Global Banks and International Business Cycles

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Abstract

This paper incorporates a global bank into a two-country business cycle model. The bank collects deposits from households and makes loans to entrepreneurs in both countries. It has to finance a fraction of loans using its own funds. We investigate how this constraint impacts on the international transmission of productivity and loan default shocks. Loan defaults reduce bank equity and induce a global increase in interest rate spreads and a decline in lending. Three findings emerge. First, the bank's balance sheet constraint is of little consequence for the international transmission of productivity shocks. Second, default shocks are of little consequence for business cycle fluctuations in normal times. Third, an exceptionally large loan loss originating in one country induces a sizeable and simultaneous decline in economic activity in both countries. This is particularly noteworthy, as the simultaneous decline in economic activity in the US and the euro area during the period 2008–2009 is a distinct feature of the global financial crisis.

Keywords: Global Bank, International business cycles, Financial crisis
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1 Introduction

During the recent global financial crisis economic activity declined simultaneously in the United States and in the euro area (EA). The high degree of synchronization in economic activity is a distinct feature of the crisis, as the business cycle in the US typically leads the business cycle in the EA. At the same time, several indicators suggest that the crisis was triggered by distinct developments in the US. House price indices, for instance, started to plummet by mid-2006 in the US, but have only leveled off by 2009 in the EA. In addition, estimates by the IMF (2010) suggest that while both, US and EA banks, suffered large loan losses, almost all writedowns were due to domestic loans in case of US banks, but mostly due to foreign loans in case of EA banks. In this paper, we assess under which circumstances country-specific events may trigger a sharp and highly synchronized international downturn.

We take up this issue within a quantitative international business cycle model. While standard macroeconomic models developed before the global financial crisis typically abstract from banks and other financial intermediaries, our model features a globally integrated banking sector. This allows us to account for a role of financial factors in international business cycle fluctuations. Our model represents a two-country world, where each country is inhabited by a representative household and an entrepreneur. Households provide labor hours to the local entrepreneur, and deposit savings at a globally operating bank which lends to entrepreneurs in both countries. Entrepreneurs accumulate capital and produce, by combining capital and labor inputs, a homogenous tradeable good. Deposits provide liquidity services to the household.

We focus on the consequences of banks' balance sheet constraints for the international transmission of business cylce shocks. In order to do so, we maintain an aggregate perspective and assume the presence of a representative global bank, i.e., we abstract from the interbank market, where liquidity shortages can emerge as an additional friction in financial intermediation.[1] Specifically, we assume that the global bank has to finance a fraction of the loans using its own funds (equity). We are agnostic as to whether this constraint reflects concrete regulatory requirements or, more broadly, market pressures.[2] In equilibrium, the loan rate exceeds the deposit rate and the interest spread is a decreasing function of the bank's 'excess' capital, i.e., of bank capital held in excess of a target level. We allow for exogenous

[1]Disruptions in the interbank market certainly played an important role in the early stages of the global financial crisis, see Brunnermeier (2009) for a detailed account and Gertler and Kiyotaki (2010) for a formal treatment of the interbank market.

[2]Consequently, we refrain from any normative assessment. Traditionally, regulating banks' capital is often justified by limiting moral hazard in the presence of informational frictions and deposit insurance, see Dewatripont and Tirole (1994). In the present paper we altogether abstract from these issues. Our focus, instead, is on the business cycle implications of banks' balance sheet constraints, which we take as given.

fluctuations in productivity and loan default and calibrate the model to match characteristics of the data for the US and EA.

Considering the period 1995–2010, we find that the model is able account for key features of the data, including the co-movement of macroeconomic aggregates across the US and the EA, as well as the behavior of financial variables of interest, including loans and interest rate spreads. As a first result, we find that the contribution of default shocks for business cycle fluctuations is negligible during normal times, i.e., given the size and frequency of default shocks in historical times-series data up to the global financial crisis. Second, we find that a constraint on the global bank's balance sheet is of little consequence for the international transmission of technology shocks. Moreover, the international co-movement triggered by an isolated technology shock is fairly low, in line with earlier research by Backus et al. (1992) and many others.

However, as a third finding, we document that losses on bank capital, which are due to defaults in one country, trigger a world-wide widening of interest rate spreads, and a simultaneous drop in lending and output in both countries. Moreover, the quantitative impact on real activity is very similar across countries. We therefore use the calibrated model and explore the global consequences of a large loan default in the domestic economy. Specifically, we consider a loss in loans amounting to five percent of domestic GDP—a value broadly in line with what is documented for the US during the 2007–2010 period. We find that the asymmetric shock triggers a global and persistent decline in output, with domestic and foreign output falling by about two percent on impact. To understand this result, note that the loan loss lowers global bank capital, raises interest rate spreads and lowers the amount of lending in both countries.[3] Put differently, a fall in the bank's wealth aggravates the financial friction, which leads to a fall in investment, employment and output. In contrast, in the absence of a constraint on the bank's balance sheet, a loan loss has virtually no effect on loan rates, output, and investment.

The literature has only started to explicitly allow for banks within quantitative business cycle models, see Goodfriend and McCallum (2007) for an early contribution within a closed economy framework. Similarly, Van den Heuvel (2008) and De Walque et al. (2009) use closed economy models to analyze the implications of banks' capital requirements. Meh and Moran (2010), Roeger (2009), Dib (2010) and Gerali et al. (2010) embed banks within fairly large, but closed economy DSGE models. The latter study estimates the model on

[3]In line with this account, Puri et al. (2010), investigating German data for the period 2006–2008, provide evidence that lending was reduced by those retails banks which were particularly exposed to loan losses in the US. Similarly, Cetorelli and Goldberg (2010) identify international banking linkages as a determinant of a reduction in loan supply in emerging market economies after 2007.

time-series data for the EA and finds that—as a results of banks' balance sheet constraints—shocks to bank capital may have sizeable effects on economic activity. Our paper has been written independently of a complementary study by Iacoviello (2010). He investigates a closed-economy framework where not only the bank, but also entrepreneurs and impatient households face a collateral constraint. He shows that a financial shock, i.e., a non-repayment of loans by impatient households, triggers a sizeable recession only if the bank faces a capital requirement constraint.

Within international business cycle models, the literature typically abstracts from banks. An exception is Olivero (2010) who studies the implications of a global, imperfectly competitive banking sector for international co-movements. In her analysis, banks do not face a balance sheet constraint. At the same time, a number of recent open-economy studies considers a wider set of financial factors in order to account for the recent global recession. Mendoza and Quadrini (2010) simultaneously analyze financial globalization and spillovers of country-specific shocks to bank capital. In their two-country model, countries are characterized by different stages of financial development, determining the extent to which households can insure themselves against idiosyncratic income risk. In contrast to our paper, the authors are not concerned with business cycles and assume a fixed level of aggregate capital and production. In a related contribution, Devereux and Yetman (2010) abstract from capital accumulation, banks and financial shocks, but focus on the international transmission of productivity shocks in the presence of portfolio holdings by leverage-constrained investors. They find that, depending on the level of financial integration, binding leverage constraints induce a high degree of international co-movement. Finally, Perri and Quadrini (2010) model financial frictions by assuming that firms are borrowing constrained as a result of imperfectly enforceable debt contracts. A country-specific tightening of borrowing constraints, or 'credit shock', leads to a synchronized decline in global economic activity, which the authors also identify as a key feature of the global financial crisis.

Against this background, our distinct contribution is to show how a country-specific loan loss triggers a worldwide recession in the presence of a balance sheet-constrained global bank. We do so within a quantitative business cycle model which captures key features of actual time-series data. However, in order to illustrate the underlying mechanism as transparently as possible, our analysis abstracts from various frictions which are often considered within larger DSGE models. We therefore see our work as complementary to the studies discussed above. The remainder of the paper is organized as follows. Section 2 discusses some data that motivate this paper. Section 3 describes the model. Section 4 presents the quantitative results. Section 5 concludes.

2 Properties of the data

Our analysis aims at accounting for the salient features of US and EA data at business cycle frequency. To start with, we display in figure 1 output fluctuations in both currency areas obtained by applying an HP-filter with a smoothing parameter of 1600 (left panel) and by subtracting year-on-year growth rates from average growth rates (right panel). Our sample covers the period 1975q1-2010q1. In the appendix, we provide a detailed description of the data sources and definition. In the panels of figure 1, the solid (dashed) line shows data for the US (EA) and the shaded areas indicate NBER recessions. Both panels suggest that the US cycle tends to lead the European cycle by a few quarters, with the exception the latest recession, i.e., during the global financial crisis, where output collapsed simultaneously in the US and the EA, see also Giannone et al. (2010) and Perri and Quadrini (2010). According to the NBER, the recession started in 2007q4 in the US. We assume that it has come to an end by 2009q3.

In the following, we focus on the period 1995q1–2010q1, because for the EA, neither financial data, nor non-synthetic time-series for macroeconomic aggregates are available for earlier periods. In figure 2, we display time-series which illustrate certain financial aspects of the 2007–2009 recession. In the upper left panel, we show loan losses for US banks and compare it to data for German banks, because aggregated data for the EA are not available. These losses are measured in percent of the total amount of outstanding loans (annualized). For the US, the data are obtained from the Federal Reserve Board and measure the charge-off and delinquency rates on loans and leases at all insured US-chartered commercial banks. The rates represent in annualized terms the value of loans removed from bank books, net of recoveries, and charged against losses. For Germany the data are obtained from IMF (2010) at annual frequency and interpolated to obtain quarterly observations. These time series illustrate that loan losses—in line with widely held notions on the origins of the global financial crisis—have indeed reached unprecedented levels during the 2007–2009 period. Note, however, that the increase is somewhat larger for US banks.

The IMF has frequently provided estimates of the overall amount of loan losses over the period 2007–2010 within its biannual Global Financial Stability Report. As of April 2010, the total worldwide writedown of banks due to losses on loans and securities is estimated to be close to 2300 billion USD, with approximately 70 percent due losses on loans. US and EA banks are estimated to facing losses totalling 588 billions and 440 billions, respectively.[4] However, loan losses due to foreign loans account for less than 10 percent at US banks, but for almost 60 percent at EA banks. Assuming that a substantial loss of EA banks is due loan

[4] For the EA ECB (2010) conducts independent calculations, but reports very similar numbers.

defaults in the US, the total amount of loan losses originating in the US then amounts to approximately 5 percent of US GDP. We will explore the consequences of a 'default shock' of this size in our quantitative business cycle model below.

The upper right panel of figure 2 shows the evolution of bank equity relative to bank assets, i.e., the banks' capital ratio, for the US (solid lines) and the EA (dashed lines). Depending on the sources, these measures differ somewhat across the US and the EA.[5] A common feature of both time series, however, is that the bank capital ratio held up fairly well during the crisis. IMF (2010) and ECB (2010) also stress these developments and highlight that banks managed to raise capital during the crisis by issuing new equity and/or by retaining profits.

At the same time, lending also declined, notably in the later stages of the crisis. This is shown in the middle left panel of figure 2, which displays loan growth in real terms, measured on a yoy-basis, for the US (solid lines) and the EA (dashed lines). At the beginning of the recession, loan growth was still positive, but set to decline substantially towards the end of the recession. In fact, by mid-2009 aggregate lending contracted sharply. In the middle right panel of figure 2, we display our measure for the interest rate spread in the US (solid line) and the EA (dashed line). Here we focus on loan rates relative to money market rates. We view these spreads as proxies for the spread between banks' lending rates and deposit rates, as consistent time series for deposit rates do not seem to be available for the US. These spreads start to rise sharply in late 2008 only, but more or less simultaneously in the US and the EA.

In the last row of figure 2 we display the performance of bank stocks relative to a broader measure of the stock market. All series are normalized price return indices (2009q1=100): the left panel shows for the US the Dow Jones bank index and the S&P 500, the right panel shows for the EA the Stoxx Europe 600 Banks and the Stoxx Europe 600. Both panels suggest that bank equity has declined strongly during the global financial crisis, notably in comparison with the relatively more muted decline of the overall stock market. In fact, the decline of bank stocks set in before 2007q4, earlier and much more pronounced than the rest of the market.

Below we will conduct quantitative experiments within a business cycle framework to explore the international transmission of a large exogenous increase in loan losses which has to be absorbed by bank capital. With respect to the 2007–2009 recession, our interest centers on the fact that this crisis is characterized by a strong and simultaneous decline of US and EA output, whereas typically US recessions lead EA recessions. We will argue that this distinguishing feature of the 2007–09 recession reflects the globalization of the banking sector.

[5] Bank equity relative to assets is considerably higher in the US than in the EA, in line with tables 7 and 9 of IMF (2010). These differences are likely to reflect differences in accounting standards.

Before turning to this experiment, however, we will assess to what extent the predictions of our business cycle model match key cyclical features of the data. These are summarized in table 1. All computations are based on real, HP-filtered series. The left panel reports standard deviations for output, consumption, investment, employment, deposits, loans, the interest rate spread, and the bank capital ratio both for the US and the EA. Except for output and the interest rate spread, all standard deviations are normalized by the standard deviation of output. The middle panel reports correlations of variables with domestic output, while the right column reports cross-country correlations.

We find, in line with earlier research, that investment and consumption are highly procyclical. This holds for loans as well, while interest rates spreads are countercyclical. EA deposits appear to be acyclical. While deposits in the US appear to be countercyclical, we note that this finding is not robust with respect to including earlier observations in our sample. In this case, deposits appear to be mildly procyclical. We also detect sizable cross-country correlations for all macroeconomic aggregates. Interestingly, we find that, for our sample, the cross-country correlation of output is lower than that of consumption and investment. Similarly, deposits, loans and spreads are positively correlated across countries as well.

3 The Model

We consider a world with two countries, called Home and Foreign. In each country there is a (representative) worker and an entrepreneur. In addition there is a bank that operates in both countries. All agents are infinitely lived. There is a final good, that is produced by both countries, using local labor and capital. The good can freely be traded. It is used for consumption (by each of the three agents), and for capital accumulation (by the entrepreneur). All markets are competitive. The focus of this analysis is on the role of bank capital requirements for the transmission of shocks. We model these capital requirements as a (flexible) collateral constraint of the global bank. In order to focus sharply on the effect of this constraint, we assume that workers and entrepreneurs do not face collateral constraints.

The following discussion focuses on the Home country. The Foreign country is a mirror image of the Home country (preferences and technologies are symmetric across countries). Foreign variables are denoted by an asterisk.

3.1 Agents and Markets

The Home worker The Home worker consumes the final good, provides labor to the Home entrepreneur and invests her savings in one-period bank deposits. Her date t budget constraint is

$$C_t + D_{t+1} = W_t N_t + D_t R_t^D, \tag{1}$$

where C_t and W_t are her consumption and the wage rate, respectively (the final good is used as numéraire). N_t are hours worked. D_{t+1} is the bank deposit held by the Home worker, at the end of period t. R_t^D is the gross interest rate on deposits, between $t-1$ and t (R_t^D is set at $t-1$). The Home worker's expected life-time utility at date t is

$$E_t \sum_{s=0}^{\infty} \beta^s [u(C_{t+s}) + \Psi^D u(D_{t+s+1}) - \Psi^N N_{t+s}], \tag{2}$$

with $\Psi^D, \Psi^N > 0$. $u(x) = (x^{1-\sigma}-1)/(1-\sigma)$, with $\sigma > 0$, is an increasing and concave function (when $\sigma = 1$, we set $u(x) = \ln(x)$). The worker maximizes (2) subject to the restriction that her period-budget constraint holds at t and at all subsequent dates. Ruling out Ponzi schemes, the worker's decision problem has these first-order conditions

$$1 = R_{t+1}^D E_t \beta u'(C_{t+1})/u'(C_t) + \Psi^D u'(D_{t+1})/u'(C_t) \tag{3}$$

$$\Psi^N = u'(C_t) W_t. \tag{4}$$

The Home entrepreneur The Home entrepreneur accumulates physical capital, and uses capital and Home labor to produce the final good. Home final good output, denoted Z_t, is produced using a Cobb-Douglas technology

$$Z_t = \theta_t K_t^\alpha N_t^{1-\alpha}, \tag{5}$$

with $0 < \alpha < 1$. Home total factor productivity θ_t is an exogenous random variable. The law of motion of the Home capital stock is

$$K_{t+1} = (1-\delta) K_t + I_t, \tag{6}$$

where K_t is the capital stock used in production at t; $0 < \delta < 1$ is the depreciation rate of capital, and I_t is gross investment. Gross investment is brought about using the final good. Let $\xi(I_t)$ be the amount of the final good needed to generate I_t, with $\xi(I_t) \geq I_t$ and $\xi''(I_t) \geq 0$. The Home entrepreneur's period t budget constraint is

$$L_t R_t^L (1-\delta_t^L) + W_t N_t + \xi(K_{t+1} - (1-\delta)K_t) + d_t^E = L_{t+1} + \theta_t K_t^\alpha N_t^{1-\alpha}, \tag{7}$$

where L_t is a one-period bank loan received by the Home entrepreneur in period t. $0 \leq \delta_t^L \leq 1$ is an exogenous stochastic loan default rate: at t, the entrepreneur only pays back a fraction $1-\delta_t^L$ of the contracted amount $L_t R_t^L$. R_t^L is set at $t-1$. However, δ_t^L is only realized at t. d_t^E is the entrepreneur's dividend income at t. The entrepreneur consumes her dividend income. Her lifetime utility at t is given by $E_t \sum_{s=0}^{\infty} \beta^s u^E(d^E_{t+s})$, with $u^E(x) = (x^{1-\sigma^E} - 1)/(1-\sigma^E)$, $\sigma^E > 0$. Maximization of life-time utility subject to (7) yields the following first-order conditions for the Home entrepreneur

$$W_t = (1-\alpha)\theta_t K_t^{\alpha} N_t^{-\alpha} \tag{8}$$

$$1 = R^L_{t+1} E_t (1-\delta^L_{t+1}) \beta \frac{u^{E\prime}(d^E_{t+1})}{u^{E\prime}(d^E_t)} \tag{9}$$

$$q_t = E_t \beta \frac{u^{E\prime}(d^E_{t+1})}{u^{E\prime}(d^E_t)} \left[\theta_{t+1} \alpha K_{t+1}^{\alpha-1} N_{t+1}^{1-\alpha} + q_{t+1}(1-\delta)\right], \tag{10}$$

where $q_t \equiv \xi'(K_{t+1} - (1-\delta)K_t)$ is the marginal cost of gross investment at date t.

The global bank In period t, the bank receives deposits D_{t+1} and D^*_{t+1} from the Home and Foreign workers, respectively, and makes loans L_{t+1} and L^*_{t+1} to the Home and Foreign entrepreneurs, respectively. Let

$$D^W_{t+1} \equiv D_{t+1} + D^*_{t+1} \quad \text{and} \quad L^W_{t+1} \equiv L_{t+1} + L^*_{t+1}$$

be total (worldwide) deposits and loans, at the end of period t. The bank faces a capital requirement: her date t capital $L^W_{t+1} - D^W_{t+1}$ should not be smaller than a fraction γ of the bank's assets L^W_{t+1}. We interpret this as a legal capital requirement.[6]

We assume that the bank can hold less capital than the required level, but that this is costly (e.g., because the bank then has to engage in creative accounting). Let $x_t = (L^W_{t+1} - D^W_{t+1}) - \gamma L^W_{t+1} = (1-\gamma)L^W_{t+1} - D^W_{t+1}$ denote bank's 'excess' capital at t. The bank bears a cost $\phi(x_t)$ as a function of x_t, with $\phi(0) = 0$ and $\phi'(0) < 0, \phi''(0) \geq 0$. Hence, that cost is decreasing and convex. When the bank strictly meets its capital requirement, then the cost is zero (a positive cost only arises when $x_t < 0$; the bank receives a benefit if $x_t > 0$). At t, the bank also bears an operating cost $\Gamma(D^W_{t+1}, L^W_{t+1})$ that is increasing and linear in deposits and loans. The bank's period t budget constraint is

$$L^W_{t+1} + D^W_{t+1} R^D_t + \Gamma(D^W_{t+1}, L^W_{t+1}) + \phi(x_t) + d^B_t = L_t R^L_t (1-\delta^L_t) + L^*_t R^{*L}_t (1-\delta^{*L}_t) + D^W_{t+1}, \tag{11}$$

[6] We take the capital requirement as given, and focus on its macroeconomic effects. A huge literature discusses micro-economic justification for bank capital requirement (see, e.g., Dewatripont and Tirole (1994), Freixas and Rochet (2008), and Dewatripont et al. (2010) for detailed references). That literature stresses that bank capital requirement can also reflect market pressures. Essentially, capital requirements help ensure that the banker acts in the interest of her creditors. A simple story, in the spirit of Kiyotaki and Moore (2005), is that the banker can walk away with a fraction γ of the bank's assets without prosecution (and start a new life next period). Incentive compatibility then requires that the banker's own funds (invested in the bank) may not fall below the assets with which the banker can abscond: $L^W_{t+1} - D^W_{t+1} \geq \gamma L^W_{t+1}$.

where d_t^B is the profit (dividend) generated by the bank at t. R_t^L and R_t^{*L} are gross interest rates between $t-1$ and t on loans made to the Home and Foreign entrepreneurs, respectively (Home and Foreign loan rates differ as loan default rates differ across countries). The banker does not have access to other assets, and thus she consumes her dividends. Her expected life-time utility at t is: $E_t \sum_{s=0}^{\infty} \beta^s u(d_{t+s}^B)$. The banker maximizes life-time utility subject to current and future budget constraints. Ruling out Ponzi schemes, that problem has these first-order conditions

$$R_{t+1}^D E_t \beta u'(d_{t+1}^B)/u'(d_t^B) = 1 - \Gamma_{D,t} + \phi_t' \tag{12}$$

$$R_{t+1}^L E_t (1-\delta_{t+1}^L) \beta u'(d_{t+1}^B)/u'(d_t^B) = 1 + \Gamma_{L,t} + (1-\gamma)\phi_t' \tag{13}$$

$$R_{t+1}^{*L} E_t (1-\delta_{t+1}^{*L}) \beta u'(d_{t+1}^B)/u'(d_t^B) = 1 + \Gamma_{L,t} + (1-\gamma)\phi_t', \tag{14}$$

where $\Gamma_{D,t}$ and $\Gamma_{L,t}$ are the marginal costs of deposits and loans, respectively and $\phi_t' \equiv \phi_{t+1}'^W - D_{t+1}^W)$. By accepting more deposits at t, the banker can increase her date t consumption, at the cost of a reduction of consumption at $t+1$. Specifically, when the bank raises deposits D_{t+1}^W by 1 unit (holding constant loans), her capital falls by one unit, which raises ϕ by $-\phi' > 0$; in addition she incurs a marginal operating cost $\Gamma_{D,t}$. Hence, the banker's marginal benefit of deposits (in utility terms) is $u'(d_t^B)(1-\Gamma_{D,t}+\phi_t')$. The discounted expected marginal cost of deposits to the bank is $R_{t+1}^D E_t \beta u'(d_{t+1}^B)$. At a maximum of the bank's decision problem, the expected marginal benefit equals the marginal cost. If the bank raises Home loans by one unit at t (holding constant deposits), this lowers her date t dividend by $1+\Gamma_{L,t}+(1-\gamma)\phi_t'$. The bank's effective (gross) real rate of return on loans to the Home entrepreneur is thus $R_{t+1}^L(1-\delta_{t+1}^L)/(1+\Gamma_{L,t}+(1-\gamma)\phi_t')$, which explains the Euler equation (13) (the same logic applies to (14)).

In contrast to much recent theoretical research on financial frictions (e.g., Kiyotaki and Moore (1997)), the model here assumes that all agents have the same subjective discount factor, and that the entrepreneur does not face a collateral constraint. In models of the Kiyotaki-Moore type, there are no financial intermediaries; entrepreneurs are less patient than workers; entrepreneurs face a collateral constraint for debt (entrepreneurs' debt cannot exceed a fraction of their physical capital stock), which allows to ensure existence of a stationary equilibrium. This paper assumes a bank that faces a 'flexible' type of collateral constrain (it bears a resource cost when deposits fall below a fraction of the bank assets), while the other agents do not face collateral constraints—as pointed out above, this allows us to focus on the effects of the bank capital restriction.

Market clearing, definition of GDP Market clearing for the final good requires

$$Z_t+Z_t^* = C_t+C_t^*+d_t^E+d_t^{*E}+d_t^B+\xi(I_t)+\xi(I_t^*)+\Gamma(D_{t+1}^W, L_{t+1}^W)+\phi(L_{t+1}^W(1-\gamma)-D_{t+1}^W). \quad (15)$$

We assume that the bank purchases the resources that are necessary for Home deposits and Home lending from the Home final good producer, and that that 50% of the resource cost of excess bank capital, ϕ, is borne in Home final good units. As Γ and ϕ are inputs used by the banking firm, they have to be subtracted from final good production when computing GDP. Hence Home GDP, denoted by Y_t, is

$$Y_t = Z_t - \Gamma(D_{t+1}, L_{t+1}) - \tfrac{1}{2}\phi(L_{t+1}^W(1-\gamma) - D_{t+1}^W). \quad (16)$$

This definition of GDP ensures that world GDP equals world consumption (by all agents) plus world physical investment. Up to a first order approximation, we have $\xi(I_t) \cong I_t$. Hence, the final good market clearing condition (15), and (16) (and the counterpart of (16) for the Foreign country) imply (to first order):

$$Y_t + Y_t^* = C_t + C_t^* + d_t^E + d_t^{*E} + d_t^B + I_t + I_t^*.$$

3.2 Discussion

Interest rate spreads and bank capital As deposits provide liquidity services to workers, and as financial intermediation is costly, the deposit rate is lower than the loan rate. Let $\tilde{R}_{t+1}^L \equiv R_{t+1}^L E_t(1-\delta_{t+1}^L)$ and $\tilde{R}_{t+1}^{*L} \equiv R_{t+1}^{*L} E_t(1-\delta_{t+1}^{*L})$ be the expected effective gross interest rate (i.e. the loan rate, net of default) on loans to the Home entrepreneur and to the Foreign entrepreneur, respectively. Up to a certainty-equivalent approximation, the bank's Euler equations (13) and (14) imply

$$\tilde{R}_{t+1}^L E_t \beta u'(d_{t+1}^B)/u'(d_t^B) \cong 1+\Gamma_{L,t}+(1-\gamma)\phi_t' \text{ and } \tilde{R}_{t+1}^{*L} E_t \beta u'(d_{t+1}^B)/u'(d_t^B) \cong 1+\Gamma_{L,t}+(1-\gamma)\phi_t'. \quad (17)$$

Thus, $\tilde{R}_{t+1}^L = \tilde{R}_{t+1}^{*L}$, i.e. the expected effective loan rates are equated across countries (up to first-order). ¿From (12) and (13) we see that $\tilde{R}_{t+1}^L / R_{t+1}^D \cong [1+\Gamma_{L,t}+(1-\gamma)\phi_t'] / [1-\Gamma_{D,t}+\phi']$ and hence

$$\tilde{R}_{t+1}^L - R_{t+1}^D \cong \Gamma_{D,t} + \Gamma_{L,t} - \gamma\phi'(L_{t+1}^W(1-\gamma) - D_{t+1}^W) > 0. \quad (18)$$

Holding constant the marginal costs of deposits and loans $(\Gamma_{D,t}, \Gamma_{L,t})$, a rise in excess bank capital $L_{t+1}^W(1-\gamma) - D_{t+1}^W$ thus *lowers* the (effective) loan rate spread $\tilde{R}_{t+1}^L - R_{t+1}^D$ when $\phi'' > 0$.

Up to a linear approximation, a date t shock that alters the expected Home loan default rate at $t+1$, $E_t\delta_{t+1}^L$, has no effect on the expected effective Home loan rate $\tilde{R}_{t+1}^L$ observed in equilibrium, and hence no effect on consumption, output, loans or deposits; such a shock only affects the contractual Home loan rate R^L_{t+1} (e.g., when the expected default rate rises by 1 percentage point, the contractual rises by approximately 1%). Only *unanticipated* changes in the default rate affect the real economy. An unanticipated increase in the date t default rate, $\delta_t - E_{t-1}\delta_t > 0$ brings about a wealth transfer from the bank to the Home entrepreneur. As shown below, such a transfer can have a sizable effect on world output, when $\phi'' > 0$.

To provide intuition for this effect, we now analyze in greater detail the optimizing behavior of the bank, for the special case where the bank has log utility ($\sigma = 1$). Up to a first-order approximation of the banker's decision rule (in the neighborhood of a deterministic steady state), her date t consumption then equals a fraction $1-\beta$ of her beginning-of-period (net) wealth

$$d^B_t = (1-\beta)\{L_t R^L_t(1-\delta^L_t) + L^*_t R^{*L}_t(1-\delta^{*L}_t) - D^W_t R^D_t\}. \tag{19}$$

Let

$$A_{t+1} \equiv L^W_{t+1} - D^W_{t+1} + \Gamma(D^W_{t+1}, L^W_{t+1}) + \phi(L^W_{t+1}(1-\gamma) - D^W_{t+1}) \tag{20}$$

be the bank's end-of-period t wealth, plus the costs incurred by the bank at t. (19) implies that the bank optimally sets A_{t+1} at a fraction β of her beginning-of-period wealth

$$A_{t+1} = \beta\{L_t R^L_t(1-\delta^L_t) + L^*_t R^{*L}_t(1-\delta^{*L}_t) - D^W_t R^D_t\}. \tag{21}$$

Note that A_{t+1} and d^B_t fall in response to bank's unanticipated credit losses at date t, but are not affected by unanticipated date t TFP changes

$$\begin{aligned} d^B_t - E_{t-1}d^B_t &= -(1-\beta)\left[L_t R^L_t(\delta^L_t - E_{t-1}\delta^L_t) + L^*_t R^{*L}_t(\delta^{*L}_t - E_{t-1}\delta^{*L}_t)\right] \\ A_{t+1} - E_{t-1}A_{t+1} &= -\beta\left[L_t R^L_t(\delta^L_t - E_{t-1}\delta^L_t) + L^*_t R^{*L}_t(\delta^{*L}_t - E_{t-1}\delta^{*L}_t)\right]. \end{aligned}$$

An unanticipated credit loss triggers a fall in the bank's end-of-period wealth (by a fraction β of the credit loss) that is much larger than the reduction in her consumption (fraction $1-\beta$ of the loss). To understand why this matters for real activity, recall that the loan/deposit interest rate spread is a decreasing function of excess bank capital $x_t \equiv L^W_{t+1}(1-\gamma) - D^W_{t+1}$. Up to a first-order approximation of (21), we have $A_{t+1} = L^W_{t+1} - D^W_{t+1}\beta R^D$. Here, and in what follows, variables without time subscripts denote steady state values.[7] Thus,

$$x_t = (1-\gamma)A_{t+1} + (\beta R^D(1-\gamma) - 1)D^W_{t+1}.$$

The simulation below sets $\gamma = 0.05$ and $\beta R^D \approx 1$ so that $x_t \approx 0.95A_{t+1} - 0.05D^W_{t+1}$. The simulations show that A_{t+1} and x_t are highly positively correlated. As an *unanticipated* credit

[7] A linear approximation of (20) gives: $A_{t+1} = L^W_{t+1}(1 + \Gamma_L + (1-\gamma)\phi') - D^W_{t+1}(1 - \Gamma_D + \phi') = L^W_{t+1}\beta\tilde{R}_L - D^W_{t+1}\beta R^D$, where we use $\beta\tilde{R}_L = 1 + \Gamma_L + (1-\gamma)\phi'$ and $\beta R^D = 1 - \Gamma_D + \phi'$, respectively (from (12) and (13)). As $\beta\tilde{R}_L = 1$ (from entrepreneur's Euler equation (8)), we have $A_{t+1} = L^W_{t+1} - D^W_{t+1}\beta R^D$.

loss at date t lowers the bank's end-of-period wealth, A_{t+1}, it triggers a fall in excess bank capital x_t, which raises the loan/deposit interest rate spread (numerical simulations show that this result is robust to assuming risk aversion different from unity). The financial friction thus becomes more severe when an unanticipated credit loss occurs.

An *unanticipated* positive Home TFP shock the Home worker's wage income and thus increases her holdings of deposits. On impact, the shock has no effect on the banker's end-of-period wealth, and thus it lowers the bank's excess capital, which raises the credit spread.

3.3 Calibration

Final good technology, capital accumulation The elasticity of final good output with respect to capital is set at $\alpha = 0.3$, consistent with the capital share of roughly 30% observed in the US and EA. One period represents 1 quarter in calendar time. Accordingly, we set the depreciation rate of physical capital at $\delta = 0.025$, as is standard in quarterly macro models (and consistent with the empirical estimates of that parameter provided by, e.g., Christiano and Eichenbaum (1992)). We assume that the cost (in final good units) of Home gross investment is given by: $\xi(I_t) = I_t + 0.5\Xi(I_t/I - 1)^2$ with $\Xi \geq 0$, where $I = \delta K$ is Home steady state investment. When $\Xi = 0$, then gross investment in a given country is excessively volatile (compared to the data). Setting $\Xi > 0$ lowers the predicted volatility of investment. In each model variant considered below, we set the parameter Ξ at the value for which (in the simultaneous presence of TFP shocks and default shocks in both countries that follow the time series processes discussed below), the predicted 'relative volatility' of investment in each country (ratio of the standard deviation of log investment to the standard deviation of log GDP) is 3.34, which is the mean value of US and EA relative quarterly investment volatility for 1995-2010.

Bank parameters, and preference parameters The required bank capital ratio is set at $\gamma = 5\%$. Empirically, the capital ratios of the major EA banks and of major US investment banks (i.e. ratios of bank equity to total (non-risk adjusted) assets) have typically ranged between 3% and 5% in the period 1995-2010, while the capital ratios of US commercial banks have generally been in the range 7%-8%; see, e.g., D'Hulster (2009) and ECB (2010)).[8] Below, we provide a sensitivity analysis with respect to γ.

We set the mean loan default rate at 0.95% per annum, which corresponds to the average US and EA loan loss rate in 1995-2010 (see Figure 2). Note that, in the model, the steady

[8]As discussed by D'Hulster (2009), p.2, US regulation prescribes a *minimum* bank capital ratio of 3% for banks rated "strong" and 4% for all other banks. "Banks' actual leverage ratios are typically higher than the minimum, however, because banks are also subject to prompt corrective action rules requiring them to maintain a minimum leverage ratio of 5% to be considered well capitalized".

state default rate does not affect real activity. The steady state deposit rate and the expected effective loan rate (net of default) are set at 1% and 2.5% per annum, respectively, which implies a steady state observed (contractual) loan rate of 3.48% p.a. Thus, the steady state credit spread is 2.48% p.a. which matches the average of US and EA lending rate spreads during the past decade.

We thus set the (quarterly) subjective discount factor at $\beta = 0.9938$ (as $\beta\tilde{R}^L = 1$, from the entrepreneur's Euler equations). We assume that the marginal bank operating costs are constant across time: $\Gamma_{D,t} = \Gamma_D,\ \Gamma_{L,t} = \Gamma_L$. The bank's Euler equations (12) and (13) imply $R^D\beta = 1 - \Gamma_D + \phi^{'}$ and $\tilde{R}^L\beta = 1 + \Gamma_L + (1-\gamma)\phi^{'}$; any combination of marginal costs $\Gamma_D, \Gamma_L, \phi'$ consistent with these conditions generates the same steady state, and the same dynamics of endogenous variables.

The baseline calibration assumes that workers and bankers have log utility: $\sigma = 1$. We assume that the entrepreneur is less risk averse, and set $\sigma^E = 0.01$ (i.e. the entrepreneur is *almost* risk neutral). Our assumption that $\sigma^E < \sigma$ implies that, in the model, entrepreneurial consumption is more volatile than aggregate consumption, which is consistent with the data.[9] We present a sensitivity analysis with respect to these assumptions about risk aversion.

We assume that excess bank capital is zero in steady state ($L^W(1-\gamma) = D^W$), and set the loans to physical capital ratio at 1/3: $L^W/K^W = 1/3$. This pins down the remaining two worker preference parameters Ψ^D, Ψ^N.[10] The calibration entails that the ratio of loans to annual GDP is 81% in steady state. Empirically, the mean ratio of bank loans to non-financial businesses divided by annual GDP was about 45% in the US, and 90% in the EA, during the past decade. The steady ratio in the model lies between these empirical ratios.[11]

The simulations below are based on a linearization of the model around a deterministic steady state. We thus have to calibrate the second derivative of the cost of excess bank

[9] Entrepreneurs are wealthier than the rest of the population; a large body of evidence documents that the consumption of the wealthy is markedly more volatile than aggregate consumption. See, e.g., Parker and Vissing-Jorgensen (2009) for evidence based on the US Consumer Expenditure Survey; Ait-Sahalia and Yogo (2004) document that sales of luxury goods are an order of magnitude more volatile than aggregate consumption. Note that, although the banker is more risk-averse than the entrepreneur, the banker's consumption turns out to fluctuate more widely than the entrepreneur's consumption (relative to steady state), in response to a credit default.

[10] Namely, we set $\Psi^D = 0.014$ and $\Psi^N = 2.478/GDP$. The calibrated Ψ^N (that delivers the targeted ratios $L/K, L^W/D^W$) depends on steady state GDP. For a given value of Ψ^N the model has a unique steady state. Ψ^N affects the scale of hours worked, output, consumption, capital, investment, deposits and loans, but not the ratios between these variables. Thus, the choice of Ψ^N does not affect the model dynamics. In the model, date t GDP equals the sum of the three agent's consumption plus gross investment. GDP corresponds also to final good output minus the bank's cost $\Gamma_t + \phi_t$.

[11] In steady state, the ratio of the capital stock to annual GDP is 2.41; the consumption of the household, the banker and the entrepreneur represent 71.56%, 0.11% and 4.01% of GDP, respectively.

capital, evaluated at the steady state, $\phi''(0)$. Linearizing (18) around the steady state gives:

$$\tilde{R}^L_{t+1} - R^D_{t+1} \cong \Gamma_D + \Gamma_L - \gamma\,\phi''(0)(L^W_{t+1}(1-\gamma) - D^W_{t+1}). \tag{22}$$

We estimate (22), using aggregate US and EA loan and deposits as a proxy for world-wide loans and deposits. We document in the Appendix, that there is a strong *negative* correlation between $L^W_{t+1}(1-\gamma) - D^W_{t+1}$ and the loan rate spread, consistent with the model. We argue that, empirically, $\phi''(0)$ normalized by quarterly world GDP is in the range of 0.25. We thus set $\phi'' = 0.25/(Y + Y^*)$ in our model simulations.

Forcing variables We assume that TFP and credit default rates follow univariate AR(1) processes that we fit to quartely US and EA time series for 1993q1-2010q1 (this is the longest period for which we could find credit losses simultaneously for the US and the EA). Home and Foreign TFP are assumed to follow these processes: $\ln\theta_t = \rho_\theta \ln\theta_{t-1} + \varepsilon_{\theta,t}$ and $\ln\theta^*_t = \rho_\theta \ln\theta^*_{t-1} + \varepsilon^*_{\theta,t}$,respectively, where $\varepsilon_{\theta,t}$ and $\varepsilon^*_{\theta,t}$ are correlated white noises. The autocorrelation of linearly detrended US and EA log TFP (Solow residuals) is 0.95. We thus set $\rho_\theta = 0.95$. The standard deviation of linearly detrended US (EA) log TFP is 1.73% (1.67%). To match that unconditional standard deviation, we set $E(\varepsilon_{\theta,t})^2 = E(\varepsilon^*_{\theta,t})^2 = (0.0053)^2$. These or very similar laws of motion of TFP are widely used in the RBC literature; see, e.g., King and Rebelo (1999). The correlation between linearly detrended log TFP in the US and EA was 0.82 during 1993Q1-2010Q1. We thus assume that the correlation between $\varepsilon_{\theta,t}$ and $\varepsilon^*_{\theta,t}$ is 0.82.

We assume that Home and Foreign credit loss rates follow the processes $\delta^L_t = (1-\rho_\delta)\delta^L + \rho_\delta\delta^L_{t-1} + \varepsilon_{\delta,t}$ and $\delta^{L*}_t = (1-\rho_\delta)\delta^L + \rho_\delta\delta^{L*}_{t-1} + \varepsilon^*_{\delta,t}$, respectively. The autocorrelations of credit loss rates in our sample period are 0.98 (US) and 0.96 (EA). The standard deviations of these rates are 0.14% (US) and 0.085% (EA). We set $\rho_\delta = 0.97$ and $E(\varepsilon_{\delta,t})^2 = E(\varepsilon^*_{\delta,t})^2 = (0.000282)^2$. That calibration implies an unconditional standard deviation of the default rate (in the model) of 0.116%, which is half-way between the empirical standard deviations of US and EA default rates. The empirical correlation between US and EA credit loss rates is 0.76; we thus set $Corr(\varepsilon_{\delta,t}, \varepsilon^*_{\delta,t}) = 0.76$.

US and EA default rates exhibit correlations in the range of -0.6 with linearly detrended log TFP in the same country and the other country; the median correlation is -0.63. We thus set $Corr(\varepsilon_{\delta,t}, \varepsilon_{\theta,t}) = Corr(\varepsilon_{\delta,t}, \varepsilon^*_{\theta,t}) = Corr(\varepsilon^*_{\delta,t}, \varepsilon_{\theta,t}) = Corr(\varepsilon^*_{\delta,t}, \varepsilon^*_{\theta,t}) = -0.63$.

As pointed out above, only unanticipated shocks to the default rate matter for real activity. Hence, the variance of real activity induced by credit losses only depends on $E_t(\varepsilon_{\delta,t})^2$. The persistence of default only matters for the behavior of the contractual loan rate R^L_t, but it is irrelevant for the behavior of the expected effective loan rate $\tilde{R}^L_{t+1} = R^L_{t+1}E_t(1-\delta_{t+1})$ and for real activity.

4 Quantitative Results

4.1 Impulse responses

Effects of a TFP shock Figure 3 reports dynamic responses to a 1% innovation to Home TFP, for the baseline version of the model (see solid lines), and for a model version in which the bank capital constraint is eliminated by setting $\phi'' = 0$ (dashed lines). The responses of interest rates, and of the loan rate spread are expressed in % per annum. The responses of all other variables are expressed as percentages of steady state values.

The responses of Home and Foreign GDP, aggregate consumption and investment to the TFP shock are very similar across the two model versions.[12] Thus the bank capital constraint does not significantly alter the effect of the TFP shock on real activity.

In the baseline structure, the 1% shock to Home TFP shock raises Home GDP, aggregate consumption, and investment by 1.87%, 0.59% and 7.75% respectively, on impact. The corresponding responses in the structure with $\phi'' = 0$ are 1.91%, 0.60% and 7.91%, respectively. Home Bank lending and deposits rise, under both structures (by about 0.4% and 0.3%, on impact). The strong rise in Home investment is accompanied by a brief fall in Home net exports (first three periods).

Foreign real activity responds much less strongly to the shock (than Home activity). As in International Real Business Cycle models with complete financial markets (e.g., Backus et al. (1992) or Kollmann (1996)), a Home TFP increase *lowers* Foreign investment, (-1.61%, on impact). This is due to the fact that the Home investment boom triggers a rise in the loan rate. Foreign aggregate consumption falls somewhat on impact (-0.05%), and thereafter rises slightly above its unshocked path (+0.16%, four periods after the shock). Foreign GDP rises, on impact (+0.03%), but thereafter falls below its unshocked path (-0.15%, 4 periods after shock).[13]

The Home TFP shock raises the Home worker's labor income. As TFP decays gradually after the shock, the increase in Home labor income is transitory; thus the Home worker saves more, i.e. her bank deposits increase. On impact, world-wide bank deposits and loans rise by 0.145% and 0.137%, respectively, in the baseline structure; thus, the bank's 'bank capital

[12] We assume that 50% of the banker's consumption is realized in the Home country; thus Home aggregate consumption is: $C_t + \frac{1}{2}d_t^B + d_t^E$.

[13] The consumption of the Foreign worker and entrepreneur falls initially (by -0.015% and -0.67%, respectively), while the consumption of the banker is initially unaffected. Consumption by these agents then rises, relative to unshocked values. Essentially, the Foreign entrepreneur finances the initial Home trade balance deficit by borrowing less, and saving more, which allows the Foreign entrepreneur to later increase her consumption. The Foreign worker likewise contributes to the financing of the initial Home trade balance deficit by slightly raising her bank deposits. Her subsequent consumption increase is accompanied by a rise in the Foreign wage rate, and a fall in Foreign hours worked which contributes to the reduction in Foreign GDP (together with the fall in the Foreign capital stock due to the fall in Foreign investment).

ratio' (ratio of the bank's equity to its assets), $cap_t \equiv (L^W_{t+1} - D^W_{t+1})/L^W_{t+1})$ falls, by -0.147% (relative to the steady state bank capital ratio of 0.05); this implies that the bank's excess bank capital (x_t) falls too (by 0.024% of world GDP).[14]

The simulations confirm thus the analytical result (see above) that, on impact, a positive Home TFP shock lowers the bank's (excess) capital. In fact, the simulation shows that the fall in the bank's capital is *persistent*. The bank's capital falls somewhat more in the model variant without bank capital constraint ($\phi'' = 0$), than in the baseline model ($\phi'' > 0$). However, in both variants, the bank capital response is very weak.

The interest rate spread is unaffected by the TFP shock, when $\phi'' = 0$. In the baseline model ($\phi'' > 0$), the interest rate spread rises, but quantitatively this effect is weak, due to the weak fall in bank capital: on impact the spread rises by merely 1 basis point; 4 quarters after the shock, the spread goes up by 5 bp. (The rise in the spread when $\phi'' > 0$ is mainly due to the fact that the deposit rate increases *slightly* less than in the model variant with $\phi'' = 0$.)

This explains why the responses of macroeconomic aggregates to the TFP shock are so similar across the two model variants. But note that Home GDP, consumption and investment rise *slightly* less in the baseline model (with bank capital constraint), as lending to the Home entrepreneur rises less strongly. Hence the presence of the bank capital constraint dampens slightly the response of Home GDP to a Home TFP shock.

Effects of a credit loss shock Figure 4 shows dynamic responses to a one-time unexpected Home credit loss shock worth 5% of steady state annual Home GDP. That shock corresponds roughly to the observed credit losses originating in the US, during the 2007-09 crisis (roughly 5% of US GDP). In the baseline model with a bank capital constraint ($\phi'' > 0$), the shock triggers a sizable fall in GDP and investment, in *both* countries. During the first year after the shock, Home and Foreign GDP *both* drop by about 1.95%. The fall in GDP is persistent: 8 quarters after the credit loss, Home and Foreign GDP are still about 1.2% below their unshocked values. By contrast, in the model variant without bank capital constraint ($\phi'' = 0$), the Home credit loss has only a minor effect on GDP (Home GDP rises by 0.02%, while Foreign GDP falls by 0.02%).

In *both* model variants, the Home credit loss lowers the bank's capital ratio by 57%, on impact. In the baseline model ($\phi'' > 0$), the bank capital ratio then *slowly* reverts to its pre-shock level (20 quarters after the shock, the bank capital ratio remains 21% below its unshocked value). By contrast, the fall in bank capital is *permanent* in the model variant

[14] cap_t is increasing in $x_t \equiv L^W_t(1-\gamma) - D^W_{t+1}$, up to a linear approximation. NB $\widehat{cap}_t = ((1-\gamma)/\gamma)(\hat{L}^W_{t+1} - \hat{D}^W_{t+1})$ and $x_t = (1-\gamma)L^W(\hat{L}^W_t - \hat{D}^W_t)$; thus $\widehat{cap}_t = x_t\gamma L^W$.

without bank capital constraint, $\phi'' = 0$ (no reversion to pre-shock value).

In the *baseline model*, the fall in bank capital leads to a sizable and persistent rise in the interest rate spread (+50 basis points, on impact).[15] There is a sizable and *persistent* fall in the deposit rate (on impact: -55 bp; after 20 quarters: -14 bp); the loan rate falls slightly, on impact (-5 bp), before rising above its pre-shock value. The rise in the credit spread (observed in the baseline model) is accompanied by a fall in loans, deposits, investment and aggregate consumption, in both countries.[16]

By contrast, loan rates and deposit rates are unaffected by the credit loss shock, in the model version without bank capital constraint. In that version, the consumption of the Home entrepreneur rises, while the consumption of the banker falls; *aggregate* Home consumption and investment change very little.

The experiment underlying figure 4 assumes that a large loan loss has to be immediately absorbed by bank equity. This is an abstraction, as actual loan losses accumulated somewhat more gradually over the period 2007–2010 (s. IMF (2010)). Given that there are only one-period loans in our model, anticipated defaults leave bank capital essentially unaffected. However, as a loan default effectively transfers resources from the bank to entrepreneurs, we can simulate a scenario of gradual defaults on the basis of a transfer scheme.

Specifically, to capture in a stylized manner the gradual build-up of banks' loan losses during the global financial crisis, we assume a transfer process resulting from two AR(1) processes: one with a autocorrelation coefficient of 0.6, the other with 0.55. Initially, both processes are hit by a shock of the same size in absolute value. The first process, however, receives a positive shock, while the second a negative one. By this, gradual transfers are obtained, similar in shape to estimates in IMF (2010). Results are shown in figure 5. In particular, the lower right panel shows the resulting transfers from banks to entrepreneurs in Home, amounting to 5% of annual steady state GDP. Overall, results are very similar to those reported in figure 4, except that the adjustment dynamics are somewhat hump-shaped. Note however, that output declines already on impact, i.e., before the transfer materializes, as the actual transfers are fully anticipated, once the initial shocks have taken place.

We also conduct a number of experiments in order to explore the robustness of the results

[15]Figure 2 considers a one-time rise in the Home default rate—hence, the expected future default rate is unaffected; the effective (expected) Home interest spread $\widetilde{R}^L_{t+1} - R^D_{t+1}$ shows thus essentially the same response to the shock as the observed (contractual) spread $R^L_{t+1} - R^D_{t+1}$.

[16]The banker's consumption falls by 57%, on impact. The consumption of the Home and Foreign entrepreneurs falls too, on impact (by about 20%), which reflects an intertemporal substitution effect caused by the rise in the (future) loan rate. Note that entrepreneurs have a very high intertemporal substitution elasticity. (But, of course, Home entrepreneur's wealth and her life-time utility increase.) By contrast, the consumption of Home and Foreign workers *rises* (the strong and persistent reduction in the deposit rate induces workers to save less).

established above. First, as the parameter $\phi''(0)$ plays an important role for the dynamics induced by default shocks, we compute statistics assuming an increase of its value by a factor of ten, i.e., we set $\phi''(0) = 2.5/Y^W$. Figure 6 displays the impulse responses to a default shock of 5% of annual GDP for this case (blue dashed lines) and contrasts it with the baseline scenario (red solid lines). We find the impact effect of the default shock magnified, but the persistence of the responses somewhat reduced. As deviations from the required bank capital ratio are more costly in this case relative to baseline, the bank adjusts bank capital more quickly, which induces a sharper initial recession, but a faster return to steady state levels.

Next, we look into the effects of an alternative assumption on the bank capital requirement. We track the effects of the default shock, but assuming $\gamma = 0.1$, i.e., twice the baseline value. The green dashed-dotted lines in figure 6 show the responses for this case. Again, results are fairly similar to the baseline scenario.

4.2 Does the bank capital channel matter for business cycles in 'normal' times?

The preceding results suggest that bank capital shocks are key to understanding the 2007–2009 recession. However, we argue next that the bank capital channel may not matter greatly for conventional business cycles. Table 3 reported predicted business cycle statistics generated by the model, using the estimated time series processes for TFP and the credit loss rate, 1993–2010 (predicted standard deviations of HP filtered variables, correlations with domestic GDP, and cross-country correlations are shown).

Table 3 again compares the baseline model ($\phi'' > 0$) to the model variant without bank capital constraint, $\phi'' = 0$.[17] In line with the impulse responses discussed above, we find that the bank capital constraint dampens the fluctuations of real activity under TFP shocks, and that it generates larger fluctuations of GDP, in response to default shocks. However, in terms of the business cycle statistics in Table, this effect is very small. The baseline model predicts that the standard deviation of GDP is 1.36% when there are just TFP shocks, 0.02% with just loan default shocks, and 1.37% under all simultaneous shocks. When the bank capital constraint is eliminated ($\phi'' = 0$), the standard deviation of GDP is 1.41% with just TFP shocks, and 0.000073% with just credit default shocks.[18] Thus, credit loss shocks only have a negligible effect on real activity, under 'normal' conditions. Recall that the estimated standard deviation of the innovations to the quarterly credit loss rate is 0.0282%, which is much smaller than the huge credit loss rates observed during the 2007-2009 recession.

[17] All variables (except the credit spread) are logged before applying the HP filter.

[18] To save space, Table 3 only reports simulation results with all shocks, and with just TFP shocks, for the model variant with $\phi\prime\prime = 0$.

Note that the model generates a predicted volatility of GDP that is roughly in line with actual volatility (actual standard deviation of GDP: 1.12% (US), 1.42% (EA)). Like conventional RBC models, the model here predicts that (aggregate) consumption is less volatile than GDP. The model underpredicts the volatility of deposit and loans (predicted relative standard deviations: about 0.6), although it captures the fact that deposits are less volatile than GDP. The model explains about a third of the actual volatility of the loan rate spread.

The model matches the fact that consumption and investment are highly positively correlated with domestic GDP. The model predicts that loans are more procyclical than deposits, which is consistent with the data. Interestingly, both the baseline model, and the model variant without bank capital constraint explain the fact that the credit spread is negatively correlated with GDP. This result is driven by the assumed negative correlation between TFP and the loan default rate.

Finally, note that the model is consistent with the fact that output, consumption, investment, deposits, loans and loan rate spreads are highly positively correlated across countries. This reflects our assumption that the shocks are highly positively correlated across countries.[19]

The irrelevance of the bank credit channel and of default shocks for 'normal' business cycles is robust to a range of parameter changes. For example, it continues to hold when the bank's cost of excess capital is made more convex. Even when $\phi''(0)$ is multiplied by a factor of 10; in that case, the predicted standard deviation of GDP remains very low when there are just default shocks (to 0.04%); the relative standard deviation of the loan rate spread (in % p.a.) too only rises very slightly (to 0.12). In the baseline model, the standard deviation of entrepreneurs' dividends and consumption (not shown in Table 3) is 4.9% (i.e. about 8 times more volatile than aggregate consumption), while the dividends (consumption) of bankers is roughly as volatile as aggregate consumption. The main business cycle results are unaffected when we make bankers less risk averse. Setting the bankers' coefficient of relative risk aversion at 0.1 implies that the predicted standard deviation of their dividend income (consumption) equals that of entrepreneurs' consumption (5%).[20] However, the predicted standard deviations of GDP (1.38%) and of the loan rate spread is essentially unaffected (compared to the baseline model).

[19]Setting the cross-country correlation of TFP to zero lowers the predicted cross-country output correlation to -0.05.

[20]High dividend volatility is a realistic feature of the model. For the US, the standard deviation of HP filtered (with smoothing parameter 400) log *annual* net real dividend payments of the Finance and Insurance industry was 12.75% in 1998-2008, while the corresponding standard deviation for the aggregate net dividend payments of other sectors was 9.75% (source: BEA NIPA; that source does not provide quarterly series for dividends). The actual standard deviations of *quarterly* logged and HP filtered real corporate profits of the US financial sector was 16.63% during the period 1995Q1-2010Q1. Corresponding statistic for the non-financial sector: 12.59% (based on BEA NIPA data).

5 Conclusion

In this paper we explored the macroeconomic consequences of a globally integrated banking sector, using a quantitative two-country business cycle model. Our investigation is motivated by key observations that suggest that financial factors played an important role for the global crisis of 2007-2009–and that both for the emergence of the crisis, and for its international transmission.

We have calibrated the model using US and Euro Area data, and shown that it delivers realistic predictions for key business cycle statistics. In the model, cyclical fluctuations are the result of productivity and loan default shocks. Several key results emerge. First, constraining the capital ratio of the global bank does not affect the transmission of productivity shocks very much. Second, loan default shocks of the magnitude observed in 'normal' times are of little consequence for the cyclical behavior of aggregate real activity. However, the countercylical behavior of interest rate spreads seen in the data can only be explained by the model here when default shocks are assumed.

A third key finding of our analysis is that, when subjected to country-specific loan default shocks of the magnitude seen in the US during 2007-2009, the model here predicts a global recession, as the default shock induces a sizable loss in the capital of the global bank. The model's prediction that a country-specific shock triggers a symmetric downturn is noteworthy, as the 2007–2009 recession was also characterized by a simultaneous decline of economic activity in both the US and the EA.

In order to highlight the importance of the global banking sector operating under a balance sheet constraint for the international transmission of the global financial crisis, our analysis abstracted from a number of issues which may have played a quantitatively important role too. Examples are the partial collapse of the interbank market in the earlier stage of the crisis, the collapse of international trade, and the zero lower bound which constrained monetary policy. The latter lead to efforts of central banks and fiscal authorities to recapitalize banks. We leave an analysis of these measures within our framework for future research.

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A Data sources and definitions

US data for GDP and its components are obtained from the BEA/NIPA. Time series for real variables are from table 1.1.6. (Billions of chained 2005 dollars; Seasonally adjusted at annual rates). Investment is gross private fixed, investment. Consumption is personal consumption expenditures. For EA (EA16: fixed composition) data are from the ECB (chain linked, seasonally adjusted): GDP (ESA.Q.I5.S.0000.B1QG00.1000.TTTT.L.U.A), final consumption of households and non-profit institutions serving households (ESA.Q.I5.S.1415.P31000.0000.TTTT.L.U.A), gross fixed capital formation (ESA.Q.I5.S.1415.P31000.0000.TTTT.L.U.A). We compute deflators on the basis of nominal GDP (US: table 1.1.5, EA: ESA.Q.I5.S.0000.B1QG00.1000.TTTT.V.U.A). We use data from the AWM modelbase (Fagan et al. (2001)) to construct a longer time series for EA output on the basis of growth rates.

US data for loan write-offs are obtained from the Federal Reserve Board (charge-off and delinquency rates on loans and leases at all insured U.S.-chartered commercial banks). As data for EA are not available, we use German data instead to proxy developments in EA. Annual data for loan write-offs of German banks are obtained from the Global Financial Stability Report (IMF (2010)) which reports loan losses in percent of total loans (their figure 1.43). We interpolate quarterly observations using cubic spline. US data for bank equity/assets are obtained from the FRED database at the St. Louis Fed (EQTA). For the EA we divide bank capital and reserves at credit institutions (BSI.Q.U2.N.R.L60.X.1.Z5.0000.Z01.E) by total assets (BSI.Q.U2.N.R.T00.A.1.Z5.0000.Z01.E).

For the US, data on loans (loans and leases in bank credit) and deposits for all commercial banks are obtained from the Federal reserve Board (H.8 Assets and Liabilities of Commercial Banks in the United States for May 28, 2010). For the EA, data on loans of MFIs to non-financial corporations (BSI.Q.U2.N.A.A20.A.1.U2.2240.Z01.E) and households (BSI.Q.U2.N.A.A20.A.1.U2.2250.Z01.E) and deposits by non-financial corporations (BSI.Q.U2.N.A.L20.A.1.U2.2240.Z01.E) and households (BSI.Q.U2.N.A.L20.A.1.U2.2250.Z01.E) are obtained from the ECB. We deflate the series with the GDP deflator.

Our measure for US interest rate spreads is from the Federal Reserve Board (survey of terms of business lending: E2 chart data), capturing commercial and industrial loan rates spreads over intended federal funds rate (all loans). For the EA we construct a measure for the loan rate, drawing on data from ECB (from July 2003 onwards: loans other than revolving loans and overdrafts, convenience and extended credit card debt, Over 1 and up to 5 years, Up to and including EUR 1, MIR.M.U2.B.A2A.I.R.0.2240.EUR.N) and Bundesbank (long term credit of firms: 500,000 to 5 Mio euro, effective rate, averages, SU0509) to backtrack the EA series using growth rates up to 1997. To obtain a measure for the EA interest rate spread comparable to the US spread, we subtract the EONIA rate obtained from the ECB (FM.Q.U2.EUR.4F.MM.EONIA.HSTA).

US data on stock market indices are obtained from www.freelunch.com (S&P 500) and from Dow Jones (price return, quarterly average of daily quotes). For the EA, data are from Euro Stoxx: Europe 600 and Europe 600 banks (price return, quarterly average of daily quotes).

We obtain a measure for productivity shocks on the basis of Solow residuals, computed on the basis of data for GDP (GDP, volume, market prices) and total employment as reported in the Economic Outlook 86 database of the OECD.

B Evidence on the sensitivity of credit spreads to excess bank capital

As shown in (22) above, the model predicts

$$\tilde{R}^L_{t+1} - R^D_{t+1} \cong \Gamma_D + \Gamma_L - \gamma\, \phi''(0)(L^W_{t+1}(1-\gamma) - D^W_{t+1}). \tag{23}$$

Excess bank capital $x_t \equiv L^W_{t+1}(1-\gamma) - D^W_{t+1}$ can be expressed as a weighted sum of the Home and Foreign loans/deposit ratios, which we denote as $\lambda_{t+1} \equiv L_{t+1}/D_{t+1}, \lambda^*_{t+1} \equiv L^*_{t+1}/D^*_{t+1}$.

$$x_t = L_{t+1}(1-\gamma) - D_{t+1} + L^*_{t+1}(1-\gamma) - D^*_{t+1} \cong (1-\gamma)L\widehat{\lambda}_{t+1} + (1-\gamma)L^*\widehat{\lambda}^*_{t+1}, \tag{24}$$

where $\widehat{\lambda}_{t+1} \equiv (\lambda_{t+1} - \lambda)/\lambda \cong \ln(\lambda_{t+1}/\lambda)$ is the relative deviation of λ_{t+1} from its steady state λ.[21] To obtain estimates of $\phi''(0)$ that do not depend on the (arbitrary) normalization (choice of units) for loans, we assume that $\phi''(0) \equiv \Phi/(Y+Y^*)$, for a constant Φ (that is invariant to steady state GDP). Using (24) we can write (23) as

$$\tilde{R}^L_{t+1} - R^D_{t+1} \cong \Gamma_D + \Gamma_L - \Phi z_t, \tag{25}$$

with $z_t \equiv \gamma(1-\gamma)\ [s(L/Y)\widehat{\lambda}_{t+1} + (1-s)(L^*/Y^*)\widehat{\lambda}^*_{t+1}]$ where $s \equiv Y/(Y+Y^*)$ is the (steady state) share of Home GDP in world GDP. We construct quarterly time series for z_t in the period 1999Q1-2010Q1, using logged time series for ratios of (stocks of) loans to GDP in the US (country 'Home') and in the EA (country F).[22] To generate z_t, we set $\gamma = 0.05$ (as in the theoretical model) and $s = 0.567$ (sample average of the share of US GDP in US+EA

[21] Here we used the assumption that steady state loans and deposit verify $L(1-\gamma) = D$, $L^*(1-\gamma) = D^*$, which follows from our assumption that countries are symmetric and that world excess bank capital is zero.

[22] We construct $\widehat{\lambda}_{t+1}$ as $\log(L_{t+1}/D_{t+1})$ minus the sample average $\frac{1}{T}\sum_1^T \log(L_{t+1}/D_{t+1})$. $\widehat{\lambda}^*_{t+1}$ is defined analogously.

GDP) and $L/Y = 1.80$, $L^*/Y^* = 3.60$ (sample averages of the ratios of loans to *quarterly* GDP in the US and EA, respectively). Recall that the model predicts that Home and Foreign effective (expected) credit spreads are identical. We fit (25) to a weighted average of US and EA credit spreads (using weights $s = 0.567$ and $1 - s$ respectively). Note that (25) pertains to the effective (expected) credit spread ($\tilde{R}^L_{t+1} \equiv R^L_{t+1}(1 - E_t\delta^L_{t+1})$). We use two proxies for (US and EA) credit spread. The first measure uses the contractual loan rates R^L_{t+1}, R^{L*}_{t+1} as proxies for the effective loan rate, (thus assuming that the conditional *expected* future default rate is constant). The second measure uses a fitted (predicted) future default rate, based on OLS regression of date $t + 1$ default rates on date t default rates.

Note that (25) implies that (effective) credit spread $\rho_t \equiv \tilde{R}^L_{t+1} - R^D_{t+1}$ is perfectly negatively correlated with z_t. It also implies that Φ equals the negative of the ratio of standard deviations of ρ_t and z_t: $\Phi = -std(\rho_t)/std(z_t)$. Table 3 reports the correlations between ρ_t and z_t ($Corr(\rho_t, z_t)$) and $-std(\rho_t)/std(z_t)$. We also report an OLS estimate of Φ based on a regression of ρ_t and z_t ($\widehat{\Phi}_{\rho,z}$) as well as the inverse of an OLS estimate of the regression coefficient of z_t on ρ_t ($\widehat{\Phi}_{z,\rho}$). The figures in parentheses are p-values.

The correlations between credit spreads and the measure of aggregate US-EA excess bank capital range between -0.55 and -0.40 and are highly statistically significant. The empirical estimates of Φ range between 0.08 and 0.62; the mean and median estimates of Φ are 0.30 and 0.25, respectively. As discussed in the main text, our baseline calibration assumes $\Phi = 0.25$.

Table 1: Business cycle properties of the data

	Standard deviation		Correlation with output		Cross-country correlation
	US	EA	US	EA	
Output	1.12	1.42	1.00	1.00	0.76
Consumption	0.82	0.59	0.85	0.87	0.85
Investment	4.18	2.50	0.94	0.94	0.79
Employment	0.92	0.56	0.81	0.87	0.72
Deposits	0.68	0.93	-0.28	-0.03	0.56
Loans	2.43	1.63	0.51	0.83	0.78
Interest rate spread	0.36	0.31	-0.14	-0.37	0.61

Statistics based on HP-filtered series (smoothing parameter 1600). Sample period: 1995q1–2010q1, except later starting dates for EA deposits (1997q3) and EA spreads (1999q1). Standard deviations for output and interest rate spread are measured in percent; for other variables relative to output. Data sources are provided in the appendix.

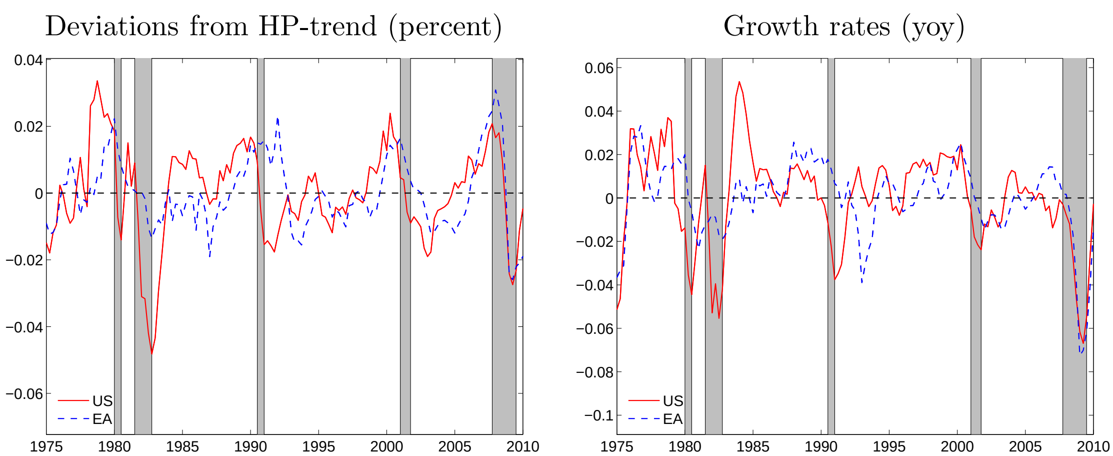

Figure 1: Cyclical component of GDP based on HP-filter with smoothing parameter of 1600 (left) and yoy-growth rate minus average growth (right). Sample: 1975q1–2010q1. Solid lines: US, dashed lines: EA. Shaded areas: NBER recessions (latest recession is assumed to have ended in 2009q3).

Table 2: BUSINESS CYCLE PROPERTIES OF THEORETICAL ECONOMIES

	Baseline model			Model with $\phi'' = 0$		
	Shocks			Shocks		Data
	All	TFP	default	All	TFP	(US & EA)
Standard deviations (in %)						
GDP (Y)	1.37	1.36	0.02	1.41	1.41	1.27
Relative std. dev. (std(x)/std(GDP))						
Aggregate consumption	0.42	0.42	0.38	0.42	0.42	0.70
Investment	3.34	3.39	3.59	3.34	3.34	3.34
Hours	0.67	0.67	1.38	0.69	0.69	0.74
Deposits	0.60	0.59	1.32	0.63	0.63	0.80
Loans	0.61	0.60	2.14	0.63	0.63	2.03
Loan rate spread	0.10	0.01	5.94	0.10	0.00	0.27
Correlations with domestic GDP						
GDP (Y)	1.00	1.00	1.00	1.00	1.00	1.00
Aggregate consumption	0.78	0.79	0.55	0.78	0.78	0.86
Investment	0.94	0.93	0.96	0.94	0.94	0.91
Hours	0.99	0.99	0.99	0.99	0.99	0.84
Deposits	0.23	0.23	0.15	0.21	0.21	-0.15
Loans	0.34	0.31	0.72	0.32	0.30	0.67
Loan rate spread	-0.62	0.42	-0.93	-0.62	0.87	-0.25
Cross country correlations						
GDP (Y)	0.79	0.79	1.00	0.81	0.81	0.76
Aggregate consumption	0.89	0.89	0.99	0.89	0.89	0.85
Investment	0.62	0.61	1.00	0.64	0.64	0.90
Hours	0.79	0.78	1.00	0.82	0.82	0.72
Deposits	0.73	0.72	1.00	0.77	0.77	0.56
Loans	0.54	0.51	0.90	0.60	0.59	0.78
Loan rate spread	0.77	1.00	0.77	0.75	1.00	0.61

Note: The table shows theoretical moments and empirical moments of variables in a given country (standard deviations, correlations with domestic GDP) and cross-country correlations. The 'loan rate spread' is the difference between the loan rate (not net of expected default), R^L_{t+1}, and the deposit rate, R^D_{t+1}, in % per annum terms. Columns labeled 'Shocks: All', 'Shocks: TFP', 'Shocks: default' show model generated statistics (with all simultaneous shocks; with just Home and Foreign TFP shocks; and with just H and F loan default rate shocks, respectively). The column labeled 'Data' shows average empirical statistics for the US and EA (1995Q1-2010Q1), see table 1. All statistics pertain to HP filtered variables; all variables (except the loan rate spread) were logged before applying the HP filter.

Table 3: Estimation of $\phi''(0)$

	$Corr(\rho_t, z_t)$	$Std(\rho_t)/std(z_t)$	$\widehat{\Phi}_{\rho,z}$	$1/\widehat{\Phi}_{z,\rho}$
First spread measure				
no filter	-0.55 (.00)	0.34	0.19 (.00)	0.62 (.00)
HP filtered	-0.75 (.00)	0.28	0.23 (.00)	0.41 (.00)
Second spread measure				
no filter	-0.42 (.00)	0.19	0.08 (.00)	0.45 (.00)
HP filtered	-0.40 (.00)	0.29	0.09 (.00)	0.56 (.00)

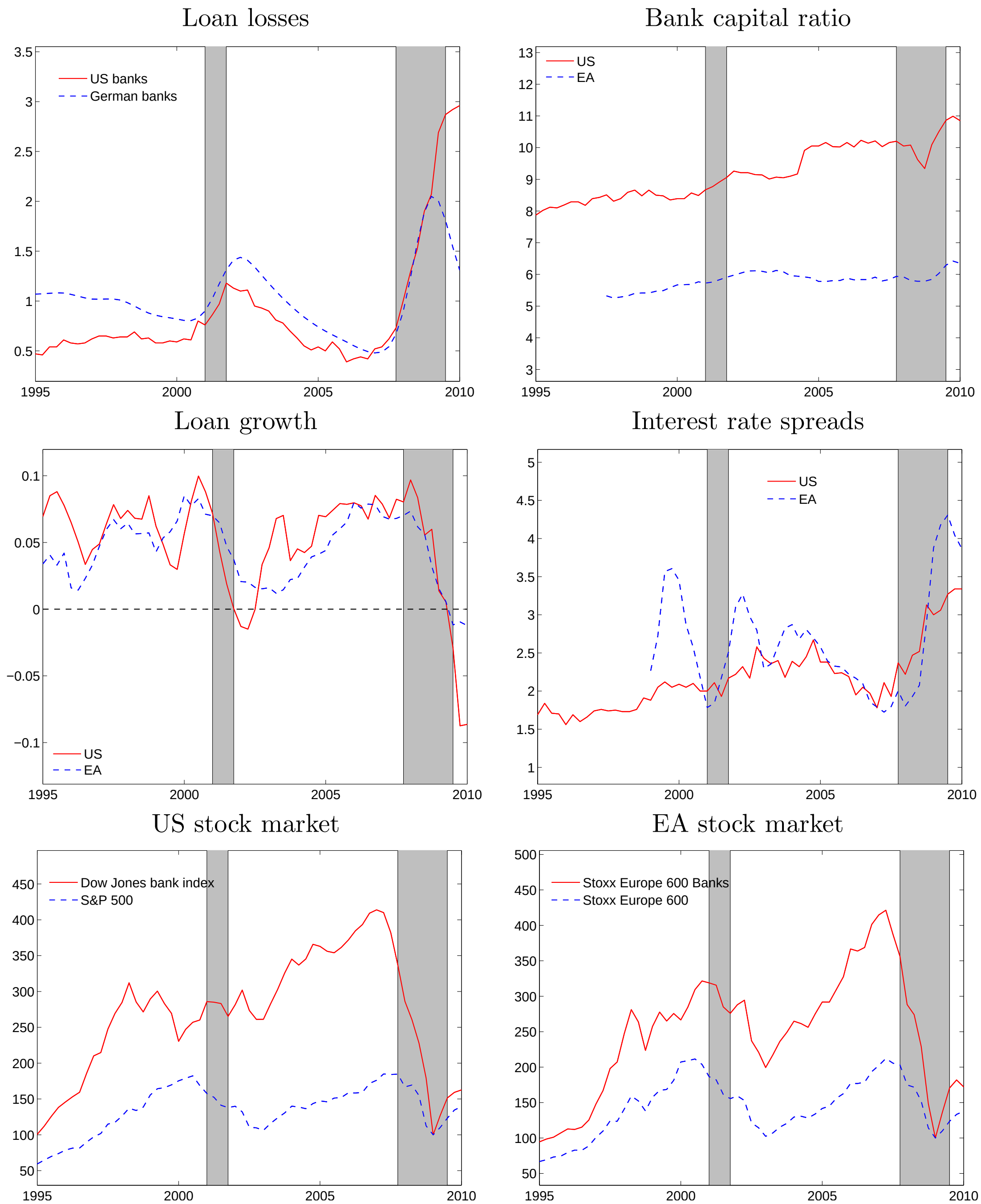

Figure 2: Financial data in US and EA. NBER recessions (latest recession is assumed to have ended in 2009q3). Loan losses are writeoffs on loans measured in percent of total loans (annualized). For loan losses we consider German data, as we lack data for the EA aggregate. Bank equity over assets are measured in percent. Loan growth is measured on a yoy-basis. The interest rate spread is measured in annualized percentage points. Stock market indices: 2009q1=100. A detailed description of the data is provided in the appendix.

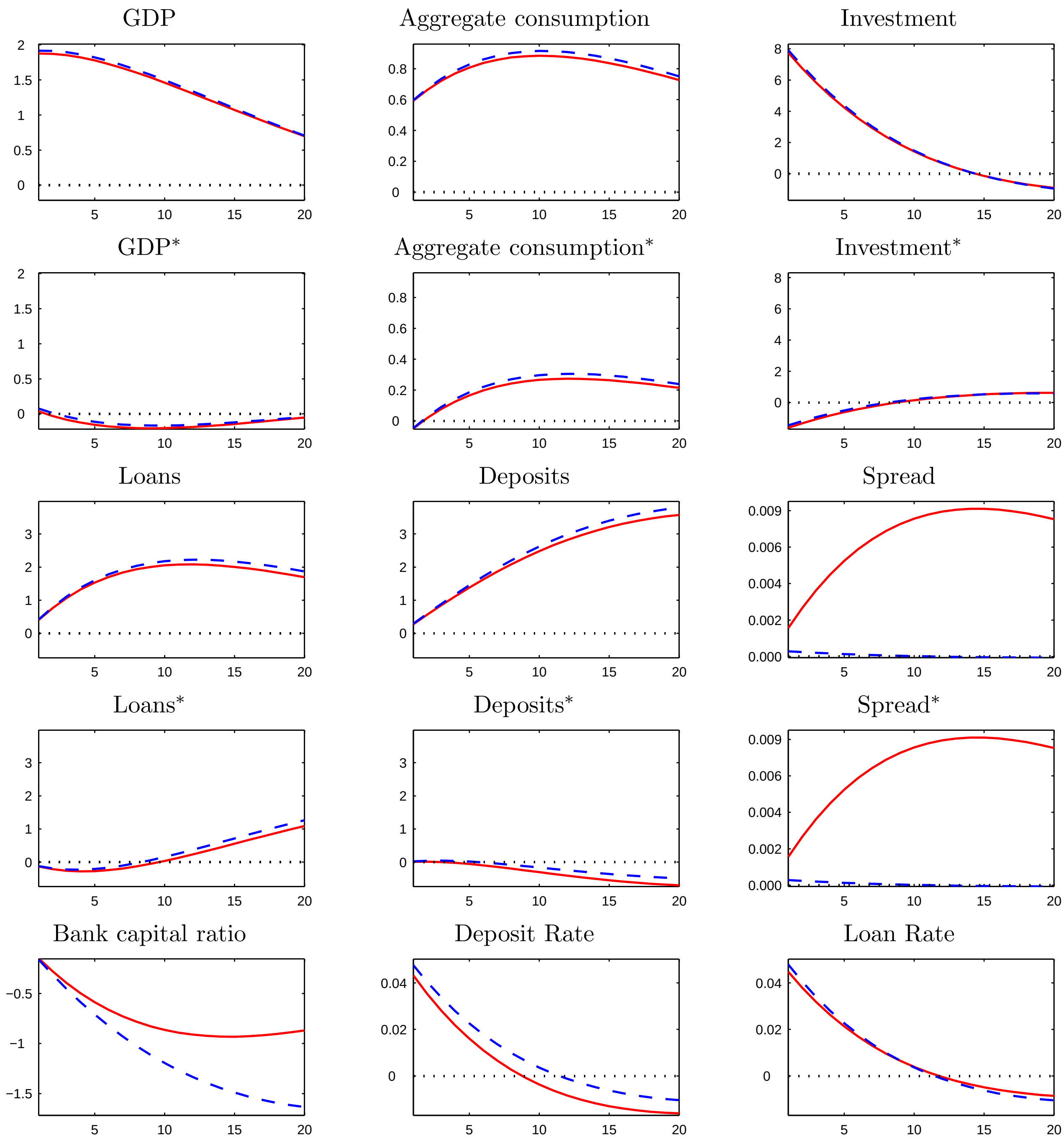

Figure 3: Impulse-response functions to a TFP shock of 1% at Home. Notes: red solid lines depict baseline case, blue dashed lines depict case of $\phi''(0) = 0$. Loans and deposits are expressed as ratio to steady-state GDP. Variables are expressed percentage deviations from steady state, interest rates in percentage points.

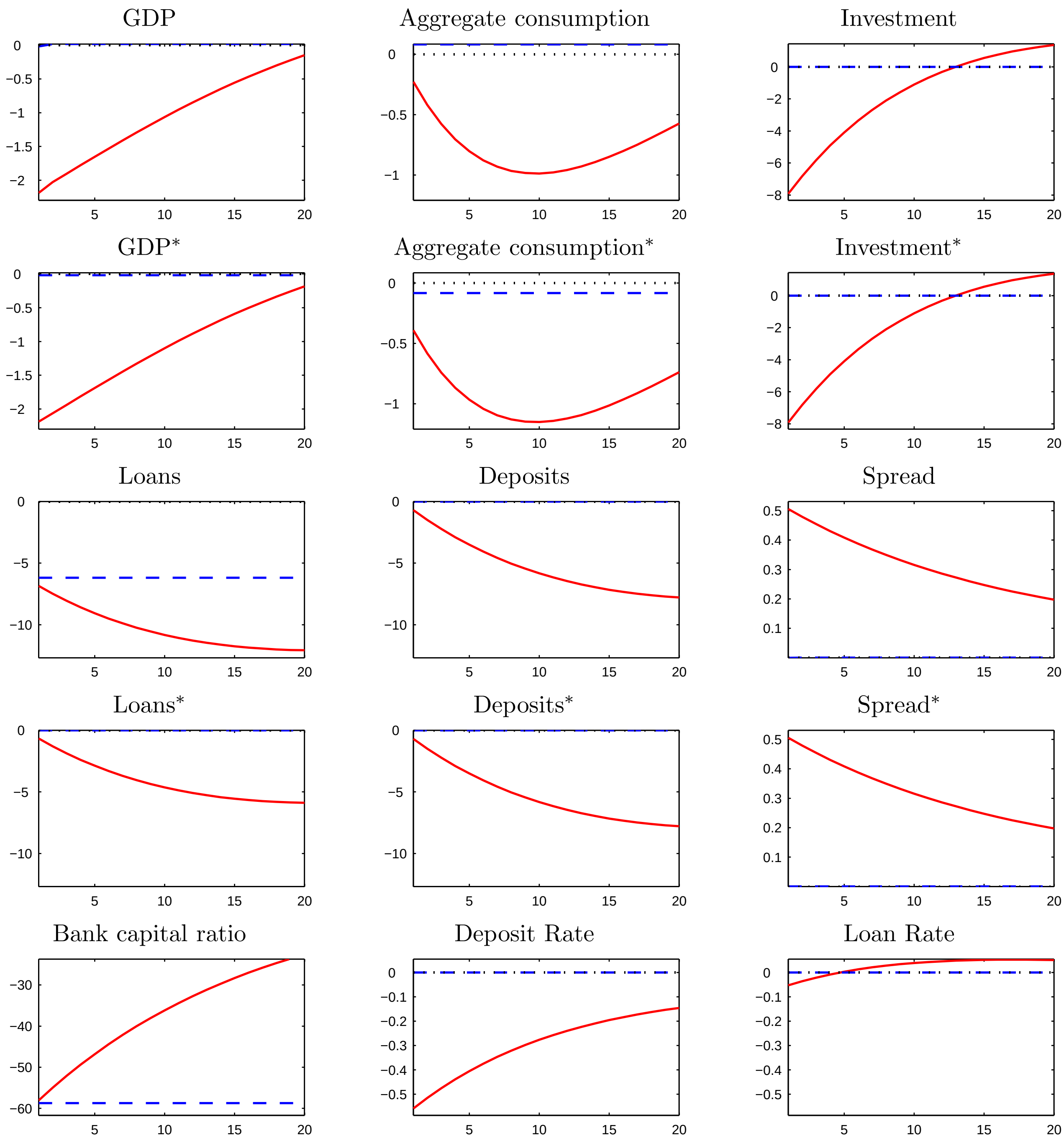

Figure 4: Impulse-response functions to a one-time increase in default rate of 5% of annual GDP at Home. Notes: red solid lines depict baseline case, blue dashed lines depict case of $\phi''(0) = 0$. Variables are expressed percentage deviations from steady state, interest rates in percentage points.

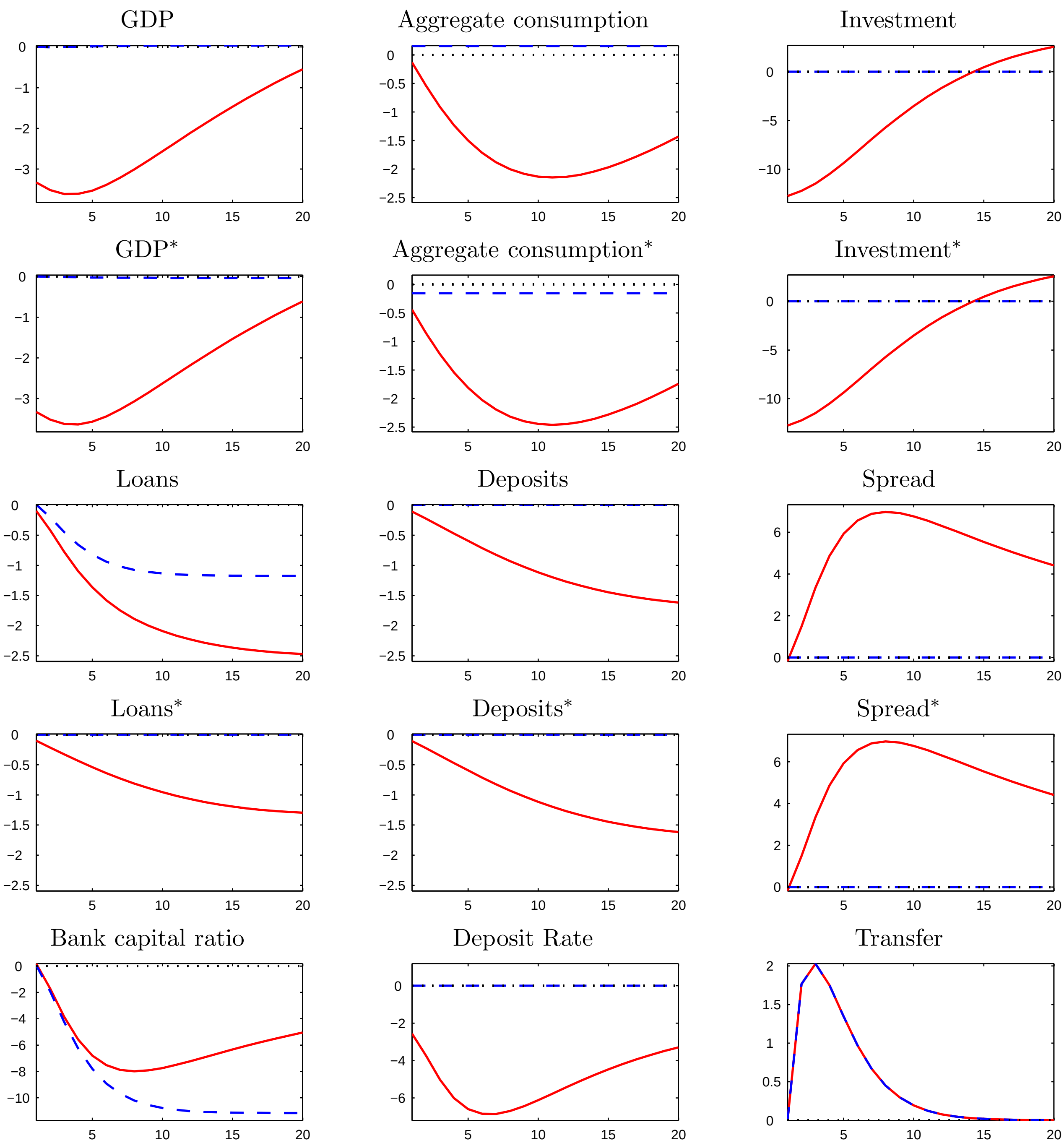

Figure 5: Impulse-response functions to an anticipated path of transfers to the entrepreneurs. Notes: transfer from the bank to entrepreneurs at Home. Total size of transfer is 5% of steady-state GDP. Red solid lines depict baseline case, blue dashed lines depict case of $\phi''(0) = 0$. Variables are expressed percentage deviations from steady state, interest rates in percentage points.

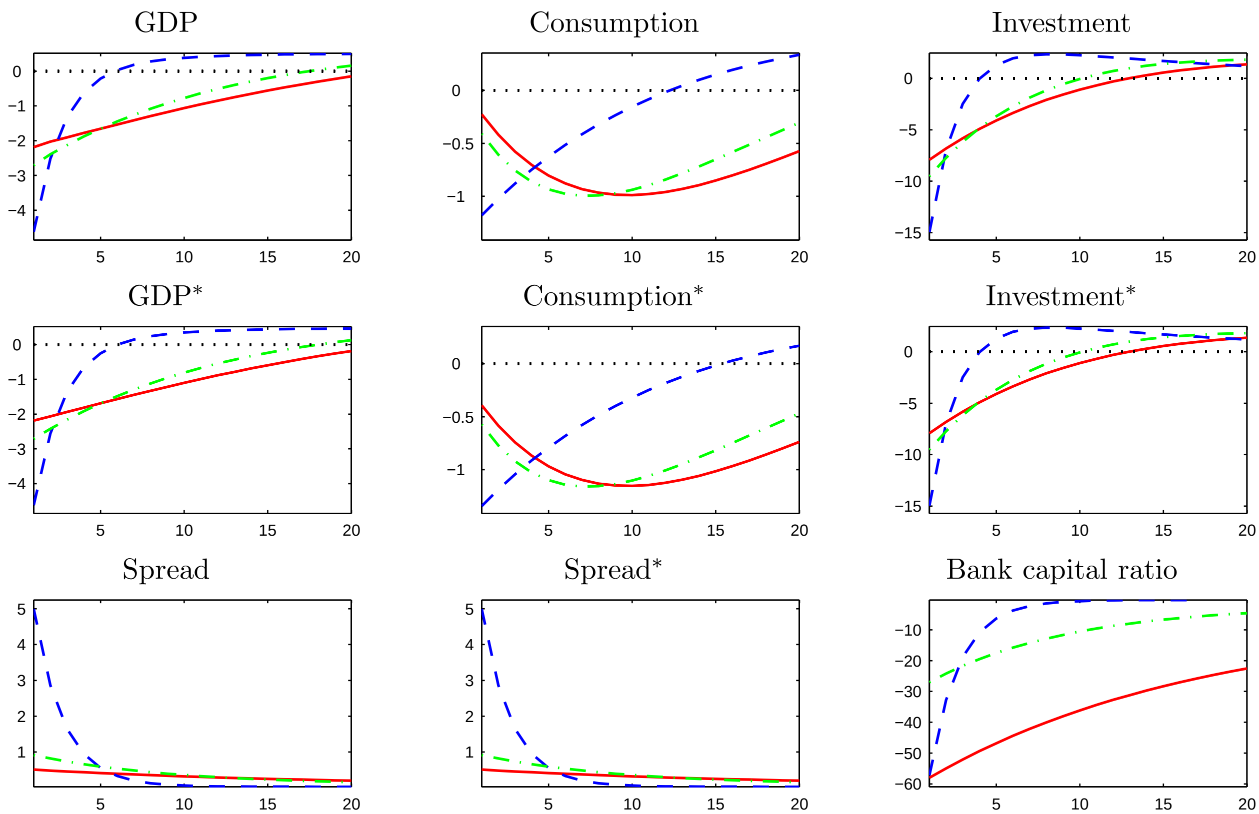

Figure 6: Impulse-response functions to a one-time increase in default rate of 5% of annual GDP at Home. Notes: red solid lines depict baseline case, blue dashed lines depict case of $\phi''(0) = 2.5/Y^W$, green dashed-dotted lines depict case of $\gamma = 0.1$. Variables are expressed percentage deviations from steady state, interest rates in percentage points.