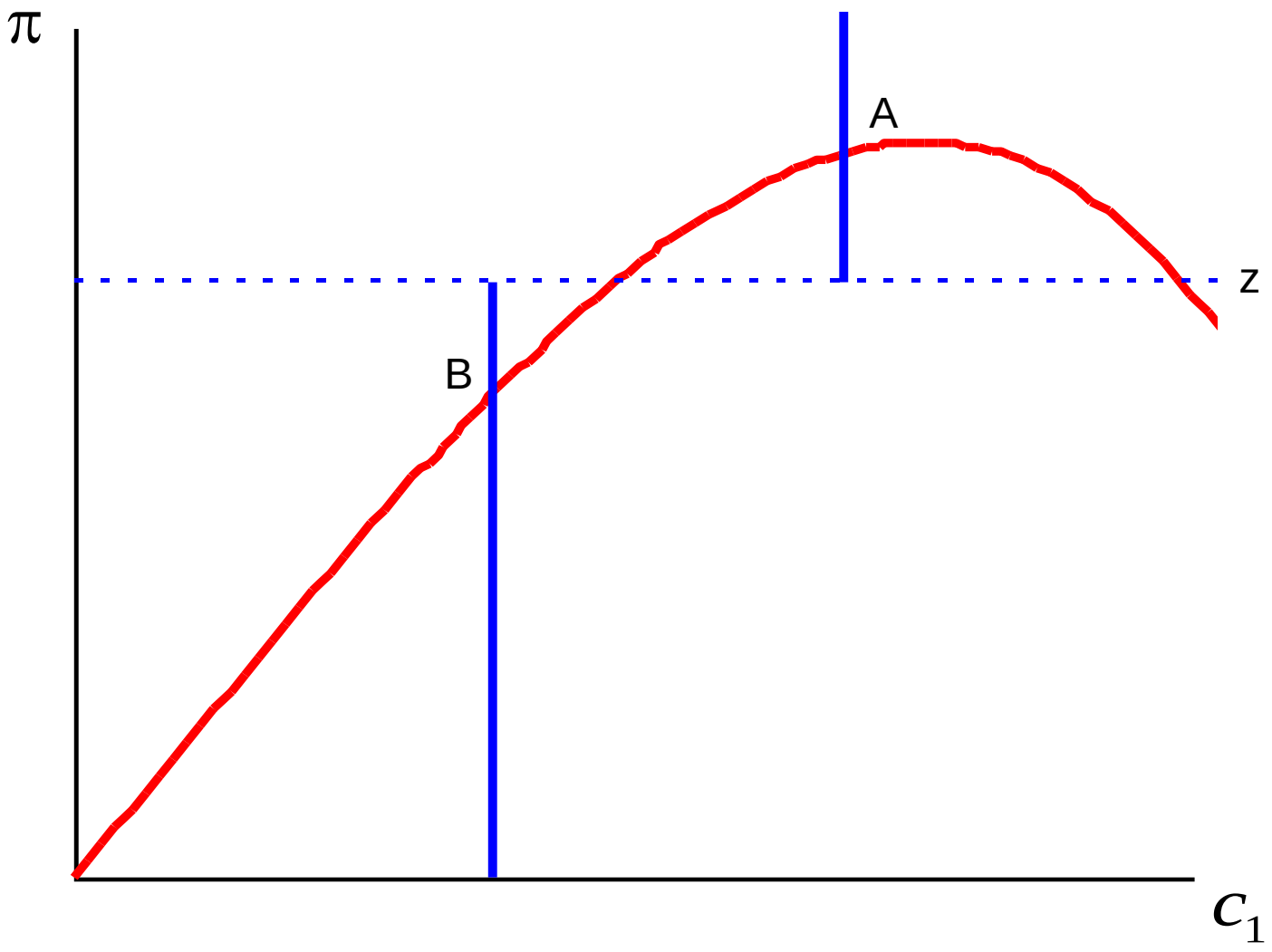


Figure 6 All Equilibria: Role of Trade Integration

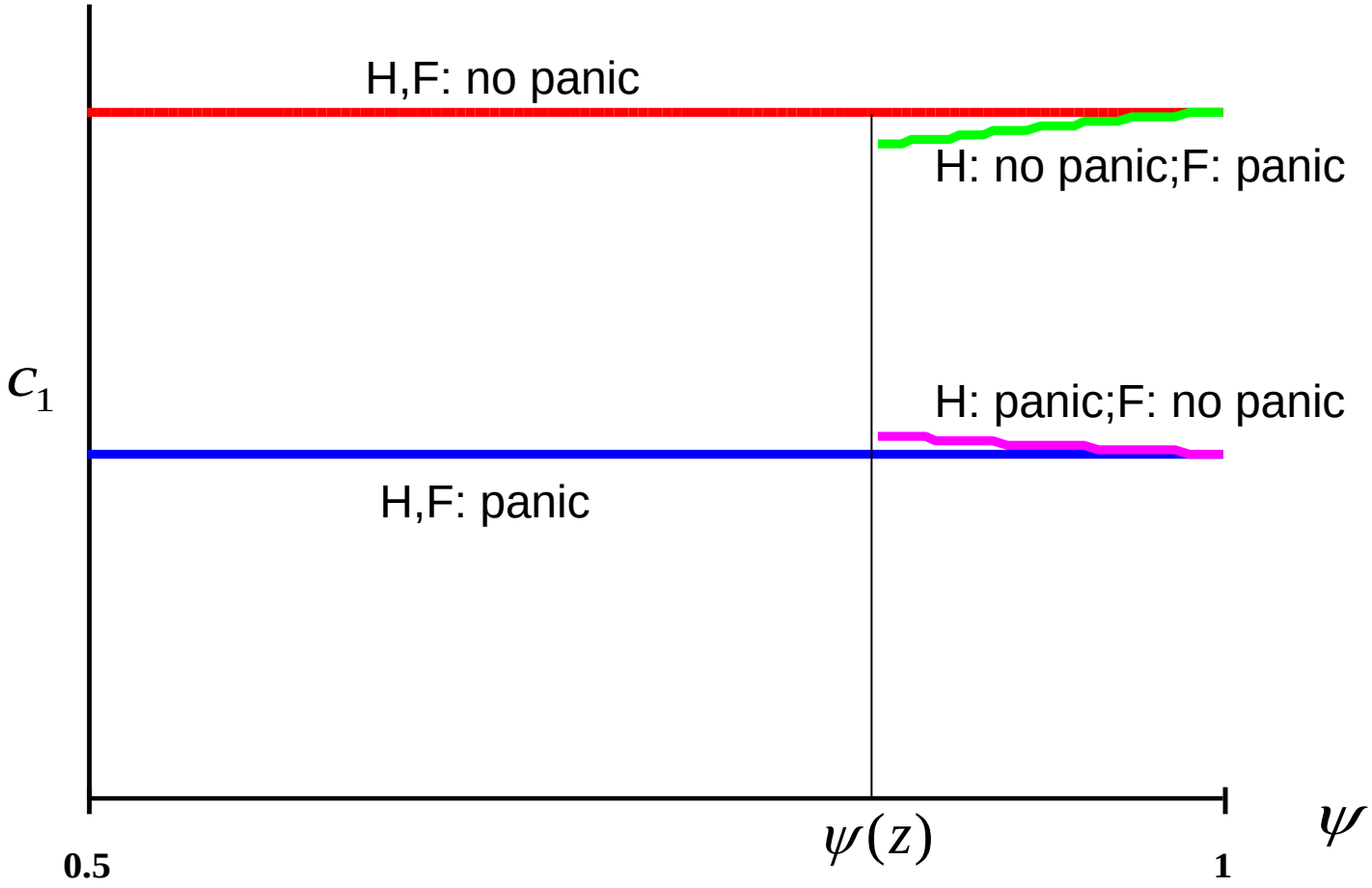
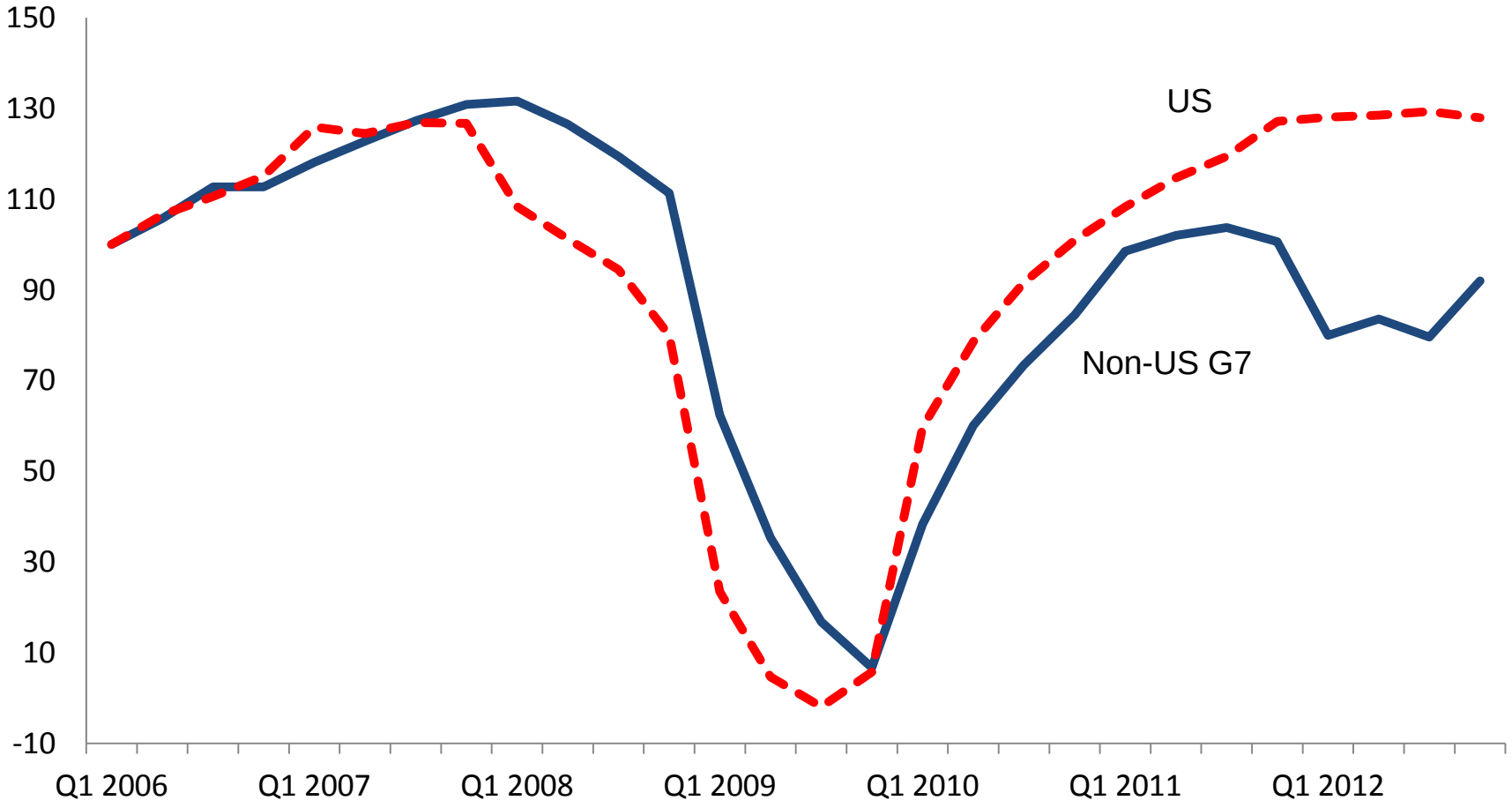


Figure 7 Corporate Profits



Source: Worldscope, *Net profits (income)*. Profits are aggregated over continuing firms firms within each country, divided by the GDP deflator, and normalized at 100 in 2006:Q1. The non-US G7 series is computed using relative PPP-adjusted GDP weights.

Figure 8 Equilibria in Home when Foreign Panic

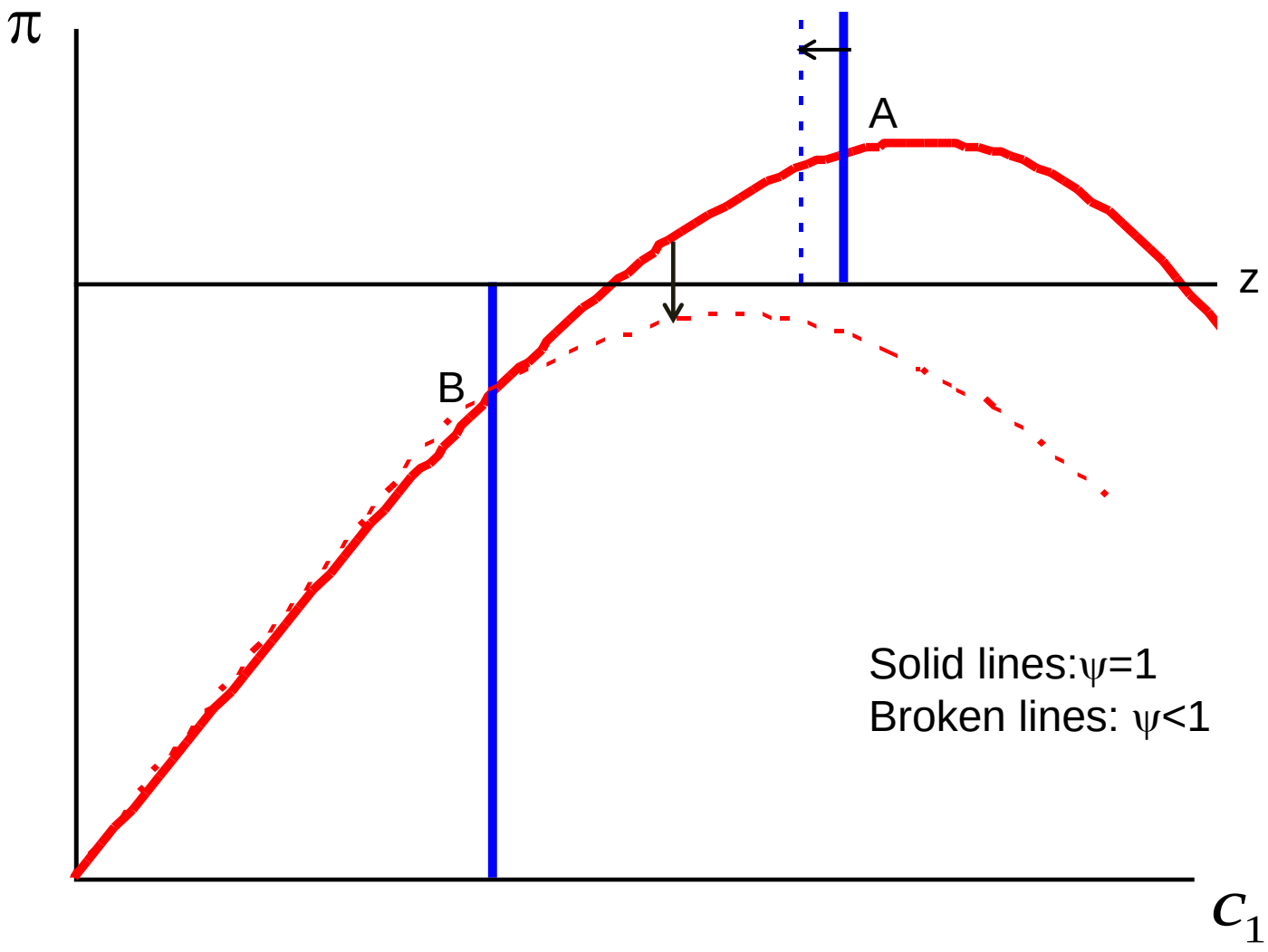


Figure 9 Equilibria in Home when no Foreign Panic

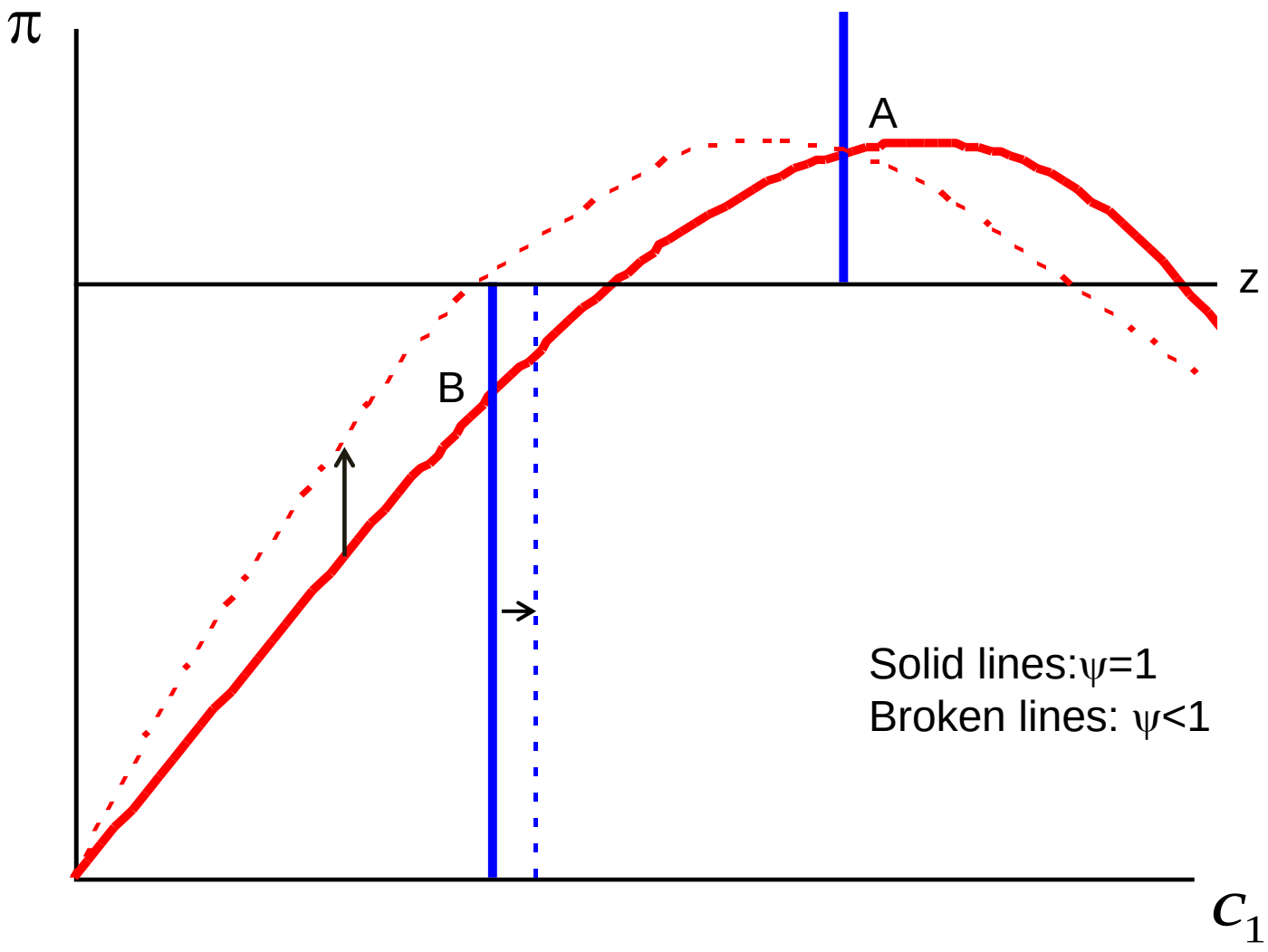


Figure 10 Panic Vulnerability: Role of Credit

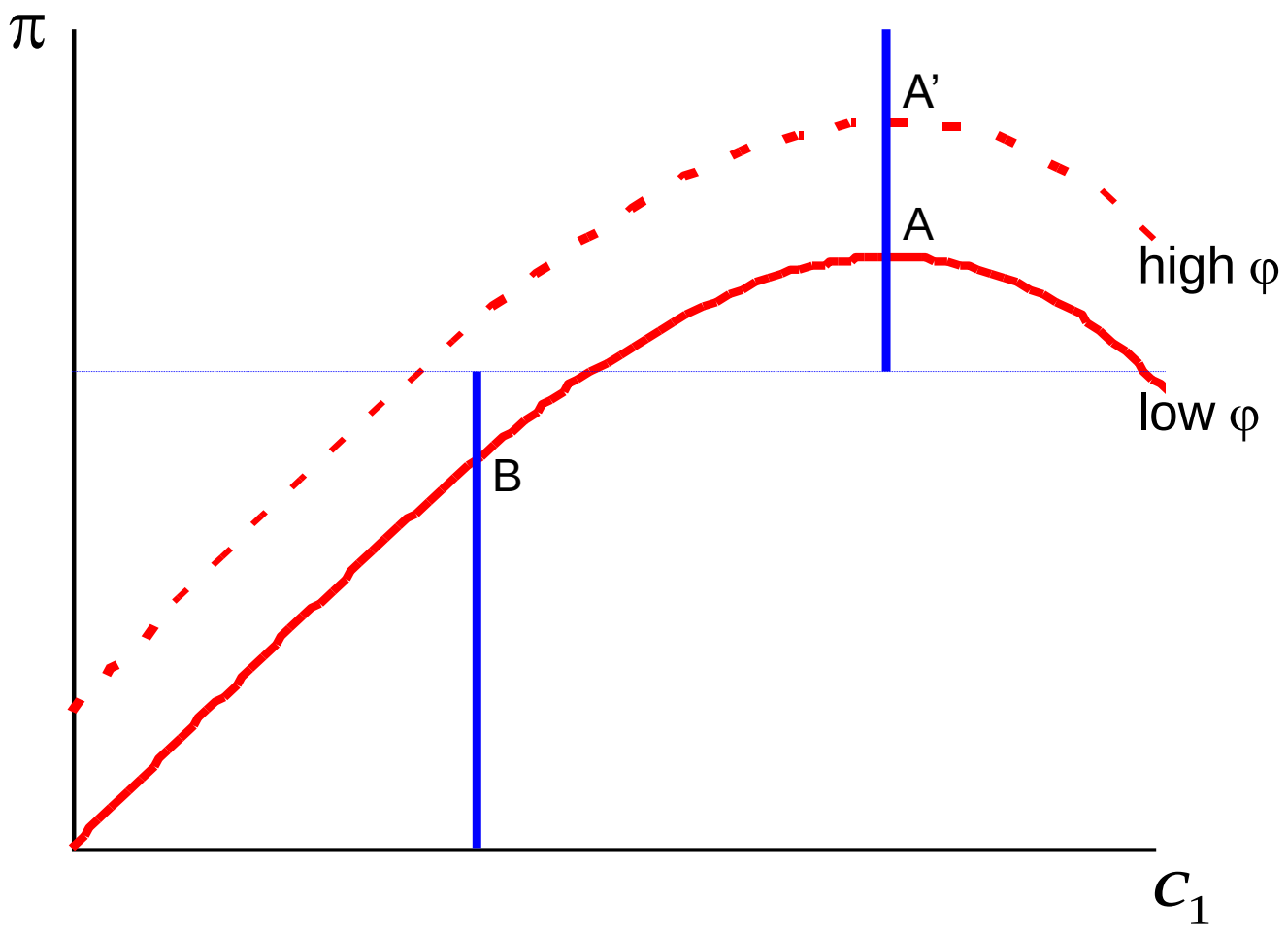


Figure 11 Panic Vulnerability: Role of Monetary Policy

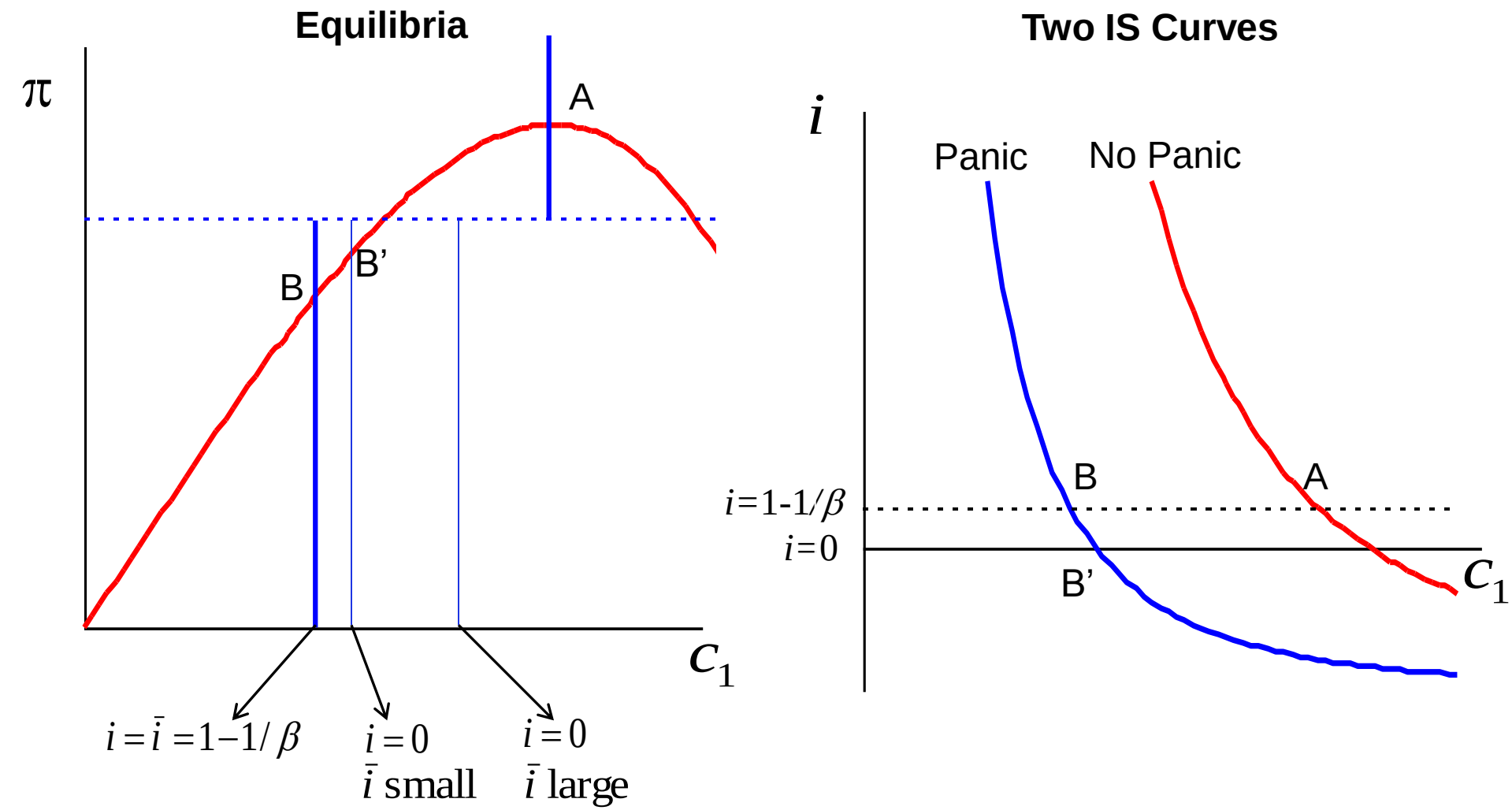


Figure 12 Panic Vulnerability: Role of Fiscal Policy*

