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### Abstract

This paper analyzes the transmission mechanism of banking sector shocks in an international real business cycle model with heterogeneous bank sizes. We examine to what extent the financial exposure of the banking sector affects the transmission of foreign banking sector shocks. In our model, the more exposed domestic banks are to the foreign economy via lending to foreign firms, the greater are the spillovers from foreign financial shocks to the home economy. The model highlights the role of openness to trade and the dynamics of the terms of trade in the international transmission mechanism of banking sector shocks. Spillovers from foreign banking sector shocks are greater the more open the home economy is to trade and the less the terms of trade respond to foreign shocks.

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# Financial exposure and the international transmission of financial shocks\*

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## **Abstract**

This paper analyzes the transmission mechanism of banking sector shocks in an international real business cycle model with heterogeneous bank sizes. We examine to what extent the financial exposure of the banking sector affects the transmission of foreign banking sector shocks. In our model, the more exposed domestic banks are to the foreign economy via lending to foreign firms, the greater are the spillovers from foreign financial shocks to the home economy. The model highlights the role of openness to trade and the dynamics of the terms of trade in the international transmission mechanism of banking sector shocks. Spillovers from foreign banking sector shocks are greater the more open the home economy is to trade and the less the terms of trade respond to foreign shocks.

# 1 INTRODUCTION

The financial crisis of 2007 to 2009 was triggered by large banking sector losses associated with US sub-prime mortgage backed securities.<sup>1</sup> A remarkable feature of the financial crisis was not just the size of the downturn of the US economy, the longest and deepest recession of the post-war era, but also the degree to which it was accompanied by simultaneous downturns in many other developed economies. Recent empirical evidence suggests that this synchronization of output was strongest in countries with greater financial ties to the US economy.<sup>2</sup>

In this paper we examine the role of financial ties, or banking sector linkages, in the international transmission mechanism of foreign shocks. We show that economies with large and internationally exposed banking sectors experience stronger output synchronization in response to a foreign financial shock than do economies with smaller and less exposed banking sectors. To carry out the analysis, we develop a two-country international real business cycle (IRBC) model where the size of one country (the domestic economy) is small relative to the other. Because our focus is on the role of the banking sector, we augment the standard IRBC model such that there is a demand for financial intermediation both at and away from steady state. To do so, we assume that each economy is populated by patient households and impatient entrepreneurs, the latter being subject to a binding borrowing constraint as in Kiyotaki and Moore (1997) and Iacoviello (2005). Furthermore, we assume that a competitive banking sector mediates between households and entrepreneurs.

Within this framework, we examine alternative assumptions about the size, and there-

fore the degree of exposure, of the banking sector in the small open economy. In particular, we assume that banks owned by small-country households intermediate all loans to domestic entrepreneurs. In addition, these banks also intermediate a small, but in relation to the size of the small country, large, proportion of loans to foreign firms. An equivalent interpretation is that small-country banks purchase foreign banking assets in the secondary market. This implies that the banking sector of the small open economy can be very large relative to the size of the economy, yet still not significantly influence the business cycle dynamics in the other country. We see this assumption as a proxy for the international financial exposure of the small country's banking sector.

Our model suggests that financial exposure via the banking sector can, both quantitatively and qualitatively, change the prediction of the model regarding the cross border transmission of shocks. For instance, the magnitude of output loss in the small country following a financial shock in the large country is proportional to the financial exposure of the small country's banking sector. Along the open economy dimension of the model, there are two partially offsetting factors affecting the transmission mechanism of financial shocks. Greater openness to trade in goods enhances the international transmission of financial shocks, but endogenous responses of the terms of trade and the real exchange rate, tend to dampen the transmission mechanism.

The remainder of the paper is structured as follows. Section 2 puts our contribution into the context of the literature and highlights the empirical evidence. Section 3 describes our model and section 4 the calibration of the model's deep parameters and driving forces. Section 5 examines the international transmission mechanism using impulse response

analysis and model-generated second moments, and carries out a number of robustness checks. Section 6 concludes.

## 2 LITERATURE

There is a large literature on the role of financial integration in the international transmission of shocks. For example Heathcote and Perri (2002), Benigno and Thoenissen (2008), Corsetti et al. (2008) and Thoenissen (2011) focus on the role of financial asset market structure and relative price movements in the international transmission of supply shocks.

Motivated by the evidence on how the recent financial crisis has spread from the US to most other developed economies, the literature has started to focus on the link between financial integration and the international transmission mechanism of financial shocks. Is the international transmission mechanism of financial shocks stronger between financially integrated economies?

This question has recently been addressed by a number of papers putting forward alternative transmission mechanisms, amongst them Kollmann et al. (2011), Kalemli-Ozcan et al. (2012), Dedola and Lombardo (2012), and Ueda (2012). The paper closest related to our work is Kollmann et al. (2011). In their paper the banking sector is perfectly integrated in the sense that there is essentially only one bank making loans to home and foreign firms. Loan losses incurred in either country affect the global bank's capital position and hence the intermediation margin, transmitting the effects of country specific loan losses across both economies. Our approach differs from Kollmann et al.

(2011) in three ways. First, our model has two independent banking sectors instead of one global bank. Second, the transmission mechanism in the model highlights the role of banks heavily exposed to foreign assets in a small open economy setting rather than between two similar size countries. Third, we do not make the ‘one-good two-countries’ assumption frequently used in the literature. We give an explicit role to the terms of trade and international relative prices in transmitting foreign financial sector shocks in our model.

The transmission mechanism in Kalemli-Ozcan et al. (2012) also relies on the concept of a global bank. However, instead of intermediating all loans in both countries as in Kollmann et al. (2011)’s model, the global bank is only active in the internationally integrated sector of each country. Financial shocks take the form of losses incurred by the global bank from holding an exogenous risky asset.

A slightly different approach is taken by Dedola and Lombardo (2012) and Ueda (2012), who develop models based on financial frictions as in Bernanke et al. (1999). Dedola and Lombardo (2012) put forward a model in which investors hold both domestic and foreign capital stock but can only borrow from the domestic capital market. As long as both home and foreign assets are traded, their return tends to be equalized through arbitrage. Thus shocks which affect the value of these assets affect the net worth and the external finance premium in both countries, leading to synchronization of credit spreads. Ueda (2012) develops a two-country DSGE model in which both entrepreneurs and financial intermediaries are credit constrained and financial intermediaries are able to undertake cross-border borrowing and lending. Although in a different setup, similarly



to our paper, his model generates a positive correlation between financial integration and business cycle synchronization.

Our modeling approach analyzes the role of direct exposure to the foreign (US) financial sector from a small open economy perspective. The larger the exposure to the source of the shock, the greater the spillover from the source to our small open economy. Our approach is in line with the conventional view which suggests that exposure to the US financial sector was one of the main international transmission channels by which US financial shocks propagated to other countries during the financial crisis.<sup>3</sup> Empirical studies have, however, initially struggled to find conclusive evidence of the existence of this channel. For example, Rose and Spiegel (2010, 2011) consider a large number of potential causes of international linkages, but fail to find a statistically significant relationship between financial exposure to the US banking sector and the severity of the recession in other economies. Similarly, Giannone et al. (2011) find no direct evidence connecting financial openness and the depth of the recession during 2007-2009.<sup>4</sup>

Our main empirical motivation in modeling the financial sector exposure as a potentially powerful transmission channel comes from Kalemli-Ozcan et al. (2012). Using a more complete and larger panel data-set of bilateral financial linkages than was available to previous studies, Kalemli-Ozcan et al. (2012) are able to find that financial crises are associated with more synchronized business cycles between financially integrated countries. In particular, compared to the previous literature, they find that countries with stronger financial ties to the US (both directly and indirectly via off-shore centers such as the Cayman Islands) experienced deeper recessions during the 2007-09 crisis.

### 3 MODEL

We propose a two-country model with infinitely lived households and entrepreneurs. The world economy is populated by a continuum of agents on the interval  $[0, 1]$ . The population on the segment  $[0, n)$  belongs to the home country, while the segment  $[n, 1]$  belongs to the foreign country. There are two types of agents in our model, households and entrepreneurs. They differ with respect to their subjective rate of time preference; the household being relatively more patient than the entrepreneur.

Because entrepreneurs are more impatient than households, they face a binding borrowing constraint, as in Iacoviello (2005). Because this constraint is also binding in the steady state, there is a steady state demand for financial intermediation that is not present in the standard IRBC framework. While households have access to a global market for deposits, entrepreneurs are financed via a competitive banking sector. To allow some countries to have larger and more exposed banking sectors than others, we assume that banks in the home country, which we assume to be relatively small, intermediate all loans to home entrepreneurs and a small, but in proportion to the size of the home country, large, fraction of loans to foreign entrepreneurs. Letting banks be large relative to the size of the economy in which they are resident is our proxy for exposure.

Entrepreneurs in both countries rent capital to competitive goods producers. The final consumption good in both countries is an aggregate of home and foreign goods, where the share of the two intermediate goods in the final good differs between the home and foreign economy, reflecting home bias in final goods.

### 3.1 Households

The representative household in each country maximizes

$$E_0 \sum_{t=0}^{\infty} \beta^t U(c_t^H, l_t) \quad (1)$$

where  $c_t^H$  is a final consumption index which is a CES aggregate of home and foreign-produced intermediate goods,  $l_t$  is labour and  $\beta$  is the household's discount factor. The representative households in each country smooths consumption over time by purchasing internationally traded deposits denominated in units of the foreign consumption good,  $d$ . The one-period expected return in terms of domestic consumption goods is  $(1 + r_t) \frac{rs_{t+1}}{rs_t}$ , where  $rs_t$  denotes the consumption based real exchange rate between the home and the foreign country at time  $t$  and  $r_t$  denotes the interest rate on the deposit held between periods  $t$  and  $t + 1$ . The representative household receives wage income,  $w_t l_t$ , as well as dividends  $\pi_t^G$  and  $\pi_t^B$  from owning domestic intermediate goods producers and the domestic banking sector.  $T_t^E$  is a transfer the household receives from the entrepreneur when the loan repayment rate differs from its expected value.<sup>5</sup>

Equation (2) shows the budget constraint for the representative household in the home country.

$$c_t^H + d_t = w_t l_t + (1 + r_{t-1}) \frac{rs_t}{rs_{t-1}} d_{t-1} + \pi_t^G + \pi_t^B + T_t^E \quad (2)$$

The standard first-order conditions arising from maximizing expected intertemporal wel-

fare, defined over consumption and labour are:

$$U_c(c_t^H, l_t) = \lambda_t \quad (3)$$

$$U_l(c_t^H, l_t) = \lambda_t w_t \quad (4)$$

$$\lambda_t = E_t \beta (1 + r_t) \frac{r_{s_{t+1}}}{r_{s_t}} \lambda_{t+1} \quad (5)$$

An analogous constraint and set of optimality conditions characterize the decision problem of the foreign-country household.

### 3.2 *Intermediate goods producers*

Intermediate goods,  $y$ , are produced using capital, rented from the entrepreneur at the rental rate  $\rho_t$ , and labour. Intermediate goods are used for both consumption and investment in both the home and the foreign economies.  $P_h$  is the price of the home-produced intermediate good relative to the home consumption good. Profits of the goods-producing firm are defined as follows:

$$\pi_t^G = P_{h,t} y_t - w_t l_t - \rho_t k_{t-1} \quad (6)$$

and are maximized subject to the production function

$$y_t = A_t k_{t-1}^\alpha l_t^{1-\alpha}. \quad (7)$$

The intermediate goods producer's maximization problem yields the following optimality conditions for labour and capital inputs:

$$P_{h,t}(1 - \alpha)A_t k_{t-1}^\alpha l_t^{1-\alpha} = w_t \quad (8)$$

$$P_{h,t}\alpha A_t k_{t-1}^{\alpha-1} l_t^{1-\alpha} = \rho_t \quad (9)$$

The foreign-country intermediate goods producer faces an analogous optimization problem.

### 3.3 *Impatient entrepreneurs*

Entrepreneurs produce the capital goods that are rented out to intermediate goods producers. Entrepreneurs differ from households with respect to their subjective rate of time preference. Entrepreneurs are assumed to be less patient than households, implying that the discount factor of entrepreneurs, denoted  $\beta^E$ , is lower than that of households. The relative impatience of entrepreneurs ensures that in the steady state, we have both borrowing and lending.<sup>6</sup>

Entrepreneurs maximize expected utility

$$E_0 \sum_{t=0}^{\infty} (\beta^E)^t U(c_t^E) \quad (10)$$

defined only over consumption, subject to the following budget, capital accumulation and borrowing constraints:

$$c_t^E = \rho_t k_t - x_t + q_t - (1 + r_{t-1}^q)\epsilon_t q_{t-1} - T_t^E \quad (11)$$

$$k_t = (1 - \delta)k_{t-1} + s \left( \frac{x_t}{k_{t-1}} \right) k_{t-1} \quad (12)$$

$$(1 + r_t^q)E_t\epsilon_{t+1}q_t = E_t\chi\varphi_{t+1}k_{t+1}(1 - \delta). \quad (13)$$

$\rho_t$  denotes the rental rate of capital paid by the good producer,  $x_t$  is investment in new capital,  $q_t$  are new loans from the domestic banking sector,  $r_{t-1}^q$  is the interest rate payable on loans and  $\epsilon_t$  is a repayment or default shock. The repayment shock represents a transfer between entrepreneurs and banks. A transfer between entrepreneurs and households,  $T_t^E$ , rules out that entrepreneurs benefit directly from a negative shock to  $\epsilon$ . As a result, this shock only affects the real economy via its effects on the bank's capital position.<sup>7</sup>

Transforming investment into capital stock incurs an adjustment cost of the type proposed by Hayashi (1982), where the function  $s(\cdot)$  has the following steady state properties:  $s(\cdot) = \delta$ ,  $s'(\cdot) = 1$  and  $s''(\cdot) < 0$ .  $\varphi$  denotes the price of capital, or Tobin's  $q$ , and  $\chi$  the loan-to-valuation ratio constraining entrepreneurial borrowing. As in Iacoviello (2005), lending to impatient entrepreneurs is constrained to a fraction,  $\chi$ , of the discounted market price of next period's un-depreciated capital stock.

The entrepreneur's maximisation problem yields the following optimality conditions for entrepreneurial consumption, borrowing and investment as well as next period's desired capital stock:

$$U_c(c_t^E) = \lambda_t^E \quad (14)$$

$$\frac{\beta^E E_t \lambda_{t+1}^E}{\lambda_t^E} (1 + r_t^q)\epsilon_{t+1} = 1 - \Delta_t (1 + r_t^q) E_t \epsilon_{t+1} \quad (15)$$

$$\varphi_t = \left[ s' \left( \frac{x_t}{k_{t-1}} \right) \right]^{-1} \quad (16)$$

$$\frac{\beta^E E_t \lambda_{t+1}^E}{\lambda_t^E} (\rho_{t+1} + \varphi_{t+1} \{(1 - \delta)\}) + E_t \varphi_{t+1} \Delta_t \chi (1 - \delta) = \varphi_t \quad (17)$$

$\lambda_t^E$  denotes the Lagrange multiplier on the entrepreneur's budget constraint and equals the marginal utility of entrepreneurial consumption.  $\Delta_t$  is the Lagrange multiplier on the entrepreneur's borrowing constraint. If  $\Delta_t = 0$  the constraint is non-binding and the entrepreneur behaves in exactly the same manner as the household. However, as long as  $\beta > \beta^E$  the borrowing constraint holds in the steady state. In the appendix, we simulate the model to show that, for our baseline calibration, the constraint is also binding for shocks taking the economy away from steady state.<sup>8</sup>

An analogous set of constraints and first-order conditions apply to the foreign economy's entrepreneurial sector.

### 3.4 *Banks*

Banks located in the home economy operate in three types of markets. A global market for household deposits and interbank borrowing; a domestic market for bank loans; and a foreign market for bank loans. All markets are competitive and the representative bank is a price taker.

#### 3.4.1 *Market for household deposits and interbank borrowing*

Households and banks in both countries trade in a perfectly competitive market for household deposits,  $d_t$ , and interbank borrowing,  $D_t$ . Both deposits and interbank borrowing

are denominated in units of the foreign consumption good. The interest rate on real deposits is equal to the real interest rate faced by the foreign household,  $(1 + r_t)$ . At the global level, the sum of home and foreign deposits must equal the sum of home and foreign interbank borrowing. At the country level, household deposits and interbank borrowing need not be in balance, the difference between the two determines the country's net foreign asset position.

### 3.4.2 *The domestic market for loans*

Impatient entrepreneurs obtain loans from competitive banks. The basic structure of the banking sector follows the wholesale banking set up in Gerali et al. (2010). In this framework, banks combine interbank borrowing,  $D_t$ , with bank capital,  $K_t^B$ , to make loans to entrepreneurs,  $q_t$ . Banks face an exogenous leverage ratio,  $z$ , determining the amount of capital they must hold as a proportion of the loans they make. Deviations from this ratio incur a cost. In the absence of this cost, there would be no intermediation margin between the interest rates on bank liabilities and assets and the financial structure of our model collapses back to that of a standard incomplete markets international real business cycle model.

When making loans to domestic firms, the home-country bank maximizes the following profit function denominated in units of the home consumption good:

$$\begin{aligned} \pi_t^B &= (1 + r_{t-1}^q)\epsilon_t q_{t-1} - q_t + D_t - (1 + r_{t-1})\frac{r_{t-1} S_t}{r_{t-1} S_{t-1}} D_{t-1} + K_t^B - K_{t-1}^B \\ &\quad - \frac{\kappa}{2} \left( \frac{K_{t-1}^B}{Q_{t-1}} - z \right)^2 K_{t-1}^B \end{aligned}$$

Each period, the bank borrows  $D_t$  and makes loans to home entrepreneurs,  $q_t$ . Only a



fraction  $\epsilon_t$  of one-period loans advanced in the previous period is repaid with interest. Bank profits are adversely affected if the realized repayment rate falls below that expected at the time the loan was made. Deviations of the actual capital-to-loans ratio,  $\frac{K_{t-1}^B}{Q_{t-1}}$  from a prescribed bank capital-to-loans ratio,  $z$ , are also costly. One can rationalize such a cost by assuming that adjusting the bank's capital position is itself costly. Kollmann et al. (2011) motivate a similar cost by the need for "creative accounting" should the bank's capital-to-loans ratio fall below the prescribed level.

As in Gerali et al. (2010), banks in the home economy face a balance sheet constraint that requires total lending to home and foreign firms,  $Q$ , to be backed by borrowed liabilities as well as banks' own capital stock:

$$Q_t = D_t + K_t^B. \quad (18)$$

The bank's capital stock evolves as follows:

$$K_t^B = (1 - \delta^B) K_{t-1}^B + \pi_t^B \quad (19)$$

where  $\delta^B$  captures the costs to the bank of managing the bank's capital stock and  $\pi_t^B$  are the profits or losses generated by the bank.

The optimization problem of the banking sector, yields the following optimality condition for the evolution of the interest rate spread:

$$(1 + r_t^g) E_t \epsilon_{t+1} - (1 + r_t) \frac{E_t(r s_{t+1})}{r s_t} = -\kappa \left( \frac{K_t^B}{Q_t} - z \right) \left( \frac{K_t^B}{Q_t} \right)^2. \quad (20)$$

The real interest rate spread between bank loans and liabilities is driven by the evolution

of the bank's capital-to-loans ratio. A ratio above  $z$  reduces the spread. In this case the bank has too much capital and can reduce the intermediation margin, whereas a ratio below  $z$  raises the spread.<sup>9</sup> In setting the interest rate on loans, the bank takes into account the expected re-payment rate (implicitly the default rate) in the period when the loan is due to be repaid. In response to an unanticipated decline in  $\epsilon_t$ , the spread rises because the default affects the bank's profits and thus its capital stock (see equation 21). For a given level of total bank lending, the intermediation margin will have to rise to generate bank profits with which to rebuild the bank's capital stock.

### **3.4.3 *The foreign market for loans***

Unlike Gerali et al. (2010) or Kollmann et al. (2011), we allow banks in the small open economy to intermediate not just all loans to domestic firms, but also a small proportion of loans to foreign firms. Home-country banks operating abroad are perfectly competitive and take the loan rate prevailing in the foreign market as given. As a result, foreign firms are indifferent between obtaining funding from home or foreign banks. Banks in the large foreign economy only intermediate loans to firms in the large country; they do not make loans to firms in the small economy.<sup>10</sup> The ownership of the banking systems rests with the representative agents in each country.

In this setup, unexpected defaults on lending to foreign firms,  $\epsilon^*$ , affect the home economy via changes in the home bank's capital stock. Losses incurred in lending abroad reduce the capital stock of the home-country bank and thus cause banks to raise the interest they charges on loans to domestic firms. Changes in total bank lending to foreign firms, such as in response to a productivity shock, also affect the home country's interest

rate spread on loans, because the inverse of the leverage ratio,  $\left(\frac{K_t^B}{Q_t}\right)$ , is defined in terms of *total* lending,  $Q = q + \frac{1-n}{n}\xi q^*$  by the home banking sector.

The per capita profit of the home bank making both domestic and foreign loans, denominated in units of the home consumption good, is characterized as follows:

$$\begin{aligned} \pi_t^B &= (1 + r_{t-1}^q)\epsilon_t q_{t-1} - q_t + D_t - (1 + r_{t-1})\frac{r_{S_t}}{r_{S_{t-1}}}D_{t-1} + K_t^B - K_{t-1}^B \\ &- \frac{\kappa}{2}\left(\frac{K_{t-1}^B}{Q_{t-1}} - z\right)^2 K_{t-1}^B + \frac{1-n}{n}\xi\left[(1 + r_{t-1}^{q^*})\epsilon_t^*\frac{r_{S_t}}{r_{S_{t-1}}}q_{t-1}^* - q_t^*\right]. \end{aligned} \quad (21)$$

We abstract from the reasons why the home-country's banking sector is active in the foreign market, and simply assume that home country banks intermediate a fraction  $\xi$  of foreign loans. As  $\pi_t^B$  are bank profits per capita, and  $q^*$  are foreign per capita loans, we adjust lending to foreign firms by the relative size of the foreign country in term of the home country. For a given  $\xi$ , the exposure of the small home country to the large foreign country is inversely related to the relative size of the home country,  $n$ . As the home country is assumed to be small relative to the foreign country, home banks take the interest rate on loans prevailing in the foreign country as given, such that  $r_t^{*q}$  is the interest on loans faced by foreign entrepreneurs.

Since the bank takes the interest on foreign loans as given, the optimal interest rate spread of the loan rate over the effective deposit rate in the home economy is the same as in equation (20), with the exception that  $Q$  refers to the bank's total lending to home and foreign firms.

An alternative way to interpret our model is to assume that home-country banks do not lend directly to foreign firms, but are able to purchase foreign banking assets on the

secondary market. As long as these assets are subject to the same kind of default risk as direct lending to foreign firms, the two interpretations are equivalent.

### 3.5 *Consolidated budget constraint*

The dynamics of the net foreign asset position of the domestic economy are derived by consolidating the household's and the entrepreneur's budget constraints. The patient household owns both the final goods producer and the bank and receives any residual profits from these two sectors. Adding the entrepreneur's constraint to the household's consolidated budget constraint yields:

$$c_t + x_t + B_t = P_t^h y_t + (1 + r_{t-1}) \frac{r s_t}{r s_{t-1}} B_{t-1} - \delta^B K_{t-1}^B + \frac{1-n}{n} \xi [(r_{t-1}^{q*} - r_{t-1}^{d*}) q_{t-1}^*] \quad (22)$$

where  $c_t$  is aggregate consumption, or the sum of household and entrepreneurial consumption and the net foreign asset position is defined as:  $B_t = (d_t + \frac{1-n}{n} \xi q_t^* - D_t)$ .  $B_t$  is denominated in units of the foreign consumption goods and is the difference between domestically held assets (agent's deposits with the global bank plus the value of overseas banking assets) and the home bank's borrowing from the global bank.<sup>11</sup> The management cost of bank capital,  $\delta^B K_{t-1}^B$  is a net resource cost to the economy.<sup>12</sup>

### 3.6 *Small open economy as a limiting case of a two country model*

In this section we show how a small open economy model, of population size  $n$ , can be nested as a special case of a two-country model. Total consumption in both countries is defined as the sum of household and entrepreneurial consumption:

$$c = c^H + c^E \quad (23)$$

Total consumption in the home country is defined as a constant elasticity of substitution (CES) aggregate of home and foreign produced goods:

$$c = \left[ v^{\frac{1}{\theta}} c_h^{\frac{\theta-1}{\theta}} + (1-v)^{\frac{1}{\theta}} c_f^{\frac{\theta-1}{\theta}} \right]^{\frac{\theta}{\theta-1}} \quad (24)$$

where  $c_h$  and  $c_f$  are home and foreign produced consumption goods, respectively, and  $\theta$  is the elasticity of substitution between these two types of goods. Following De Paoli (2009) we link the share of home-produced goods in home total consumption  $v$  to the relative size of the country and its openness to trade,  $\gamma$ :

$$v = 1 - (1-n)\gamma$$

The share of home-produced goods in foreign total consumption,  $v^*$  becomes:

$$v^* = n\gamma$$

In the limit, when  $n$  approaches zero the share of home-produced goods in foreign consumption tends to zero,  $v^* = 0$ , and the foreign economy behaves just like a closed economy. In the home economy, the share of home-produced goods in total consumption,  $v$ , becomes a function of the degree of openness of the home economy,  $v = 1 - \gamma$ .

### **3.7 *International relative prices***

Finally, two important relative prices in any IRBC model are the terms of trade, defined as the price of imports relative to exports,  $Tot = \frac{P_f}{P_h}$  and the real exchange rate  $rs_t = \frac{P_t^*}{P_t}$ . In linearized form, these two relative prices (from the home country's perspective) are

related by the degree of openness to trade:

$$\hat{r}s_t = (1 - \gamma)\hat{t}ot_t \quad (25)$$

## 4 CALIBRATION

The two countries in our calibration exercise are the United Kingdom as the small home economy and the United States as the large foreign economy. We chose the UK as the home economy because it is a small open economy with a large and exposed banking sector for which there is good data availability. The relative size of the home economy,  $n$ , is calibrated as the size of the United Kingdom economy relative to that of the rest of world.<sup>13</sup>

Table 1 reports the initial calibrated parameters. Throughout, the unit of time is one quarter. The discount factor for patient households is set to 0.99, implying an annual interest rate on deposits held with the global bank of 4% in both countries. Impatient entrepreneurs discount future income streams at an annualized rate of 8%. We adopt the following functional forms for the period utility function of the household and entrepreneurs:

$$U(c_t^H, l_t) = \log(c_t^H) - \eta l_t \quad (26)$$

$$U(c_t^E) = \log(c_t^E) \quad (27)$$

where  $\eta$  is set as to generate a steady state value of hours of 1/3.

We set the openness parameter,  $\gamma$ , to match the average import share of consumption and investment goods in the UK. Bussiere et al. (2011) report total import shares of

consumption and investment of 27.2% and 25.4%, respectively for the UK. Given the relative size of consumption and investment in total absorption, these values correspond to an openness parameter for the UK,  $\gamma$ , of about 0.25. The intratemporal elasticity of substitution between home and foreign-produced intermediate goods in both consumption and investment,  $\theta$ , is set to 0.9 to match the volatility of the terms of trade, relative to UK GDP.

In the production function, the elasticity of output to capital,  $\alpha$ , is set to 0.3 while the depreciation rate,  $\delta$ , is set to 0.025 implying an annualized depreciation rate of 10%. Given our estimated shock processes, the calibrated model generates series for investment that are not as volatile as the data, hence we set the capital adjustment cost parameter,  $s'$  to zero.

In our sample the ratio of bank loans to annual GDP is about 0.9. We set the loan-to-valuation ratio,  $\chi$ , faced by impatient entrepreneurs to 0.5. This yields a steady state loan to GDP ratio of 0.9 in the model. Our calibration of the share of foreign assets is based on data from McGuire and von Peter (2012). Over the period 1999-2007, the average ratio of foreign claims to GDP for the UK is 1.05. In our baseline calibration, we set  $\xi$  equal to the relative size of the small open economy. That implies that the size foreign claims is roughly equal to the size of domestic assets. In section 5.4, we examine the sensitivity of our results to alternative calibration of the parameter  $\xi$ .

Calibrating the deep parameters of the financial intermediaries in our model, we use US data on total equity to total assets ratio of commercial banks to calibrate the steady state bank capital-to-loans ratio. Accordingly, the parameter  $z$  is set to 10%, its mean

value over 1988-2010 period. Following Gerali et al. (2010), we set  $\kappa$  to 10 in our baseline calibration, and check the sensitivity of our results to various values of this parameter. The value of  $\delta_b$  is derived from the steady state relationships of the model and equals 0.01 implying that the bank capital depreciates in an annual rate of roughly 4%.

The dynamics of the model are driven by country specific exogenous shocks to total factor productivity (TFP) and the repayment rate on bank loans. These exogenous variables are all assumed to follow AR(1) processes. Table 1 reports the AR(1) coefficients, the standard errors of the innovations as well as the correlation coefficients between domestic repayment and TFP shocks. These estimates are derived from the data on TFP and default shocks for the US and UK economies shown in Figures 1 and 2. Default rates rise dramatically in both economies during the 2007 financial crisis. The data appendix describes the data used to create these shock processes.

As the main motivation of the paper is to investigate the role of financial intermediation on the international transmission of shocks, we abstract from the cross-country correlation of the shock processes and focus on the endogenous propagation mechanisms originating from the presence of the financial intermediation.

[Table 1 about here.]

Figures 1 and 2 about here.

## **5 INTERNATIONAL TRANSMISSION MECHANISM OF BANKING SECTOR SHOCKS**

There are two shocks driving our model: financial or default shocks and total factor productivity shocks. Using the calibration set out above, this section employs impulse



responses to analyze how default and productivity shocks originating in the large foreign economy are transmitted to the small open economy. In Figures 3 to 5 we compare our baseline model (solid lines) to an alternative model (dashed lines) where banks in the small open economy do not intermediate foreign loans ( $\xi = 0$ ).

### 5.1 *Foreign default shocks*

Figure 3 reports the impulse response functions for a unit decrease in the foreign loan repayment rate,  $\epsilon$ . In the foreign economy, a default shock causes the banking sector to incur a trading loss which adversely affects the representative bank's capital stock. As the bank's capital stock initially declines by more than bank lending, the leverage ratio rises which implies that the spread between the loan and deposit rates has to increase. For the entrepreneur, the increased cost of borrowed funds leads to a large decline in investment which contributes to a decline in GDP. Consumption, on the other hand, rises following a default shock.

The extent to which a foreign default shock transmits to the home economy depends on whether or not home-country banks have direct exposure to foreign loan defaults. When banks only lend to domestic firms, as seen in the the dashed impulse responses, the effects on the home economy of a foreign default shock are modest. The decline in GDP reflects a worsening net foreign asset position, while consumption and investment actually increase, albeit modestly. Importantly, a foreign default shock has no discernible effect on the home country's banking sector.

When the home country has relatively large banks that intermediate not just domestic loans, but are also active in lending directly to foreign firms,  $\xi = n$  in our case, foreign

defaults have a negative impact on the capital stock of home-country banks. Given our calibration, the spillovers are significant. The decline in bank capital, output and investment is about half of that observed in the foreign economy.

The terms of trade and the degree of trade openness, play a vital role in determining how shocks are transmitted between economies. Even though our baseline calibration assumes that both home and foreign economies are relatively closed with a high degree of home bias,  $\gamma = 0.25$ , the model still generates large spillovers in response to a foreign default shock and does so via the foreign lending channel of the home banking sector. An alternative way to generate large spillovers in the components of GDP is to assume a greater degree of openness to trade in both economies. In figure 4, we explore the extreme case of complete openness to trade when  $\gamma = 1$ . In this case, spillovers between the foreign and the home economy are large, regardless of the proportion of foreign loans intermediated by home banks. Because there is no home bias and the home economy is small, almost all demand for domestic production comes from foreign agents, so that a shock in the large economy has a direct effect on the home economy's output.

International consumption risk is shared through trade in net foreign assets,  $B_t$ , and through movements in the terms of trade. A shock that reduces foreign consumption by more than home consumption causes the home country's terms of trade, and via equation (25) the real exchange rate, to depreciate (rise). A depreciation of the home country's terms of trade shifts purchasing power from home to foreign consumers, thus sharing risk. In figure 3, the home country's terms of trade appreciate (fall) initially, followed by a more pronounced depreciation after the first few periods. As is well known, the real

exchange rate shares consumption risk and can isolate the path of home consumption from the path of foreign consumption.<sup>14</sup> The terms of trade are more volatile in the case of no foreign lending ( $\xi = 0$ ) where the spillover effects of the foreign shock is modest. In figure 4, the case where there is no home bias, the terms of trade depreciate while the real exchange rate remains constant (see equation (25)). Without the real exchange rate acting as a shock absorber for the domestic economy, the spillovers from the foreign to the home economy are much larger.

[Figures 3 and 4 about here.]

## 5.2 *Foreign productivity shocks*

Next, we examine the effect of exposure to foreign banking assets on the transmission of total factor productivity shocks. Figure 5 shows the impulse response functions to a unit decline in the foreign country's total factor productivity. Figure 5 suggests that the extent to which the home country's banks are lending abroad has little effect on the transmission mechanism of supply shocks. In the foreign economy, output and investment fall leading to a decline in borrowing by entrepreneurs. As borrowing declines faster than the bank's capital stock, the spread between the loan and deposit rates falls. Thus unlike for default shocks, the spread is pro-cyclical following a TFP shock, increasing the impact of the shock. As in a standard IRBC model, the home terms of trade depreciate following negative foreign demand shock and help to share risk between home and the foreign economy.

[Figure 5 about here.]

### 5.3 *Second moments*

In this section, we analyze how well our calibrated IRBC model matches key second moments such as the volatility and cyclical nature of bank lending and the interest rate spread as well as the international correlation of output over the business cycle.

Table 2 compares the business cycle properties of the model economy to UK and US data. Our sample period spans 1987 Q1 to 2009 Q4. In terms of business cycle properties of GDP and its components, the UK is quite similar to the US. Bank lending, measured as M4 lending to private non-financial corporations (PNFCs) in the UK and loans and leases in bank credit in the US, is more volatile in the UK than in the US. Bank spreads, defined as the difference between corporate and government bond yields in both the UK and the US are also more volatile in the UK than in the US. Whereas bank lending is pro-cyclical, the spread, or the intermediation margin, is counter-cyclical in both economies.<sup>15</sup>

The shocks driving the model are country specific. The UK total factor productivity shock, defined as the Solow residual, has very similar characteristics in terms of its AR(1) coefficient and standard deviation as its US counterpart. Our calculations suggest that the US default rate is as volatile, but more more persistent than its UK counter part. The data also suggests that in both countries default (loan repayment rate) and productivity shocks are negatively (positively) correlated.

Given the estimated shock processes, we calibrate the elasticity of substitution between home and foreign-produced goods,  $\theta$ , to match the relative standard deviation of the UK terms of trade. Setting  $\theta = 0.9$  yields a standard deviation of the UK's terms of

trade relative to UK GDP of 1.13.

[Table 2 about here.]

The columns headed [1] report selected second moments for the small open economy (UK) and the large virtually-closed economy (US) driven by both TFP and “default” shocks. With these shocks, the model captures about 70% and 90% of the volatility of UK and US GDP, respectively. For both economies, the model under-predicts the volatility of investment and consumption relative to GDP. Given the calibrated loan-to-valuation ratio and the subjective discount factor applicable to entrepreneurs, there are no values of the capital adjustment cost parameter which allow the model to match the relative volatility of investment, for either economy.

A further point of departure between model and data is the relative volatility of bank loans. In the data, loans are between 2.5 and 4.3 times as volatile as GDP, whereas our model predicts these to be significantly less volatile than GDP. For the US economy, the model captures most of the relative volatility of the bank spread.

A key feature of the data is the counter-cyclical bank spread. When driven by both TFP and default shocks, our model generates counter-cyclical spreads for both the large and the small economy. As per the data, the model suggests that the US bank spread is somewhat more counter-cyclical than the UK one. Bank lending is pro-cyclical in the data and in the models. Finally, the correlations of the UK’s terms of trade and net trade with UK GDP are of the correct sign.

The columns headed [2] report second moments generated by our baseline model when “default” shocks are the exclusive source of fluctuations. Default shocks alone explain

only about 1% of the volatility of GDP. In both economies, default shocks generate strongly counter-cyclical and volatile bank spreads. Because banks in the small economy are directly exposed to foreign default shocks, the correlation between home and foreign GDP is relatively high at 0.74.

The column headed [3] repeats the default-shock-only simulation for the case where UK banks do not intermediate US loans. The key difference between the two simulations is the correlation between home and foreign GDP, which drops to 0.21. The banking spread is, unsurprisingly, more strongly correlated with GDP in this case.

In the column headed [4], we explore how the model, driven only by “default” shocks, behaves under an alternative calibration where there is no lending to foreign firms, but also no consumption home bias. In this case, the economy is completely open to trade, the real exchange rate is constant, and there is a high degree of international risk sharing. Because of risk sharing, the model suggests a very weak correlation between home country investment and borrowing on the one hand and home GDP on the other. The cross-country correlations, such as between home and foreign GDP are higher than in the benchmark case, even without allowing for lending to foreign firms.

#### **5.4 *Sensitivity analysis***

A key finding of our analysis is that small open economies with large banking sectors, relative to the size of the economy, are more exposed to foreign financial shocks than are similar economies with smaller, domestically-oriented banking sectors. Table 3 summarizes a number of robustness checks to support this finding. Specifically, we examine how the contribution of foreign default shocks to the variance of home GDP changes as

we alter some of the key parameters of the model. For each alternative specification, we report the percentage contribution of foreign default shocks to the variance of home GDP with ( $\xi = 0.04$ ) and without ( $\xi = 0$ ) lending to foreign firms. Our calibration suggests that the magnitude of default shocks is small relative to the magnitude of TFP shocks, therefore we only report the variance decomposition of model economies driven solely by our estimated default shocks.

For the baseline model, the contribution of foreign shocks to the variance of home GDP drops from about 56% with foreign lending to about 4% without foreign lending. We examine two alternative values for the loan-to-valuation ratio constraining entrepreneurial borrowing. When the loan-to-valuation ratio is higher (lower) than in our baseline calibration, the contribution of foreign shocks diminishes (increases) relative to the baseline model, for both values of  $\xi$ . Altering the degree of impatience of the entrepreneurs, for a given discount factor of the household, has only a very modest effect. At the margin, the contribution of foreign shocks to the variance of home GDP declines as entrepreneurs become less impatient. In summary, foreign shocks become somewhat more important for the home economy, the further the model is away from the standard IRBC model where the borrowing constraint is not binding and entrepreneurs do not differ from households.

Our results are also robust to changing the parameters of the model determining the endogenous banking spread: the inverse of the desired leverage ratio,  $z$ , and the elasticity of bank spread to deviations from the desired leverage ratio,  $\kappa$ . The smaller these two parameters are, the more important are foreign shocks for the home economy.

One reason why foreign default shocks contribute so little to the variance of GDP

without foreign lending by home firms is that the real exchange rate acts like a shock absorber for the home economy, isolating it from foreign shocks. Foreign shocks gain in importance when the real exchange rate is less responsive to foreign shocks. According to equation (25) the log-linearized real exchange rate is a linear transformation of the terms of trade. The degree to which the terms of trade respond to shocks depends on the elasticity of substitution between home and foreign-produced goods,  $\theta$ . The greater  $\theta$ , the smaller the response of the terms of trade and thus the real exchange rate. Table 3 shows that when  $\theta = 10$ , the terms of trade response is greatly reduced and foreign shocks have a large influence on home GDP, even without foreign lending by home banks. In this case the terms of trade and therefore the real exchange rate no longer insulate the home economy from foreign shocks. In examining further values of  $\theta$ , we find that the contribution of foreign shocks declines with the elasticity of substitution.

The parameter determining how open the home economy is to trade,  $\gamma$ , also has a direct effect on the response of the real exchange rate to foreign shocks. In the extreme case when the economy is fully open to trade and there is no home bias ( $\gamma = 1$ ), purchasing power parity holds and the real exchange rate is constant. In this case over 97% of the variance of home GDP is driven by foreign shocks. The less open the home economy, the smaller the contribution of foreign shocks. Interestingly, even if the home economy is virtually closed, with  $\gamma = 0.01$ , foreign default shocks are still important with direct lending, while having no effect on home GDP without direct exposure to the foreign banking sector.

Finally, we analyze the contribution of foreign shocks to the variance of home GDP



in a model where both home and foreign economies are of equal size. In this case, foreign default shocks still contribute more to the variance of home GDP when home banks intermediate home as well as the same small fraction,  $\xi$ , of foreign loans, but overall foreign shocks contribute little to the variance of home GDP. This final robustness check shows that it is not foreign exposure per se that matters, but the degree of exposure relative to the size of the domestic banking sector.

[Table 3 about here.]

As a final robustness check, we analyze the contribution of foreign default shocks for different values of the parameter  $\xi$ , which determines the proportion of foreign loans intermediated by home country banks. Figure 6 reports sensitivity analysis around the parameter  $\xi$  and shows the contribution to the variance of home country GDP of the foreign default shock when the model is driven only by home and foreign default shocks for various values of domestic exposure to foreign banking shocks,  $\xi$ .

The contribution of foreign shocks rises with the share of foreign loans intermediated by home-country banks. The greater the banking sector's exposure to the foreign economy, the greater the spillover of foreign default shock onto home country GDP.

[Figure 6 about here.]

## 6 CONCLUSION

This paper analyzes a potentially important channel through which financial shocks can be transmitted between economies. Our work is motivated by recent empirical evidence on the role of direct and indirect financial ties to the US for the synchronization of output

during the 2007 - 2009 financial crisis. The more a country's banking sector was exposed to US financial assets, the more synchronized its business cycle was with that of the US during the financial crisis.

To capture this exposure to foreign banking assets, we set up what is essentially an IRBC model with patient households and borrowing constrained impatient entrepreneurs. We augment this model with a competitive banking sector and allow for asymmetries in the relative size of the banking sector. In the model, foreign financial shocks have a greater effect on domestic GDP, the bigger and more exposed the domestic banking sector is to the foreign economy. As banks only intermediate loans to entrepreneurs, we proxy exposure with direct lending to foreign firms by home-country banks.

Using an IRBC model with specialized production, we are able to examine the influence of openness to trade and terms of trade dynamics on the transmission of financial shocks. For a small open economy, the transmission of foreign shocks is increasing in the openness of the domestic economy and decreasing in the degree of home bias in the production of final goods. The terms of trade and the real exchange rate help to insulate the home economy from foreign financial shocks.

The transmission channel we highlight is potentially important, but by no means the only channel through which financial shocks can propagate across economies. The literature has highlighted a number of alternative mechanisms, from completely globalized banking through to equalization of banking spreads through arbitrage of risky assets. An interesting extension would be to explicitly take into account of financial frictions in the interbank market.

## A IS THE BORROWING CONSTRAINT BINDING?

We set the discount factors such that the borrowing constraint for the entrepreneurs binds at the steady state, and therefore the multiplier on the borrowing constraint is positive at the steady state. In this subsection, we check whether the borrowing constraint is binding in our stochastic simulations. To do so, we simulate the model under our baseline calibration of structural parameters and shocks and construct artificial data for the multiplier on the borrowing constraint. The constraint is binding if the multiplier remains positive under stochastic simulations. Figure 7 reports the percentage of time the constraint is not binding when we simulate the model for 50000 periods. Additionally, we plot this percentage as a function of two parameters: the loan-to-valuation ratio and the parameter governing capital adjustment costs. Under our baseline calibration (no adjustment costs and  $\chi=0.5$ ), the multiplier is always positive under stochastic simulations. This result seems to be robust for various values of the loan-to-valuation ratio and adjustment cost parameter. The percentage of time the constraint is binding drops somewhat when we assume either a high loan-to-valuation ratio or a high adjustment cost. A high  $\chi$  implies a looser borrowing constraint for entrepreneurs and increases the probability of the constraint not binding. A high adjustment cost yields an increase in the volatility of the price of capital, which in turn determines the total value of the collateral. Overall, we conclude that the Lagrange multipliers obtained from the stochastic simulations of the model are positive for our baseline calibration and for most of the parameter values that we consider.

## B DATA SOURCES AND DEFINITIONS

The business cycle moments are calculated over the period 1987Q1:2009Q4. The beginning of our sample is dictated by the availability of default rate data for US. In Table 2, US GDP, consumption and investment refer to seasonally adjusted real per capita series. GDP is from the BEA's NIPA table 7.1, "Selected Per Capita Product and Income Series in Current and Chained Dollar". Consumption is from NIPA Table 2.3.5, "Personal Consumption Expenditures" and deflated by the relevant GDP deflator from NIPA table 1.1.9. Investment is "Real Private Fixed Investment" from NIPA table 5.3.3. Data on loans are from the Federal Reserve Board (Table H.8, Assets and Liabilities of Commercial Banks in the United States) and corresponds to "Break-Adjusted Loans and Leases in Bank Credit" for all commercial banks, which we deflate using the GDP deflator. We convert consumption, investment and loans in per capita terms by dividing each series by population; which is from NIPA table 7.1.

Data for the UK are from the Office for National Statistics. GDP is Gross Domestic Product, consumption is consumption by households and general government, and investment is gross fixed capital formation respectively (all from the natpc2 dataset). We convert these series into per capita terms by dividing each series by population (from the lmsum01 dataset). The terms of trade for the UK is defined as the ratio of the import price deflator over the export price deflator. The import (export) price deflator is calculated by dividing imports (exports) at current prices by imports (exports) at constant prices (from the natpc1 and natpc2 datasets). Net trade is from HAVER and corresponds to the "Balance on Current Account as a percentage of GDP". Our measure of

loans is from the Bank of England and refers to seasonally adjusted “Quarterly amounts outstanding of monetary financial institutions’ sterling net lending excluding securitisations to private non-financial corporations”, which we convert to real per capita terms by dividing by the GDP deflator and population.

Our measure of interest rate spreads for both the UK and US is obtained from Datastream, and is the quarterly average of monthly differences between corporate (USACRPB and UKMCRPB) and government (USAGLTB, UKMGLTB) bond yields.

### **B.1 *Data for exogenous processes***

The total factor productivity (TFP) processes for both the US and UK are constructed as a residual using the production function presented in the text. For both countries, we use data from the OECD’s Economic Outlook via HAVER. Capital stock corresponds to the “Capital stock of the total economy”. Total hours data are obtained as the product of “Employment” and “Hours worked per employee”. We then assume that the percentage deviations of TFP from a trend follow an AR(1) process and estimate the following equation for the US and the UK on linearly detrended TFP:

$$\widehat{A}_t = \rho_A \widehat{A}_{t-1} + \sigma_A \tag{B.1}$$

The default rate for the US is from the Federal Reserve Board and refers to “loan delinquency rate on commercial and industrial loans” for all insured commercial banks. We calculate the default rate for the UK as the ratio of “Quarterly amounts UK resident monetary financial institutions’ sterling write-offs of lending to private non-financial corporations” (RPQTFHB) and total loans, which we defined above. As for total factor

productivity, we assume that the exogenous repayment process in our model corresponds to deviations of the default rate from a trend. We estimate the following AR(1) process for the US and the UK on default rates:

$$\hat{\epsilon}_t = \rho_\epsilon \hat{\epsilon}_{t-1} + \sigma_\epsilon \tag{B.2}$$

## C LOG-LINEAR MODEL

Home and foreign households

$$-\hat{c}^H = \hat{\lambda}_t \quad (\text{C.1})$$

$$0 = \hat{\lambda}_t + \hat{w}_t \quad (\text{C.2})$$

$$\hat{\lambda}_t + (1 - \gamma)\hat{T}_t = \hat{\lambda}_{t+1} + \widehat{(1 + r_t)} + (1 - \gamma)\hat{T}_{t+1} - \Omega B_t \quad (\text{C.3})$$

$$-\hat{c}^{H*} = \hat{\lambda}_t^* \quad (\text{C.4})$$

$$0 = \hat{\lambda}_t^* + \hat{w}_t^* \quad (\text{C.5})$$

$$\hat{\lambda}_t^* = \hat{\lambda}_{t+1}^* + \widehat{(1 + r_t)} + \frac{nn}{1 - nn}\Omega B_t \quad (\text{C.6})$$

where  $\Omega$  represents a small bond holding cost.

Home and foreign intermediate goods producers

$$\hat{y}_t = \hat{a}_t + \alpha k_{t-1} + (1 - \alpha)\hat{l}_t \quad (\text{C.7})$$

$$\hat{w}_t = (n - 1)\gamma\hat{T}_t + \hat{y}_t - \hat{l}_t \quad (\text{C.8})$$

$$\hat{\rho}_t = (n - 1)\gamma\hat{T}_t + \hat{y}_t - \hat{k}_{t-1} \quad (\text{C.9})$$

$$\hat{y}_t^* = \hat{a}_t^* + \alpha k_{t-1}^* + (1 - \alpha)\hat{l}_t^* \quad (\text{C.10})$$

$$\hat{w}_t^* = n\gamma\hat{T}_t + \hat{y}_t^* - \hat{n}_t^* \quad (\text{C.11})$$

$$\hat{\rho}_t^* = n\gamma\hat{T}_t + \hat{y}_t^* - \hat{k}_{t-1}^* \quad (\text{C.12})$$

Home and foreign entrepreneurs

$$\hat{k}_t = (1 - \delta)\hat{k}_{t-1} + \delta\hat{x}_t \quad (\text{C.13})$$

$$\hat{k}_t^* = (1 - \delta)\hat{k}_{t-1}^* + \delta\hat{x}_t^* \quad (\text{C.14})$$

$$-\hat{c}^E = \hat{\lambda}_t^E \quad (\text{C.15})$$

$$\hat{\lambda}_t^E \beta^E = \hat{\lambda}_{t+1}^E \beta^E + \beta \widehat{(1 + r_t^q)} + \beta \hat{\epsilon}_{t+1} + \hat{\Delta}_t \Delta \quad (\text{C.16})$$

$$\hat{\varphi}_t = \left[ \hat{\lambda}_{t+1}^E - \hat{\lambda}_t^E \right] \beta^E (\rho + (1 - \delta)) + \hat{\rho}_{t+1} \beta^E \rho + \hat{\varphi}_{t+1} [1 - \beta^E \rho] + \hat{\Delta}_t \Delta \chi (1 - \delta) \quad (\text{C.17})$$

$$\hat{\varphi}_t = (1 + \beta^E) S'' \hat{x}_t - S'' \hat{x}_{t-1} - \beta^E \hat{x}_{t+1} \quad (\text{C.18})$$

$$-\hat{c}^{E*} = \hat{\lambda}_t^{E*} \quad (\text{C.19})$$

$$\hat{\lambda}_t^{E*} \beta^E = \hat{\lambda}_{t+1}^{E*} \beta^E + \beta \widehat{(1 + r_t^{q*})} + \beta \hat{\epsilon}_{t+1}^* + \hat{\Delta}_t^* \Delta \quad (\text{C.20})$$

$$\hat{\varphi}_t^* = \left[ \hat{\lambda}_{t+1}^{E*} - \hat{\lambda}_t^{E*} \right] \beta^{E*} (\rho + (1 - \delta)) + \hat{\rho}_{t+1}^* \beta^E \rho + \hat{\varphi}_{t+1}^* [1 - \beta^E \rho] + \hat{\Delta}_t^* \Delta \chi (1 - \delta) \quad (\text{C.21})$$

$$\hat{\varphi}_t^* = (1 + \beta^E) S'' \hat{x}_t^* - S'' \hat{x}_{t-1}^* - \beta^E \hat{x}_{t+1}^* \quad (\text{C.22})$$

$$\hat{c}_t^E \frac{C^E}{y} = \hat{\rho}_t \rho \frac{k}{y} + \hat{k}_{t-1} \rho \frac{k}{y} - \hat{x}_t \frac{x}{y} + \hat{q}_t \frac{q}{y} - \hat{R}_{t-1}^q (1 + r^q) \frac{q}{y} - \hat{q}_{t-1} (1 + r^q) \frac{q}{y} \quad (\text{C.23})$$

$$\hat{c}_t^{E*} \frac{C^E}{y} = \hat{\rho}_t^* \rho \frac{k}{y} + \hat{k}_{t-1}^* \rho \frac{k}{y} - \hat{x}_t^* \frac{x}{y} + \hat{q}_t^* \frac{q}{y} - \hat{R}_{t-1}^{q*} (1 + r^q) \frac{q}{y} - \hat{q}_{t-1}^* (1 + r^q) \frac{q}{y} \quad (\text{C.24})$$

where  $\hat{R}_t^q = \widehat{(1 + r_t^q)} + E_t \hat{\epsilon}_{t+1}$  ie it is the expected interest rate on loans made today that are payable tomorrow.



Home and foreign banks

$$\widehat{(1+r_t^q)} + \hat{q}_t = \hat{\varphi}_{t+1} + \hat{k}_t \quad (\text{C.25})$$

$$\widehat{(1+r_t^{q*})} + \hat{q}_t^* = \hat{\varphi}_{t+1}^* + \hat{k}_t^* \quad (\text{C.26})$$

$$\hat{c}_t^H \frac{c^H}{y} + \hat{c}_t^E \frac{c^E}{y} + x_t \frac{x}{y} + \frac{dB_t}{y} = (nn-1)\gamma \hat{T}_t + \hat{y}_t + \frac{\beta dB_{t-1}}{y} - \hat{K}_{t-1}^B \delta^B \frac{K^B}{y} \quad (\text{C.27})$$

$$\widehat{(1+r_t^q)}\beta + \hat{\epsilon}_{t+1}\beta - \widehat{(1+r_t^{*d})}\beta - (1-\gamma)\beta (\hat{T}_{t+1} - \hat{T}_t) = -\kappa z^3 \hat{K}_t + \kappa z^3 \hat{Q}_t \quad (\text{C.28})$$

$$\widehat{(1+r_t^{q*})}\beta + \hat{\epsilon}_{t+1}^*\beta - \widehat{(1+r_t^{*d})}\beta = -\kappa z^3 \hat{K}_t^* + \kappa z^3 \hat{Q}_t^* \quad (\text{C.29})$$

$$\hat{Q}_t = \hat{q}_t \frac{q}{Q} + \hat{q}_t^* \left(1 - \frac{q}{Q}\right) + (1-\gamma)\hat{T}_t \left(1 - \frac{q}{Q}\right) \quad (\text{C.30})$$

$$\hat{K}_t^B = \hat{K}_{t-1}^B(1-\delta) + \hat{\pi}_t^B r \quad (\text{C.31})$$

$$\hat{K}_t^{B*} = \hat{K}_{t-1}^{B*}(1-\delta) + \hat{\pi}_t^{B*} r \quad (\text{C.32})$$

$$\begin{aligned} \hat{\pi}_t^B &= \left[\widehat{(1+r_{t-1}^q)} + \hat{\epsilon}_t\right] \frac{1}{1-\beta} \frac{q}{Q} \frac{Q}{K^B} - \widehat{(1+r_{t-1})} \frac{1}{1-\beta} \frac{D}{K^B} \\ &\quad - (1-\gamma) \left[\hat{T}_t - \hat{T}_{t-1}\right] \frac{1}{1-\beta} \frac{D}{K^B} \\ &\quad + \left[\widehat{(1+r_{t-1}^{q*})} + \hat{\epsilon}_t^*\right] \frac{1}{1-\beta} \left(1 - \frac{q}{Q}\right) \frac{Q}{K^B} + (1-\gamma) \left[\hat{T}_t - \hat{T}_{t-1}\right] \frac{1}{1-\beta} \left(1 - \frac{q}{Q}\right) \frac{Q}{K^B} + \hat{K}_{t-1}^B \end{aligned} \quad (\text{C.33})$$

$$\pi_t^{B*} = \left[ (\widehat{1+r_{t-1}^{q*}}) + \hat{\epsilon}_t^* \right] \frac{1}{1-\beta} \frac{q^*}{K^B} - \left[ (\widehat{1+r_{t-1}}) \right] \frac{1}{1-\beta} \frac{D^*}{K^B} + \hat{K}_{t-1}^{B*} \quad (\text{C.34})$$

$$\hat{Q}_t = \hat{q}_t \frac{q}{Q} + \hat{q}_t^* \left( 1 - \frac{q}{Q} \right) + (1-\gamma) \hat{T}_t \left( 1 - \frac{q}{Q} \right) \quad (\text{C.35})$$

Market clearing

$$\hat{y}_t = \hat{c}_t^h \frac{c^h}{y} + \hat{c}_t^{h*} + \hat{x}_t^h \frac{x^h}{y} + \hat{x}_t^{h*} \frac{x^{h*}}{y} + \hat{K}_{t-1}^{hB} \frac{K^B}{y} + \hat{K}_{t-1}^{hB*} \frac{K^{B*}}{y} \quad (\text{C.36})$$

$$\hat{y}_t^* = \hat{c}_t^f \frac{c^f}{y^*} + \hat{c}_t^{f*} + \hat{x}_t^f \frac{x^f}{y^*} + \hat{x}_t^{f*} \frac{x^{f*}}{y^*} + \hat{K}_{t-1}^{fB} \frac{K^B}{y} + \hat{K}_{t-1}^{fB*} \frac{K^{B*}}{y} \quad (\text{C.37})$$

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# Notes

<sup>1</sup>See for instance Mendoza and Quadrini (2010), Kollmann et al. (2011) and references therein.

<sup>2</sup>See Imbs (2010) and Perri and Quadrini (2011) for evidence of the strong and unprecedented international business cycle synchronization during the financial crisis, and Kalemli-Ozcan et al. (2012) for the link between output synchronization and financial linkages to the US during the financial crisis.

<sup>3</sup>Losses at European banks in 2007 and 2008 were mostly due to losses incurred on US subprime mortgage debt, for example: IKB Bank, BNP Paribas, HSBC, Sachsen LB, UBS, Barclays Bank, Royal Bank of Scotland all posted actual or expected losses prior to the actual collapse of Lehman Brothers.

<sup>4</sup>Giannone et al. (2011) suggest that financial sector regulation was important in determining the degree to which countries were affected by the financial crisis. Countries with more highly regulated financial sectors are shown to have been less affected by the financial crisis.

<sup>5</sup> $T^E$  offsets the redistribution that occurs between entrepreneurs and the owners of the bank when the entrepreneurs is subjected to a ‘default’ shock. Since the aim of this paper is to examine how lending losses affect the real economy via their effects on the asset side of the banking sector’s balance sheet, we abstract from the redistributive effect of default shocks, that would lead to a counter-intuitive rise in entrepreneurial consumption following a default shock.

<sup>6</sup>An alternative to this assumption would be to create a demand for deposits and thus loans by introducing deposit holdings into the household’s utility function.

<sup>7</sup>The redistributive shock,  $\epsilon$ , is a proxy for default and as such there should not be a welfare gain associated with default for the entrepreneur. Because the entrepreneur is borrowing-constrained, a negative shock to  $\epsilon$  will raise entrepreneurial consumption by more than it reduces consumption of bank’s owners, an effect we offset with the transfer payment.

<sup>8</sup>The steady state value of  $\Delta$  is only zero if the entrepreneur is as patient as the household. Using the steady state of the entrepreneur’s optimal borrowing condition we find that  $\Delta = \beta - \beta^E$ .

<sup>9</sup>The corresponding bank lending spread for the foreign economy is:

$$(1 + r_t^{q*})E_t\epsilon_{t+1}^* - (1 + r_t) = -\kappa \left( \frac{K_t^{B*}}{Q_t^*} - z \right) \left( \frac{K_t^{B*}}{Q_t^*} \right)^2.$$

<sup>10</sup>One could easily make the model symmetric by letting banks resident in the large country intermediate a small fraction of loans in the small country. This would not, however, have a significant on either economy, as long as the bank only intermediates a ‘small’ fraction of loans.

<sup>11</sup>Implicitly, we treat adjustment cost faced by banks,  $\frac{\kappa}{2} \left( \frac{K_t^B}{Q_t} - z \right)^2 K_t^B$ , as a tax on banks that gets rebated to the representative consumer and thus does not represent a resource cost to the economy.

<sup>12</sup>To ensure that the net foreign asset position remains stationary, we include a small external-debt elastic interest rate premium applicable to the home consumer. See Schmitt-Grohe and Uribe (2003) and Bodenstein (2011) for the effect of these interests rate premia in small open and larger open economies.

<sup>13</sup>An alternative would have been to set the relative size of the small country as the UK’s GDP relative to the US. This would, however, overstate the relative importance of UK shocks on the rest of the world.

<sup>14</sup>This becomes clear when looking at the Euler equations of the home and foreign households.

<sup>15</sup>Appendix B contains detailed data sources.

Table 1: Calibration

Parameter	Description	UK	US (if different)
$\beta$	Discount factor HHs	0.9901	
$\beta^E$	Discount factor E	0.9804	
$\theta$	CES btw home and foreign goods	0.9	
$\alpha$	Share of capital in output	0.3	
$\gamma$	Openness	0.25	
$\delta$	Depreciation rate	0.025	
$s'$	Capital adjustment costs	0	
$\chi$	Loan-to-valuation ratio	0.5	
$\kappa$	Elasticity of spread to capital to loan ratio	10	
$z$	Steady state capital to loan ratio	0.1	
$\delta_b$	Bank capital depreciation rate	0.01	
$\xi$	UK banks' share of US lending	0.04	
$n$	Relative country size	0.04	0.96
$\rho_A$	Persistence: Technology shock	0.9822	0.9021
$\sigma_A$	Standard deviation: Technology shock	0.0062	0.0051
$\rho_\epsilon$	Persistence : Write-off shock	0.8362	0.9033
$\sigma_\epsilon$	Standard deviation : Write-off shock	0.0003	0.0003
$\text{Corr}(A,\epsilon)$		0.10	0.37

Table 2: Business Cycle properties

	UK Data		UK models				US Data		US models	
			[1]	[2]	[3]	[4]			[1]	[2]
<i>Standard deviation</i>										
GDP	1.31	0.94	0.01	0.02	0.02	0.02	1.16	1.04	0.02	0.02
<i>Std relative to GDP</i>										
Consumption	0.70	0.55	0.43	0.40	0.39	0.82	0.45	0.44	0.45	0.44
Investment	3.52	2.28	6.65	8.64	8.13	3.81	3.51	6.76	3.51	6.76
Loans	4.31	0.22	0.59	0.77	0.78	2.45	0.30	0.60	0.30	0.60
Net trade	0.69	0.51	1.12	1.76	6.47					
Terms of trade	1.125	1.13	0.30	0.56	0.36					
Bank spread	0.11	0.04	2.20	2.07	1.95	0.07	0.04	1.98	0.04	1.98
<i>Correlation with GDP</i>										
Consumption	0.80	0.99	-0.81	-0.73	-0.81	0.90	0.97	-0.80	0.97	-0.80
Investment	0.81	0.98	0.94	0.93	0.03	0.92	0.99	0.98	0.99	0.98
Loans	0.41	0.22	0.48	0.58	0.02	0.59	0.40	0.54	0.40	0.54
Net trade	-0.40	-0.1	-0.17	-0.21	-0.04					
Terms of trade	0.20	0.71	0.17	-0.29	-0.07					
Bank spread	-0.34	-0.16	-0.64	-0.94	-0.11	-0.36	-0.35	-0.99	-0.35	-0.99
<i>International correlations</i>										
Home and Foreign GDP	0.83	0.17	0.74	0.21	0.95					

Note: The table shows the business cycle characteristics of United States(US) and United Kingdom (UK) for the period 1987:1 to 2009:4. Except for the interest rate spread, all the data has been logged and HP filtered prior to the calculations. [1] = TFP and default shocks, [2] = only default shocks, [3] = only default shocks and no foreign lending, [4] = only default shocks and no foreign lending and no home bias ( $\xi = 0$  and  $\gamma = 1$ ).

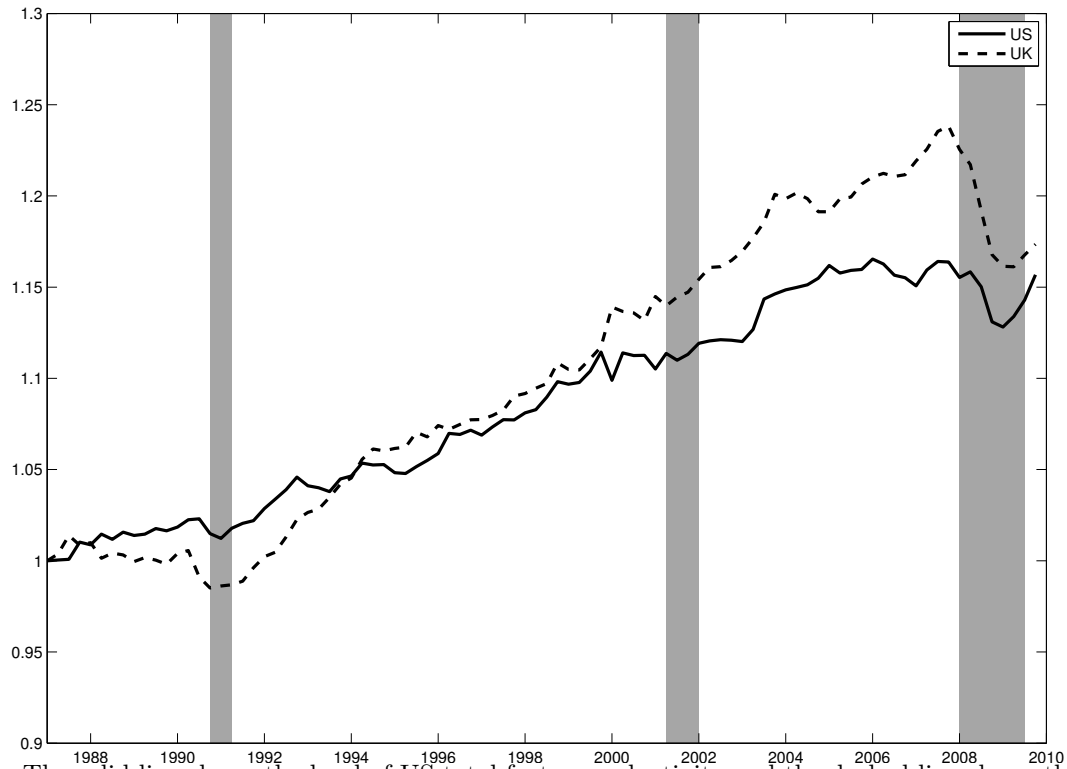


Table 3: Contribution of foreign default shocks to the variance of home GDP

	$\xi = 0.04$	$\xi = 0$
<i>Baseline</i>	55.83%	4.08%
<i>Loan-to-valuation ratio</i>		
$\chi = 0.7$	42.53%	1.03%
$\chi = 0.3$	63.60%	7.62%
<i>Impatience of entrepreneurs</i>		
$\beta^E = 0.985$	55.12%	3.87%
$\beta^E = 0.971$	56.98%	4.43%
<i>Leverage ratio</i>		
$z = 0.15$	43.20%	2.19%
$z = 0.05$	59.40%	5.01%
<i>Elasticity of spread to bank leverage ratio</i>		
$\kappa = 15$	50.56%	3.07%
$\kappa = 5$	59.77%	5.11%
<i>CES home and foreign goods</i>		
$\theta = 10$	93.58%	75.06%
$\theta = 1.5$	63.62%	9.03%
$\theta = 1$	57.12%	4.73%
<i>Openness</i>		
$\gamma = 1$	97.47%	94.02%
$\gamma = 0.5$	76.46%	27.92%
$\gamma = 0.01$	36.93%	0%
<i>Size of home country</i>		
$n = 0.5$	1.72%	0.95%

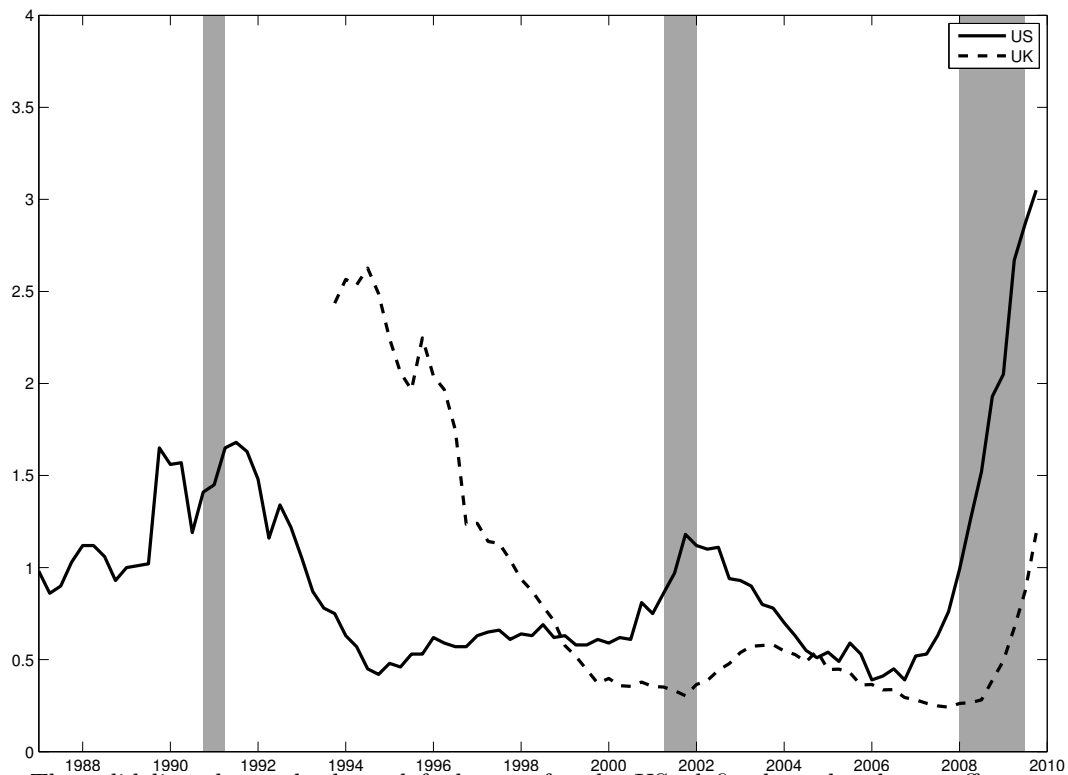
Note: The table shows the contribution to the variance of home country GDP of foreign default shock when the model is driven only by home and foreign default shocks.

Figure 1: Total factor productivity



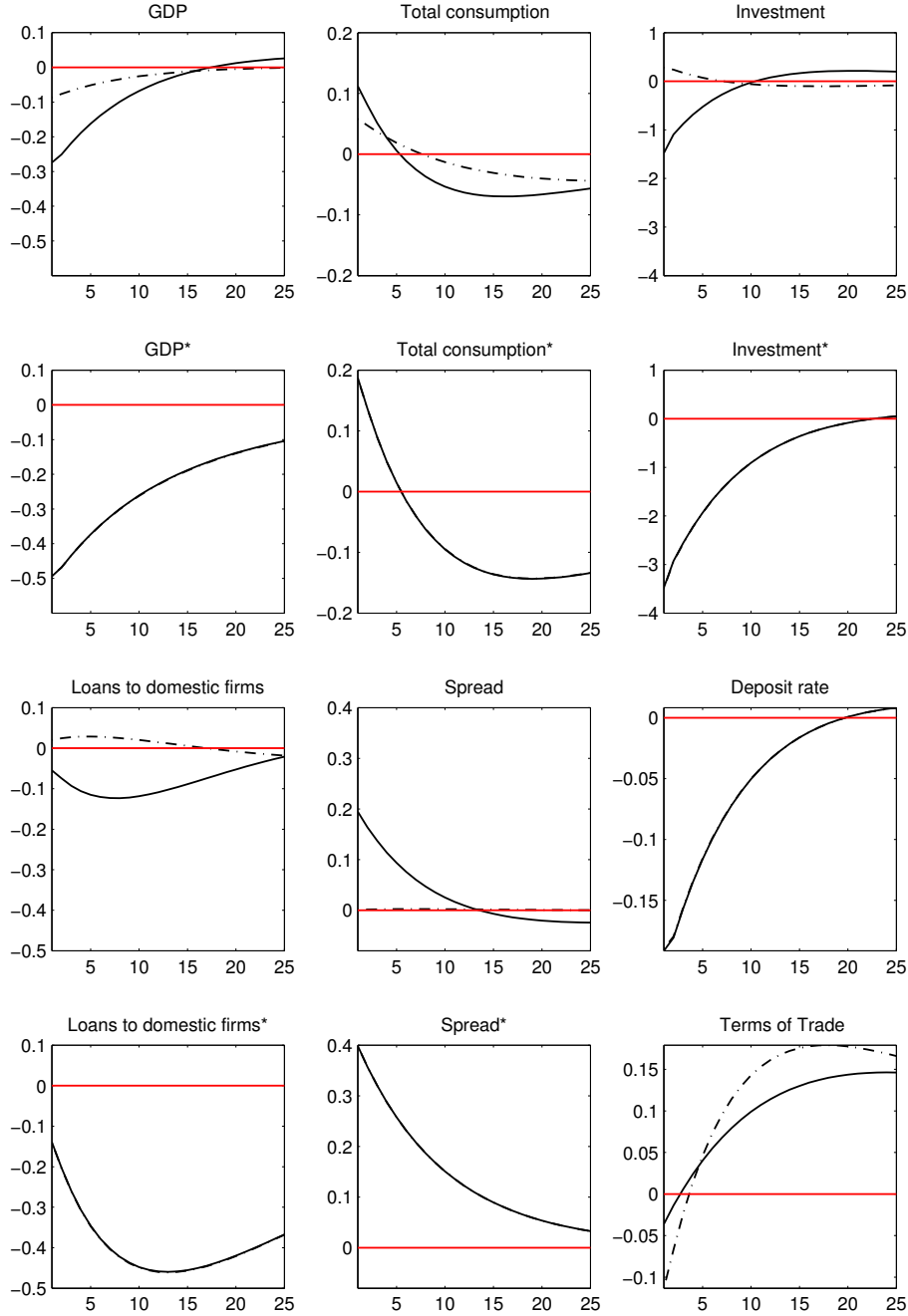
Notes: The solid line shows the level of US total factor productivity and the dashed line shows the level of UK total factor productivity. For both series, we set 1987Q1 = 1. The data appendix contains sources and construction methods.

Figure 2: Loan default rates



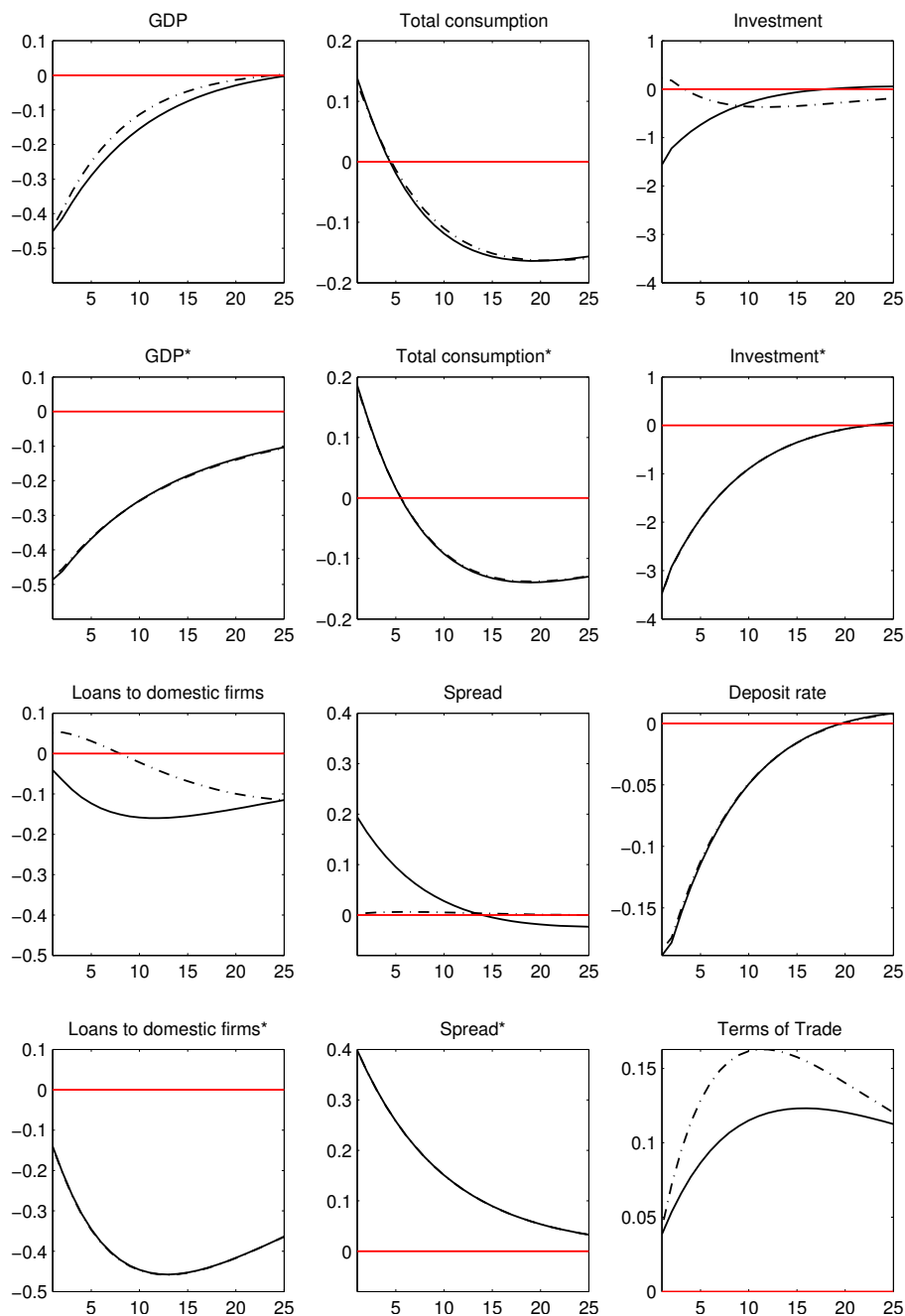
Notes: The solid line shows the loan default rate for the US, defined as the charge-off rate on total loans and leases at commercial banks. The dashed lines show the UK default rate, defined as a ratio of quarterly amounts UK resident monetary financial institutions' sterling write-offs of lending to private non-financial corporations (PNFC) over total loans to PNFCs.

Figure 3: Impulse responses to a unit decline in the foreign repayment rate



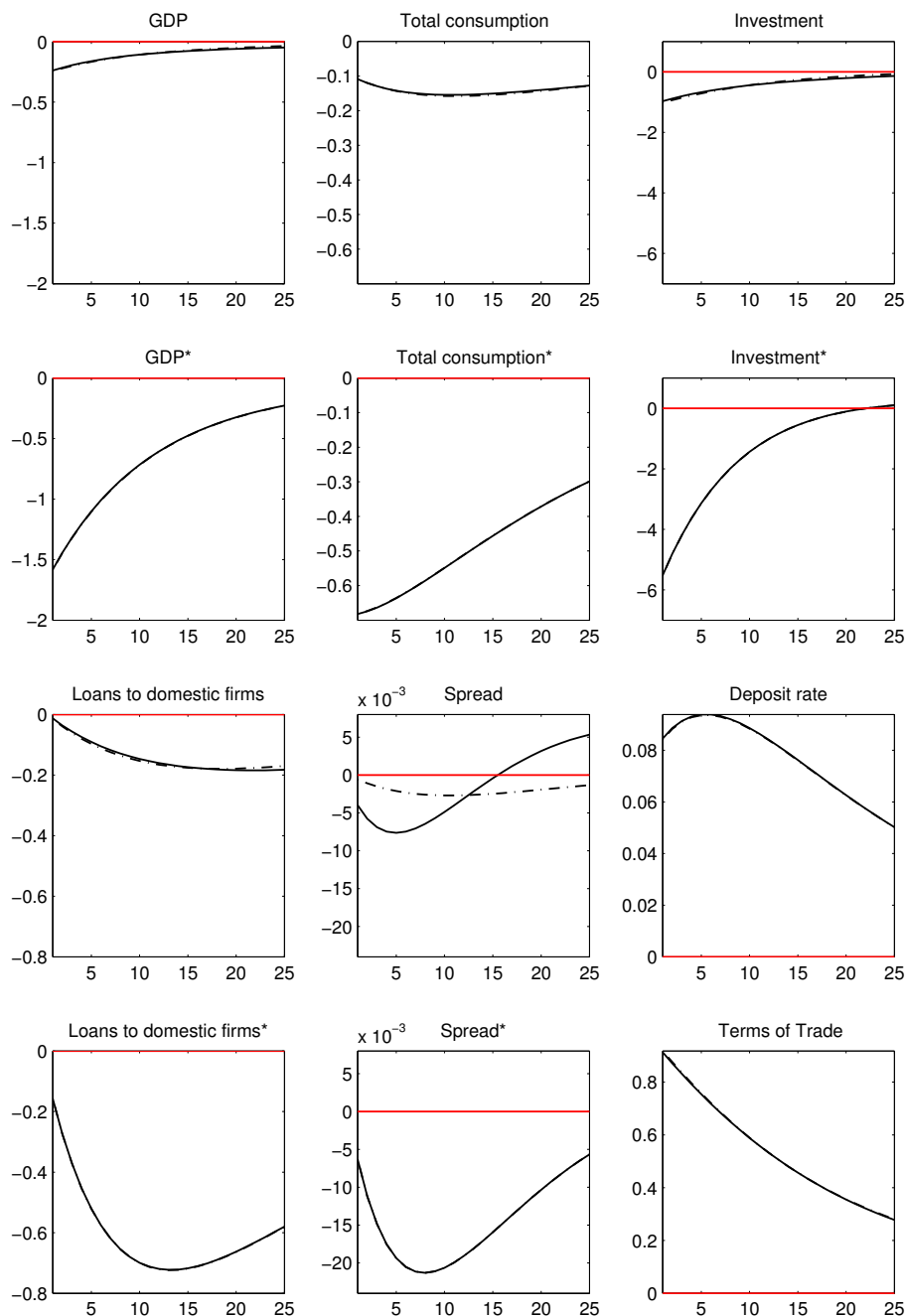
Notes: The solid lines represent the baseline model with international lending where domestic banks' share of foreign lending,  $\xi$ , is equal to the relative size of the home country,  $n$ . The dashed lines represent the responses of an alternative model where  $\xi = 0$ . Variables are expressed in percentage deviation from steady state and interest rates in annual percentage points. Foreign variables are denoted by “\*”. Given our small open economy assumption, the response of foreign variables are similar under alternative models.

Figure 4: Impulse responses to a unit decline in the foreign repayment rate - no home bias  $\gamma = 1$



Notes: The solid lines represent the baseline model with international lending where domestic banks' share of foreign lending,  $\xi$ , is equal to the relative size of the home country,  $n$ . The dashed lines represent the responses of an alternative model where  $\xi = 0$ . Variables are expressed in percentage deviation from steady state and interest rates in annual percentage points. Foreign variables are denoted by “\*”. Given our small open economy assumption, the response of foreign variables are similar under alternative models.

Figure 5: Impulse responses to unit decline in foreign total factor productivity



Notes: The solid lines represent the baseline model with international lending where domestic banks' share of foreign lending,  $\xi$ , is equal to the relative size of the home country,  $n$ . The dashed lines represent the responses of an alternative model where  $\xi = 0$ . Variables are expressed in percentage deviation from steady state and interest rates in annual percentage points. Foreign variables are denoted by “\*”. Given our small open economy assumption, the response of foreign variables are similar under alternative models.

Figure 6: Sensitivity analysis: contribution to the variance of home country GDP of foreign default shock when the model is driven only by home and foreign default shocks for various values of domestic exposure to foreign banking shocks,  $\xi$

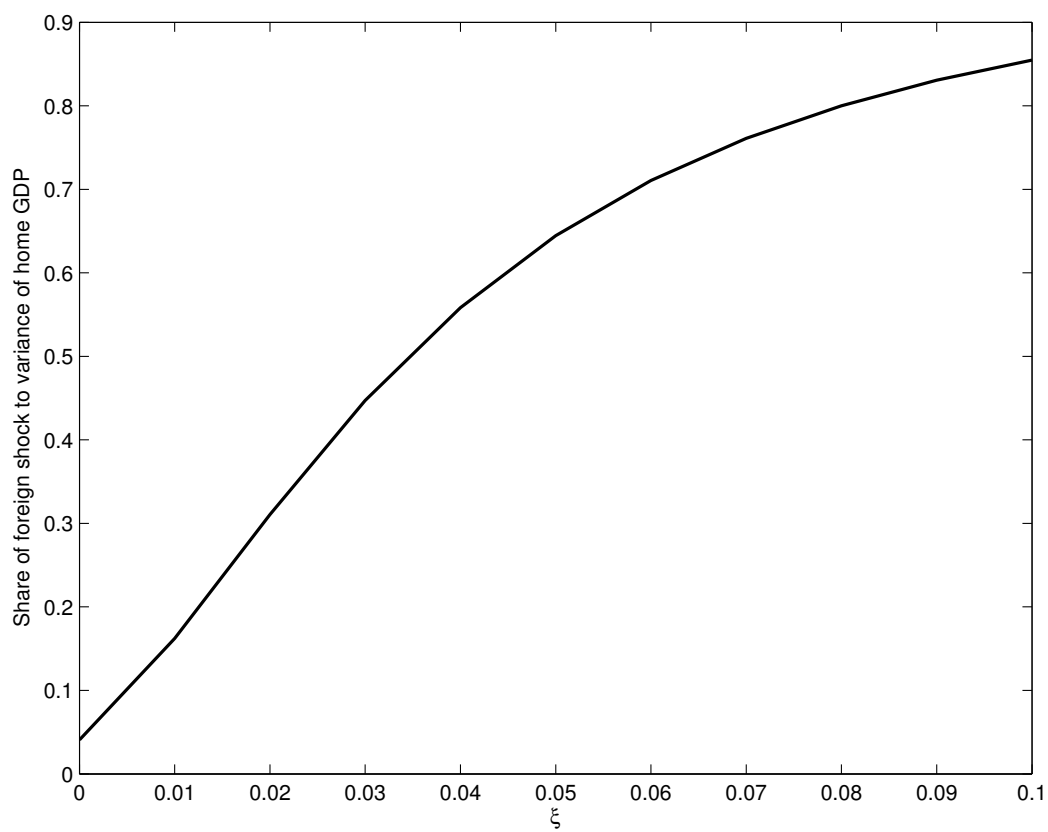


Figure 7: Percentage of time the borrowing constraint is binding as a function of the loan-to-value ratio,  $\chi$ , and the capital adjustment cost parameter

