Financial intermediation and the international business cycle:

The case of small countries with big banks *

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Abstract

We examine the transmission mechanism of banking sector shocks in a two-country DSGE model. Assuming that the home country is small relative to the rest of the world, we find that spillovers from foreign banking sector shocks are modest unless banks in the small country hold foreign banking assets. The correlation between home and foreign GDP rises with the exposure of the domestic banking sector to foreign bank assets.

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1 Introduction

The 2007 financial crisis originated in the United States and was the longest contraction (measured in months from peak to trough) since the great depression. A feature that differentiates the 2007 recession from previous post-war US recessions is the degree to which it was accompanied by simultaneous downturns in many other other developed economies. This feature suggests a strong international transmission mechanism of shocks originating in the banking sector.

Figure 1 shows the response of GDP following the financial crisis and considers the path of output relative to its value in 2007 Q4 for three groups of economies: small open economies with relatively small banking sectors (unexposed sectors), small open economies with relatively large banking sectors, as well as the remaining G7 economies. The path of US GDP is shown in red. Whereas GDP declined in all countries, with the

Figure 1: Output responses during the 2007 US recession

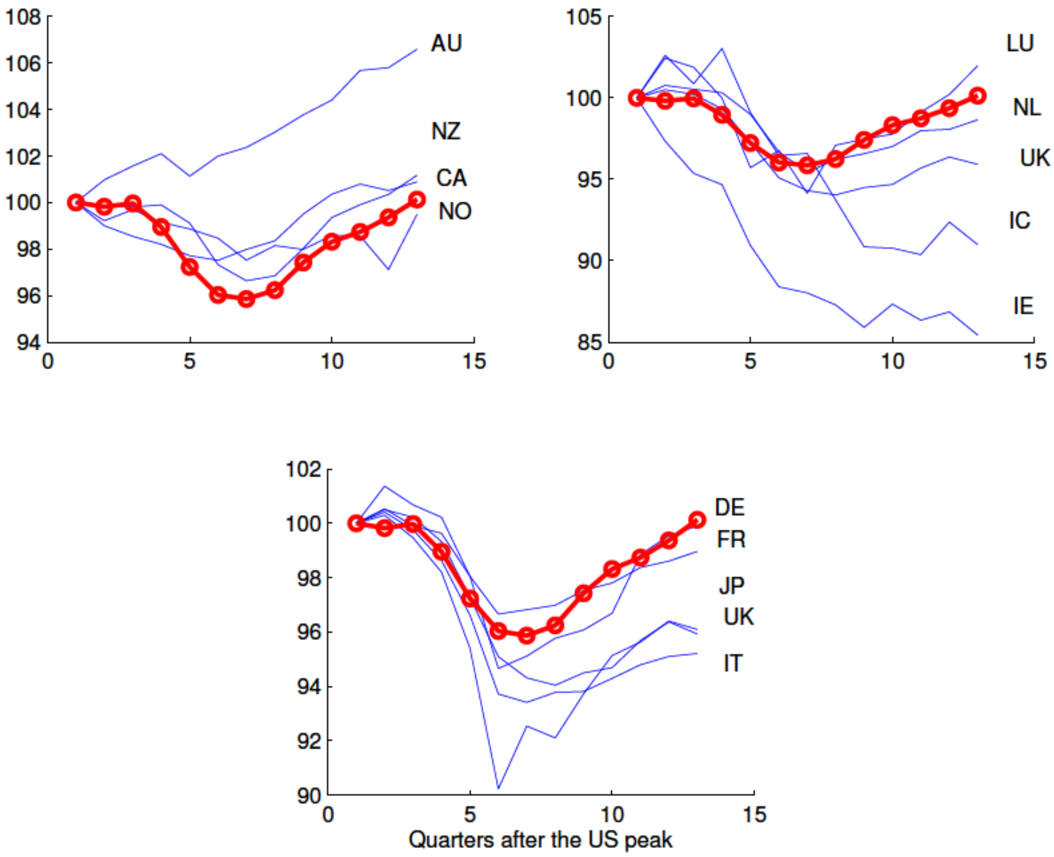
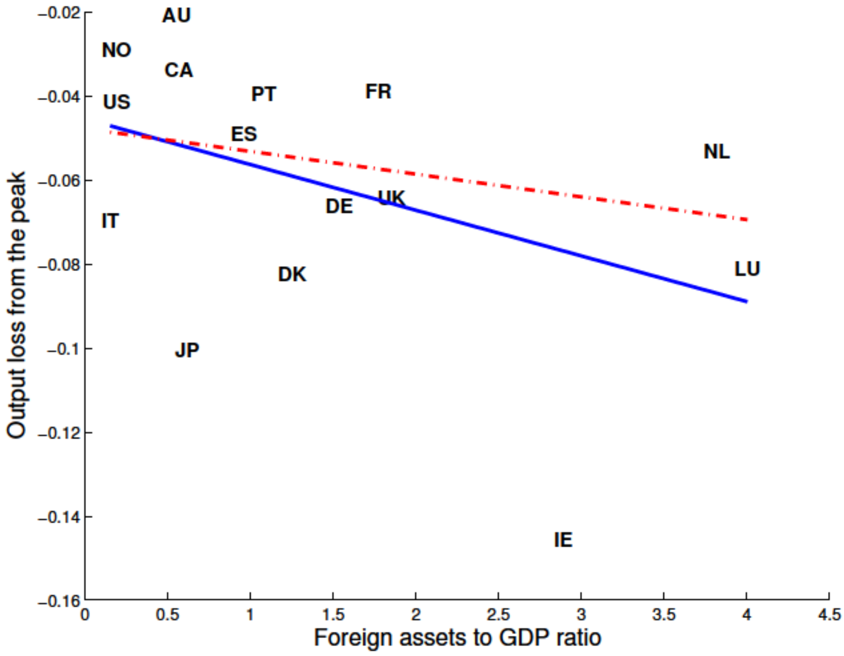


Figure 2: Output contractions during the financial crisis v foreign asset position of banks



Note: For each country, the cumulative output loss is defined as the percentage difference between the peak and the trough of GDP during the financial crisis.

exception of Australia, in our sample the magnitude of the contraction differs across the three groups of countries.

In countries with relatively small and domestically focussed banking sectors, as measured by McGuire and von Peter (2009), such as Australia, Canada, New Zealand and Norway, the post-2007 downturns tended to be less severe than in the US. In contrast, countries with large banking sectors and high exposure to foreign assets, such as the United Kingdom, Ireland, Iceland, and the Netherlands, the spillovers from the US tended to be more pronounced and often more severe than in the US itself. Figure 1 suggests a degree of heterogeneity in the international transmission mechanism across countries.

Figure 2 plots the cumulative output loss during the financial crisis against the banking sector's net foreign asset position relative to GDP at the end of 2007. The solid line in Figure 2 is the implied fitted line of the scatter plot and the dashed line is the the one that emerges if we leave out Ireland from the sample.[1] The negative

[1] Kelly (2010) and Lane (2011) argue strongly that the Irish financial crisis should be seen as largely

correlation suggests that countries with banks that hold large foreign currency asset positions, are associated with larger output losses during the financial crisis.

This paper analyses the international transmission mechanism of banking sector shocks for small open economies with relatively large banks. Our model shows that spillovers from banking sector shocks are small if home and foreign banks are largely independent and large if banks in the small country intermediate both domestic as well as a small fraction of foreign country loans.

Modeling financial intermediation in closed economy DSGE models goes back at least to the financial accelerator model of Bernanke et al. (1999) and more recently to Goodfriend and McCallum (2007), Nolan and Thoenissen (2009), Meh and Moran (2010), Gertler and Kiyotaki (2010), Benk et al. (2010) and Gerali et al. (2010). The literature on financial intermediation in open economies is less voluminous. Recent examples of papers looking at the effects of financial intermediation in open economy DSGE models include Olivero (2010) and Kollmann et al. (2011).

Our analysis is related to Kollmann et al. (2011) who show that with a fully globalized banking sector, large spillovers are possible from country-specific banking sector shocks. Our approach differs from theirs in a number of dimensions. First, we focus not on the spillovers arising from two equally sized economies, but focus instead on the interactions between a large economy, say the US, on the one hand and a small open economy, on the other. Second, instead of assuming a fully globalized banking sector, our focus is on banking sectors that are largely independent. To capture the effects of large banks in small countries, we allow banks resident in the small country to have small, yet large relative to the size of their economy, exposure to foreign bank assets. Third, we consider a richer open economy framework, that allows us to analyze both terms of trade or real exchange rate as well as current account dynamics in response to banking sector shocks.

The remainder of the paper is structured as follows: Section 2 sets out a two-country business cycle model with financial intermediation. Section 3 describes the model's deep parameters and our estimated driving processes. Section 4 analyzes the model using impulse response analysis as well as second moments generated by the

independent of the US financial crisis and was not triggered by bank losses arising from holdings of US sub-prime debt, but rather by domestic loan losses.

model economies. Finally, Section 5 concludes.

2 The model

At its core, the model is a two-country international business cycle model with flexible prices and wages. Departing from the standard international real business cycle (IRBC) model, a competitive banking sector that stands in between households and entrepreneurs is introduced. Households are assumed to be more patient than entrepreneurs, ensuring that in steady state, there is demand for both deposits and loans. In both countries, patient households hold deposits in a global bank that issues loans to home and foreign banks. Each representative bank combines bank liabilities with bank capital to make loans to impatient entrepreneurs.

The model is applied to a setting where one country is small, relative to the other. A defining feature of the small economy is that its banking sector is relatively large, given the relative size of the economy. Banks owned by small-country households make loans to both domestic and foreign-country entrepreneurs.

The dynamics of the model are driven by country specific shocks to total factor productivity in the goods producing sector and shocks that redistribute income between entrepreneurs and banks.

2.1 Households

We propose a two-country model with infinitely lived consumers. 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. The representative agent in both countries smoothes consumption over time by purchasing deposits issued in units of foreign currency with a one-period return of r_t^{*d}. The representative household receives wage income, $w_t l_t$, as well as dividends, T_t, from owning domestic final goods producers as well as the domestic banking sector.

Equation (1) shows the budget constraint for the representative household in the home country.

$$P_t c_t + d_t S_t = P_t w_t l_t + (1 + r_{t-1}^{*d}) d_{t-1} S_t + T_t + t_t^E \tag{1}$$

P_t denotes the price of the domestic consumption good. The final consumption good, c_t, is a CES aggregate of home and foreign-produced final goods. S_t denotes the nominal exchange rate, defined as the home-currency price of unit of foreign currency. Throughout the paper, we assume that the agent's decision on how much to save or dis-save in period t depends on the interest rate available in the spot market on savings (deposits) in period t. $(1 + r_t)$ is the total nominal return to one unit of savings held in the form of deposits between periods t and $t + 1$.

The standard first-order conditions arising from maximizing expected intertemporal welfare, defined over consumption and labour are:

$$U_c(c_t, l_t) = \lambda_t \tag{2}$$

$$U_l(c_t, l_t) = \lambda_t w_t \tag{3}$$

$$\lambda_t = E_t \beta (1 + r_t^{d*}) \frac{P_t}{P_{t+1}} \frac{S_{t+1}}{S_t} \lambda_{t+1} \tag{4}$$

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

2.2 International Risk-sharing

The consumption-based real exchange rate deviates from purchasing power parity because of home bias in consumption. Movements in the real exchange rate, defined as $RS_t = \frac{S_t P_t^*}{P_t}$ are related to movements in the relative marginal utilities of consumption via the the standard international risk sharing condition under incomplete markets:

$$\frac{E_t \lambda_{t+1}}{E_t \lambda_{t+1}^*} \frac{\lambda_t^*}{\lambda_t} = \frac{RS_t}{E_t(RS_{t+1})} \tag{5}$$

2.3 Final goods producers

Final goods, y, are produced using capital, rented from the entrepreneur, and labour. Final goods are used for both consumption and investment in both the home and the foreign economy. P_H is the price of the home-produced traded good. Profits of the goods producing firm are defined as follows:

$$\pi_t^G = \frac{P_{H,t}}{P_t} y_t - w_t l_t - \rho_t k_t \tag{6}$$

and are maximized subject to the production function:

$$y_t \leq A_t {k_t}^{\alpha} l_t^{1-\alpha} \tag{7}$$

As the goods producer is owned by the household, future profits are discounted by the representative household's stochastic discount factor. The maximisation problem yields the following optimality conditions for labour and capital inputs:

$$\frac{P_{H,t}}{P_t}(1-\alpha)A_t k_t^{\alpha} l_t^{-\alpha} = w_t \tag{8}$$

$$\frac{P_{H,t}}{P_t}\alpha A_t k_t^{\alpha-1} l_t^{1-\alpha} = \rho_t \tag{9}$$

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

2.4 Banks

Apart from the goods producer, the representative agent also owns the banking system. Home and foreign banks both raise deposits from the global bank. The foreign bank, resident in the large economy, only advances loans to foreign-country entrepreneurs. Home-country banks, on the other hand, make loans to entrepreneurs in both countries.

Our model of financial intermediation follows the wholesale banks set up in Gerali et al. (2010). The profit function of the home bank, denominated in units of domestic currency per capita, is characterized as follows:

$$\begin{aligned}\pi_t^B = {} & (1+r_{t-1}^q)\epsilon_t q_{t-1} - q_t + \frac{1-n}{n}\xi S_t\left[(1+r_{t-1}^{*q})\epsilon_t^* q_{t-1}^* - q_t^*\right] \\ & + S_t\left[D_t - (1+r_{t-1}^{d*})D_{t-1}\right] + K_t^B - K_{t-1}^B - \frac{\kappa}{2}\left(\frac{K_t}{Q_t} - z\right)^2 K_t \end{aligned} \tag{10}$$

Each period, the bank makes loans to home entrepreneurs, q_t. Home-country banks also intermediate a fraction, ξ of the foreign country's total loans. We are at this stage abstracting from the reasons why the home banking sector is active in the foreign market, and assume simply that home country banks intermediate a fraction ξ of foreign loans. As π_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. 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. Following Kollmann et al. (2011), we assume that each period only a fraction ϵ_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. As the home-country bank makes loans at home as well as abroad, shocks to the foreign repayment rate have a direct affect on bank profits.

Banks are funded via liabilities obtained from the 'global' bank. Bank liabilities, D_t are denominated in foreign currency. The interest rate payable on liabilities is the interest rate on deposits available to the representative consumer

Banks face a balance sheet constraint that requires total lending to be backed by borrowed liabilities as well as banks' own capital stock:

$$Q_t = D_t S_t + K_t^B \tag{11}$$

where total lending is denoted: $Q_t = q_t + \xi S_t q_t^*$. Banks accumulate capital via retained earnings.

$$K_t^B = \left(1 - \delta^B\right) K_{t-1}^B + \omega \pi_t^B \tag{12}$$

Each period, the financial intermediary distributes a constant fraction $(1 - \omega)$ of profits (π_t^B) to shareholders while using the remainder to augment the bank's own capital stock. δ^B captures the costs to the bank of managing the bank's capital stock.

Deviations from a prescribed bank capital-to-loans ratio, z, are costly. One can rationalize such a cost by assuming that adjusting the bank's capital position is costly. Kollmann et al. (2011) motivate a similar cost by the need for "creative accounting" should the bank capital-to-loans ratio fall below the prescribed level.

The optimization problem of the banking sector, using the owner's stochastic discount factor, yields the following optimality condition for the evolution of the interest rate spread:

$$\frac{\beta E_t \lambda_{t+1}}{\lambda_t} \left[(1 + r_t^q) \frac{P_t}{P_{t+1}} \epsilon_{t+1} - (1 + r_t^{d*}) \frac{P_t}{P_{t+1}} \frac{S_{t+1}}{S_t} \right] = -\kappa \left(\frac{K_t^B}{Q_t} - z \right) \left(\frac{K_t^B}{Q_t} \right)^2 \tag{13}$$

The discounted real interest rate spread between bank loans and liabilities is driven by the evolution of the bank capital-to-loans ratio. A ratio above z reduces the spread, whereas a ratio below z raises the spread. [2] 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. Because the bank makes loans to entrepreneurs in both countries, unanticipated shocks to the repayment rates in both countries (ϵ and ϵ^*) affect the interest rate spread faced by domestic entrepreneurs. An unanticipated decline in ϵ_t raises $(1+r_t^q)$ directly. By leading to a loss for the bank, equation (10), a decline in ϵ_t reduces the bank's capital stock. 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. When there is a negative repayment shock on lending to foreign entrepreneurs, the domestic spread rises due to resulting reduction in bank profits.

2.5 Impatient entrepreneurs

Entrepreneurs produce capital goods that are rented out to final goods producers. Entrepreneurs differ from households with respect to their subjective rate of time preference, they are assumed to be less patient than households. The relative impatience of entrepreneurs ensures that in the steady state, we have both borrowing and lending.[3]

Entrepreneurs maximize expected utility

$$E_0 \sum_{t=0}^{\infty} \beta^{Et} U(c_t^E) \tag{14}$$

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

$$c_t^E = \rho_t k_t - x_t + \frac{q_t}{P_t} - (1 + r_{t-1}^q)\epsilon_t \frac{q_{t-1}}{P_{t-1}} \frac{P_{t-1}}{P_t} - t_t^E \tag{15}$$

$$k_{t+1} = (1-\delta)k_t + \left[1 - s(\frac{x_t}{x_{t-1}})\right] x_t \tag{16}$$

[2]The corresponding bank lending spread for the foreign economy is:

$$\frac{\beta E_t \lambda_{t+1}^*}{\lambda_t^*} \left[(1 + r_t^{q*})\frac{P_t^*}{P_{t+1}^*}\epsilon_{t+1}^* - (1 + r_t^{d*})\frac{P_t^*}{P_{t+1}^*}\right] = -\kappa \left(\frac{K_t^{B*}}{Q_t^*} - z\right)\left(\frac{K_t^{B*}}{Q_t^*}\right)^2$$

[3]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.

$$(1 + r_t^q) E_t \epsilon_{t+1} \frac{P_t}{P_{t+1}} \frac{q_t}{P_t} = E_t \chi \varphi_{t+1} k_{t+1} (1 - \delta) \tag{17}$$

Where ρ is the rental rate of capital paid by the good producer, q_t are new loans from the banking sector, $(1+r_{t-1}^q)\epsilon_t$ is the fraction of the interest rate payable plus the principle of last period's loans that are repaid. As in Kollmann et al. (2011), the repayment shock represents a transfer between entrepreneurs and banks. In order to rule out that entrepreneurs benefit directly from a negative shock to ϵ, we introduce a transfer, t^E, from the entrepreneur to the owners of the bank that prevents entrepreneurial consumption from rising when ϵ declines. This shock only affects the real economy via its effects on the bank's capital position.[4]

$s(.)$ captures investment adjustment costs as proposed by Christiano et al (2005), φ denotes the price of capital and χ the loan-to-valuation ratio constraining entrepreneurial borrowing. At time t, lending to entrepreneurs is constrained to a fraction, χ, 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, investment as well as next period's desired capital stock:

$$U_c(c_t^E) = \lambda_t^E \tag{18}$$

$$\frac{\beta^E E_t \lambda_{t+1}^E}{\lambda_t^E} (1 + r_t^q) \frac{P_t}{P_{t+1}} \epsilon_{t+1} = 1 - \Delta_t (1 + r_t^q) E_t \epsilon_{t+1} \frac{P_t}{P_{t+1}} \tag{19}$$

$$\varphi_t \left(1 - s\left(\frac{x_t}{x_{t-1}}\right) - \frac{x_t}{x_{t-1}} s'\left(\frac{x_t}{x_{t-1}}\right) \right) = 1 - \beta^E E_t \frac{\lambda_{t+1}^E}{\lambda_t^E} \varphi_{t+1} \left(\frac{x_{t+1}}{x_t}\right)^2 s'\left(\frac{x_{t+1}}{x_t}\right) \tag{20}$$

$$\frac{\beta^E E_t \lambda_{t+1}^E}{\lambda_t^E} \left(\rho_{t+1} + \varphi_{t+1} \{(1-\delta)\} \right) = \varphi_t - E_t \varphi_{t+1} \Delta_t \chi (1 - \delta) \tag{21}$$

Δ_t is the Lagrange multiplier on the entrepreneur's borrowing constraint. If $\Delta_t = 0$ and the constraint is non-binding, then the entrepreneur behaves in exactly the same

[4] The redistributive shock, ϵ, 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 ϵ will raise entrepreneurial consumption by more than it reduces consumption of bank's owners, hence the need for the transfer payment.

manner as the household.[5]

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

2.6 Small open economy as a limiting case of a two country model

The relative size of the home economy, n, is small. Sutherland (2005) shows a simple way to nest a small open economy model as a special case of a two-country model. Total consumption in both countries is defined as the sum of household and entrepreneurial consumption:

$$c^T = c + c^E \tag{22}$$

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

$$c^T = \left[v^{\frac{1}{\theta}} C_H^{\frac{\theta-1}{\theta}} + (1-v)^{\frac{1}{\theta}} C_F^{\frac{\theta-1}{\theta}} \right]^{\frac{\theta}{\theta-1}} \tag{23}$$

where C_H and C_F are home and foreign produced consumption goods, respectively. θ is the elasticity of substitution between these two types of goods. Sutherland (2005) links the share of home-produced goods in home total consumption v to the relative size of the country and its openness to trade, γ:

$$\begin{aligned} 1 - v &= (1-n)\gamma \\ v &= 1 - (1-n)\gamma \end{aligned}$$

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

$$\begin{aligned} v^* &= n\gamma \\ 1 - v^* &= 1 - n\gamma \end{aligned}$$

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, $v = 1 - \gamma$.

[5] Δ is, however, only zero if the entrepreneur is as patient as the household. In the steady state, where there there is no spread between deposits and loans, $\Delta = \beta - \beta^E$.

Two important relative prices in any IRBC model are the terms of trade, defined as the price of imports relative to exports, $T = \frac{P_F}{SP_H^*}$ and the real exchange rate $RS_t = \frac{S_t P_t^*}{P_t}$. In linearized form, these two relative prices (from the home country's perspective) are related by the degree of openness to trade

$$\hat{RS}_t = (1-\gamma)\hat{T}_t \tag{24}$$

2.7 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:

$$\begin{aligned} P_t c_t^T + P_t x_t + S_t B_t &= (1 + r_{t-1}^{*d}) S_t B_{t-1} + P_{H,t} y_t - \delta^B K_{t-1} \\ &\quad + \frac{1-n}{n} \xi S_t \left[(r_{t-1}^{*q} - r_{t-1}^{*d}) q_{t-1}^* \right] \end{aligned} \tag{25}$$

where the net foreign asset position, $B_t = \left(d_t + \frac{1-n}{n}\xi q_t^* - D_t\right)$ 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, determines the home country's net foreign asset position.[6] The management cost of bank capital, $\delta^B K_{t-1}^B$ is a net resource cost to the economy.[7]

2.8 Closing the model

We have assumed that agents accumulate deposits denominated in units of foreign-country currency. As a result, we have written down what is essentially a nominal model. It is straightforward to convert the model into a canonical international real business cycle model by assuming that the monetary authority follows a strict policy of setting producer price inflation to zero. As there are no nominal rigidities, this can

[6] 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.

[7] 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.

be achieved at all times.

3 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. 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.[8]

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 6%. We adopt the following functional form for the period utility function of the household:

$$U(c_t, l_t) = \frac{c_t^{1-\sigma}}{1-\sigma} - \frac{l_t^{1+\eta}}{1+\eta} \tag{26}$$

and posit a log-utility function in consumption and labour by setting $\eta = \sigma = 1$.

The calibration sets the the share of home-produced intermediate goods in total consumption and investment to 0.75 to match the average share of imports in the UK over our sample period. Given the relative size of the UK, this implies an openness parameter, γ of 0.26. Initially, the intratemporal elasticity of substitution between home and foreign-produced intermediate goods both in consumption and investment, is set to 1.

In the production function, the elasticity of output to capital is set to 0.25 while the depreciation rate is set to 0.025, its standard value in the literature. Initially for our analysis of impulse responses, the value of the investment adjustment cost parameter is set to zero. Below, we choose slightly different values of the parameter in order to match the observed relative volatility of investment in both the UK and the US. Impatient entrepreneur's borrowing is constrained by a loan-to-valuation ratio, χ of 0.70, a value suggested by Gerali et al. (2010)

Calibrating the deep parameters of the financial intermediaries in our model, we

[8] 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.

use US data on total equity to total assets ratio of commercial banks to calibrate the steady state bank capital-to-loan ratio. Accordingly, the parameter z is set to 10%, its mean value over 1988-2010 period. Following Gerali et al. (2010), we set κ to 10 in our baseline calibration, and check the sensitivity of our results to various values of this parameter. Finally we assume that 50% of bank profits are reinvested in bank capital and set ω to 0.5. The value of δ_b is derived from the steady state relationships and equals 0.005 implying that the bank capital depreciates in an annual rate of roughly 2%.

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. Figures 3 and 4 show the evolution of TFP and default shocks for the UK and US economies. Whereas default rates rise dramatically in both economies during the 2007 financial crisis, Figure 4 suggests that default rates are systematically higher in the US than in the UK. The data appendix describes the data used to create these shock processes.

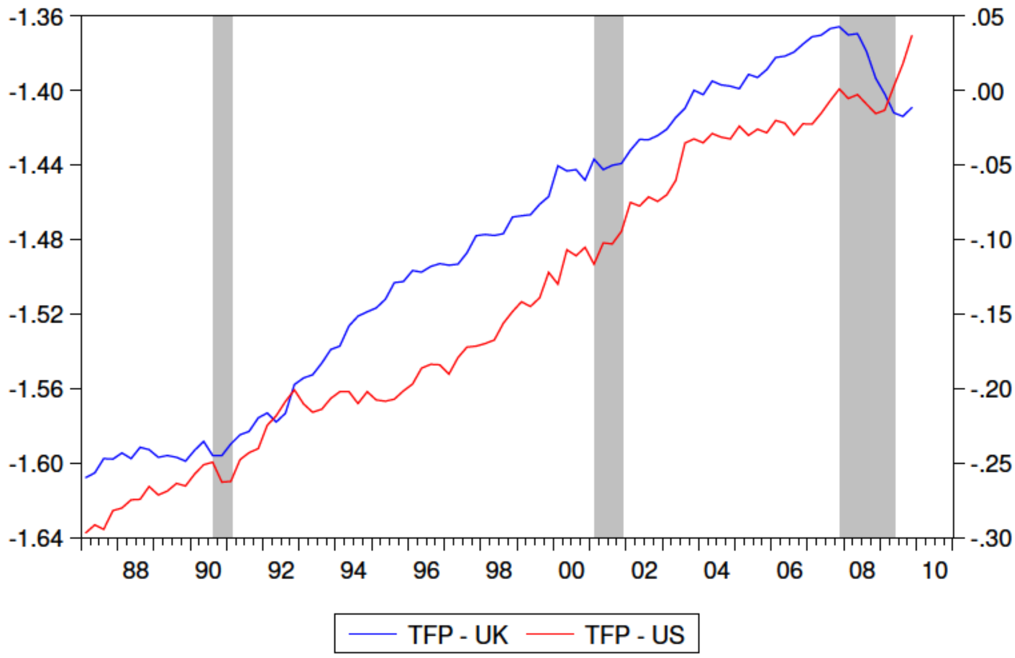
The main motivation of the paper is to investigate the role of financial intermediation on the international transmission of shocks. Therefore we abstract from the cross-country correlation of the shock processes and focus on the endogenous propagation mechanisms originating from the presence of the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

4 International transmission mechanism

This section addresses three issues. First, how does the addition of a banking sector into a canonical international business cycle model affect the transmission of productivity shocks? Second, how do repayment, or default, shocks transmit between open economies? Finally, how is this transmission mechanism altered if the small country has relatively large banks?

To address these issues, we initially consider impulse responses to real and financial shocks originating in the large economy and discuss how macroeconomic variables

Figure 3: Total factor productivity

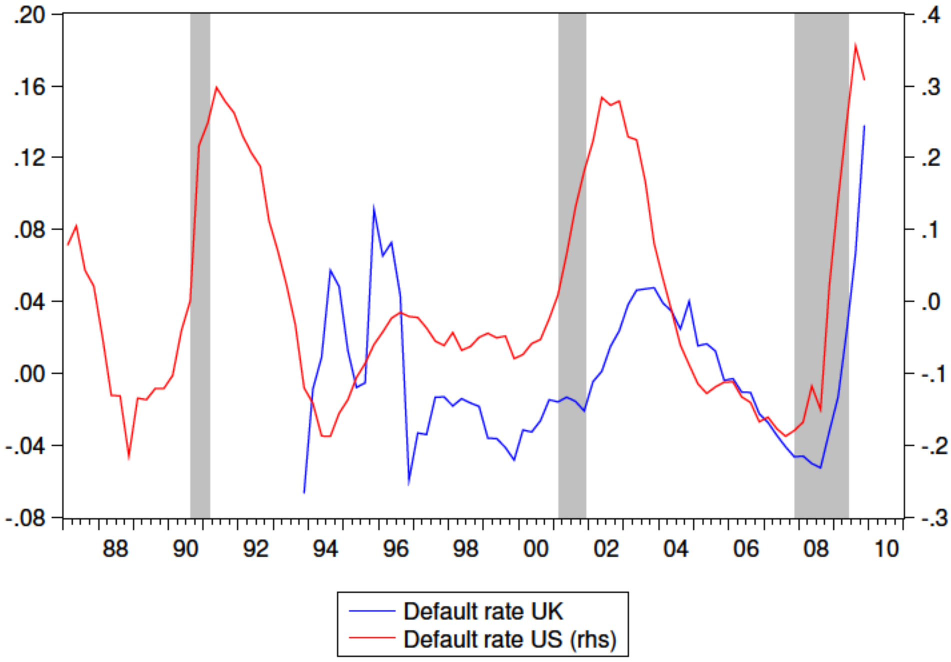


respond to these shocks. We then analyze the statistical properties of the model in order to assess its ability to match a selection of second moments of US and UK data.

4.1 Impulse response analysis

The solid lines in Figures 5 - 12 show the response of home-country (the small open economy) variables and the dashed lines show those of the foreign economy. Figure 5 shows the response of selected variables to a negative unit TFP shock located in the foreign economy. This analysis helps to illustrate the role of banks in our model economy. As output and investment demand falls in foreign economy, so does the demand for bank loans. For a given stock of bank capital, the decline in bank lending also lowers the bank spread, i.e. the difference between the interest rate on bank loans, r^{*q} versus bank liabilities, r^{*d}. Foreign shocks are transmitted to the home economy via changes in the terms of trade, which via equation (24) is a linear function of the real exchange rate. In Figure 5, the home country real exchange rate depreciates and acts to share consumption risk between the home and foreign country. As a result there is a modest decline in the components of domestic GDP.

Figure 4: Loan default rate



Adding more financial frictions amplifies the effects of the banking sector on the model. In Figure 6, the required bank leverage ration, z, is raised to 0.25 from its calibrated value of 0.1. In this case, there is a larger effect on the spread and therefore a smaller response of foreign investment to the foreign shock. Compared to the baseline calibration, there is a greater response of foreign consumption and a somewhat dampened response of foreign output. The response of the real exchange rate is a larger depreciation compared to the baseline case. Unlike the familiar financial accelerator approach, financial intermediation in this model tends to attenuate the effects productivity shocks on investment and output.

Figure 7 repeats the exercise of Figure 5 for the case in which the bank faces no cost associated with changing the bank capital-to-loans ratio $(\kappa = 0)$. Apart from the behaviour of the interest rate spread, Figures 5 and 7 are virtually identical, implying that for our baseline calibration, there is only a modest effect of adding a financial sector into an IRBC model. As in Kollmann et al. (2011) and Gerali et al. (2010), the effects of banks on the transmission of supply shocks is modest and the bank spread is pro-cyclical following a supply shock. This suggests that in order to generate a

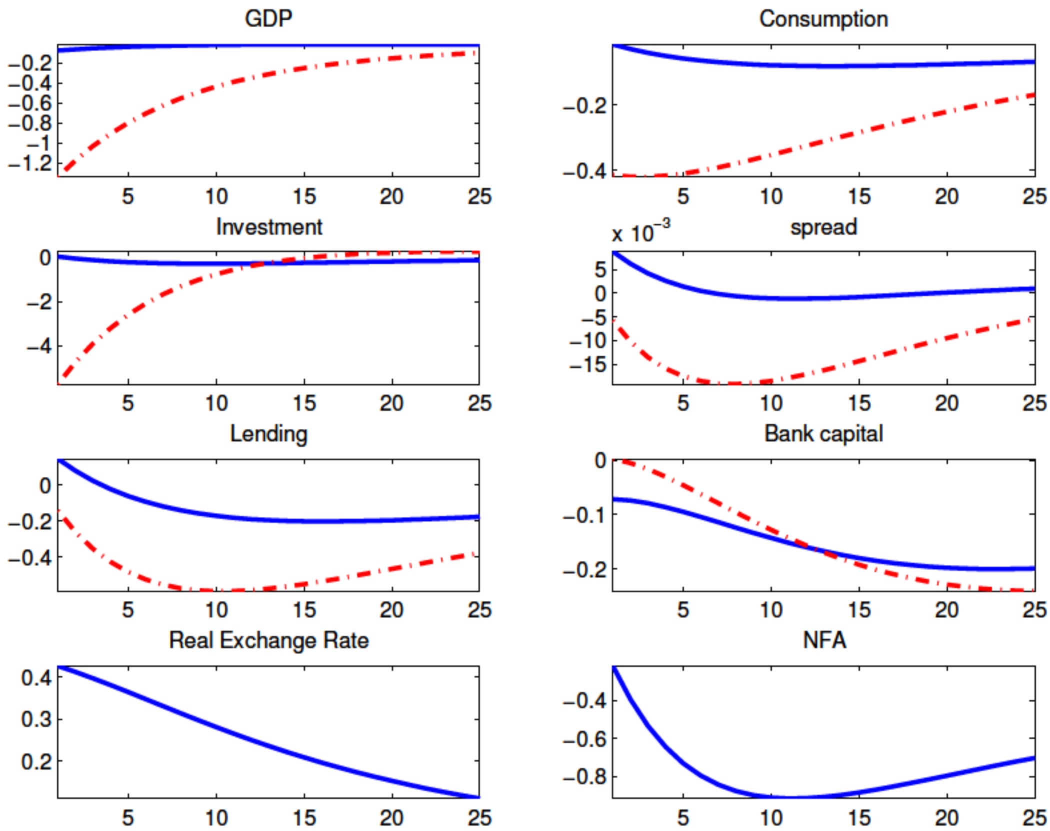
Table 1: Initial calibration

Parameter	Description	UK	US (if different)
β	Discount factor HHs	0.9901	
β^E	Discount factor E	0.9852	
σ	Elasticity of intertemp. substitution (HH)	1	
σ^E	Elasticity of intertemp. substitution (E)	1	
η	Inverse of Frisch elasticity	1	
θ	CES btw home and foreign goods	1	
v	Home-bias in consumption and investment	0.75	
δ	Depreciation rate	0.025	
s''	Investment adjustment costs	0	
κ	Elasticity of spread to capital to loan ratio	10	
z	Steady state capital to loan ratio	0.1	
ω	Bank's dividend policy	0.5	
δ_b	Bank capital depreciation rate	0.005	
ξ	UK banks' share of US lending	0.04	
n	Relative country size	0.04	0.96
ρ_A	Persistence: Technology shock	0.8669	0.8615
σ_A	Standard deviation: Technology shock	0.0053	0.0056
ρ_ϵ	Persistence : Write-off shock	0.7314	0.9582
σ_ϵ	Standard deviation : Write-off shock	0.0002	0.0004
Corr(A,ϵ)		0.28	0.18

data congruent counter-cyclical spread, the model needs to be augmented by shocks originating in the financial sector.

Figure 8 shows impulse responses to an unexpected, one-off reduction of ϵ^*, the foreign loan repayment rate, for the special case in which home-country banks do not advance loans to foreign firms ($\xi = 0$). A negative shock to the loan repayment rate in our model, is a transfer from the banking sector to entrepreneurs. To avoid entrepreneurial consumption rising in response to such a shock, entrepreneurs are taxed and proceeds rebated to the owners of the bank. Nonetheless, bank profits and therefore bank capital accumulation are adversely affected by the shock. The spread rises by about one per cent per quarter. It does so for two reasons: first, to take into account the expected path of the repayment rate, and second because of a decline in the bank capital stock. The decline in output and bank lending in the foreign economy is due only to that part of the increase in the spread caused by the

Figure 5: Impulse responses to a unit TFP shock in the foreign country

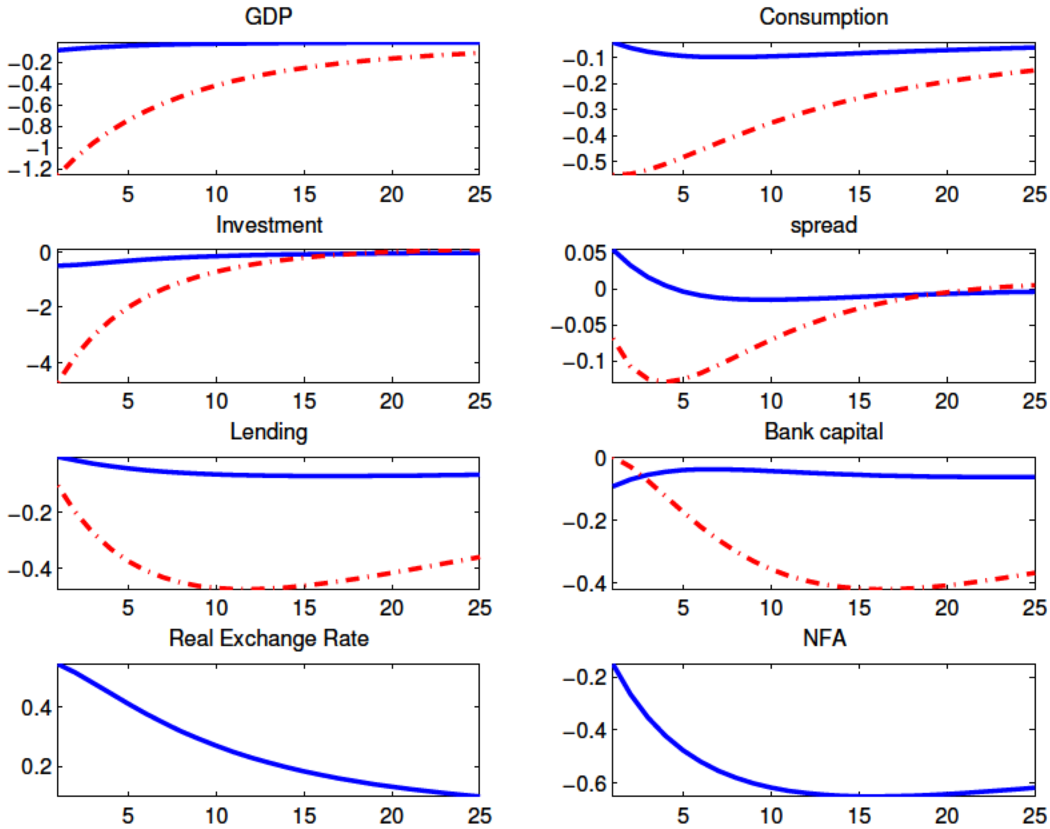


decline in bank capital.[9] The components of foreign GDP do not all move in the same direction. There is a notable decline in investment as well as a rise in consumption. A similar counter-cyclical response of consumption is also found in response to investment specific technology shocks (Basu and Thoenissen (2011), Justiniano et al. (2011)) and in response to entrepreneurial net worth shocks in financial accelerator models (Gilchrist and Leahy (2002) and Nolan and Thoenissen (2009)).

The international spillovers of repayment, or default shocks to our small economy are modest. Figure 8 suggests a very small initial decline in home GDP associated with a persistently worsening net foreign asset position. The initial response of the home-country's real exchange rate (terms of trade) is to appreciate followed by a protracted depreciation. Just as with TFP shocks, the movements in the real exchange rate largely insulate the home economy against the effects of a foreign banking sector shock.

[9]If deviations in bank capital have no effect on the spread, i.e. if $\kappa = 0$, a "default" shock would only effect $(1 + r_t^{*q})$ in a way that leaves $(1 + r_t^{*q})E_t\epsilon_{t+1}^*$ unchanged. There would therefore be no effect on the real economy.

Figure 6: Impulse responses to a unit TFP shock in the foreign country - large z

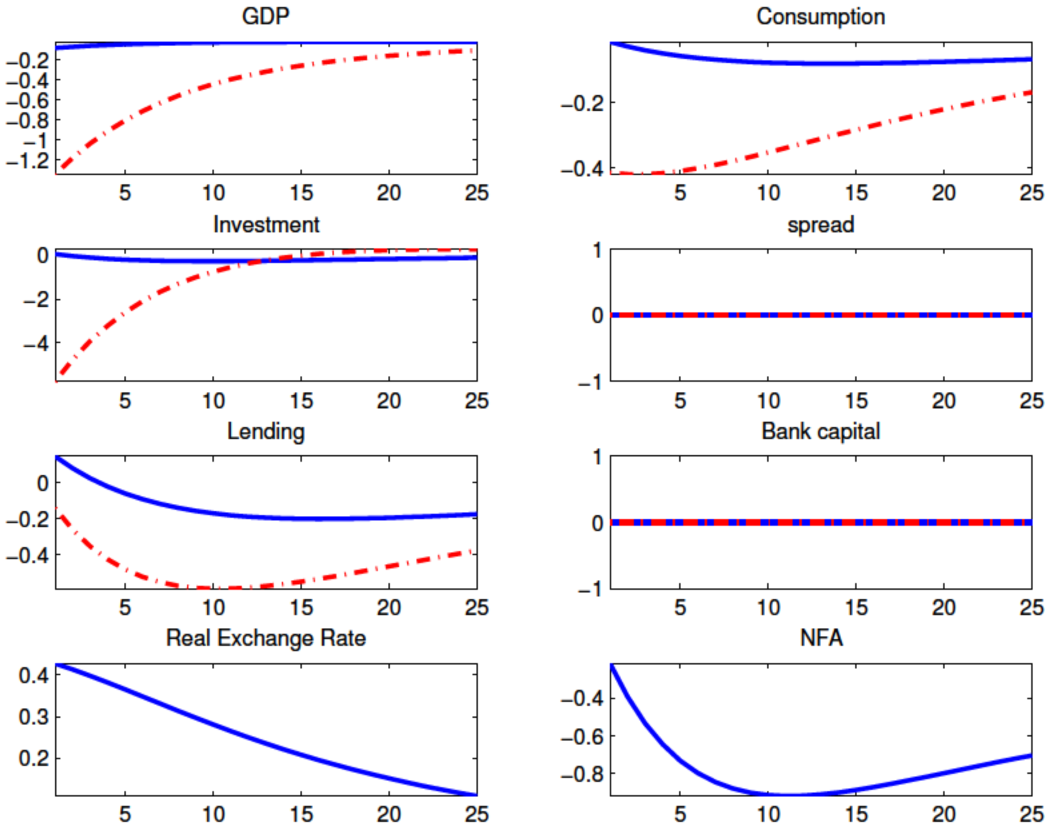


Interestingly, home-country banking variables such as the spread (measured on the left hand axis), bank lending or the bank capital stock are also virtually unaffected by a foreign default shock.

The role of real exchange rate movements in insulating the home economy from foreign banking shocks is highlighted in Figure 9 where the small economy is assumed to be completely open to trade, i.e. $\gamma = 1$ such that purchasing power parity holds at all time. In this case, the risk sharing condition, equation (5), implies a tight link between home and foreign consumption. Under this calibration, home output declines by almost as much as foreign output.

In order to capture the synchronized downturns observed in the US and most other OECD countries, one needs to account for the degree of international integration in the banking sector. Kollmann et al. (2011) propose a global banking sector, where one bank essentially does all the intermediation in both countries. A default shock in either economy leads to a decline in bank capital and thus to an equal size rise in

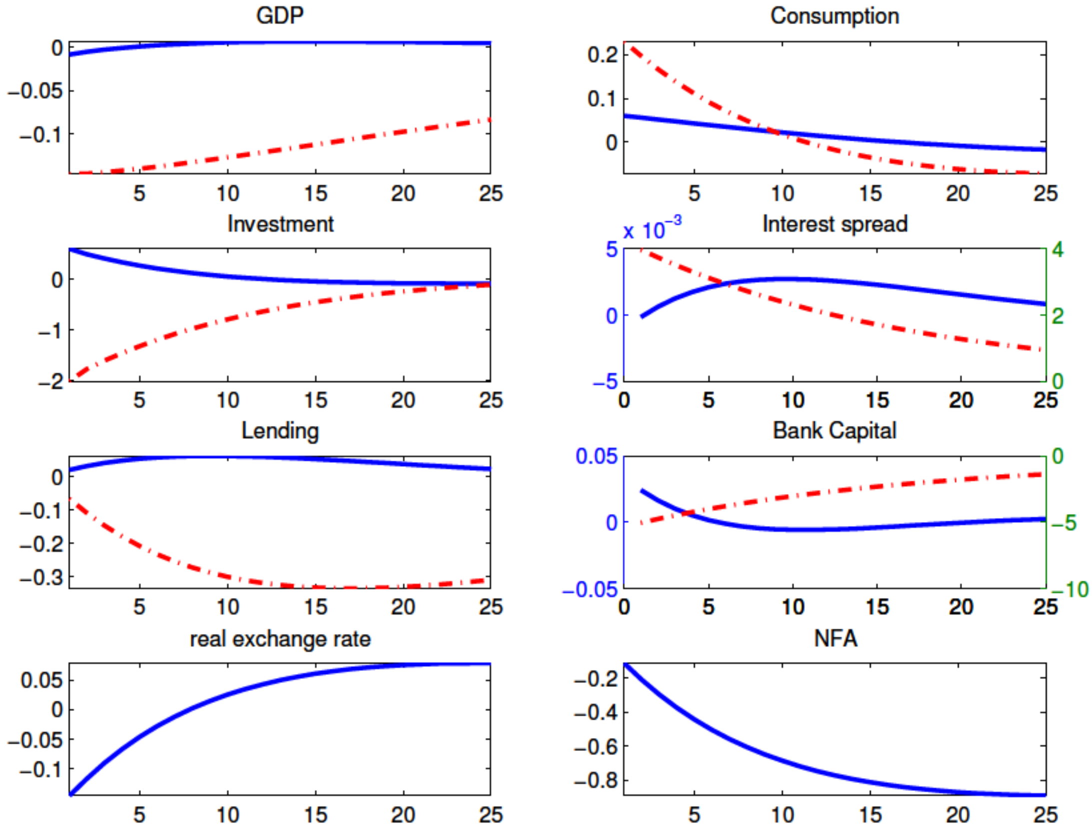
Figure 7: Impulse responses to a unit TFP shock in the foreign country - no banking sector



the spread in both countries. Instead of assuming a fully integrated banking sector, we consider the case where the banking sector in the small country is relatively large and where home-country banks intermediate a small (but compared to home-country output, relatively large) fraction of foreign-country loans. Foreign banks only lend to foreign entrepreneurs, but home-country banks can lend to both home and foreign entrepreneurs.

In Figure 10 the small economy consists of 4% of world households. Banks resident in the home country intermediate all home country loans as well as 4% of foreign loans. Under this calibration, we get a significant decline in home-country output following a default shock by foreign entrepreneurs. Home output declines by about half as much as foreign output. A default by foreign entrepreneurs adversely affects home-country bank profits, reducing bank capital and therefore raising the intermediation margin faced by domestic firms. Allowing home country banks to be exposed to foreign lending greatly increases correlation between home and foreign output following foreign banking sector

Figure 8: Impulse responses to a unit decline in the foreign repayment rate - no foreign lending



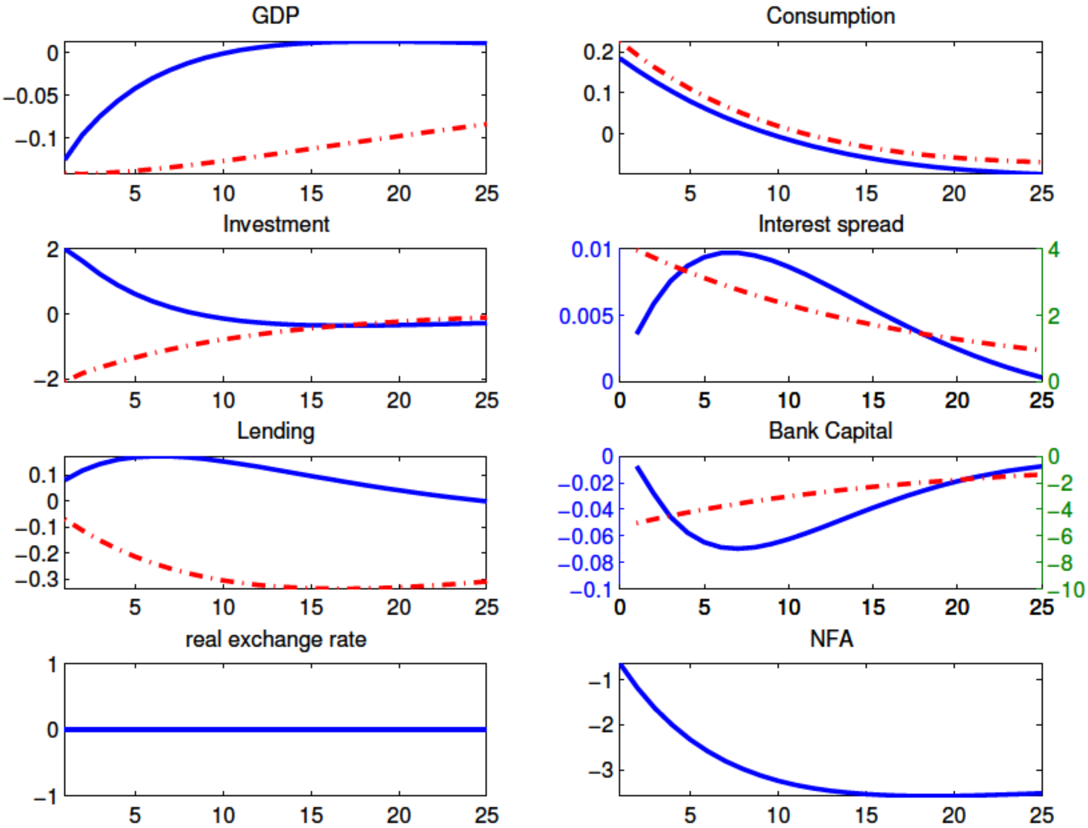
shocks.

Figures 11 and 12 explore the transmission of foreign default shock when allowing for further heterogeneity between the home and foreign banking sectors. In Figure 11, the banks in the home country maintain a higher bank capital-to-loans ratio, z, than do foreign banks. Paradoxically, maintaining a higher bank capital stock implies a larger increase in the home-country spread and subsequent larger decline in home-country investment and GDP.

In Figure 12, banks in the home country face a higher cost of deviating from the target bank capital-to-loan ratio, κ than do foreign banks. A higher κ is associated with a more volatile interest rate spread, which increases the degree to which foreign repayment or default shocks spillover to the home economy.

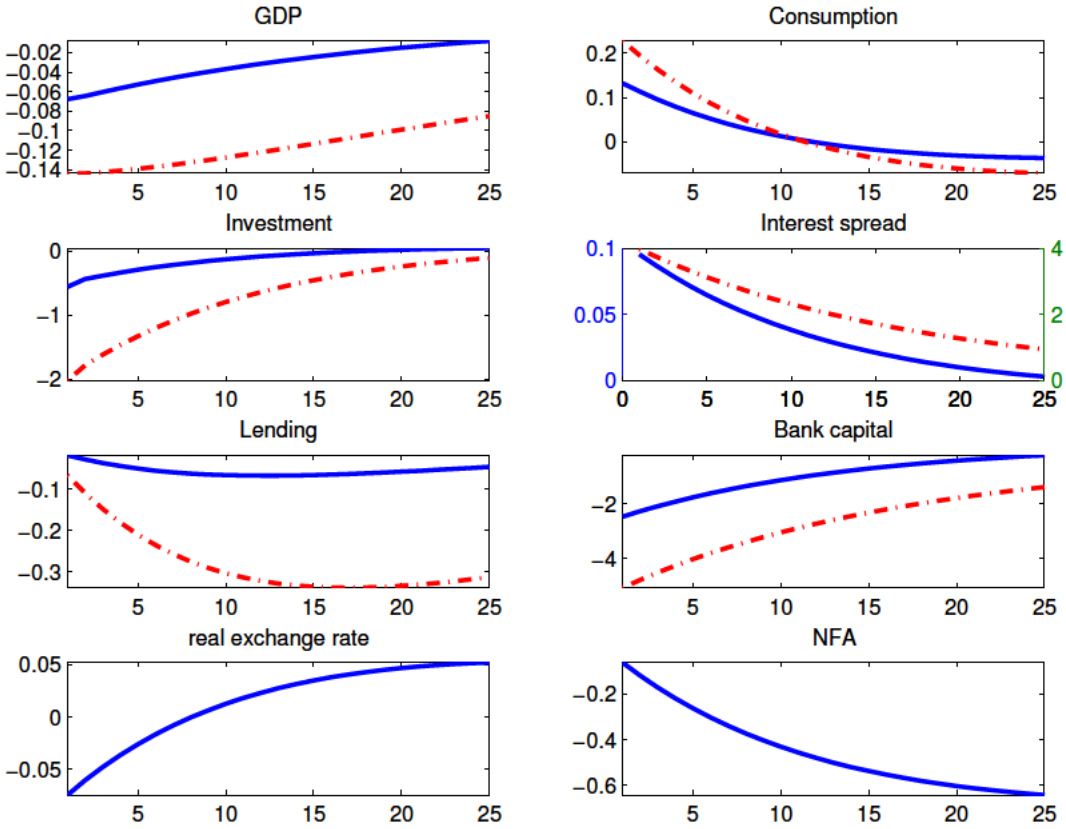
The focus of this section has been on shocks originating in the foreign (large) economy. In summarizing our results so far, we find the following: The existence of

Figure 9: Impulse responses to a unit decline in the foreign repayment rate - no consumption home-bias



banks *per se* does not significantly alter the transmission mechanism of productivity shocks, hence 'normal' recessions, are not amplified or dampened by the existence of banks in our model. For shocks originating in the banking sector, the international transmission mechanism depends on the degree of exposure of home banks to foreign loans. Spillovers are modest if home country banks are not directly exposed to foreign loans. In this case, movements in the terms of trade are sufficient to insulate the home economy from the foreign shock. When domestic banks undertake financial intermediation in both the home and the foreign market, a default shock on foreign loans adversely affects the capital position of domestic banks. The result is a rise in the intermediation margin on loans to domestic firms as banks attempt to increase profits with which to re-build their capital stock. A rise in the borrowing rate brings about a recession by reducing investment and output.

Figure 10: Impulse responses to a unit decline in the foreign repayment rate - foreign lending ($\xi = n$)



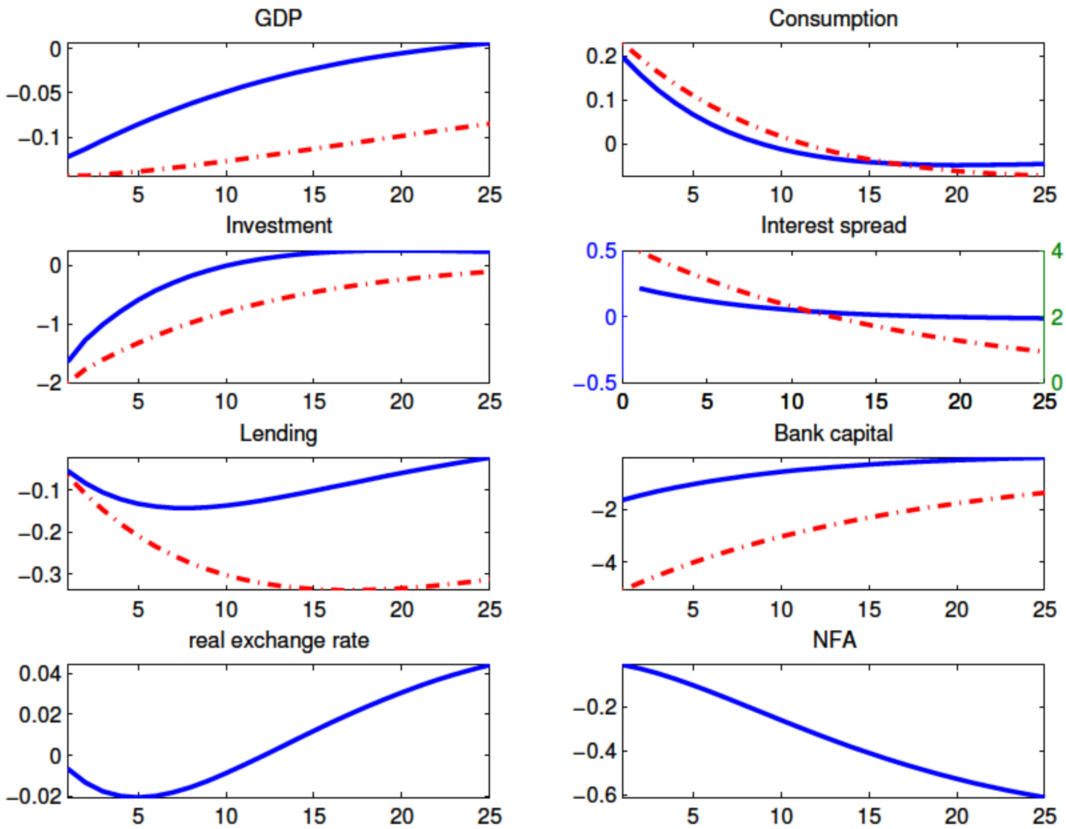
4.2 Second moments

Table 2 compares the business cycle properties of the model economy to US and UK data. 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 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 the UK, and in the US is also more volatile in the UK than in the US. Whereas bank lending is pro-cyclical, the spread, or intermediation margin, is counter-cyclical in both countries.[10]

The shocks driving the model are country specific. The UK total factor productivity shock, defined as the Solow residual, has very similar characteristics to its US counter part. Table 1 suggests very similar AR(1) coefficients and standard deviation for the

[10] See the data appendix for detailed data sources.

Figure 11: Impulse responses to a unit drop in the foreign repayment rate - foreign lending ($\xi = n$) and higher target bank capital-to-loans ratio in the home economy (z = 0.15)

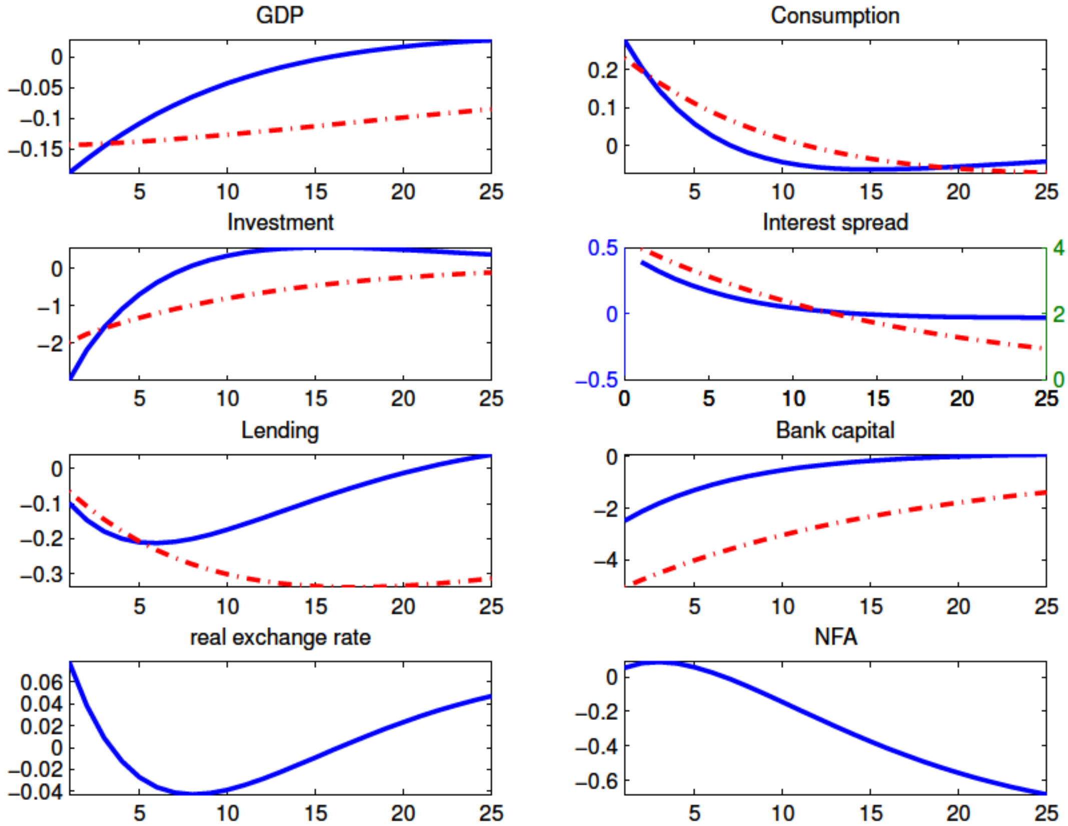


two TFP shocks. Our calculations suggest that the US default rate is both more volatile and more persistent than its UK counter part. The data suggests that in both countries default (loan repayment rate) and productivity shocks are negatively (positively) correlated.

Given the estimated shock processes, we calibrate the adjustment cost parameter, s'' in each country to match the relative standard deviation of investment. For the UK, a value of 0.78 and for the US a value of 0.41 allows the model to match the standard deviation of investment relative to GDP. As in Thoenissen (2011), we use the elasticity of substitution between home and foreign-produced goods, θ, to match the relative standard deviation of the UK terms of trade. Setting $\theta = 0.605$ allows us to match the standard deviation of the UK's terms of trade relative to UK GDP.[11]

[11]This value of θ is below the usual value of 1 - 1.5 used in the literature, but is still in the range for which the model generates a "standard" transmission mechanism of productivity shocks, as opposed to "negative" transmission as highlighted by Corsetti et al. (2008).

Figure 12: Impulse responses to a unit decline in the foreign repayment rate - foreign lending ($\xi = n$) and higher cost of deviating from the target bank capital-to-loans ratio in the home economy ($\kappa = 40$)



The columns headed *TFP + def* report selected second moments for the large (US) and the small open economy (UK) driven by both TFP and "default" shocks. With these shocks, the model captures about 80% and 60% of the volatility of US and UK GDP, respectively. Whereas the model matches the relative volatility of investment exactly, it under-predicts the volatility of consumption. For the large economy, the model captures most of the relative volatility of the bank spread, but for both sets of economies fails to match the volatility of bank lending.

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 in the data, 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, relative to UK GDP are of the correct sign.

The column headed "Def" reports second moments generated by our model when driven only by "default" shocks. Default shocks alone explain less than 1% of the volatility of GDP, but account for most of the variation in the bank lending as well as the interest rate spread. Crucially, the default shocks account for the counter-cyclicality of the bank spread.

The column headed "Def $\xi = 0$" 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. Whereas the GDP in the small and the large country are highly correlated under default shocks if the small open economy is exposed loans written in the large economy, the correlation is close to zero when home and foreign banks are entirely separate. Figure 13 reports sensitivity analysis around the parameter ξ and shows the correlation between home and foreign GDP rising rapidly as the share of foreign bank assets in the small open economy rises. As in Figure 2, the correlation between home and foreign (US) GDP following default shocks is larger the greater is the ratio of foreign banking assets to GDP in the small country.

The final column of Table 2 confirms the high correlation between outputs in the absence of consumption home-bias.

Figure 13: Sensitivity analysis: correlation between home and foreign GDP under default shocks for various values of domestic exposure to foreign banking shocks: ξ

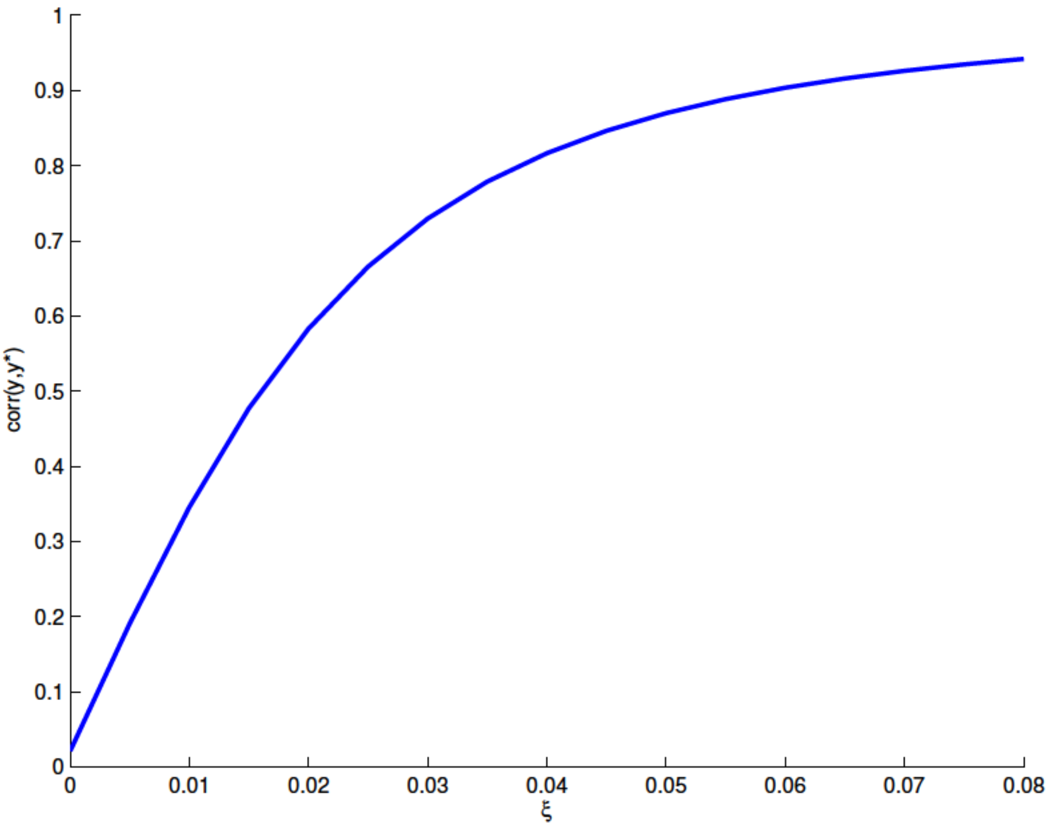


Table 2: Business Cycle properties

	UK Data	UK models				US Data	US models	
		TFP+ def	Def	Def - $\xi = 0$	Def - $\xi = 0$ no home bias		TFP + def	Def
Standard deviation								
GDP	1.31	0.79	0.004	0.004	0.01	1.16	0.93	0.01
Consumption	0.70	0.54	1.47	1.33	2.08	0.82	0.42	1.45
Investment	3.52	3.52	10.69	14.25	15.50	3.81	3.81	12.60
Loans	4.31	0.30	1.03	1.38	1.46	2.45	0.31	1.19
Net trade	0.69	1.15	1.61	3.05	15.59			
Terms of trade	1.12	1.12	0.94	2.28	0.93			
Bank spread	0.11	0.02	4.55	4.86	3.08	0.07	0.06	6.85
Correlation with GDP								
Consumption	0.76	0.96	-0.87	-0.68	-0.89	0.89	0.97	-0.89
Investment	0.80	0.98	0.95	0.91	-0.48	0.90	0.99	0.96
Loans	0.35	0.48	0.63	0.62	-0.14	0.58	0.39	0.60
Net trade	-0.55	-0.11	0.03	-0.13	-0.04			
Terms of trade	0.20	0.60	0.21	-0.26	-0.04			
Bank spread	-0.28	-0.11	-0.46	-0.77	-0.04	-0.37	-0.16	-0.98
International correlations								
Home and Foreign GDP	0.83	0.12	0.82	0.02	0.86			0.83

Note: The table shows the business cycle characteristics of United States(US) and United Kingdom (UK) for the period 1986:1 to 2009:4. Except for the interest rate spread, all the data has been logged and HP filtered prior to the calculations.

5 Conclusion

Including a banking sector in an otherwise standard international real business cycle model does not significantly alter the transmission mechanism of productivity shocks. Movements in the real exchange rate insulate the home economy from foreign shocks. A default shock that adversely affects the foreign bank's capital position results in a real appreciation of the home country's real exchange rate. Whereas foreign GDP declines, home GDP remains largely unaffected by a foreign banking sector shock. When we allow the home country's banks to intermediate a small proportion of foreign bank lending, a foreign-country default shock has a significant negative effect on home-country GDP.

Our findings suggest that small open economies with large and internationally exposed banking sectors are more affected by foreign banking sector shocks than countries with relatively self contained banking sectors. The response to foreign supply shocks does not appear to be affected by the structure of the banking sector.

Appendix

A Data sources and definition

GDP data in Figure 1 and Figure 2 is taken from HAVER and refers to seasonally adjusted quarterly GDP in constant prices in national currencies. The following countries are included in the graphs: Australia, Canada, Denmark, France, Germany, Iceland, Ireland, Italy, Japan, Luxemburg, Netherlands, New Zealand, Norway, Portugal, Spain and the United Kingdom. In Figure 1, the GDP of each country is normalized to 100 at 2007:Q4.

In Figure 3, data on foreign claims over GDP for 2007 is taken from McGuire and von Peter (2009). In these calculations, foreign claims for a particular banking system is the claims booked by all worldwide operations of banks headquartered in that country. As a result this measure does not include positions booked by foreign banks located in that particular country, and exclude the positions of the foreign offices that particular country's banks.

Unless otherwise indicated, the business cycle moments are calculated over the period 1987Q1:2009Q4. In Table 2, US GDP, consumption and investment refer to seasonally adjusted real per capita series. GDP is from BEA's NIPA table 7.1, "Selected Per Capita Product and Income Series in Current and Chained Dollar". Consumption is from BEA's NIPA Table 2.3.5 , "Personal Consumption Expenditures" and deflated by the relevant GDP deflator from BEA's NIPA table 1.1.9. Investment is "Real Private Fixed Investment " from BEA's 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 that 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 BEA's NIPA table 7.1.

Data for UK are from 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 natpc2 dataset). We convert these series in per capita terms by dividing each series by population (lmsum01 dataset). The terms of trade for UK is defined as the ratio of import price deflator over export price deflator. Import (export) price deflator is calculated by dividing imports (exports) at current prices by imports (exports) at constant prices (natpc1 and natpc2 datasets). Net trade is from HAVER and corresponds to "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 it by the GDP deflator and population.

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

Data for exogenous processes

The total factor productivity (TFP) processes for both US and UK are constructed as a residual using the production function presented in the text. For US, capital is private fixed assets from BEA's NIPa table 5.9 and labor is hours of all persons in the nonfarm business sector from Bureau of Labor Statistics. For UK, capital and labor are from ONS and correspond to "Gross Capital Stock" (ZLDO) and "Total actual weekly hours worked" (YBUS) from ONS. For both US and UK the capital stock is extrapolated from annual to quarterly frequency using quarterly investment data. We then assume that the percentage deviations of TFP from a trend follow an AR(1) process and estimate the following equation for US and UK on linearly detrended TFP:

$$\widehat{A}_t = \rho_A \widehat{A}_{t-1} + \sigma_A \tag{27}$$

The default rate for US is from HAVER and refers to "loan delinquency rate on commercial and industrial loans" for all insured commercial banks. We calculate the default rate for UK as a ratio of Quarterly amounts UK resident monetary financial institutions' sterling write-offs of lending to private non-financial corporations" (RPQTFHB) and total loans which is defined above. As for the 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 US and UK on HP filtered default rates:

$$\widehat{\epsilon}_t = \rho_\epsilon \widehat{\epsilon}_{t-1} + \sigma_\epsilon \tag{28}$$

Given the recent financial crisis and the possible increase in the volatility of the shock processes, we calculate the standard deviations of the exogenous driving processes using data up to the end of 2007.

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