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Global Banks, Financial Shocks, and International Business Cycles: Evidence from an Estimated Model

This paper estimates a two-country model with a global bank, using U.S. and euro area (EA) data. Empirically, a model version with a bank capital requirement outperforms a structure without such a constraint. A loan loss originating in one country triggers a global output reduction. Banking shocks matter more for EA macro variables than for U.S. real activity. Banking shocks account for about 2–5% of the unconditional variance of U.S. GDP and for 3–14% of the variance of EA GDP. During the 2007–09 recession, banking shocks accounted for about 15% of the fall in U.S. and EA GDP, and for more than a third of the fall in EA investment and employment.

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THE RECENT FINANCIAL CRISIS began in U.S. financial markets in 2007 and was quickly and strongly transmitted to Europe and other parts of the world. The crisis revealed the fragility of major financial institutions, and led to the worst global recession since the Great Depression. These dramatic events require a

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rethinking of the role of financial intermediaries for real activity. Before the financial crisis, standard applied macro models abstracted from financial intermediaries (e.g., Christiano, Eichenbaum, and Evans 2005). The crisis revealed the stark limitations of those models.

The crisis has stimulated much research that incorporates banks into dynamic stochastic general equilibrium (DSGE) models. Given the global nature of the banking industry, and of the financial crisis, that research has frequently focused on *open* economy models; see, for example, Devereux and Sutherland (2011), Kollmann, Enders, and Müller (2011), Perri and Quadrini (2011), Kamber and Thoenissen (2013), and van Wincoop (2013). *Closed* economy DSGE models with banks were presented by Aikman and Paustian (2006), Van den Heuvel (2008), Gerali et al. (2010), and Meh and Moran (2010).[1] In this new class of DSGE models, bank capital is a key state variable for the supply of credit, and for real activity; negative shocks to bank capital are predicted to increase the spread between banks' lending and deposit rates, and to trigger a fall in bank credit and output; with a globalized banking system, a loan loss in one country can thus lead to a worldwide recession.

So far, this new macro-banking literature has mainly used calibrated models—a systematic empirical evaluation, using econometric methods, is necessary to guide further model building and policy. In order to provide an empirical assessment of the role of banks as a source of shocks and as a transmission channel in the *global* economy, the paper here *estimates* (using Bayesian methods) a two-country DSGE model with a global bank. Quarterly U.S. and euro area (EA) macro data and banking data (bank loans, bank capital ratio, loan spread) for the period 1990q1–2010q3 are used.[2] Specifically, I take the Kollmann, Enders, and Müller (2011) two-country model with a banking sector to the data—that structure is used as it features a "bank capital channel" that is broadly representative of other recent macro-banking models.

The structure builds on the International Real Business Cycle (RBC) literature, but while standard International RBC models assume direct frictionless international borrowing and lending (e.g., Backus, Kehoe, and Kydland 1992, Baxter and Crucini 1995, Kollmann 1996), the model here assumes that a global bank intermediates between savers and borrowers in the two countries. Importantly, the bank has to finance a fraction of its assets using equity (own funds). This capital requirement can reflect legal constraints and, more broadly, market pressures. It implies that the loan rate spread (relative to the deposit rate) is a decreasing function of bank capital. To focus on the role of bank capital for international shock transmission, I adopt an

1. Other open economy models with banks can be found in Correa, Sapriza, and Zlate (2010), Davis (2010), Nguyen (2011), Andreasen, Sondergaard, and Paustian (2010), Ueda (2010), Dedola and Lombardo (2012), and Lipinsky (2012); for *closed* economy DSGE models with banks, see also Brunnermeier and Sannikov (2010), de Walque, Pierrard, and Rouabah (2010), Gertler and Karadi (2011), Gertler and Kiyotaki (2011), Iacoviello (2010), Del Negro et al. (2011), Benes and Kumhof (2011), Dewachter and Wouters (2012), He and Krishnamurthy (2012), Kollmann, Roeger, and in't Veld (2012), and Kollmann et al. (2013).

2. Some previous papers have estimated open economy DSGE models *without* banks; for example, de Walque, Smets, and Wouters (2005), Adolfson et al. (2007), Justiniano and Preston (2010), Le et al. (2010), and Jacob and Peersman (2013).

aggregate perspective and assume a *representative* bank that may be thought of as the global financial system; thus, I abstract from frictions in the interbank market that played an important role in the early stages of the financial crisis (Brunnermeier 2009). The estimated model assumes exogenous demand and supply shocks in home and foreign labor and good markets. In addition, there are exogenous loan losses (defaults) in the two countries, and exogenous fluctuations in the required (target) bank capital ratio—henceforth, I refer to these shocks as "banking shocks." (Other recent studies on DSGE models with banks discuss too—but do not estimate—exogenous shocks to bank revenue/capital; see, e.g., Gerali et al. 2010, Meh and Moran 2010, Gertler and Karadi 2011.)

The estimated banking model matches key cyclical properties of U.S. and EA macro and banking variables. For example, it captures the fact that U.S. and EA loans are procyclical, while the loan spread is countercyclical. The estimation results indicate that the bank capital requirement, and the banking shocks, matter for the dynamics of macro and banking variables. A model with these ingredients outperforms a model variant *without* an operative bank capital requirement (and without banking shocks)—the model with the bank capital requirement generates predicted second moments of key macro and banking variables that are mostly closer to empirical moments; the marginal likelihood of that model is markedly higher.

The model estimates suggest that global banking is a powerful international transmission channel for *financial* shocks. In the presence of a bank capital requirement, loan losses and shocks to the required bank capital ratio induce sizable *common* responses of home and foreign real activity. That positive international transmission mechanism is not present in standard International RBC models (without banks). According to the baseline model estimates, a 1 percentage point fall in the global bank capital ratio raises the loan rate spread by about 20 basis points. An unanticipated U.S. loan loss worth 1% of steady-state quarterly GDP lowers U.S. *and* EA quarterly GDP by about 0.10% and 0.12%, respectively, on impact; an EA loan loss of the same size lowers U.S. and EA GDP by 0.14% and 0.18%, respectively. A U.S. loan loss thus lowers EA real activity *more* than U.S. real activity. An unanticipated increase in the required bank ratio by 1 percentage point lowers U.S. and EA GDP by 0.10% and 0.11%, respectively.

Banking shocks account for a nonnegligible share of the unconditional variance of real activity. Specifically, banking shocks explain about 2%–5% of the variance of U.S. GDP, and 3%–14% of the variance of EA GDP. These shocks account for higher variance shares of employment and investment—especially of EA investment (above 20%). Thus, banking shocks matter more for EA real activity than for U.S. real activity. U.S. loan losses account for a greater share of the variance of EA real activity than of the variance of U.S. real activity. Exposure to U.S. loan losses (via the global banking system) thus deepened the recent recession in the EA.

However, despite the positive international transmission of banking shocks, the model here cannot account for the high positive (unconditional) cross-country correlation of real activity seen in the data, unless total factor productivity (TFP) is strongly correlated across countries. For TFP shocks (and other nonbanking shocks) are the dominant source of real activity fluctuations, according to the model estimates. Like standard open economy models without banks (e.g., Backus, Kehoe, and Kydland 1992), the model here predicts that a positive shock to home TFP raises home GDP, but *lowers* foreign GDP. Conventional models too require shocks that are positively correlated across countries, to explain the empirical cross-country correlation of real activity.

The model estimates suggest that banking shocks contributed noticeably to the "Great Recession" of 2007–09, but were not its dominant cause: banking shocks accounted for about 15% of the fall in U.S. and EA GDP during the recession—but they explained more than a third of the fall in EA investment and employment. During the previous two U.S. recessions in the estimation period (1990–91 and 2001), banking shocks accounted for a roughly similar share of the fall in U.S. output, investment, and employment as in the 2007–09 recession.

I consider several empirical measures of credit and lending spreads and find that the key results are robust across the different measures.

This paper is complementary to Gerali et al. (2010) who *estimated* (using EA data) a *closed* economy New Keynesian macro model with a banking sector that faces a bank capital requirement. The paper here differs (*inter alia*) from Gerali et al. by estimating a real (flex-price) *two-country* world with a *global* bank that experiences *loan loss* shocks. By contrast, the empirical analysis of Gerali et al. focuses on the role of shocks to *borrowers*' collateral constraints.

Section 1 presents the model. Section 2 discusses the econometric approach. Section 3 describes key data features. Section 4 reports the estimation results. Section 5 concludes.

1. A TWO-COUNTRY WORLD WITH A GLOBAL FINANCIAL INTERMEDIARY

As mentioned above, this paper takes the theoretical two-country model of Kollmann, Enders, and Müller (2011) to U.S. and EA data.[3] In each of the two countries, called "Home" (H) and "Foreign" (F), there is a representative worker, an entrepreneur and a government. A global bank collects deposits from workers, and makes loans to entrepreneurs, in both countries. The bank faces a capital requirement: a fraction of bank assets has to be financed using the bank's own funds (equity). Entrepreneurs produce a homogenous tradable good that is used for consumption and for capital accumulation. All agents are infinitely lived. Markets are competitive. Preferences and technologies have the same structure in both countries.

3. Governments and a rich set of (banking and nonbanking) shocks are added to the Kollmann, Enders, and Müller (2011) model, to permit an empirical evaluation of the bank capital channel, and of the contribution of banking shocks to historical data for key macro variables. Also, the present paper allows for asymmetries between countries, to capture differences between the sensitivity of the U.S. and EA economies to banking shocks.

The following exposition focuses thus on the Home country. Foreign variables are denoted by an asterisk.

1.1 Preferences, Technologies, Markets

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

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

where C_t^S and N_t are the worker's consumption and hours worked, respectively. ω_t is the real wage rate. D_{t+1} is the bank deposit held by the saver at the end of period t. R_t^D is the gross interest rate on deposits, between t–1 and t. T_t^S is a lump sum tax. The worker's date t expected lifetime utility, V_t^S, is

$$V_t^S = u\left(C_t^S\right) + \Psi^D u(D_{t+1}) - \Psi_t^N N_t + E_t \beta_{t+1}^S V_{t+1}^S,$$

with $u(x) = (x^{1-\sigma} - 1)/(1 - \sigma)$, $\sigma > 0$, and $\Psi^D > 0$. The worker's marginal disutility of labor, $\Psi_t^N > 0$, is an exogenous random variable that will be referred to as the Home labor supply shock. Note that deposits provide utility to the worker (liquidity services). This ensures that, in equilibrium, the deposit rate is smaller than the loan rate, and that workers hold deposits while entrepreneurs borrow. The worker's subjective discount factor is decreasing in her future consumption: $\beta_{t+1}^S \equiv \beta^S(\overline{C_{t+1}^S})$, with $0 < \beta^S(\overline{C_{t+1}^S}) < 1$, $\beta^{S\prime}(\overline{C_{t+1}^S}) < 0$. The subjective discount factors of other agents are likewise decreasing functions of their own consumption (this induces mean-reversion in individual wealth, and thus ensures stationarity, as required for the numerical solution and estimation methods). Agents treat their subjective discount factors as given; that is, they do not internalize the effect of consumption on the discount factor—I thus write the argument of the subjective discount factor with an upper bar. It is assumed that all agents have the same *steady-state* rate of time preference, and the same risk aversion coefficient, σ.

The Home worker maximizes her lifetime utility subject to the period-by-period budget constraint (1). That decision problem has these first-order conditions:

$$u'\left(C_t^S\right)\omega_t = \Psi_t^N,$$

$$R_{t+1}^D E_t \beta_{t+1}^S u'(C_{t+1}^S)/u'\left(C_t^S\right) + \Psi^D u'(D_{t+1})/u'\left(C_t^S\right) = 1.$$

The Home entrepreneur. The Home entrepreneur accumulates physical capital and uses capital and local labor to produce output. Her technology is $Z_t = \theta_t(K_t)^\alpha(N_t)^{1-\alpha}$, $0 < \alpha < 1$,where Z_t, K_t, and N_t are output, capital, and labor, respectively. Total factor productivity (TFP), $\theta_t > 0$, is an exogenous random variable. The law of motion of the capital stock is $K_{t+1} = (1 - \delta)K_t + \Xi_t I_t$, where $0 \leq \delta \leq 1$ is the capital depreciation rate and I_t is gross investment. $\Xi_t > 0$ is an exogenous random shock to investment efficiency (Fisher 2006, Justiniano, Primiceri, and Tambalotti 2008). Gross investment is generated using output. Let $I\xi(I_t/I)$ be the amount of output needed to generate I_t, where I is steady-state investment, and ξ an increasing, strictly convex function with $\xi(1) = \xi'(1) = 1$. Henceforth, variables without time subscripts denote steady-state values. The Home entrepreneur's period t budget constraint is

$$L_t R_t^L - \Delta_t + \mathrm{I}\xi(I_t/I) + \omega_t N_t + d_t^E + T_t^E = L_{t+1} + \theta_t (K_t)^\alpha (N_t)^{1-\alpha}, \qquad (2)$$

where L_t is a one-period bank loan received by the Home entrepreneur in period t – 1. R_t^L is the gross interest rate on that loan, set at t – 1. In period t, the Home entrepreneur defaults by an exogenous random amount Δ_t on the amount $L_t R_t^L$ that she owes the bank. T_t^E is a lump sum tax. d_t^E is the entrepreneur's dividend income at t. The entrepreneur consumes her dividend income. Her expected lifetime utility at t, V_t^E, is $V_t^E = u(d_t^E) + E_t \beta_{t+1}^E V_t^E$, with $\beta_{t+1}^E = \beta^E(\overline{d_{t+1}^E}) < 1$. Utility maximization by the entrepreneur (subject to (2)) yields these first-order conditions:

$$\omega_t = (1-\alpha)\theta_t K_t^\alpha N_t^{-\alpha},$$

$$R_{t+1}^L E_t \beta_{t+1}^E u'(d_{t+1}^E)/u'(d_t^E) = 1, \qquad (3)$$

$$E_t \beta_{t+1}^E (u'(d_{t+1}^E)/u'(d_t^E))\{\theta_{t+1}\alpha K_{t+1}^{\alpha-1} N_{t+1}^{1-\alpha} + q_{t+1}(1-\delta)\}/q_t = 1,$$

with $q_t \equiv \xi'(I_t/I)/\Xi_t$.

The Home government. At date t, the Home government makes exogenous random output purchases G_t that are financed using lump sum taxes: $G_t = T_t^W + T_t^E + T_t^B$, where T_t^B is a tax paid by the bank (see below). Each Home agent bears a *constant* share of the total Home tax burden, equal to her share in Home steady-state consumption: $T_t^i = \lambda^i G_t^i$ for $i = S, E, B$ where λ^i is time invariant. In setting taxes, the Home and Foreign governments assume that 50% of the banker's consumption takes place in country Home.

The global bank. The paper focuses on the role of bank capital for the transmission of macroeconomic and financial shocks to global real activity. I therefore adopt an *aggregate* perspective, and assume a representative global bank that may be thought of as the global financial system.[4] At t, the global 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 Home and Foreign entrepreneurs, respectively. Let $D_{t+1}^W \equiv D_{t+1} + D_{t+1}^*$ and $L_{t+1}^W \equiv L_{t+1} + L_{t+1}^*$ denote worldwide deposits and loans. The bank faces a capital requirement: its date t capital $L_{t+1}^W - D_{t+1}^W$ should not be smaller than a fraction γ_t of the bank's assets L_{t+1}^W. This may reflect a legal requirement (macroprudential policy) or, more broadly, market pressures. To allow for time variation in

4. Thus, the interbank market is not modeled here. Frictions in that market would matter for aggregate activity if they affected the flow of funds from savers to borrowers. The model here captures empirical fluctuations in the loan spread and in the volume of intermediation. To investigate the potential role of an interbank market, I studied a model variant with a global savings bank and a global investment bank. The savings bank gets deposits from households and lends to the investment bank (interbank market), which lends to firms. Each bank faces a capital requirement. Aggregate dynamics hinges on *total* bank capital—thus that setup is observationally equivalent to the representative-bank model.

these factors, I assume that γ_t is an exogenous random variable. A sensitivity analysis below considers a model variant with a constant bank capital requirement ($\gamma_t = \gamma$). Bank capital requirements are often justified as limiting moral hazard in the presence of informational frictions and deposit insurance (see Freixas and Rochet 2008). This issue is not modeled here. Instead, I take the capital requirement as given, and focus on its macroeconomic effects.[5]

I assume that the bank can hold less capital than the required level, but that this is costly. Let $x_t \equiv (L^W_{t+1} - D^W_{t+1}) - \gamma_t L^W_{t+1} = (1-\gamma_t)L^W_{t+1} - D^W_{t+1}$ denote the bank's "excess" capital at the end of period t. The bank bears a cost (penalty) $L^W \phi(x_t/L^W)$ as a function of x_t, where L^W is the steady-state stock of loans. ϕ is a smooth, convex function ($\phi'' \geq 0$) for which I assume: $\phi(x_t/L^W) > 0$ for $x_t < 0$; $\phi(0) = 0$. Thus, for $x_t < 0$ the bank incurs a positive cost; the cost is zero when the bank meets its capital requirement.[6]

At t, the bank also bears an operating cost $\Gamma \cdot (D^W_{t+1} + L^W_{t+1})$, where $\Gamma > 0$ is the (constant) real marginal cost of taking deposits and making loans. The bank's period t budget constraint is

$$L^W_{t+1} + D^W_t R^D_t + \Gamma \cdot (D^W_{t+1} + L^W_{t+1}) + L^W \phi(x_t/L^W) + d^B_t + T^B_t + T^{B*}_t$$
$$= L^W_t R^L_t - \Delta_t - \Delta^*_t + D^W_{t+1}, \quad (4)$$

where $\Delta_t + \Delta^*_t$ is the bank's total loan loss, and $T^B_t + T^{B*}_t$ is the total tax paid by the bank (in the two countries). d^B_t is the dividend generated by the bank at t. As the bank acts competitively, loan rates and deposit rates are equated across countries. Equation (4) implies that bank capital at the end of period t equals bank capital at the end of t–1, plus retained bank earnings in t. The banker consumes her dividend income, and selects the path of loans and deposits to maximize her welfare. The banker's expected lifetime utility at t, V^B_t, is

$$V^B_t = u(d^B_t) + E_t \beta^B_{t+1} V^B_{t+1}, \quad \text{with} \quad \beta^B_{t+1} = \beta^B(\overline{d^B_{t+1}}) < 1.$$

The banker's utility maximization problem has these first-order conditions:

$$R^D_{t+1} E_t \beta^B_{t+1} u'(d^B_{t+1})/u'(d^B_t) = 1 - \Gamma + \phi_t{}'(x_t/L^W),$$

$$R^L_{t+1} E_t \beta^B_{t+1} u'(d^B_{t+1})/u'(d^B_t) = 1 + \Gamma + (1-\gamma_t)\phi'(x_t/L^W).$$

5. See Meh and Moran (2010) for a *closed* economy DSGE model in which bank capital mitigates an agency problem between banks and their creditors. The model here could be used to evaluate macro-prudential government *policies* that set γ_t as a function of the state of the economy—this is beyond the scope of the paper. Mendicino and Punzi (2011) and Brzoza-Brzezina, Kolasa, and Makarski (2013) show that macro-prudential policy may have important effects on real activity and welfare.

6. Gerali et al. (2010) assume a quadratic function $\phi = \chi \cdot (x_t)^2$, $\chi > 0$,under which the bank also bears a positive cost for $x_t > 0$. That function satisfies my assumptions. My setup is more general: it allows for the *possibility* that positive excess capital generates a convenience yield ($\phi < 0$ for $x_t > 0$). Up to a linear approximation (around $x = 0$), both specifications yield identical predictions; importantly, the loan spread is decreasing in x_t if and only if $\phi'' > 0$ (see below); the key (uncontroversial) assumption is, thus, the convexity of ϕ. Benes and Kumhof (2011) assume $\phi < 0$ for $x_t < 0$, and $\phi = 0$ for $x_t \geq 0$; that cost function is not differentiable at $x = 0$; the numerical solution method (linearization) used here cannot be applied to a model with that function.

A linear approximation of these Euler equations (around $x = 0$) gives

$$R^L_{t+1} - R^D_{t+1} \cong 2\Gamma - \gamma_t \phi'(x_t/L^W) \cong 2\Gamma - \gamma_t \phi'(0) - \gamma \phi''(0) \cdot (x_t/L^W). \quad (5)$$

Hence, the loan rate spread $R^L_{t+1} - R^D_{t+1}$ is a function of the required capital ratio γ_t and of the bank's excess capital, x_t.[7] Note that if the bank raises deposits *and* loans by one unit, then its operating cost rises by 2Γ units; excess bank capital falls by γ_t, which raises the penalty $L^W \phi(x_t/L^W)$ by $-\gamma_t \phi'(x_t/L^W)$. The bank's Euler equations imply that the spread between the loan rate and the deposit rate $R^L_{t+1} - R^D_{t+1}$ covers the marginal cost $2\Gamma - \gamma_t \phi'(x_t/L^W)$. Under strict convexity of ϕ (i.e., $\phi'' > 0$), the marginal benefit of excess capital $-\phi'$ is a decreasing function of (excess) bank capital, which implies that the loan rate spread is likewise a decreasing function of excess bank capital.

The sensitivity of the loan rate spread to changes in bank capital is governed by ϕ''. Note that $x_t/L^W \cong cr_t - \gamma_t$, where $cr_t \equiv (L^W_{t+1} - D^W_{t+1})/L^W_{t+1}$ is the bank's capital ratio, that is, the ratio of bank equity to bank assets. A 1 percentage point rise in the capital *ratio* lowers the loan rate spread by $4\gamma\phi''$ percentage points per annum (p.a.), while a 1 percentage point increase in the required bank capital ratio (holding constant cr_t) raises the spread by $4[\gamma\phi'' - \phi']$ percentage points p.a.

Market clearing. Market clearing for the output good requires[8]

$$Z_t + Z^*_t = C^S_t + C^{S*}_t + d^E_t + d^{E*}_t + d^B_t + I\xi(I_t/I) + I^*\xi(I^*_t/I^*)$$
$$+ G_t + G^*_t + L^W \phi(x_t/L^W) + \Gamma(L^W_{t+1} + D^W_{t+1}).$$

Forcing variables. Steady-state TFP and investment efficiency are normalized to unity ($\theta = \theta^* = \Xi = \Xi^* = 1$). There are 11 forcing variables: Home and Foreign TFP (θ_t, θ^*_t), investment efficiency (Ξ_t, Ξ^*_t), government purchases (G_t, G^*_t), labor supply shocks(Ψ^N_t, Ψ^{N*}_t), loan losses (Δ_t, Δ^*_t), and the required bank capital ratio (γ_t). I refer to the first eight shocks as "nonbanking" shocks, and to the last three shocks as "banking" shocks. A large number of nonbanking shocks is assumed so that the model has the potential to capture important features of macro data, even in the absence of banking shocks. Other recent estimated DSGE models likewise assume many shocks (e.g., Smets and Wouters 2007).

Following the empirical DSGE literature, I consider a baseline specification in which all 11 forcing variables are *independent* univariate AR(1) processes:

7. Gerali et al. (2010) assume a constant target bank capital ratio, but postulate exogenous changes in bank markups (market power) that likewise impact the spread; see also Kannan, Rabanal, and Scott (2012).

8. The bank operating cost and cost of excess bank capital represent inputs used by the bank and have thus to be subtracted from entrepreneurs' output when computing GDP. I assume the bank purchases the resources $\Gamma(L_{t+1} + D_{t+1})$, and a fraction L/L^W of the resource cost $L^W \phi(x_t/L^W)$ from the Home entrepreneur. Thus, Home GDP is: $Y_t \equiv Z_t - \Gamma(L_{t+1} + D_{t+1}) - L\phi(x_t/L^W)$, and $Y_t + Y^*_t = C^S_t + C^{S*}_t + d^E_t + d^{E*}_t + d^B_t + I\xi(I_t/I) + I^*\xi(I^*_t/I^*) + G_t + G^*_t$.

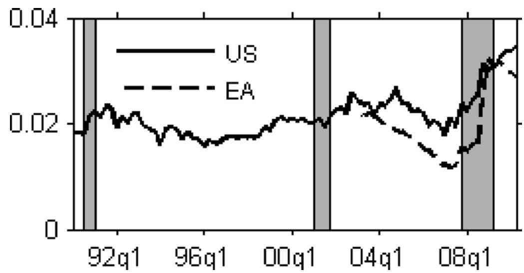

FIG. 1. U.S. and EA Loan Rate Spreads (p.a.).

NOTE: Sample period for U.S. (EA) loan spread: 1990q1–2010q3 (2003q1–2010q3). Shaded areas: U.S. recessions (NBER dates).

$$\ln(z_t/z) = \rho^z \ln(z_{t-1}/z) + \varepsilon_t^z,$$

for variable z_t, with $0 \leq \rho^z < 1$, where ε_t^z is a normally distributed white noise.

1.2 Model Solution

A linear approximation (around the deterministic steady state) is used to solve the model. The solution can be expressed as

$$s_t = \Lambda_1 s_{t-1} + \Lambda_2 \varepsilon_t, \tag{6}$$

where s_t is a vector consisting of states and controls chosen (or realized) at date t, expressed as deviations from steady-state values. ε_t is the vector of innovations to forcing variables. Λ_1, Λ_2 are matrices whose elements are functions of model parameters.

2. ECONOMETRIC APPROACH

The model is estimated using quarterly time series for 12 macro and banking variables, in 1990q1–2010q3: U.S. and EA GDP, total private consumption, investment, employment, commercial bank credit (deflated using the GDP deflator), the loan rate spread of U.S. commercial banks, and the capital ratio of U.S. commercial banks. U.S. (EA) data are taken as empirical counterparts of Home (Foreign) variables in the model. The baseline estimates use data on *total* bank credit (to all sectors) by U.S. commercial banks and by EA monetary financial institutions (MFI). Below, I also report estimation results that use data on credit to the business sector. (I use *total* credit for the baseline estimates, as that variable accounts for a greater share of bank assets.) The baseline measure of the U.S. loan rate spread is the "commercial and industrial loan rates spread over intended federal funds rate," from the Federal Reserve Board's (FRB) Survey of Terms of Business Lending (Table E.2). Data on the EA loan rate spread are only available for the period since 2003q1; as shown in Figure 1, the available EA loan spread closely tracks the U.S. loan spread (correlation: 0.90). (The EA spread plotted in Figure 1 is the difference between the EA MFI loan rate and the EONIA rate.) I thus use the U.S. loan rate spread as a measure of the global loan spread. The U.S. commercial bank capital ratio is taken as a proxy for the capital ratio of the global bank. Following Kollmann and Zeugner (2012), the empirical bank capital ratio measure is constructed as (total financial assets – total liabilities)/total financial assets, using Flow of Funds (FRB) data. In estimation, the loan spread and the capital ratio are demeaned; the other empirical variables are linearly detrended in log form. See the Appendix for further information on empirical variables.

The number of data series used for estimation (12) exceeds the number of shocks (11). To avoid stochastic singularity of the model, I assume that *all* observed variables contain measurement error. Allowing for measurement error also seems important because (especially) the empirical banking series might be imperfect measures of the theoretical concepts.[9] The period t data used in estimation, y_t^{obs}, are a subset of the states and controls included in the vector s_t (see (6)):

$$y_t^{obs} = \Gamma s_t + \mu_t,$$

where Γ is a matrix, and μ_t is a vector of Gaussian i.i.d. measurement errors that are independent of the true state variables at all leads and lags. I use a Bayesian approach to estimate a subset of the parameters, while the remaining parameters are calibrated.

2.1 *Estimated Parameters*

I *estimate* the (scaled) curvature of the bank capital penalty function $4\gamma\phi''$, the curvature of the investment cost function ξ'', and the risk aversion coefficient σ. The first two parameters do not affect the steady state, but are key for the dynamic properties of the model. In particular, $4\gamma\phi''$ (sensitivity of the loan rate spread to changes in the bank capital ratio) is crucial for the transmission of banking shocks to real activity.

The means and standard deviations of the prior distributions of these parameters are shown in columns (1) and (2) of Table 1. I set the mean of the prior distribution of $4\gamma\phi''$ at 0.2, a value consistent with time-series regressions of the loan rate spread on aggregate bank capital reported by Kollmann, Enders, and Müller (2011). (As discussed below, I set the steady state required bank capital ratio at $\gamma = 11.17\%$.) Investment is excessively volatile when the capital accumulation technology is linear ($\xi'' = 0$), as then international capital flows respond very strongly to country-specific shocks. I set the mean of the prior distribution of ξ'' at 1; for that value, the ratio of the standard deviation of investment divided by the standard deviation of GDP is about 3 in the model variants discussed below (when the other parameters are set

9. To break the singularity, measurement error in just one observable is sufficient. To determine the presence of measurement error empirically, I allow for it in *all* series. Assuming measurement error *just* in banking variables gives similar results. For recent estimated DSGE models with measurement error, see Ireland (2004), Boivin and Giannoni (2006), Galí, Smets, and Wouters (2011) and de Antonio Liedo (2011). Sizable estimated measurement error may suggest model misspecification (Canova 2007).

at prior mean values), and thus roughly in the range of the relative volatility of EA investment. The mean of the prior distribution of σ is set at 2. (The prior distributions of σ, $4\gamma\phi''$, and ξ'' are Gamma distributions with standard deviations set at half the prior means. Thus a reasonably wide range of parameter values around the mean has nonnegligible mass.)

I also estimate the autocorrelations of the 11 forcing variables, and the standard deviations of the 11 shock innovations, as well as the standard deviation of measurement errors. The prior distributions of autocorrelations [standard deviations of innovations] of forcing variables have mean 0.5 [0.5%] and a standard deviation of 0.1 [0.1%]. The prior means and prior standard deviations of the standard deviations of *measurement errors* are one-fourth and one-twentieth, respectively, of standard deviations of corresponding (demeaned/detrended) empirical series. Using more diffuse priors leaves the results unchanged.

2.2 *Calibrated Parameters*

I *calibrate* the remaining structural parameters so that the steady state matches long-run properties of the data. It would be difficult to estimate the calibrated parameters through the lens of the model, using the (detrended) empirical time series used for estimation (see Smets and Wouters 2007). One period in the model represents one quarter in calendar time. As is standard in the macro literature, the (quarterly) depreciation rate of physical capital is set at $\delta = 0.025$. The elasticity of output with respect to capital is set at $\alpha = 0.3$, consistent with long-run average historical U.S. and EA labor shares of about 70%.

The two-country model here abstracts from U.S. and EA trade with third countries; I thus use the sum of U.S. government consumption and of U.S. net exports to countries other than the EA as an empirical measure of U.S. "autonomous" spending, G_t; EA autonomous spending is constructed analogously. During 1990q1–2010q3, U.S. [EA] autonomous spending represented 14.2% of U.S. GDP [21.2% of EA GDP], on average. I thus set $G/Y = 14.2$, $G^*/Y^* = 21.2$.

Most DSGE studies calibrate the subjective discount factor to match average historical returns. I use the same approach. As mentioned above, it is assumed that all agents have the same steady-state subjective discount factor, here denoted by β. β, is set so that the steady-state loan rate matches the mean 1990q1–2010q3 U.S. real loan rate. I use the interest rate on "commercial and industrial loans made by all commercial banks" from the FRB Survey of Terms of Business Lending as a measure of the nominal loan rate, from which I subtract the quarterly growth rate of the U.S. GDP deflator to construct the real loan rate. The average U.S. real loan rate 1990q1–2010q3 was 3.440% p.a. Accordingly, I set the (quarterly) steady-state subjective discount factor at $\beta = 0.9918$ (as $\beta R^L = 1$, from the entrepreneur's Euler equation (3)).

I assume that all agents' subjective discount factors have the same elasticity with respect to consumption, denoted by ε_β. I set ε_β at a small absolute value, $\varepsilon_\beta = -0.001$, that yields a stationary equilibrium, while generating (essentially) the same

TABLE 1

PARAMETERS: PRIOR AND POSTERIOR DISTRIBUTIONS FOR TWO MODEL VARIANTS

	Prior distribution			Posterior distributions			
				Model with $\phi'' > 0$, banking shocks		Model with $\phi'' = 0$, no banking shocks	
Parameter	Mean (1)	Std (2)	Distr. (3)	Mean (4)	Std (5)	Mean (6)	Std (7)
Behavioral parameters							
$4\gamma\phi''$	0.20	0.10	G	0.21	0.04	–	–
ξ''	1.00	0.50	G	0.28	0.04	0.19	0.02
σ	2.00	1.00	G	0.85	0.10	0.93	0.09
Standard deviations (%) of innovations to forcing variables							
σ^{θ}	0.50	0.10	IG	0.43	0.04	0.40	0.04
$\sigma^{\theta*}$	0.50	0.10	IG	0.44	0.04	0.43	0.04
σ^{Ξ}	0.50	0.10	IG	0.97	0.14	0.48	0.06
$\sigma^{\Xi*}$	0.50	0.10	IG	0.49	0.06	0.34	0.04
σ^{G}	0.50	0.10	IG	0.51	0.10	1.43	0.23
σ^{G*}	0.50	0.10	IG	1.45	0.19	0.45	0.08
σ^{Ψ}	0.50	0.10	IG	0.46	0.05	0.52	0.05
$\sigma^{\Psi*}$	0.50	0.10	IG	0.40	0.04	0.34	0.03
σ^{Δ}	0.50	0.10	IG	0.71	0.10	–	–
$\sigma^{\Delta*}$	0.50	0.10	IG	0.79	0.10	–	–
σ^{γ}	0.50	0.10	IG	0.61	0.10	–	–
Autocorrelations of forcing variables							
ρ^{θ}	0.50	0.10	B	0.97	0.01	0.97	0.01
$\rho^{\theta*}$	0.50	0.10	B	0.95	0.01	0.97	0.01
ρ^{Ξ}	0.50	0.10	B	0.80	0.04	0.84	0.04
$\rho^{\Xi*}$	0.50	0.10	B	0.90	0.03	0.86	0.03
ρ^{G}	0.50	0.10	B	0.52	0.10	0.91	0.02
ρ^{G*}	0.50	0.10	B	0.91	0.02	0.51	0.11
ρ^{Ψ}	0.50	0.10	B	0.96	0.01	0.98	0.01
$\rho^{\Psi*}$	0.50	0.10	B	0.91	0.01	0.96	0.01
ρ^{Δ}	0.50	0.10	B	0.69	0.06	–	–
$\rho^{\Delta*}$	0.50	0.10	B	0.82	0.04	–	–
ρ^{γ}	0.50	0.10	B	0.88	0.03	–	–

(Continued)

TABLE 1

CONTINUED

Parameter	Prior distribution Mean (1)	Prior distribution Std (2)	Prior distribution Distr. (3)	Posterior: Model with $\phi'' > 0$, banking shocks Mean (4)	Posterior: Model with $\phi'' > 0$, banking shocks Std (5)	Posterior: Model with $\phi'' = 0$, no banking shocks Mean (6)	Posterior: Model with $\phi'' = 0$, no banking shocks Std (7)
Standard deviations (%) of measurement errors							
GDP U.S.	0.79	0.16	IG	0.46	0.07	0.39	0.04
GDP EA	0.54	0.11	IG	0.30	0.04	0.31	0.04
C U.S.	0.78	0.16	IG	0.63	0.09	0.39	0.04
C EA	0.44	0.09	IG	0.32	0.04	0.31	0.04
I U.S.	3.15	0.63	IG	2.86	0.41	4.99	0.38
I EA	1.33	0.26	IG	0.85	0.11	0.78	0.10
N U.S.	0.47	0.09	IG	0.41	0.05	0.38	0.04
N EA	0.45	0.09	IG	0.29	0.04	0.25	0.03
Loans U.S.	0.85	0.17	IG	0.88	0.09	0.96	0.08
Loans EA	1.10	0.22	IG	0.49	0.06	2.86	0.21
Bank capital ratio	0.21	0.04	IG	0.45	0.06	0.75	0.05
Loan spread	0.03	0.01	IG	0.02	0.00	0.09	0.01

NOTES: Columns (1) and (2) show the mean and standard deviation of the prior distribution for model parameters listed in the left-most column. Column (3): the distribution function of the prior (B: Beta; G: Gamma; IG: Inverted Gamma; N: Normal).

Columns (4)–(7): statistics of posterior parameter distribution (mean, standard deviation), for two model variants.
Columns (4) and (5): baseline model with operative bank capital requirement ($\phi'' > 0$) and banking shocks.
Columns (6) and (7): model variant without operative bank capital requirement ($\phi'' = 0$), no banking shocks.
Entries "—" in columns (6) and (7) represent parameters that are set at zero.

Posterior distributions were obtained using the Random Walk Metropolis algorithm (250,000 draws of which the first 50,000 were discarded).

Parameter definitions:
$4\gamma\phi''$: sensitivity of loan rate spread to bank capital ratio; a 1 percentage point increase in the bank capital ratio lowers the lending rate spread by $4\gamma\phi''$ percentage points (γ: steady-state bank capital requirement).
ξ'': curvature of investment cost function.
σ: coefficient of relative risk aversion.
σ^z, ρ^z: standard deviation of innovation to forcing variable "z," and autocorrelation of "z," with z representing the following (U.S./EA) variables—θ, θ^*: TFP; Ξ, Ξ^*: investment efficiency; G, G^*: government purchases; Ψ, Ψ^*: labor supply shock; Δ, Δ^*: loan loss; γ: required bank capital ratio.

The estimation uses quarterly time series on 12 time series: U.S. and EA GDP, consumption, investment, employment, and real loans; the U.S. commercial bank loan rate spread and the U.S. commercial bank capital ratio. The loan spread and the bank capital ratio are demeaned; other empirical variables are linearly detrended in log form. See Figure 2 for data plots and the Appendix for data sources. Sample period: 1990q1–2010q3 (83 periods).

short-run dynamics as a model with a constant subjective discount factor. (Impulse responses over the first 100 periods are very similar across model variants with $\varepsilon_\beta = 0$ and $\varepsilon_\beta = -0.001$.)

The sample mean (1990q1–2010q3) of the U.S. loan rate spread was 2.161% p.a.; I set the steady-state deposit rates in the model at 1.279% p.a., so that the steady-state loan spread matches the mean historical spread. The mean EA loan spread was 2.01% in 2003–10 (see above), which is close to the steady-state spread used in the calibration.

I set the steady-state actual and required bank capital ratios at $cr = \gamma = 11.17\%$, which corresponds to the average capital ratio of U.S. commercial banks during the sample period (from Flow of Funds data). The bank's Euler equations imply $R^D\beta = 1 - \Gamma + \phi'$ and $R^L\beta = 1 + \Gamma + (1-\gamma)\phi'$. Given R^D and R^L, these conditions pin down the bank's marginal operating cost Γ and the steady-state slope of the bank's penalty function, ϕ': $\Gamma = 0.25\%$, $\phi' = -0.28\%$. $cr = \gamma$ implies that steady-state excess bank capital is zero, $x = 0$, that is, $L^W(1-\gamma) = D^W$. (Setting $x \neq 0$ generates the same behavior, provided the calibration matches the same steady-state deposit and loan rates, as the baseline calibration with $x = 0$.) I set $L(1-\gamma) = D$ and $L^*(1-\gamma) = D^*$; that is, the steady-state ratio of deposits to loans is the same in both countries (consistent with the data). The mean ratios of outstanding U.S. and EA bank loans to annual domestic GDP were 53% and 87%, respectively, in 1990q1–2010q3. Thus, the U.S. has a noticeably lower loans/GDP ratio than the EA. I assume that the steady-state ratios of loans to annual GDP are 53% in country "Home," and 87% in "Foreign." Finally, I assume that both countries have the same steady-state GDP, normalized at unity: $Y = Y^* = 1$. These steady-state targets pin down the remaining preference parameters (weights of deposits in Home and Foreign workers' utility functions, Ψ^D, Ψ^{D*}, and steady-state marginal disutilities of labor, Ψ^N, Ψ^{N*}). In steady state, consumption by the Home [Foreign] worker and the entrepreneur represent, respectively, 58.2% and 4.8% [52.3% and 3.5%] of domestic GDP, and the banker's consumption is 0.21% of world GDP.

3. DATA PLOTS AND BUSINESS CYCLES

Figure 2 plots the (demeaned/detrended) 12 empirical quarterly time series (1990q1–2010q3) used in estimation. Macro aggregates comove closely across the U.S. and the EA—the synchronicity was especially high during the "Great Recession" of 2007q4–2009q2 (as dated by the NBER). (Shaded areas in figures indicate NBER recessions.) Relative to trend, U.S. output fell by 8.5%, during the recession, while EA output fell by 7.5%; U.S. consumption (–7.3%) and investment (–35.1%) fell more sharply than EA consumption (–4.0%) and investment (–15.9%). U.S. and EA bank lending grew strongly in the years before 2008, and then decreased sharply. The loan rate spread fell during the 3 years prior to the crisis, but rose sharply during the Great Recession. The empirical bank capital ratio exhibits relatively mild

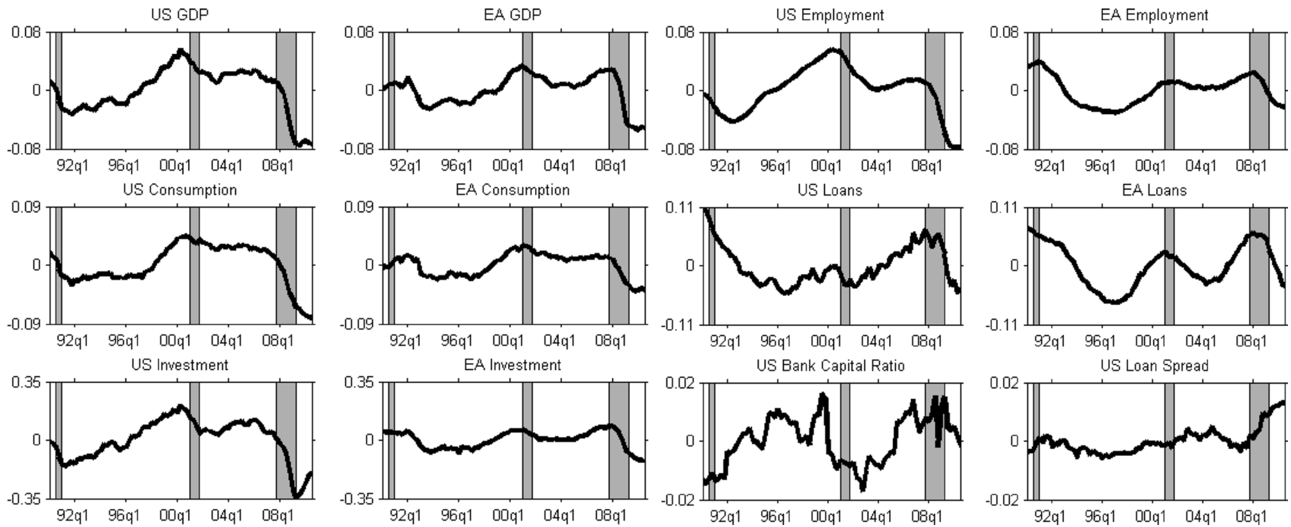

FIG. 2. Time Series Used in Estimation.

NOTE: The figure shows the U.S. and EA time series (1990q1–2010q3) used in estimation. “Loans” represent total credit by U.S. commercial banks and EA monetary financial institutions (MFI). The “U.S. Bank Capital Ratio” is the capital ratio of U.S. commercial banks. Bank capital ratio and loan spread (p.a.) are demeaned. Other variables are logged and detrended. Shaded areas indicate U.S. recessions (NBER dates).

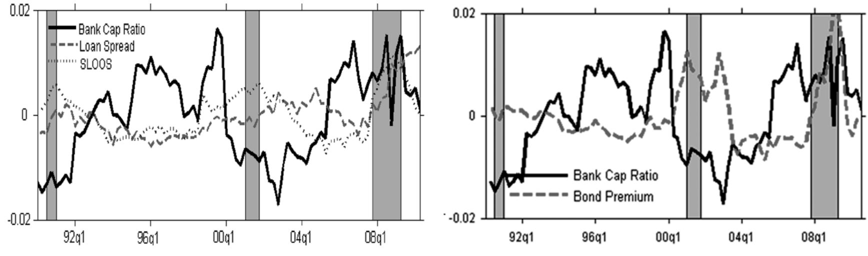

FIG. 3. U.S. Bank Capital, U.S. Loan Spreads, and U.S. Excess Bond Premium.

NOTE: In both panels, the solid line shows the demeaned U.S. bank capital ratio (1990q1–2010q3). The left-hand panel also plots the demeaned baseline U.S. loan spread p.a. (dashed line) and the demeaned net percentage of U.S. banks increasing spread, from Senior Loan Officers Opinion Survey (SLOOS) (dotted line). (The SLOOS series is scaled so that its standard deviation equals that of the baseline loan spread.) The right-hand panel plots the demeaned U.S. excess commercial bond premium (p.a.) of Gilchrist and Zakrajsek (2011a) (dashed line). Shaded areas: U.S. recessions (NBER dates).

fluctuations—throughout the sample period it stays in a ±2% range around the sample mean of 11.17%. Interestingly, the bank capital ratio has had a flat trend since about 2005. This pattern is in line with the finding of Kalemli-Ozcan, Sorensen, and Yesiltas (2012) (based on microlevel bank data for 68 countries) that there was no visible increase in commercial bank leverage, prior to the crisis; the authors argue that "excessive risk taking before the crisis was not easily detectable because the risk involved the quality rather than the quantity of assets" (p. 1). It has been argued that the stability of the observed capital ratio *during* the crisis may partly reflect accounting discretion, which has allowed banks to overstate the value of their assets in the crisis (Huizinga and Laeven 2009).

Figure 3 plots the bank capital ratio, together with the baseline loan spread series and two other spread measures that are used for robustness checks below (all series in Figure 3 are demeaned). Except for the period of the financial crisis, the bank capital ratio and the baseline loan rate spread comove negatively. The correlation between the bank capital ratio and the baseline lending spread was –0.46 during the period 1990–2007, and –0.06 over the whole sample period.

Figure 3 also plots the U.S. series "net percentage of banks increasing spreads of loan rates over cost of funds," from the FRB Senior Loan Officer Opinion Survey on Bank Lending Practices (SLOOS). (The series represents the percentage of banks increasing spreads minus the percentage of banks lowering spreads; the plotted series is scaled so that its standard deviation equals that of the baseline loan spread.) That series is positively correlated with the baseline loan spread (correlation: 0.39 for 1990–2010), and negatively correlated with the bank capital ratio (–0.47 for 1990–2007; –0.21 for 1990–2010). Also plotted in Figure 3 (see right-hand panel) is Gilchrist and Zakrajšek's (2011a) excess U.S. commercial bond premium, constructed by subtracting expected bond default probabilities from the spread between the yield on U.S. commercial bonds and the yield on U.S. Treasury bonds. As commercial banks are key players in the commercial bond market, the commercial bond premium might be informative about credit spreads/market conditions. (Gilchrist and Zakrajšek (2011a, p. 31) argue that "an increase in the excess bond premium reflects ... a contraction of the supply of credit with significant adverse consequences for the macroeconomy.") The excess bond premium, too, is negatively correlated with the bank capital ratio (correlation: –0.49 for 1990–2007; –0.15 for 1990–2010). The bond premium is positively correlated with the baseline loan rate spread (0.29) and with the SLOOS "net percentage of banks increasing spreads" (0.79).

Overall, the data are thus consistent with the model's key prediction that the spread is inversely related to the bank capital ratio (see (5)). The absence of a pronounced inverse relation during the crisis might be due to the fact that the measured bank capital ratio overstates the true capital ratio during the crisis (see discussion above), or that the *required* bank capital ratio rose during the crisis (this could rationalize the observed increase in the loan rate spread, during the crisis, without a fall in the bank capital ratio).

The last column of Table 2 reports moments of Hodrick–Prescott (HP) filtered quarterly macro and banking variables, for the U.S. and the EA (1990q1–2010q3). (The smoothing parameter is set at 1600.) The standard deviation of GDP is very similar in the U.S. (1.12%) and the EA (1.14%). Consumption is less volatile than GDP, while investment is markedly more volatile than GDP. U.S. investment is almost twice as volatile as EA investment. In both "countries," loans are more volatile than output and procyclical, while the loan spread is countercyclical. Real activity and loans are positively correlated across the U.S. and EA.

4. ESTIMATION RESULTS

4.1 Posterior Parameter Estimates

Columns (4) and (5) of Table 1 report the mean and standard deviation of the posterior parameter distribution, for the baseline model. (The posterior distribution was obtained using the Random Walk Metropolis algorithm; see An and Schorfheide 2007.)

The data are informative about the estimated parameters: in almost all cases, the posterior parameter distribution has lower standard deviation than the prior distribution; the posterior means often differ noticeably from the prior means (posterior means and modes are very close). The posterior mean of $4\gamma\phi''$ indicates that a 1 percentage point increase in the bank capital ratio leads to a 21 basis point reduction in the annualized loan rate spread, and that a 1 percentage point rise in the required bank capital ratio (γ_t) increases the loan rate spread by 19 basis points p.a.[10]

The posterior estimates indicate that EA loan loss shocks are roughly as volatile as U.S. loan loss shocks—the posterior means of the standard deviations of innovations to U.S. and EA loan losses (normalized by steady-state GDP) are 0.71% and 0.79%,

10. The posterior mean of the spread sensitivity $4\gamma\phi''$ is close to the prior mean. I experimented with smaller and larger prior means for that parameter—the posterior mean remains close to the posterior mean reported in Table 1, which indicates that the data are informative about $4\gamma\phi''$.

TABLE 2

BUSINESS CYCLE STATISTICS GENERATED BY TWO MODEL VARIANTS

	Model with $\phi'' > 0$, banking shocks									Model with $\phi'' = 0$, no banking shocks		
Shocks:	All (1)	NonBk (2)	Bnk (3)	TFP (4)	Invest. eff. (5)	G (6)	LabS (7)	Loan loss (8)	γ (9)	All (10)	NonBk (11)	Data (12)
Panel A. U.S. moments												
Standard deviations (in %)												
GDP	1.14	1.03	0.20	0.78	0.23	0.09	0.62	0.18	0.08	1.01	0.94	1.12
Consumption	0.93	0.72	0.07	0.57	0.14	0.04	0.40	0.07	0.03	0.79	0.69	0.92
Investment	4.58	3.38	1.13	1.07	3.11	0.12	0.80	1.04	0.43	5.52	2.70	5.08
Employment	1.13	1.02	0.28	0.41	0.29	0.12	0.88	0.26	0.11	0.96	0.89	1.15
Loans	1.73	1.03	1.10	0.20	0.99	0.07	0.16	1.10	0.08	1.20	0.76	1.88
Bank cap ratio	0.66	0.03	0.51	0.01	0.03	0.00	0.01	0.49	0.12	0.72	0.02	0.49
Loan spread	0.21	0.01	0.19	0.00	0.01	0.00	0.00	0.10	0.17	0.37	0.00	0.19
Correlations with domestic GDP												
Consumption	0.56	0.80	−0.57	0.89	−0.43	−0.99	0.85	−0.52	−0.84	0.72	0.88	0.89
Investment	0.31	0.40	0.99	0.87	0.38	−0.92	0.82	0.99	0.99	0.27	0.59	0.92
Employment	0.74	0.85	0.98	0.85	0.93	0.99	0.99	0.98	0.99	0.72	0.84	0.79
Loans	0.14	0.18	0.41	0.23	0.58	−0.03	0.17	0.42	0.76	0.13	0.23	0.48
Bank cap ratio	0.09	−0.21	0.73	−0.20	−0.59	0.06	−0.22	0.79	0.33	−0.01	−0.17	0.19
Loan spread	−0.11	0.22	−0.72	0.20	0.64	0.09	0.23	−0.79	−0.97	0.00	0.15	−0.52

(Continued)

TABLE 2

CONTINUED

Shocks:	Model with $\phi'' > 0$, banking shocks									Model with $\phi'' = 0$, no banking shocks		
	All (1)	NonBk (2)	Bnk (3)	TFP (4)	Invest. eff. (5)	G (6)	LabS (7)	Loan loss (8)	γ (9)	All (10)	NonBk (11)	Data (12)
Panel B. EA moments												
Standard deviations (in %)												
GDP	1.22	1.16	0.24	0.89	0.34	0.22	0.62	0.22	0.09	0.95	0.90	1.14
Consumption	0.73	0.66	0.11	0.55	0.17	0.10	0.30	0.10	0.03	0.69	0.63	0.77
Investment	2.47	2.02	1.17	1.11	1.55	0.12	0.67	1.09	0.43	2.33	2.20	2.87
Employment	1.22	1.13	0.34	0.46	0.46	0.31	0.87	0.32	0.11	0.80	0.77	0.70
Loans	1.10	0.36	0.93	0.06	0.35	0.01	0.07	0.93	0.07	2.78	0.37	2.08
Bank cap ratio	0.66	0.03	0.51	0.01	0.03	0.00	0.01	0.49	0.12	0.72	0.02	0.49
Loan spread	0.21	0.01	0.19	0.00	0.01	0.00	0.00	0.10	0.17	0.37	0.00	0.37
Correlations with domestic GDP												
Consumption	0.61	0.74	−0.80	0.95	−0.87	−0.99	0.90	−0.80	−0.84	0.74	0.87	0.83
Investment	0.51	0.53	0.99	0.97	−0.24	0.94	0.94	0.99	0.99	0.56	0.63	0.93
Employment	0.84	0.88	0.99	0.96	0.98	1.00	1.00	0.99	0.99	0.72	0.79	0.83
Loans	0.12	0.10	0.53	0.41	0.11	−0.12	0.18	0.55	0.83	0.03	0.21	0.62
Bank cap ratio	0.14	−0.15	0.75	−0.27	−0.19	0.46	−0.22	0.80	0.34	−0.12	−0.13	−0.01
Loan spread	−0.13	0.15	−0.69	0.23	0.29	−0.33	0.13	−0.80	−0.97	0.00	0.19	−0.91
Panel C. Cross-country correlations												
GDP	−0.26	−0.34	0.99	−0.39	0.28	0.87	−0.47	0.99	0.99	−0.16	−0.18	0.56
Consumption	0.24	0.34	0.43	0.28	0.81	0.94	0.39	0.38	0.99	0.11	0.14	0.39
Investment	−0.02	−0.23	1.00	0.26	−0.44	−0.90	0.40	1.00	0.99	−0.10	−0.22	0.45
Employment	−0.24	−0.36	0.99	−0.92	0.56	0.90	−0.47	0.99	0.99	−0.10	−0.12	0.53
Loans	0.10	−0.39	0.34	−0.04	−0.40	−0.46	−0.58	0.34	0.81	−0.03	−0.34	0.64
Loan spread	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.79

NOTES: Moments of HP filtered model variables (computed at the posterior mode of model parameters) are shown for two model variants.

Columns (1)–(9): baseline model with operative bank capital requirement ($\phi'' > 0$) and banking shocks. Column (1) ["All"] assumes all 11 joint shocks and measurement error. In columns (2)–(9), subsets of shocks used, *without* measurement error (model not reestimated). Column (2) ["NonBk"]: just eight "nonbanking" shocks; column (3) ["Bnk"]: just three banking shocks. Column (4) ["TFP"]: just U.S. and EA TFP shocks; column (5) ["Invest.eff"]: just investment efficiency shocks; column (6) ["G"]: just government purchases shocks; column (7) ["LabS"]: just labor supply shocks; column (8) ["Loan loss"]: just loan loss shocks; column (9) ["γ"]: just shocks to required bank capital ratio.

Columns (10) and (11): model variant without operative bank capital requirement ($\phi'' = 0$), no banking shocks. Column (10) ["All"]: all nonbanking shocks and measurement error; column (11) ["NonBk"]: just nonbanking shocks, no measurement error.

The bank capital ratio is expressed in factional units. The loan rate spread is in fractional units per annum. Other variables are normalized by steady-state values.

Column (12): empirical moments of HP filtered data (GDP, consumption, investment, employment, and loans are logged before filtering). Statistics for the EA bank capital ratio use the U.S. capital ratio as a proxy. Sample: 1990q1–2010q3 (EA loan spread: 2003q1–10q3).

respectively. The required bank capital ratio undergoes sizable fluctuations (posterior mean of std. of innovation to γ_t : 0.61%). The posterior means of the standard deviations of measurement errors are mostly smaller than the prior means (an exception is the measurement error for the bank capital ratio).

All model-predicted moments and other model properties discussed in what follows are computed at the posterior mode of the estimated parameters.

4.2 Business Cycle Moments Implied by Posterior Parameter Estimates

Columns (1)–(9) of Table 2 report model-predicted moments of HP filtered U.S. and EA variables. Column (1) [labeled "All"] assumes all 11 structural shocks, and measurement error. Columns (2)–(9) show moments generated by different subsets of the structural shocks, in isolation, without measurement error. Specifically, column (2) ["NonBk"] assumes just the eight nonbanking shocks, and column (3) ["Bnk"] assumes just the three exogenous banking shocks. Columns (4)–(9) assume just a single type of shock (column (4): just TFP shocks; column (5): just investment efficiency shocks; etc.).

The model with all shocks and measurement error generates predicted standard deviations that are mostly in the range of the empirical statistics. The predicted standard deviations of U.S. GDP (1.14%) and of EA GDP (1.22%) are close to the empirical standard deviations (1.12%, 1.14%); see columns (1) and (12). The model (with all shocks) captures the fact that investment is more volatile than GDP. The model also captures the high volatility of U.S. loans, but it underpredicts the volatility of EA loans. It matches the procyclical behavior of the macro aggregates, employment, and loans, and correctly predicts that the loan spread is countercyclical. However, the baseline model with all (independent) shocks predicts cross-country correlations of GDP (–0.26), investment (–0.02), and employment (–0.24) that are *negative*, and thus markedly below the empirical (positive) correlations. But note that the predicted cross-country consumption correlation (0.24) is positive, and thus much closer to the empirical correlation (0.39).[11]

Standard open economy macro models without banks (Backus, Kehoe, and Kydland 1992, Baxter and Crucini 1995, Kollmann 1996), too, generate cross-country correlations of output and investment that are lower than the empirical cross-country correlations, unless TFP (and other nonbank) shocks are highly correlated across countries—the same also holds for a variant of the present model without an operative bank capital requirement ($\phi'' = 0$). (A model variant with correlated shocks is discussed below.)

Taken in isolation, TFP shocks and labor supply shocks induce by far the largest fluctuations in real activity (predicted standard deviations of U.S. GDP with just these shocks: 0.78% and 0.62%, respectively). The predicted standard deviations of U.S.

11. In open-economy DSGE models, the predicted cross-country consumption correlation exceeds the cross-country output correlation, if internationally traded assets allow residents of different countries to share their consumption risk (Kollmann 1996, 2012a). Consumption would be perfectly correlated across countries if financial markets were complete.

GDP with just loan loss shocks (0.18%) and with just shocks to the required bank capital ratio (0.08%) are noticeably lower. With just TFP shocks, and just labor supply shocks, GDP is negatively correlated across countries. This is due to the fact that these shocks are negatively transmitted internationally—for example, a positive shock to Home TFP raises Home GDP, but lowers Foreign GDP; see below. By contrast, banking shocks induce fluctuations in output, investment and employment that are (almost) perfectly positively correlated across countries, in the estimated banking model. Nevertheless, the model with *all* simultaneous (independent) shocks cannot account for the high empirical *unconditional* cross-correlation of business cycles, as TFP shocks (and labor supply shocks) are the dominant source of output fluctuations, according to the model estimates. Notice also that banking shocks induce a strong negative correlation between the loan rate spread and GDP.

4.3 Variance Shares Accounted for by Banking Shocks

Panel A of Table 3 reports the percentage shares of the predicted variances of HP filtered endogenous variables (with measurement error) that are accounted for by the eight nonbanking shocks (see rows labeled "NonBk"), and by the three banking shocks (rows labeled "Bank"), respectively; the remainder represents the contribution of measurement error to the predicted variance.

According to the baseline model, the banking shocks account for a 3.1% share of U.S. GDP variance, but explain larger shares of the variances of U.S. investment: 6.1%; employment: 6.3%; loans: 41.0%. Banking shocks account for greater variance shares of EA variables—GDP: 4.0%; investment: 22.6%; employment: 7.8%; loans: 72.0%. Thus, roughly one-fifth of the variance of EA investment is due to banking shocks, according to the baseline model. The differences between EA and U.S. variance shares (explained by banking shocks) are highly statistically significant.[12] The greater role of banking shocks for EA real activity is due to the fact that (calibrated) steady-state loans/GDP and deposits/GDP ratios are higher in the EA than in the U.S.[13]

Note also that banking shocks account for 59.7% of the variance of the bank capital ratio, and for 84.7% of the variance of the loan rate spread (the bank capital ratio is mainly driven by U.S. and EA loan losses, while the loan rate spread is mostly driven by shocks to the required bank capital ratio).[14]

12. I randomly picked 10,000 of the parameter vectors generated by the Metropolis algorithm, and computed variance decompositions for each parameter draw; for more than 97.4% of the draws, the three joint banking shocks—and U.S. and EA loan losses individually—explain greater shares of the variances of EA GDP, investment, and employment than of the corresponding U.S. variables.

13. A given deposit rate change, due to a banking shock, has a greater effect on the EA worker's consumption and hours worked, than on the U.S. worker's decisions; thus, EA output and investment respond more.

14. Nonbanking shocks explain negligible shares of the variances of the bank capital ratio and the loan spread. Thus, a sizable share of the bank capital ratio variance (40.1%) is accounted for by measurement error.

TABLE 3

SHARE (%) OF VARIANCE OF HP FILTERED VARIABLES DUE TO NONBANKING SHOCKS AND TO BANKING SHOCKS

	GDP		Consumption		Investment		Employment		Loans			
	U.S. (1)	EA (2)	U.S. (3)	EA (4)	U.S. (5)	EA (6)	U.S. (7)	EA (8)	U.S. (9)	EA (10)	Bank cap. ratio (11)	Loan spread (12)
Panel A. Baseline model ($\phi'' > 0$, banking shocks) [$4\gamma\phi'' = 0.21$; LML=3,300.06]												
NonBk	82.40	90.56	59.75	81.71	54.70	67.23	82.19	87.21	35.70	10.84	0.23	0.11
Bank	3.08	3.99	0.59	2.21	6.06	22.62	6.28	7.81	41.04	72.01	59.68	84.67
Δ^{US}	0.69	0.98	0.37	0.10	1.43	5.40	1.50	1.89	37.88	0.71	20.21	8.59
Δ^{EA}	1.88	2.50	0.15	1.98	3.73	14.22	3.82	5.05	2.89	70.90	36.15	15.36
γ	0.50	0.50	0.07	0.13	0.89	2.99	0.95	0.87	0.26	0.38	3.31	60.71
Panel B. Model variant with correlated nonbanking shocks [$4\gamma\phi'' = 0.48$; LML=3,323.88]												
NonBk	85.70	75.11	81.56	80.21	51.96	34.90	71.48	66.83	40.48	7.00	0.30	10.40
Bank	5.54	14.21	1.04	3.14	10.60	52.99	14.12	24.77	27.27	75.79	12.23	84.80
Panel C. Model variant with constant required bank capital ratio, $\gamma_t = \gamma$ [$4\gamma\phi'' = 0.69$; LML=3,229.48]												
NonBk	78.57	87.09	58.21	82.75	46.36	58.24	76.30	81.03	34.75	11.97	0.08	0.45
Bank	5.87	6.98	0.84	2.52	8.83	32.79	11.91	13.75	34.87	63.89	16.94	85.72
Panel D. Estimates of baseline model based on alternative loan rate spread and bank loans data												
D1. Loan spread replaced by loan officer survey (SLOOS) spread measure [$4\gamma\phi'' = 0.21$; LML=3,275.21]												
NonBk	81.26	90.16	62.14	80.49	54.78	69.82	81.38	86.55	35.00	12.45	0.27	0.09
Bank	3.45	4.37	0.72	2.40	6.19	21.11	6.98	8.48	42.38	70.02	65.14	90.17

(Continued)

TABLE 3

CONTINUED

	GDP		Consumption		Investment		Employment		Loans		Bank cap. ratio	Loan spread
	U.S. (1)	EA (2)	U.S. (3)	EA (4)	U.S. (5)	EA (6)	U.S. (7)	EA (8)	U.S. (9)	EA (10)	(11)	(12)
D2. Loan spread replaced by Gilchrist–Zakrajsek excess bond premium [$4\gamma\phi'' = 0.30$; LML=3,239.21]												
NonBk	80.57	88.93	61.59	80.56	52.92	64.09	79.46	84.17	34.06	11.87	0.25	0.07
Bank	4.72	5.74	0.89	2.76	8.43	27.02	9.32	11.04	43.26	71.09	66.57	91.85
D3. Total bank loans replaced by business loans [$4\gamma\phi'' = 0.18$; LML=3,080.35]												
NonBk	71.98	88.15	62.13	80.98	30.52	77.89	81.37	85.89	2.42	1.05	0.30	0.07
Bank	1.62	2.62	0.41	0.62	2.56	12.14	4.21	6.34	3.72	2.26	62.71	82.09
D4. U.S. business lending capacity; EA business loans [$4\gamma\phi'' = 0.10$; LML=3,090.46]												
NonBk	84.99	91.03	50.02	82.70	48.72	61.36	84.23	87.32	12.09	4.64	0.01	0.02
Bank	2.65	3.82	0.87	2.73	9.59	27.60	5.26	7.82	70.16	78.63	12.23	81.12

NOTE: This table reports shares of the variances of endogenous variables (HP-filtered) that are accounted for by different types of shocks (variance shares are computed at the posterior mode of the estimated parameters).
Panel A: Baseline banking model ($\phi'' > 0$,banking shocks).
Panel B: Model variant with correlated nonbanking shocks (Kollmann 2012b).
Panel C: Model variant with constant required bank capital ratio.
Panel D: Estimates of the baseline model based on alternative measures of spreads and loans. D1: Baseline loan rate spread replaced by "net percentage of banks increasing spreads of loan rates over cost of funds" from the U.S. Senior Loan Officer Opinion Survey. D2: Baseline loan rate spread replaced by the Gilchrist and Zakrajsek (2011a) excess bond premium series. D3: Baseline U.S. and EA loan series replaced by loans to the nonfinancial business sector. D4: Baseline U.S. loan series replaced by U.S. "business lending capacity" measure of Gilchrist and Zakrajsek (2011b); baseline EA loan series replaced by EA bank lending to the nonfinancial business sector.
Rows labeled "NonBk" show variance shares accounted for by the eight "nonbanking" shocks.
Rows labeled "Bank": variances shares accounted by the three banking shocks.
Rows labeled "Δ^{US}," "Δ^{EA}," and "γ": variance shares accounted for by shocks to U.S. loan losses, to EA loan losses, and to the required bank capital ratio, respectively.
Variance shares are shown for variables listed above columns (1)–(12): U.S. and EA GDP (columns (1) and (2)); consumption (columns (3) and (4)); investment (columns (5) and (6)); employment (columns (7) and (8)); loans (columns (9) and (10)); bank capital ratio (column (11)); loan spread (column (12)).
$4\gamma\phi''$: a 1 percentage point increase in the bank capital ratio lowers the lending rate spread by $4\gamma\phi''$ percentage points per annum.
LML: log marginal likelihood.

Table 3 shows furthermore that loan loss shocks are more important drivers of *real activity* than shocks to the required bank capital ratio; the latter explain merely 0.5% of the variances of U.S. and EA GDP (see rows labeled "Δ^{US}", "Δ^{EA}", and "γ" in Panel A). Interestingly, U.S. loan losses account for a greater share of the variance of EA GDP, investment, and employment than of the variances of the corresponding U.S. variables. This finding is in line with Helbling et al. (2011) who argue, based on vector autoregressions, that U.S. credit supply shocks account for a greater share of fluctuations in global real activity than of U.S. real activity.[15]

A robustness analysis below confirms the findings discussed in this section.[16]

4.4 Impulse Responses

Impulse responses (reported in Table 4) help to understand the model's mechanics, and the predicted business cycle moments. Each impulse response focuses on an isolated innovation, assuming that all other exogenous innovations are zero. (To save space, Table 4 does not show responses to EA "nonbanking" shocks—those responses are qualitatively similar to the responses to U.S. "nonbanking" shocks.)

A positive innovation to Home TFP raises Home GDP and investment, but leads to a fall in Foreign GDP. The shock raises the income of the Home worker; thus, that worker saves more, and her holdings of bank deposits increase—that is, the bank's debt rises, which lowers the bank capital ratio. The deposit rate falls (due to the greater supply of deposits), and so does the loan rate—however, the loan rate spread rises. The Foreign worker responds to the fall in the deposit rate by consuming more, and working less, and hence Foreign GDP falls. (Foreign investment rises slightly, due to the fall in the loan rate.) Country-specific labor supply shocks likewise drive Home and Foreign GDP in opposite directions.

By contrast, global banking is a powerful international transmission channel for *financial shocks*. Loan losses and shocks to the required bank capital ratio induce sizable *common* responses of Home and Foreign real activity (and loans). For example, a loan loss in one country lowers the global bank's capital ratio, which triggers a rise in the loan rate spread—the deposit rate falls, while the loan rate rises. In response to this, loans, investment, and GDP fall in *both* countries. A rise in the required capital ratio (γ_t) likewise raises the loan rate spread; on impact, this also lowers loans, investment, and real activity in *both* countries. Note also that banking shocks drive the loan spread and output in opposite directions. According to the baseline model, an unanticipated U.S. loan loss worth 1% of steady state quarterly U.S. GDP reduces the

15. 5. See Eickmeier and Ng (2012) for related VAR evidence on the international transmission of credit supply shifts.

16. Nolan and Thoenissen (2009) and Jermann and Quadrini (2012) use closed economy models with collateral-constrained *firms* (no banks) to estimate shocks to firms' funding, and argue that those shocks explain up to half of U.S. GDP variance. In the model here, only the bank faces a capital requirement. The estimates here suggest a more important role for banking shocks than illustrative calibrations in Kollmann, Enders, and Müller (2011), according to which banking shocks account for less than 0.2% of the variance of real activity. This greater role is due to the fact that the *estimated* sensitivity of the loan spread to bank capital here, and the *estimated* variance of loan losses, are larger than in those calibrations.

bank capital ratio by 14.9 basis points, on impact, and it lowers U.S. and EA quarterly GDP by, respectively, 0.10% and 0.12%, on impact. An unanticipated EA loan loss of the same size lowers U.S. and EA GDP by 0.14% and 0.18%, respectively. Thus, EA GDP is more sensitive to domestic and foreign loss shock than U.S. GDP. A U.S. loan loss lowers EA GDP more than U.S. GDP. An unanticipated increase in the required bank capital ratio by 1 percentage point lowers U.S. *and* EA GDP by 0.10% and 0.11%, respectively, on impact.[17]

4.5 Decomposing Historical Time Series

Figure 4 plots the estimated contributions of the banking shocks and of U.S. and EA nonbanking shocks to the historical time series. Thick continuous lines show the historical data; the thin continuous lines indicate the contribution of banking shocks, while the dashed–dotted and dashed lines represent the contributions of U.S. and EA nonbanking shocks, respectively. The historical decomposition yields a picture that is consistent with the variance decompositions. Fluctuations in the bank capital ratio and in the loan rate spread were mainly driven by banking shocks. Banking shocks matter more for EA GDP than for U.S. GDP. During the "Great Recession" of 2007q4–2009q2, banking shocks account for a 1.0 percentage point [1.2 ppt.] fall in U.S. [EA] GDP—that is, the banking shocks capture 12% [16%] of the 8.5 ppt. [7.5 ppt.] fall in U.S. [EA] GDP, relative to trend. Banking shocks also capture 15% [35%] of the fall in U.S. [EA] investment, and 19% [56%] of the fall in U.S. [EA] employment, during the recession. Thus, more than one-third of the fall in EA investment and employment is accounted for by the banking shocks.

In the previous U.S. recession (2001q1–2001q4), banking shocks accounted for 11% of the fall in U.S. output and investment, and for 21% [29%] of the fall in EA output [investment]. During the 1990q3–1991q1 U.S. recession, banking shocks accounted for 6%, 10%, and 16%, respectively, of the fall in U.S. GDP, investment, and employment (the EA did not experience a recession in 1990–91).

Figure 4 shows that the output components accounted for by the *domestic* nonbanking shocks track historical U.S. and EA GDP very closely. This result parallels the finding by de Walque, Smets, and Wouters (2005) and Le et al. (2010) that *domestic* macro shocks are the main drivers of U.S. and EA GDP. Foreign nonbanking shocks had a *stabilizing* effect on domestic real activity; for example, during the 2007–09 recession, EA nonbanking shocks had a positive influence on U.S. GDP, and thus mitigated the U.S. recession. This reflects the fact that, in the model here, TFP shocks and labor supply shocks are *negatively* transmitted internationally (see above).

17. The (almost) perfect international synchronization of responses to banking shocks reflects the assumption that loan and deposit rates are equated across countries (due to competitive banking)—national segmentation of banking markets would lower the international synchronization of responses to banking shocks. Analysis of models with (partially) segmented banking markets is left for future research.

TABLE 4

Baseline Model ($\phi'' > 0$, Banking Shocks): Dynamic Responses to Innovations

Horizon	GDP		Consumption		Investment		Employment		Loans		Bank cap. ratio	Loan spread
	U.S. (1)	EA (2)	U.S. (3)	EA (4)	U.S. (5)	EA (6)	U.S. (7)	EA (8)	U.S. (9)	EA (10)	(11)	(12)
Panel A. U.S. TFP shock (1%)												
0	1.36	−0.21	1.01	0.10	1.88	0.11	0.50	−0.29	0.04	0.03	−0.36	0.06
4	1.20	−0.16	0.99	0.09	1.46	0.15	0.36	−0.23	0.10	0.11	−1.36	0.28
20	0.93	−0.07	0.93	0.06	0.88	0.20	0.16	−0.11	0.06	0.26	−2.01	0.41
Panel B. U.S. investment efficiency shock (1%)												
0	0.10	0.28	−0.07	−0.14	2.74	−0.48	0.14	0.39	0.27	−0.06	−0.77	0.23
4	0.13	0.02	0.04	−0.04	0.93	−0.22	0.09	0.05	0.92	−0.08	−2.07	0.46
20	0.05	−0.05	0.07	0.00	−0.21	0.02	−0.01	−0.06	0.83	−0.01	−0.41	0.09
Panel C. U.S. government purchases shock (1%)												
0	0.05	0.04	−0.03	−0.02	−0.04	−0.06	0.07	0.05	−0.01	−0.01	0.08	0.00
4	0.01	−0.00	−0.01	−0.00	0.01	−0.01	0.01	−0.00	0.00	0.00	0.13	−0.03
20	0.00	−0.00	−0.00	−0.00	0.00	−0.00	0.00	−0.00	0.00	0.01	0.05	−0.01
Panel D. U.S. labor supply shock (1%)												
0	−1.02	0.20	−0.67	−0.10	−1.34	−0.15	−1.44	0.28	−0.01	−0.03	0.27	−0.04
4	−0.85	0.14	−0.65	−0.08	−0.96	−0.17	−1.16	0.20	−0.01	−0.11	1.02	−0.20
20	−0.40	−0.02	−0.49	−0.03	−0.25	−0.17	−0.46	0.00	0.25	−0.33	1.23	−0.25

(*Continued*)

TABLE 4

CONTINUED

	GDP		Consumption		Investment		Employment		Loans			
Horizon	U.S. (1)	EA (2)	U.S. (3)	EA (4)	U.S. (5)	EA (6)	U.S. (7)	EA (8)	U.S. (9)	EA (10)	Bank cap. ratio (11)	Loan spread (12)
Panel E. U.S. loan loss shock (1% of steady state quarterly GDP)												
0	−0.10	−0.12	0.06	0.01	−0.57	−0.60	−0.14	−0.17	−0.51	−0.03	−14.96	3.17
4	−0.09	−0.12	0.04	−0.01	−0.50	−0.52	−0.12	−0.15	−1.53	−0.12	−37.15	7.88
20	−0.03	−0.05	0.00	−0.06	−0.09	−0.09	−0.00	−0.02	−2.01	−0.16	−21.14	4.48
Panel F. EA loan loss shock (1% of steady state quarterly GDP)												
0	−0.14	−0.18	0.01	0.10	−0.81	−0.86	−0.20	−0.25	−0.07	−0.32	−14.49	3.07
4	−0.15	−0.18	−0.02	0.07	−0.77	−0.80	−0.18	−0.23	−0.34	−1.16	−45.27	9.60
20	−0.07	−0.08	−0.08	−0.00	−0.20	−0.19	−0.02	−0.04	−0.77	−1.85	−37.23	7.90
Panel G. Shock to required bank capital ratio (1 percentage point)												
0	−0.10	−0.11	0.03	0.03	−0.54	−0.53	−0.14	−0.14	−0.05	−0.03	0.13	22.33
4	−0.02	−0.03	−0.01	−0.01	−0.10	−0.09	−0.02	−0.02	−0.01	0.04	15.40	10.62
20	0.04	0.05	0.00	−0.00	0.18	0.19	0.04	0.06	0.28	0.25	19.81	−2.13

NOTE: The table shows dynamic responses to exogenous shocks, after 0, 4, and 20 quarters (see left-most column labeled "Horizon"), of the variables listed at the top of the table. The responses are computed at the posterior modes of the estimated parameters. In each case, an isolated innovation is considered, assuming that all other exogenous innovations are zero. Panel A: 1% innovation to U.S. TFP (θ); Panel B: 1% innovation to U.S. investment efficiency (Ξ); Panel C: 1% innovation to U.S. government purchases (G); Panel D: 1% innovation to U.S. labor supply preference parameter (Ψ^N); Panel E: innovation to U.S. loan loss (Δ) worth 1% of steady state quarterly GDP; Panel F: innovation to EA loan loss (Δ^*) worth 1% of steady-state quarterly GDP; Panel G: innovation that raises required bank capital ratio (γ) by 1 percentage point.
Columns (1) and (2): Responses of U.S. and EA GDP; columns (3) and (4): U.S. and EA consumption; columns (5) and (6): U.S. and EA investment; columns (7) and (8): U.S. and EA employment; columns (9) and (10): U.S. and EA loans; column (11): bank capital ratio; column (12): loan rate spread. Responses of the bank capital ratio are in basis points. Responses of the loan spread are in basis points per annum. Other responses are in percentage points of steady-state values.

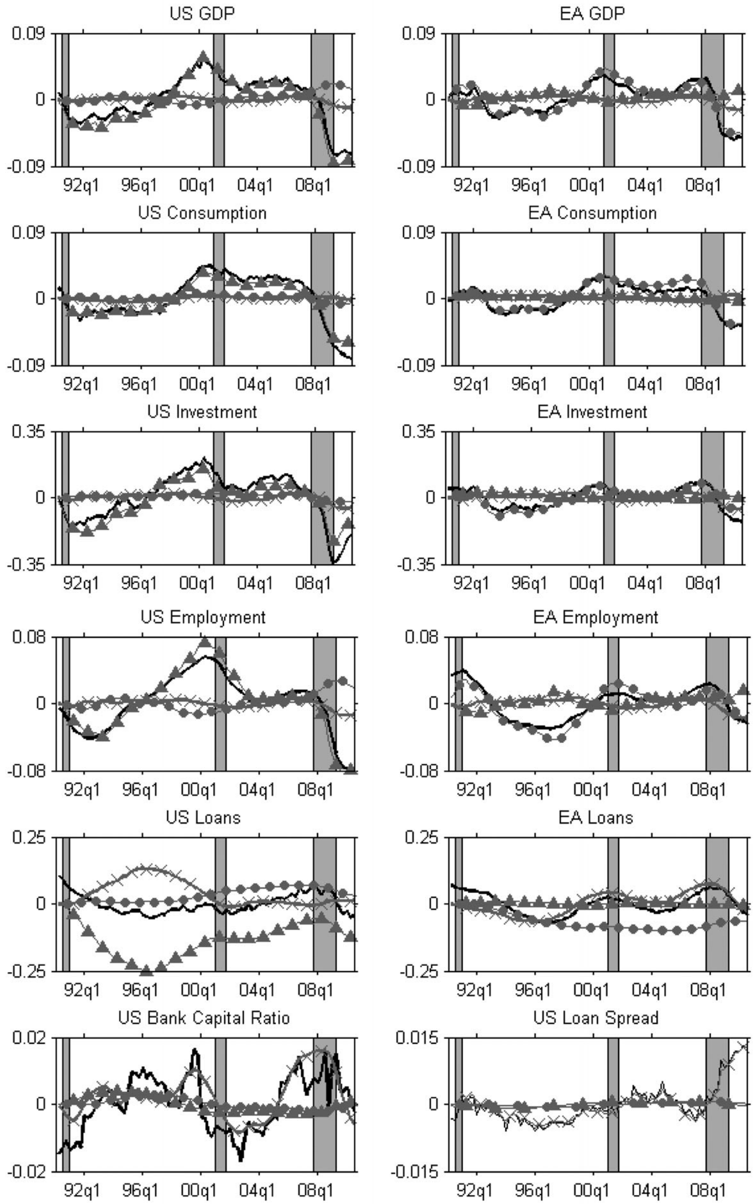

FIG. 4. Historical Decompositions, Baseline Model ($\phi'' > 0$, Banking Shocks).

NOTE: ▬ historical data; –×– : contribution of banking shocks; –▲–: contribution of U.S. nonbanking shocks; –●– : contribution of EA nonbanking shocks. Using the baseline model (at posterior mode of estimated parameters), the figure shows the historical contributions of banking shocks (thin black lines with crosses: –×–), U.S. nonbanking shocks (thin gray lines with triangles: –▲–), and EA nonbanking shocks (thin gray lines with circles: –●–) to historical series, 1990q2–2010q3 (thick black lines: ▬). The historical bank capital ratio and loan rate spread series (p.a.) are demeaned, the other historical series are linearly detrended in log form. Shaded areas: U.S. recessions (NBER dates).

4.6 The Role of the Bank Capital Requirement and of Banking Shocks

The presence of an operative bank capital requirement $\phi'' > 0$ is key for the transmission of banking shocks to domestic and foreign real activity. Banking shocks have a negligible effect on real activity, but remain important drivers of loans and the bank capital ratio, when $\phi'' = 0$. (An estimated model variant with $\phi'' = 0$ predicts that banking shocks explain merely 0.002% of the variance of HP filtered GDP and investment, but between one-third and two-thirds of the variances of loans and the bank capital ratio.)

Columns (6) and (7) of Table 1 report posterior parameter estimates for a model variant *without* an operative bank capital requirement ($\phi'' = 0$),and *without* banking shocks. (The priors for the remaining (nonbanking) parameters are the same as in the baseline model; the posterior estimates of most parameters are similar to the estimates in the baseline model.) That model variant resembles standard International RBC models with incomplete financial markets in which just an unconditional bond can be traded internationally (see, e.g., Baxter and Crucini 1995, Kollmann 1996). Columns (10) and (11) of Table 2 report the implied business cycle moments.

Table 2 shows that the baseline banking model (*with* $\phi'' > 0$ and banking shocks) generates business cycles moments that are mostly closer to the empirical moments than the moments predicted by the variant *without* the operative bank capital requirement (and no banking shocks); see columns (1) and (10) of Table 2. (Of the 32 moments considered in the table, 21 are more closely matched by the baseline model.)

For example, predicted standard deviations of U.S. and EA GDP in the baseline model (1.14% and 1.22%, respectively) are larger than in the structure without the operative bank capital requirement (1.01%, 0.95%), and closer to the empirical standard deviations (1.12%, 1.14%). Note that the model variant with $\phi'' = 0$ also generates predicted cross-country correlations of GDP (–0.16), investment (–0.10), and employment (–0.10) that are markedly below the empirical cross-country correlations (like the baseline structure).[18]

Model fit can be evaluated using the marginal likelihood (that statistic measures the out-of-sample predictive ability of the model; see Geweke 2001). The log marginal likelihood (LML) of the baseline model is 3,300.06, while the LML of the model variant without the operative bank capital requirement and without banking shocks is

18. Surprisingly, predicted cross-country correlations of GDP and employment with $\phi'' = 0$ are slightly higher than in the baseline model ($\phi'' > 0$). This is i.a. due to the fact that *estimated* standard deviations of TFP shocks (inducing negative cross-country GDP correlations) are slightly lower in the $\phi'' = 0$ model variant. Setting $\phi'' = 0$ and eliminating banking shocks, while holding *constant* all other parameters at estimates for the baseline model, *lowers* predicted cross-country correlations of GDP, investment, and employment to –0.30, –0.14, and –0.32, respectively (compared to –0.26, –0.02, –0.24, in the baseline model). Similarly, when nonbanking parameters are held fixed at estimated values from the model variant with $\phi'' = 0$ (and no banking shocks), then setting $\phi'' > 0$ and introducing banking shocks *raises* the cross-country correlations.

3,104.02.[19] This implies a Bayes factor (ratio of posterior odds to prior odds) of $e^{196.04}$ that massively favors the baseline model. The model variant *with* an operative bank capital requirement, but *without* banking shocks has an LML of 3,105.36; a model variant *without* an operative bank capital requirement but *with* banking shocks has an LML of 3,212.29. This suggests that both the operative bank capital requirement *and* the banking shocks help the model capture the joint dynamics of the macro and banking variables used in estimation. The presence of these model ingredients also helps to better explain the eight U.S. and EA *macro* variables used in estimation. For these eight macro variables, the baseline model has an LML of 2,041.23, while the model variant without an operative bank capital requirement and without banking shocks has an LML of 2,036.88.

4.7 Robustness Checks

The key findings about the role of the bank capital requirement and of banking shocks continue to hold in model variants with *correlated* shocks, and they are also robust to using alternative measures of banking variables.

The working paper version of this paper (Kollmann 2012b) estimates a variant of the banking model ($\phi'' > 0$) in which the covariance matrix of the eight *nonbanking shocks* is set equal to the sample covariance matrix of empirical measures of U.S. and EA nonbanking shocks.[20] The empirical cross-country correlations of TFP (0.51) and investment efficiency (0.84) are sizable. The model variant with correlated nonbanking shocks generates positive cross-country correlations of output (0.45) and investment (0.31) that are close to empirical correlations, but the predicted cross-country consumption correlation (0.75) exceeds the empirical correlation. Panel B of Table 3 reports variance decompositions, for the correlated-shocks model variant. In that variant, the banking shocks account for slightly higher variance shares of real activity than in the baseline model, namely, for 5.5% [14.2%] of the variance of U.S. [EA] GDP, and 10.6% [53%] of the variance of U.S. [EA] investment.

Panel C of Table 3 reports variance shares for a variant of the banking model (independent shocks), in which the required bank capital ratio is constant, $\gamma_t = \gamma$, so that loan losses are the only banking shocks. In that variant too, banking shocks explain somewhat greater shares of the variance of real activity than in the baseline model.

As a further robustness check, I reestimated the baseline model using other empirical measures of the loan rate spread and of bank loans. Panel D of Table 3 reports the resulting variance shares accounted for by banking shocks. Those variance shares are

19. The LMLs reported here were computed using a Laplace approximation. Geweke's (1999) harmonic mean estimator, based on parameter draws from the Metropolis algorithm, yields very similar LMLs.

20. That variant also assumes that loan losses and the required capital ratio are partly endogenous, as these variables are modeled as linear functions of *GDP*, and of exogenous disturbances that are independent of the nonbanking shocks. The variance shares explained by banking shocks discussed below pertain to the exogenous disturbances. The (partial) endogeneity of loan losses and of the required capital ratio does not affect the key estimation results (the estimated feedback to GDP is weak).

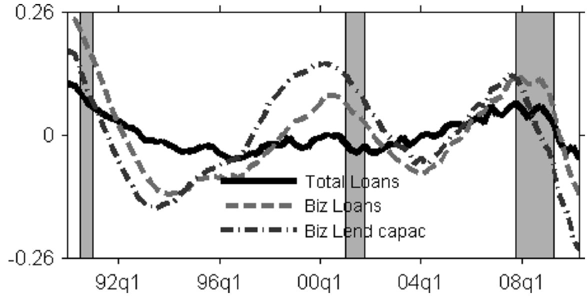

FIG. 5. U.S. Commercial Banks: Total Loans, Business Loans, and Business Lending Capacity.

NOTE: The solid line shows total U.S. bank credit (baseline measure); dashed line: business lending; dashed–dotted line: U.S. business lending capacity (Gilchrist and Zakrajsek 2011b). All series are linearly detrended in log form. Sample period: 1990q1–2010q3. Shaded areas: U.S. recessions (NBER dates).

broadly in the same range as the baseline shares discussed above (Panel A). (Posterior parameter estimates obtained from the alternative data sets are in the same range as the baseline estimates, and are thus not reported.)

In Panel D1 of Table 3, the baseline loan rate spread is replaced by the series "net percentage of banks increasing spreads of loan rates over cost of funds" from the Senior Loan Officer Opinion Survey (SLOOS), while Panel D2 uses the Gilchrist–Zakrajšek (2011a) excess bond premium series in lieu of the baseline loan rate spread. The importance of banking shocks in explaining real activity fluctuations rises somewhat when those alternative spread measures are used to estimate the model. (The same result holds when the SLOOS series "*net percentage of banks tightening lending standards*" is used instead of the baseline lending spread.) For example, when the Gilchrist–Zakrajšek excess bond premium is used, about 5% of the variance of U.S. and EA GDP is attributed to banking shocks.[21]

In Panel D3 of Table 3, U.S. and total bank credit are replaced by bank loans to the *nonfinancial business sector*. Panel D4 replaces total U.S. bank credit by Gilchrist and Zakrajšek's (2011b) measure of U.S. "*business lending capacity*" (sum of loans outstanding and of unused credit lines), while EA total credit is replaced by bank loans to the nonfinancial business sector. The motivation for using the U.S. lending capacity measure is that many U.S. business loans are offered under prior commitment (credit lines); Gilchrist and Zakrajšek (2011b) argue that "lending capacity" is, hence, more informative than loans outstanding for identifying loan supply shifts (no comparable measure exists for the EA). Figures 5 and 6 plot the business loans, and loan capacity, series. Business loans are highly positively correlated with total loans, but more volatile, especially in the U.S. U.S. lending capacity fell earlier

21. The empirical lending rate spread may be affected by factors that are not captured by the model, such as liquidity tensions and banking competition. The fact that the SLOOS index and the Gilchrist–Zakrajšek bond premium explain a slightly greater share of the variance of real activity might indicate that these spread measures capture better those other determinants of credit supply.

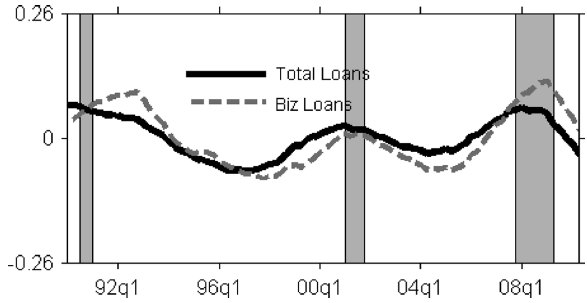

FIG. 6. EA Banks: Total Loans and Business Loans.

NOTE: The solid line shows total EA bank credit (baseline measure); dashed line: loans to nonfinancial corporations. Both series are linearly detrended in log form. Sample period: 1990q1–2010q3. Shaded areas: U.S. recessions (NBER dates).

and much more sharply than total lending, during the 2007–09 recession. Panels D3 and D4 of Table 3 show that the business lending measure yields smaller variance shares due to banking shocks than the baseline total bank credit measure, while the U.S. lending capacity measure yields roughly similar variance shares as the baseline measure.[22]

Table 3 suggests that banking shocks account for about 2%–5% of the unconditional variance of GDP and for 3%–14% of the variance of EA GDP. The variance shares of employment and (especially) of investment accounted for by banking shocks are higher; in most specifications, these shocks explain more than 20% of the variance of EA investment.

5. CONCLUSION

This paper has estimated a two-country model with a global banking system, using U.S. and EA data (1990q1–2010q3), and Bayesian methods. The estimated model matches key U.S. and EA business cycle statistics. Empirically, a model version with an operative bank capital requirement outperforms a structure without such a constraint. Banking shocks account for a nonnegligible share of the unconditional variance of real activity. EA real activity depends more on banking shocks than U.S. real activity. U.S. loan losses account for a greater share of the variance of EA real activity than of the variance of U.S. real activity. During the Great Recession (2007–09), banking shocks explained about 15% of the fall in U.S. and EA GDP, and more than a third of the fall in EA investment and employment.

22. I also estimated the model using alternative measures of the U.S. bank capital ratio, namely, the ratios of Tier 1 capital, and of Tier 1+2 capital, to *risk-weighted* bank assets (Federal Reserve Bank of New York, 2013). The key estimation results are robust to using those measures.

APPENDIX: DATA

A.1 Baseline Data Set Used for Estimation

(1) U.S. GDP, private consumption (total), investment (all at constant prices): from U.S. National Income and Product Accounts (Bureau of Economic Analysis, BEA); the investment series include private and government investment.
(2) U.S. employment: "Total nonfarm payrolls: all employees" (Bureau of Labor Statistics).
(3) U.S. bank loans: outstanding "total bank credit" by commercial banks (Flow of Funds, Table L109), deflated using GDP deflator.
(4) U.S. bank capital ratio: (total financial assets − total liabilities)/(total financial assets) for commercial banks (Flow of Funds, Table L109). The raw capital ratio series has a permanent level shift in 2000q1 (mean ratio in 1990–99: 3.7%; mean in 2000–10: 11.2%). To correct for the break, I regressed the capital ratio on a constant and a dummy that equals 1 for dates before 2000q1; I then adjusted the raw ratio before 2000q1 for the dummy coefficient. A break correction based on a regression that also includes a linear time trend (and the product of the trend and the dummy) gives similar results.
(5) U.S. loan rate spread: "Commercial and industrial loan rates spread over intended federal funds rate" ("All loans" series, Survey of Terms of Business Lending, Table E.2, FRB).
(6) EA GDP, private consumption (total), investment (all at constant prices): from ECB Area-Wide Model (AWM) database (10th update, September 2010).
(7) EA employment: from AWM database.
(8) EA bank loans: MFI loans to private sector (from ECB monthly bulletin), deflated using the GDP deflator.

A.2 Variables Used for Estimation of Model Variants

(1) Excess bond premium: spread between the yield on U.S. commercial bonds and the yield on Treasury bonds, minus expected bond default probabilities, as constructed by Gilchrist and Zakrajšek (2011a) using data for a panel of individual bonds.
(2) "Net percentage of banks increasing spreads of loan rates over cost of funds": percentage of banks increasing spreads minus the percentage of banks lowering spreads, from the SLOOS (FRB). The SLOOS reports a series (net percentages of banks raising spreads) for loans to "large and middle-market firms" and one for loans to "small firms." The two series are very similar (correlation: 0.95). I use the average of the two series.
(3) U.S. business loans: outstanding commercial bank loans to the nonfinancial business sector, constructed by Gilchrist and Zakrajšek (2011b).
(4) EA business loans: MFI loans to nonfinancial corporations (NFC), from ECB monthly bulletin, deflated using the GDP deflator.

(5) U.S. business lending capacity: outstanding commercial bank loans plus unused commercial bank lending commitments (credit lines) to the nonfinancial business sector, constructed by Gilchrist and Zakrajšek (2011b).

A.3 Other Variables (Used for Model Calibration)

(1) "Autonomous spending" (G): government purchases plus net exports to third countries (deflated using GDP deflator). Data sources: AWM, BEA, and ECB monthly bulletin.

All series are quarterly and seasonally adjusted (when relevant).

LITERATURE CITED

Adolfson, Malin, Stefan Laséen, Jesper Lindé, and Mattias Villani. (2007) "Bayesian Estimation of an Open Economy DSGE Model with Incomplete Pass-Through." *Journal of International Economics*, 72, 481–511.

Aikman, Daniel, and Matthias Paustian. (2006) "Bank Capital, Asset Prices and Monetary Policy." Working Paper No. 305, Bank of England.

An, Sungbae, and Frank Schorfheide. (2007) "Bayesian Analysis for DSGE Models." *Econometric Reviews*, 26, 113–72.

Andreasen, Martin, Jens Sondergaard, and Matthias Paustian. (2010) "Portfolio Linkages, Financial Shocks and International Business Cycles." Working Paper, Bank of England.

Backus, David, Patrick Kehoe, and Finn Kydland. (1992) "International Real Business Cycles." *Journal of Political Economy*, 100, 745–75.

Baxter, Marianne, and Mario Crucini. (1995) "Business Cycles and the Asset Structure of Foreign Trade." *International Economic Review*, 36, 821–54.

Benes, Jaromir, and Michael Kumhof. (2011) "Risky Bank Lending and Optimal Capital Adequacy Regulation." IMF Working Paper 11/130.

Boivin, Jean, and Marc Giannoni. (2006) "DSGE Models in a Data Rich Environment." NBER Working Paper No. 12772

Brunnermeier, Markus. (2009) "Deciphering the Liquidity and Credit Crunch 2007–2008." *Journal of Economic Perspectives*, 23, 77–100.

Brunnermeier, Markus, and Yuliy Sannikov. (2010) "A Macroeconomic Model with a Financial Sector." Working Paper, Princeton University.

Brzoza-Brzezina, Michal, Marcin Kolasa, and Krzysztof Makarski. (2013) "Macroprudential Policy and Imbalances in the Euro Area." Working Paper, National Bank of Poland.

Canova, Fabio. (2007) *Methods for Applied Macroeconomic Research*. Princeton, NJ: Princeton University Press.

Christiano, Lawrence, Martin Eichenbaum, and Charles Evans. (2005) "Nominal Rigidities and the Dynamic Effects of a Shock to Monetary Policy." *Journal of Political Economy*, 113, 1–45.

Correa, Ricardo, Horacio Sapriza, and Andrei Zlate. (2010) "International Banks, the Interbank Market, and the Cross-Border Transmission of Business Cycles." Working Paper, International Finance Section, Federal Reserve Board.

Davis, Scott. (2010) "The Adverse Feedback Loop and the Effects of Risk in Both the Real and Financial Sectors." Working Paper No. 66, Globalization and Monetary Policy Institute, Federal Reserve Bank of Dallas.

de Antonio Liedo, David. (2011) "What Are Shocks Capturing in DSGE Modeling? Noise versus Structure." Working Paper, National Bank of Belgium.

Dedola, Luca, and Giovanni Lombardo. (2012) "Financial Frictions, Financial Integration and the International Propagation of Shocks." *Economic Policy*, 27, 319–59.

Del Negro, Marco, Gauti Eggertsson, Andrea Ferrero, and Nobuhiro Kiyotaki. (2011) "The Great Escape? A Quantitative Evaluation of the Fed's Liquidity Facilities." Staff Report No. 520, Federal Reserve Bank of New York.

Devereux, Michael, and Alan Sutherland. (2011) "Evaluating International Financial Integration under Leverage Constraints." *European Economic Review*, 55, 427–42.

Dewachter, Hans, and Rafael Wouters. (2012) "Endogenous Risk in a DSGE Model with Capital-Constrained Financial Intermediaries." Working Paper 235, National Bank of Belgium.

de Walque, Gregory, Olivier Pierrard, and Abdelaziz Rouabah. (2010) "Financial (In)Stability, Supervision and Liquidity Injection: A Dynamic General Equilibrium Approach." *Economic Journal*, 120, 1234–61.

de Walque, Gregory, Frank Smets, and Rafael Wouters. (2005) "An Estimated Two-Country DSGE Model for the Euro Area and the US Economy." Working Paper, National Bank of Belgium.

Eickmeier, Sandra, and Tim Ng. (2012) "How Do Credit Supply Shocks Propagate Internationally?" Working Paper, Bundesbank and Reserve Bank of New Zealand.

Federal Reserve Bank of New York. (2013) "Quarterly Trends for Consolidated U.S. Banking Organizations."

Fisher, Jonas. (2006) "The Dynamic Effects of Neutral and Investment-Specific Technology Shocks." *Journal of Political Economy*, 114, 413–52.

Freixas, Xavier, and Jean-Charles Rochet. (2008) *The Microeconomics of Banking*. Cambridge, MA: MIT Press.

Galí, Jordi, Frank Smets, and Rafael Wouters. (2011) "Unemployment in an Estimated New Keynesian Model." NBER Working Paper No. 17084.

Gerali, Andrea, Stefano Neri, Luca Sessa, and Federico Signoretti. (2010) "Credit and Banking in a DSGE Model of the Euro Area." *Journal of Money, Credit and Banking*, 42, 107–41.

Gertler, Mark, and Peter Karradi. (2011) "A Model of Unconventional Monetary Policy." *Journal of Monetary Economics*, 58, 17–34

Gertler, Mark, and Nobuhiro Kiyotaki. (2011) "Financial Intermediation and Credit Policy in Business Cycle Analysis." In *Handbook of Monetary Economics*, edited by Benjamin Friedman and Michael Woodford, Vol. 3A, pp. 547–99. Amsterdam: Elsevier.

Geweke, John. (1999) "Using Simulation Methods for Bayesian Econometric Models: Inference, Development and Communication." *Econometric Reviews*, 18, 1–126.

Geweke, John. (2001) "Bayesian Econometrics and Forecasting." *Journal of Econometrics*, 100, 11–5.

Gilchrist, Simon, and Egon Zakrajšek. (2011a) "Credit Spreads and Business Cycle Fluctuations." NBER Working Paper No. 17201.

Gilchrist, Simon, and Egon Zakrajšek. (2011b) "Bank Lending and Credit Supply Shocks." Working Paper, Boston University.

He, Zhiguo, and Arvind Krishnamurthy. (2012) "A Macroeconomic Framework for Quantifying Systemic Risk." Working Paper, University of Chicago.

Helbling, Thomas, Raju Huidrom, Ayhan Kose, and Christopher Otrok. (2011) "Do Credit Shocks Matter? A Global Perspective." *European Economic Review*, 55, 340–53.

Huizinga, Harry, and Luc Laeven. (2009) "Accounting Discretion of Banks during a Financial Crisis." CEPR Discussion Papers No. 7381.

Iacoviello, Matteo. (2010) "Financial Business Cycles." Working Paper, Boston College.

Ireland, Peter. (2004) "A Method for Taking Models to the Data." *Journal of Economic Dynamics and Control*, 28, 1205–26.

Jacob, Punnoose, and Geert Peersman. (2013) "Dissecting the Dynamics of the US Trade Balance in an Estimated Equilibrium Model." *Journal of International Economics*, 90, 302–15.

Jermann, Urban, and Vincenzo Quadrini. (2012) "Macroeconomic Effects of Financial Shocks." *American Economic Review*, 102, 238–71.

Justiniano, Alejandro, and Bruce Preston. (2010) "Can Structural Small Open Economy Models Account for the Influence of Foreign Disturbances?" *Journal of International Economics*, 81, 61–74.

Justiniano, Alejandro, Giorgio Primiceri, and Andrea Tambalotti. (2008) "Investment Shocks and Business Cycles." *Journal of Monetary Economics*, 57, 132–45.

Kalemli-Ozcan, Sebnem, Bent Sorensen, and Sevcan Yesiltas. (2012) "Leverage across Firms, Banks and Countries." Working Paper, University of Maryland.

Kamber, Güneş, and Christoph Thoenissen. (2013) "Financial Intermediation and the International Business Cycle: The Case of a Small Country with Big Risk." *Journal of Money, Credit and Banking*, 45(S2), 127–58.

Kannan, Prakash, Pau Rabanal, and Alasdair Scott. (2012) "Monetary and Macroprudential Policy Rules in a Model with House Price Booms." *B.E. Journal of Macroeconomics*, 12, Article 16.

Kollmann, Robert. (1996) "Incomplete Asset Markets and the Cross-Country Consumption Correlation Puzzle." *Journal of Economic Dynamics and Control*, 20, 945–62.

Kollmann, Robert. (2012a) "Limited Asset Market Participation and the Consumption-Real Exchange Rate Anomaly." *Canadian Journal of Economics*, 45, 566–84.

Kollmann, Robert. (2012b) "Global Banks, Financial Shocks and International Business Cycles: Evidence from an Estimated Model." CEPR Discussion Paper No. 8985.

Kollmann, Robert, Zeno Enders, and Gernot Müller. (2011) "Global Banking and International Business Cycles." *European Economic Review*, 55, 407–26.

Kollmann, Robert, Marco Ratto, Werner Roeger, and Jan in't Veld. (2013) "Fiscal Policy, Banks and the Financial Crisis." *Journal of Economic Dynamics and Control*, 37, 387–403.

Kollmann, Robert, Werner Roeger, and Jan in't Veld. (2012) "Fiscal Policy in a Financial Crisis: Standard Policy versus Bank Rescue Measures." *American Economic Review*, 102, 77–81.

Kollmann, Robert, and Stefan Zeugner. (2012) "Leverage as a Predictor of Real Activity and Volatility." *Journal or Economic Dynamics and Control*, 36, 1267–83.

Le, Vo, David Meenagh, Patrick Minford, and Michael Wickens. (2010) "Two Orthogonal Continents? Testing a Two-Country DSGE Model of the US and the EU Using Direct Inference." *Open Economies Review*, 21, 23–44.

Lipinsky, Fabian. (2012) "Imbalances in the Euro Area and Macroprudential Policies." Working Paper, London Business School.

Meh, Césaire, and Kevin Moran. (2010) "The Role of Bank Capital in the Propagation of Shocks." *Journal of Economic Dynamics and Control*, 34, 555–76.

Mendicino, Caterina, and Maria Teresa Punzi. (2011) "Stabilization Policy and Boom-Bust Cycles: Monetary and Macro-Prudential Rules." *Bank of Portugal Economic Bulletin*, 17, 97–105.

Nguyen, Ha. (2011) "International Crisis Transmission and Asymmetric Recoveries." Working Paper, World Bank.

Nolan, Charles, and Christoph Thoenissen. (2009) "Financial Shocks and the US Business Cycle." *Journal of Monetary Economics*, 56, 596–604.

Perri, Fabrizio, and Vincenzo Quadrini. (2011) "International Recessions." Working Paper, University of Minnesota.

Smets, Frank, and Rafael Wouters. (2007) "Shocks and Frictions in US Business Cycles: A Bayesian DSGE Approach." *American Economic Review*, 97, 586–660.

Ueda, Kozo. (2010) "Banking Globalization and International Business Cycles." Working Paper, Institute for Monetary and Economic Studies, Bank of Japan.

Van den Heuvel, Skander. (2008) "The Welfare Cost of Bank Capital Requirements." *Journal of Monetary Economics*, 55, 298–320.

van Wincoop, Eric. (2013) "International Contagion through Leveraged Financial Institutions." *American Economic Journal: Macroeconomics*, 5, 152–89.