"Shadow Banking and Financial Regulation: A Small-Scale DSGE Perspective"

Toulouse School of Economics

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Patrick Fève[a]*   Alban Moura[b]   Olivier Pierrard[b]

[a] *Toulouse School of Economics and University of Toulouse I - Capitole*

[b] *Banque Centrale du Luxembourg*

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Abstract

This paper estimates a small-scale DSGE model of the US economy with interacting tradi-
tional and shadow banks. We find that shadow banks amplify the transmission of struc-
tural shocks by helping escape constraints from traditional intermediaries. We show how
this leakage toward shadow entities reduces the ability of macro-prudential policies target-
ing traditional credit to reduce economic volatility. A counterfactual experiment suggests
that a countercyclical capital buffer, if applied only to traditional banks, would have in fact
amplified the boom-bust cycle associated with the financial crisis of 2007-2008. On the other
hand, a broader regulation scheme targeting both traditional and shadow credit would have
helped stabilize the economy.

KEYWORDS: Shadow banking, DSGE models, macro-prudential policy.

JEL CLASSIFICATION: C32, E32.

1 Introduction

There is now a general agreement that the limited regulation of non-depository financial institutions, or shadow banks, was a major cause of the subprime mortgage crisis and the ensuing Great Recession.[1] As a result, both academics and policy makers have called for financial regulation to move toward a more global and macro-prudential direction (see for instance Adrian and Shin, 2009; Gorton and Metrick, 2010; Hanson et al., 2011; Bernanke, 2013). However, most macro models with a financial sector feature only traditional banks, so they probably miss important considerations about macro-prudential regulation. In this paper, we propose and estimate a small-scale dynamic stochastic general equilibrium (DSGE) model with interacting traditional and shadow banks. We then use the model to evaluate alternative forms of financial regulation aimed at stabilizing economic and credit cycles.

Our model works as follows. As in Gertler et al. (2016) and Meeks et al. (2017), we start from a standard real-business-cycles (RBC) model and augment it with a financial sector including traditional and shadow banks. Both types of banks intermediate credit between saving households and borrowing non-financial firms. Traditional banks mostly finance through deposits, but also hold capital to comply with macro-prudential regulation. On the other hand, shadow banks finance on wholesale markets by issuing asset-backed securities (ABS) against their pool of loans and completely escape regulation. Because they are easily tradable on financial markets, ABS are subject to less regulation than standard loans, so that traditional banks have incentives to substitute loans with ABS in order to increase their leverage. While the general logic is similar to Gertler et al. and Meeks et al., there is one key difference. In these papers, shadow banking increases the efficiency of credit intermediation by relaxing financial frictions associated with the limited pledgeability of assets.[2] In contrast, in our framework shadow banking increases efficiency because of asymmetric regulation since shadow banks do not face the same regulatory constraints as traditional intermediaries.

In the model, two structural parameters define the interactions between traditional and shadow banks: a portfolio cost limiting the ability to substitute traditional loans and ABS, and a bank capital cost defining how regulation affects the supply of traditional credit. To identify these parameters, we estimate the model on quarterly US data for the period 1980-2016 using Bayesian methods and a selection of observables that includes both real (consumption, investment, hours

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[1]Online Appendix I provides more details on the differences between traditional and shadow banks.

[2]These authors assume that traditional banks may divert loans more easily than ABS, and that shadow banks divert loans less than traditional banks.

worked) and financial (the ratio between shadow and total credit, the leverage of traditional banks, and a lending-deposit spread) variables. Estimation results are plausible — in particular, the estimates imply a cost of macro-prudential regulation in line with values reported in the literature — and the model has a reasonable fit. The decomposition of business cycles is fairly standard for a real model, with the neutral productivity shock playing a leading role. Still, financial shocks explain between 30 and 40 percent of the fluctuations in output and investment, suggesting that the model is able to propagate financial disturbances to the real economy.

The estimated model suggests that shadow banking constitutes an important amplification mechanism in general equilibrium because it helps escape constraints arising from the traditional sector. For instance, after a positive technology shock economic activity and credit expand jointly. Because raising additional capital is slow, the leverage of traditional banks increases and this translates into higher spreads. When credit intermediation can be partly redirected toward the shadow sector, the rise in traditional bank leverage and spreads is smaller, which stimulates the expansion. Highlighting this amplification effect associated with shadow banking is our first contribution.

We also study the stabilization properties of different macro-prudential policies in presence of shadow banks. Our second contribution is to demonstrate how asymmetries between traditional and shadow intermediaries dampen the ability of regulators to stabilize the economy. For instance, the model implies that intermediation migrates to the shadow sector after an exogenous increase in the capital adequacy ratio of traditional banks, which limits the effects of asymmetric regulation. This property is consistent with Buchak et al. (2017), who find in the data that shadow banks are more likely to enter markets in which traditional banks face tight regulation. This regulatory arbitrage also affects the ability of a countercyclical capital buffer to reduce aggregate fluctuations. Using historical counterfactual simulations, we show that a countercyclical buffer targeting and applied to traditional loans only would have amplified, rather than dampened, the boom-bust cycle associated with the financial crisis of 2007-2008 in the US. On the other hand, a broader regulation scheme targeting both traditional and shadow credit would have been more successful in stabilizing the economy. Overall, our findings thus support the recent shift in banking regulation toward a more global approach, as advocated in the Basel III package.

Our paper belongs to a recent strand of the literature integrating shadow banking in DSGE models. Above, we have briefly described the modeling approach used in Gertler et al. (2016) and Meeks et al. (2017), and how our framework differs from their. Our focus is also different:

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Gertler et al. explain how their model captures systemic financial collapses, whereas Meeks et al. consider a calibrated model and study its ability to reproduce business-cycle moments. Verona et al. (2013) propose a different approach with a monopolistic shadow banking system and a countercyclical markup rule. Their model predicts a substantial boom-bust cycle when monetary policy is too loose for too long. We can also mention Goodhart et al. (2013), who use a simple 2-period model with traditional and shadow banks to study various regulation schemes, and Moreira and Savov (2017), who develop a continuous-time model to study episodes of liquidity crisis in shadow banking. There is a broader literature on macro-prudential regulation in DSGE models. For example, De Walque et al. (2010) and Covas and Fujita (2010) illustrate the procyclicality of time-varying capital requirements, while Angeloni and Faia (2013) and Angelini et al. (2014) characterize optimal capital requirements in various contexts. Our paper also addresses macro-prudential regulation but takes into account the existence of the shadow sector.

The paper is organized as follows. Section 2 describes the model, while Section 3 presents our empirical strategy and the estimation results. Section 4 introduces our main results, while Section 5 concludes.

2 Model

We augment a standard RBC model with a banking sector composed of traditional and shadow banks. Both types of banks intermediate credit between savers (households) and borrowers (non-financial firms) but finance through different liabilities and face different levels of macro-prudential regulation. In particular, traditional banks finance via household deposits and own bank capital, whereas shadow banks finance through wholesale markets. Additionally, traditional banks face capital requirements while shadow banks are not regulated.[3]

2.1 Non-financial firm

The representative firm produces the final good using a Cobb-Douglas technology

$$f_t = \epsilon_t^z k_{t-1}^{1-\alpha} h_t^{\alpha},$$

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[3]This simple framework is in line with the Basel I Accord, which was in force during most of our estimation sample. Indeed, according to the Basel I regulation, traditional banks' own capital had to be above a given fraction $\bar{\eta} > 0$ of risk-weighted assets. The weight on traditional loans was 100%, while that on securitized assets with the highest rating (i.e., most securitized assets before the 2008 crisis) was 0%. Shadow banks were not regulated.

where ϵ_t^z, k_{t-1}, and h_t respectively denote total factor productivity (TFP), capital, and hours worked, while $\alpha \in (0, 1)$ is the elasticity of output with respect to hours. TFP evolves according to

$$\ln \epsilon_t^z = \rho_z \ln \epsilon_{t-1}^z + \sigma_z u_{z,t},$$

where $\rho_z \in (0, 1)$, $\sigma_z > 0$, and $u_{z,t} \sim i.i.d. N(0, 1)$.

The firm rents capital at price r_t^k and pays an hourly wage w_t. Profit maximization requires

$$(1 - \alpha) f_t / k_{t-1} = r_t^k, \quad \alpha f_t / h_t = w_t.$$

Because the firm borrows capital from traditional and shadow banks, the general equilibrium of the model will be such that $k_t = l_t + s_t$, where l_t denotes traditional loans and s_t is shadow credit.

2.2 Traditional bank

The representative traditional bank holds two types of assets, traditional loans and asset-backed securities issued by shadow banks, respectively denoted l_t and abs_t. It finances through household deposits d_t and own capital n_t, so that its balance sheet verifies

$$q_t l_t + abs_t = n_t + d_t,$$

where q_t is the price of capital.

Because loans are usually long-term assets while ABS are normally liquid and marketable, we introduce a portfolio adjustment cost limiting the bank's ability to substitute between assets. This cost is given by the quadratic function

$$\Gamma \left(\frac{abs_t}{q_t l_t} \right) = \frac{\gamma}{2} \left(\frac{abs_t}{q_t l_t} - \frac{\overline{abs}}{\overline{l}} \right)^2,$$

where bars denote steady-state levels and $\gamma \geq 0$. This function verifies $\Gamma(\overline{abs}/\overline{l}) = \Gamma'(\overline{abs}/\overline{l}) = 0$, so that portfolio costs only affect the dynamic of the model and not its steady state (we also exploit the fact that $\overline{q} = 1$ in these expressions). Andrès et al. (2004) and Chen et al. (2012) use a very similar setup to capture imperfect substitution between short- and long-term assets.

Turning to macro-prudential regulation, bank capital n_t should not be lower than a given fraction $\overline{\eta}$ of risk-weighted assets. Since we assume a zero weight on ABS, risk-weighted assets correspond to traditional loans $q_t l_t$. Despite this asymmetric regulation, the bank has an incentive to hold traditional loans because the return on ABS is lower in equilibrium (see equation (5)

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below). Formally, we define excess bank capital as $x_t = n_t - \bar{\eta} q_t l_t$ and the capital constraint should imply $x_t \geq 0$. Because dealing with this type of occasionally binding constraints remains computationally challenging, we follow Enders et al. (2011) and Kollmann (2013) and instead assume that the bank can hold less capital than required subject to a penalty cost proportional to the capital gap. This capital cost function is given by

$$\Theta(x_t) = -\theta_1 \ln(1 + \theta_2 x_t),$$

with $\theta_1, \theta_2 \geq 0$ and $\bar{x} = 0$ in steady state. This specification implies that $\Theta(0) = 0$, $\Theta'(0) = -\theta_1 \theta_2 \leq 0$ and $\Theta''(0) = \theta_1 \theta_2^2 \geq 0$, so that capital costs are decreasing and convex in x_t around the steady state.

At any given date, the bank receives income from its holdings of loans and ABS, inherited from the previous period. On top of the two costs Γ_t and Θ_t, it also pays an interest on household deposits and incurs a loan monitoring cost ϵ_t^l per unit of supplied loans. We introduce this cost, which directly affects the lending rate in equilibrium, to capture time variations in the risk premium that our framework does not explicitly consider. Summing up, the traditional bank's profit function verifies

$$
\begin{aligned}
\pi_t^b &= \left[r_t^k + (1 - \delta) q_t \right] l_{t-1} + (1 + r_{t-1}^a) abs_{t-1} + d_t \\
&\quad - \Gamma \left[abs_t / (q_t l_t) \right] - \Theta(x_t) - (1 + r_{t-1}^d) d_{t-1} - (1 + \epsilon_t^l) q_t l_t - abs_t,
\end{aligned}
\tag{1}
$$

where $\delta \in (0, 1)$ is the depreciation rate of physical capital. Remark that the rate of return on ABS, r_{t-1}^a, is predetermined with respect to date-t events, whereas the rate of return on loans is not. This timing difference captures the idea that ABS are fixed-income instruments supposed to provide a safe return. The rate of return on household deposits is also predetermined. The loan monitoring cost evolves according to

$$\epsilon_t^l = \rho_l \epsilon_{t-1}^l + \sigma_l u_{l,t},$$

with $\rho_l \in (0, 1)$, $\sigma_l > 0$, and $u_{l,t} \sim i.i.d.N(0,1)$.

Profit maximization with respect to deposits, loans, and ABS implies

$$
\begin{aligned}
1 + \Theta_t' &= E_t \Lambda_{t,t+1} (1 + r_t^d), \\
\epsilon_t^l - \bar{\eta} \Theta_t' - \Gamma_t' \frac{abs_t}{(q_t l_t)^2} &= E_t \Lambda_{t,t+1} \left[\frac{(1 - \delta) q_{t+1} + r_{t+1}^k}{q_t} - (1 + r_t^d) \right], \\
\Gamma_t' \frac{1}{q_t l_t} &= E_t \Lambda_{t,t+1} (r_t^a - r_t^d),
\end{aligned}
\tag{2}
$$

where $\Lambda_{t,t+1}$ is the household's stochastic discount factor between periods t and $t+1$. These conditions all have simple interpretations. The first one equalizes the marginal costs of issuing liabilities through bank capital or deposits. The second one shows that the spread between the lending and deposit rates covers all costs related to traditional loans (i.e. the loan monitoring, portfolio, and regulation costs). The third one shows that the spread between the ABS return and the deposit rate only needs to cover the portfolio cost since there is neither monitoring nor regulation cost related to ABS holdings.

The last condition is key for the interaction between traditional and shadow banks in our model. Taking a linear approximation around the deterministic steady state, we obtain

$$\frac{\gamma}{\overline{l}} \left(\widehat{\frac{abs_t}{q_t l_t}} \right) = \overline{\Lambda} \left(\hat{r}_t^a - \hat{r}_t^d \right), \tag{3}$$

where hats denote (level) deviations from the steady state. This equation demonstrates that an increase in the return on ABS stimulates ABS holdings by the traditional bank, all other things equal. Moreover, the lower the portfolio adjustment cost γ, the higher the transmission.

Of course, this stylized representation abstracts from many forces driving the shadow sector. To capture the dynamics of shadow credit in the data, we introduce an additional disturbance in the model. We call it the shadow wedge and interpret it as a shadow default shock. Hence, we slightly modify the above setup by assuming that, in every period, the shadow bank may partially default on the ABS it has issued in the past. However, in the event of default, the shadow bank compensates the traditional bank through a lump-sum transfer. Corsetti et al. (2013) use a similar specification in a model of sovereign credit risk. Letting ϵ_t^a and t_t denote the rate of default on ABS and the transfer, the profit of the traditional bank (1) and the optimality condition with respect to ABS holdings (2) become

$$\pi_t^b = \left[r_t^k + (1-\delta)q_t \right] l_{t-1} + (1-\epsilon_t^a)(1+r_{t-1}^a)abs_{t-1} + d_t + t_t$$
$$- \Gamma \left[abs_t / (q_t l_t) \right] - \Theta(x_t) - (1+r_{t-1}^d)d_{t-1} - (1+\epsilon_t^l)q_t l_t - abs_t,$$

$$\Gamma_t' \frac{1}{q_t l_t} = E_t \Lambda_{t,t+1} \left[(1-\epsilon_{t+1}^a)(1+r_t^a) - (1+r_t^d) \right].$$

In that case, equation (3) becomes

$$\frac{\gamma}{\overline{l}} \left(\widehat{\frac{abs_t}{q_t l_t}} \right) + E_t \epsilon_{t+1}^a = \overline{\Lambda} \left(\hat{r}_t^a - \hat{r}_t^d \right), \tag{4}$$

so that an increase in the shadow wedge raises the required return on ABS and reduces ABS holdings, all other things equal. The shadow wedge evolves according to

$$\epsilon_t^a = \rho_a \epsilon_{t-1}^a + \sigma_a u_{a,t},$$

with $\rho_a \in (0,1)$, $\sigma_a > 0$, and $u_{a,t} \sim i.i.d.N(0,1)$.

2.3 Shadow bank

We model shadow banking using an overlapping generation structure in which each shadow intermediary lives for 2 periods. At any date t, a new shadow bank enters the market and issues ABS in order to lend to the non-financial firm.[4] ABS issuance entails a per-unit cost $0 < \bar{a} < 1$,[5] so that the shadow bank's balance sheet verifies $q_t s_t = (1 - \bar{a}) abs_t$. At date $t + 1$, the bank earns a profit

$$\pi_t^s = \left[r_t^k + (1 - \delta) q_t \right] s_{t-1} - (1 - \epsilon_t^a)(1 + r_{t-1}^a) abs_{t-1} - t_t$$

and leaves the market. As already mentioned, ϵ_t^a is the rate of shadow default and t_t the lump-sum compensation paid to the traditional bank.

We assume free entry in shadow banking with an expected 0-profit condition $E_t \Lambda_{t,t+1} \pi_{t+1}^s = 0$. Using the bank's balance sheet, this yields

$$(1 - \bar{a}) E_t \Lambda_{t,t+1} \frac{r_{t+1}^k + (1 - \delta) q_{t+1}}{q_t} = E_t \Lambda_{t,t+1} \left[(1 - \epsilon_{t+1}^a)(1 + r_t^a) + \frac{t_{t+1}}{abs_t} \right].$$

When the lump-sum transfer fully compensates the losses, $t_t = \epsilon_t^a (1 + r_{t-1}^a) abs_{t-1}$ and the equation becomes

$$(1 - \bar{a}) E_t \Lambda_{t,t+1} \frac{r_{t+1}^k + (1 - \delta) q_{t+1}}{q_t} = (1 + r_t^a) E_t \Lambda_{t,t+1}. \tag{5}$$

Condition (5) simply equates the expected return of issuing one additional ABS with its marginal cost. Again, notice that the shadow bank is not regulated in the model, in accordance with the Basel I Accord.

2.4 Household

The household owns the whole economy and maximizes

$$U_0 = E_0 \sum_{t=0}^{\infty} \beta^t \left[\ln c_t + \epsilon_t^d \ln d_t - \frac{\epsilon_t^m}{1 + \psi} \left(\frac{h_t}{h_{t-1}^\phi} \right)^{1+\psi} \right],$$

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[4]Since ABS are held by traditional banks in our model, the shadow bank has the flavor of a special-purpose vehicle (SPV) created by the bank to achieve off-balance sheet accounting treatment for its loans and improve its capital ratio. See the Basel Committee on Banking Supervision (2009) for a comprehensive presentation of SPVs.

[5]This cost is a shortcut for more sophisticated management costs, such as those considered in Christiano et al. (2003), Enders et al. (2011), or Ireland (2014).

where $\beta \in (0, 1)$ is the discount rate and c_t is consumption. Deposits provide utility through a standard liquidity motive, which is shifted over time by the disturbance ϵ_t^d. The latter evolves according to

$$\ln \epsilon_t^d = \rho_d \ln \epsilon_{t-1}^d + (1 - \rho_d) \ln \bar{\epsilon}^d + \sigma_d u_{d,t},$$

where $\bar{\epsilon}^d > 0$, $\rho_d \in (0, 1)$, $\sigma_d > 0$, and $u_{d,t} \sim i.i.d.N(0,1)$.[6]

The parameter $\psi \geq 0$ captures the curvature in labor disutility and ϕ measures habit persistence in labor: $\phi < 0$ implies intertemporal substitutability in labor supply, whereas $\phi > 0$ implies intertemporal complementarity. Empirically, the specification with complementarity seems more relevant because it translates habits in labor into output persistence.[7] Labor disutility is subject to a preference or labor wedge shock ϵ_t^m, which captures unmodeled distortions in the labor market (Chari et al., 2007). This shock evolves according to

$$\ln \epsilon_t^m = \rho_m \ln \epsilon_{t-1}^m + (1 - \rho_m) \ln \bar{\epsilon}^m + \sigma_m u_{m,t},$$

where $\bar{\epsilon}^m > 0$, $\rho_m \in (0, 1)$, $\sigma_m > 0$, and $u_{m,t} \sim i.i.d.N(0,1)$.

Finally, the household faces a flow budget constraint given by

$$c_t + d_t = w_t h_t + (1 + r_{t-1}^d) d_{t-1} + \pi_t^b + \pi_t^s.$$

Utility maximization with respect to consumption, deposits, and hours worked yields

$$\frac{1}{c_t} = \frac{\epsilon_t^d}{d_t} + \beta E_t \frac{1 + r_t^d}{c_{t+1}},$$

$$m_t z_t = \frac{\alpha f_t}{c_t} + \beta \phi E_t m_{t+1} z_{t+1},$$

where $z_t \equiv (h_t / h_{t-1}^\phi)^{1+\psi}$. The first condition is the intertemporal Euler equation pinning down the optimal consumption-saving plan, whereas the second one defines the labor supply schedule.

2.5 Closing the model

The household's stochastic discount factor between t and $t+1$ is $\Lambda_{t,t+1} = \beta c_t / c_{t+1}$. We define physical investment as $\epsilon_t^i i_t = k_t - (1 - \delta) k_{t-1}$, where ϵ_t^i is an investment-specific efficiency

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[6]The parameter $\bar{\epsilon}^d$ allows to calibrate $\Theta' < 0$ at the steady state. Indeed, it is easy to show that when $\bar{\epsilon}^d = 0$, the general equilibrium is such that $\beta(1 + \bar{r}^d) = 1$ from the household's Euler equation, which implies $\overline{\Theta}' = 0$ from the traditional bank's first-order conditions. A strictly positive $\bar{\epsilon}^d$ lowers $\bar{r}^d$ and allows for a negative marginal capital cost.

[7]See, e.g., Bouakez and Kano (2006), Dupaigne et al. (2007), or Fève et al. (2013).

shock evolving according to

$$\ln \epsilon_t^i = \rho_i \ln \epsilon_{t-1}^i + \sigma_i u_{i,t},$$

where $\rho_i \in (0, 1)$, $\sigma_i > 0$, and $u_{i,t} \sim i.i.d.N(0, 1)$. It is straightforward to verify that the equilibrium price of capital verifies $q_t = 1/\epsilon_t^i$.

Summing all budget constraints, we recover the aggregate resource constraint of the model:

$$f_t = c_t + i_t + \Gamma \left(\frac{abs_t}{q_t l_t} \right) + \Theta(x_t) + \epsilon_t^l q_t l_t + \bar{a} \, abs_t.$$

Finally, we define GDP, the share of shadow banking in total credit, the leverage in the traditional banking sector, and the lending-deposit spread as

$$y_t = c_t + i_t, \quad \text{share}_t = \frac{s_t}{l_t + s_t}, \quad \text{leverage}_t = \frac{q_t l_t}{n_t}, \quad \text{spread}_t = \frac{r_t^k + (1 - \delta) q_t}{q_{t-1}} - (1 + r_{t-1}^d).$$

3 Econometric Approach

We solve the model with standard linearization techniques and estimate it using Bayesian methods. This section discusses the data, the parameter estimates, and the fit of the model.

3.1 Data

We estimate the model using six observables: consumption, investment, hours worked, the share of shadow banking in total credit, the leverage in the traditional banking sector, and the credit spread:

$$[\ln c_t, \ln i_t, \ln h_t, \text{share}_t, \text{leverage}_t, \text{spread}_t].$$

This selection of observables is helpful to identify the key parameters of the model from the data. In particular, the joint behavior of the shadow share and the spread should be informative about the size of portfolio costs, while the joint properties of leverage and the credit spread should identify the convexity of the excess capital cost function. We remove quadratic trends from all series, except for the spread which is simply demeaned.[8]

The estimation sample is quarterly and runs from 1980Q1 to 2016Q4. The series for consumption and investment come from the Bureau of Economic Analysis, whereas the hours series is borrowed from Neville and Ramey (2009). For the definitions of the traditional and shadow

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[8]Iacoviello (2015) also detrends his observables prior to estimating a model with financial variables. In the data, financial variables typically have their own trends, that a model with balanced-growth restrictions cannot easily capture.

Table 1: Calibrated Parameters

Parameter	Value	Description
α	2/3	Labor share
β	0.975	Discount factor
δ	0.025	Capital depreciation rate
$\overline{h}$	0.20	Steady-state hours
ψ	2	Hours curvature in utility
$\overline{\text{share}}$	0.26	Shadow share
$\overline{\eta}$	0.10	Capital requirement
$-\Theta'(0)$	0.025	Marginal excess capital cost
$\overline{a}$	0.0026	ABS issuance cost

banking sectors, we follow Meeks et al. (2017). In particular, we consider security brokers and dealers and issuers of asset-backed securities as shadow banks and define shadow credit as the sum of their financial assets, extracted from the Financial Accounts of the United States. We consider private depository institutions as traditional banks and define traditional credit as their total financial assets minus vault cash, reserves at the Federal Reserve, and holdings of agency- and GSE-backed securities. The shadow share is then the ratio between shadow credit and total credit, defined as the sum of traditional and shadow credit. We use the leverage of commercial banks to proxy for the leverage of traditional banks. Finally, our spread measure is Moody's seasoned Baa corporate bond yield relative to the yield on 10-year treasury bonds. Appendix A provides more details on the data.

3.2 Estimation results

We partition the parameters in two sets. The first one contains 9 parameters kept fixed during estimation. Regarding standard parameters, we set $\alpha = 2/3$, $\beta = 0.975$, and $\delta = 0.025$. We also calibrate $\overline{\epsilon}^m$ so that hours equal $\overline{h} = 0.2$ in steady state and set the labor supply parameter ψ to 2, in accordance with previous studies.[9] We calibrate the preference weight on deposits $\overline{\epsilon}^d$ to replicate the average shadow share of 0.26 we find in the data. We also set the steady-state capital adequacy ratio to $\overline{\eta} = 10\%$, which implies an average leverage ratio of 10 for traditional banks. Finally, we calibrate $\Theta'(0)$ and $\overline{a}$ to reproduce 2 targets: zero excess bank capital ($\overline{x} = 0$) and zero real return on deposits ($\overline{r}^d = 0$).[10] These values are reported in Table 1.

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[9]For instance, Smets and Wouters (2007) estimate this parameter at 1.92 in a model without leisure habits, which implies a Frisch elasticity of labor supply close to 0.5. In our setup with habits, the Frisch elasticity becomes $1/[(1-\phi)(1+\psi)-1]$, so that our estimated elasticity may differ from 0.5 depending on the value of ϕ.

[10]The calibration implies that ABS issuance costs represent about 0.9% of GDP in steady state, in line with the related literature (see Enders et al., 2011).

Table 2: Estimation Results

Parameter	Description	Prior distribution			Posterior distribution	
		Distribution	Mean	SD	Mode	[5%, 95%]
ϕ	Labor habits	Beta	0.60	0.15	0.65	[0.60, 0.69]
γ	Portfolio adjustment cost	Gamma	0.20	0.10	0.17	[0.15, 0.19]
θ_2	Convexity of excess capital cost	Gamma	0.20	0.10	0.11	[0.09, 0.14]
ρ_z	AR technology shock	Beta	0.60	0.20	0.95	[0.95, 0.96]
ρ_i	AR investment shock	Beta	0.60	0.20	0.24	[0.17, 0.31]
ρ_m	AR labor wedge shock	Beta	0.60	0.20	0.71	[0.65, 0.77]
ρ_l	AR monitoring cost shock	Beta	0.60	0.20	0.96	[0.95, 0.97]
ρ_a	AR shadow wedge shock	Beta	0.60	0.20	0.99	[0.98, 0.99]
ρ_d	AR deposit preference shock	Beta	0.60	0.20	0.89	[0.86, 0.92]
$100\sigma_z$	SD technology shock	Inv. Gamma	1.00	3.00	0.60	[0.56, 0.65]
$1000\sigma_i$	SD investment shock	Inv. Gamma	1.00	3.00	2.39	[2.19, 2.62]
$100\sigma_m$	SD labor wedge shock	Inv. Gamma	1.00	3.00	1.26	[1.15, 1.39]
$10000\sigma_l$	SD monitoring cost shock	Inv. Gamma	1.00	3.00	4.05	[3.71, 4.56]
$10000\sigma_a$	SD shadow wedge shock	Inv. Gamma	1.00	3.00	4.48	[4.08, 5.12]
$100\sigma_d$	SD deposit preference shock	Inv. Gamma	1.00	3.00	1.46	[1.28, 1.70]

Notes. The posterior distribution is constructed from the random-walk Metropolis-Hastings algorithm with a single chain of 250,000 draws, after a burn-in period of 250,000 draws.

The second set contains 15 parameters estimated from the data. Three of them have a structural interpretation: the labor habit parameter ϕ, the portfolio adjustment cost γ, and the convexity of the excess capital cost function θ_2. The last two are especially important because they largely determine the degree of interaction between the traditional and shadow banking sectors in the model. The twelve other parameters define the shock processes. Table 2 reports the prior and posterior distributions. We adopt a standard Beta prior for the habit coefficient, while we use Gamma priors centered at moderate values for the portfolio and excess capital cost parameters. Additionally, we follow Christiano et al. (2011) in introducing an endogenous prior term penalizing parameter vectors that result in a poor match between the theoretical and empirical standard deviations of our observables.[11]

At the posterior mode, the estimated value of ϕ is close to that obtained in Dupaigne et al. (2007) and Fève et al. (2013), indicating strong intertemporal complementarity in labor supply. Both the portfolio adjustment cost γ and the curvature of the excess capital cost function θ_2 are well identified from the data, with tight posterior distributions. The estimates imply that a temporary one percentage point (pp.) increase in the capital adequacy ratio $\bar{\eta}$ raises the annual loan-deposit spread by about 8 basis points on impact (see Figure 3 below). This is somewhat below the 20 basis points reported in Kollmann (2013), but very much in line with the 8.5

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[11]We use the Dynare implementation of this approach.

Table 3: Model Fit

Variable	Moments					
	σ_x		ρ_x		ρ_{xy}	
	Data	Model	Data	Model	Data	Model
Consumption	0.02	0.03	0.97	0.99	0.85	0.81
Investment	0.09	0.10	0.98	0.96	0.96	0.91
Hours	0.03	0.03	0.97	0.97	0.65	0.50
Share	0.04	0.05	0.99	0.98	0.47	0.02
Leverage	0.22	0.26	0.89	0.94	0.56	-0.35
Spread	0.71	0.92	0.86	0.48	-0.15	-0.28

Notes. The sample is 1980Q1-2016Q4 for empirical moments, while theoretical moments are computed at the posterior mean. σ_x denotes the standard deviation, ρ_x the first-order autocorrelation, and ρ_{xy} the contemporaneous correlation with GDP. The spread is expressed in annualized percentage points.

basis points estimated by Baker and Wurgler (2015) from individual bank data.[12] This bolsters confidence in our identification strategy.

3.3 Fit and model properties

In spite of its simplicity, the model provides a reasonable fit of the data, as can be seen from Table 3. Thanks to the endogenous prior, the volatilities of all observables are correctly reproduced. In terms of persistence, the fit is also good, except for the spread whose theoretical autocorrelation is about half that measured in the data. Finally, the model captures well the comovements between output on the one hand, and consumption, investment, hours worked, and the spread on the other hand. It has difficulty reproducing that traditional and shadow credit are very procyclical in the data, but this reflects to a certain extent our modeling approach matching total credit intermediation with the capital stock, which is a very smooth variable.[13]

The model also yields a fairly standard decomposition of business cycles in a real economy.[14] The neutral productivity shock accounts for about 60, 70, and 45 percent of the unconditional variances of GDP, consumption, and investment, while the labor wedge shock drives about 50 percent of movements in hours worked. The loan monitoring cost has significant effects on real and financial variables: in particular, it explains between 15 and 30 percent of GDP,

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[12]Baker and Wurgler (2015) estimate that a 1 pp. increase in bank capital requirements would raise the annual average cost of bank capital by 8.5 basis points. They remark that with competitive financial markets, lending-deposit spreads would rise by the same amount.

[13]Many mechanisms that we omit for simplicity, such as a working capital channel or binding collateral constraints would help make credit intermediation more procyclical in the model.

[14]We report the exact decomposition in Online Appendix II.

Table 4: Amplification Effects from the Shadow Sector

Variables	Shocks						
	All	u^z	u^i	u^m	u^l	u^d	u^η
GDP	1.05	1.06	1.05	1.03	0.89	0.99	0.85
Investment	1.04	1.09	1.01	1.04	0.85	1.07	0.78

Notes. Entries represent the standard deviation of the variable in the baseline model relative to that in the counterfactual economy with fixed shadow credit. An entry above (below) 1 implies that shadow banking amplifies (dampens) the volatility of the variable after the shock(s). Column 'All' corresponds to the estimates in Table 2 with all shocks (excluding regulation); u^z is the neutral productivity shock, u^i is the investment shock, u^m is the labor wedge shock, u^l is the loan monitoring cost shock, u^d is the deposit shock, and u^η is the regulation shock introduced in Section 4.2.

consumption, and investment fluctuations. Finally, the shadow wedge accounts for about 70 percent of the movements in the shadow share and 30 percent of those in leverage, which is also explained by the deposit preference shock. Overall, the three financial shocks (loan monitoring cost, shadow wedge, and deposit preference) cause between 30 and 40 percent of the fluctuations in output and investment, suggesting that the model contains enough propagation mechanisms to ensure the transmission of financial shocks to the real economy.

# 4   Shadow Banking in General Equilibrium

This section analyzes how the introduction of shadow banks in the model affects its behavior. To do so, we contrast our benchmark economy with shadow banks to a counterfactual one in which shadow credit is fixed at its steady-state level. Formally, we obtain the counterfactual economy by (i) replacing the first-order condition of the traditional bank with respect to ABS, eq. (4), by $abs_t = \overline{abs}$, (ii) replacing the free-entry condition in the shadow sector, eq. (5), by $r_t^a = \overline{r}^a$, and (iii) removing the shadow wedge shock. We keep all parameters at their estimated values.

4.1   A source of amplification...

Our first finding is that shadow banking is a powerful source of amplification in general equilibrium. Indeed, the effects of most shocks hitting the economy are larger in our baseline model than in the counterfactual economy with fixed shadow credit.

To demonstrate this, we report in Table 4 the ratios between the standard deviations of GDP and investment in the benchmark model and the same statistics for the counterfactual econ-

Figure 1: Impulse Response Functions after a Positive Productivity Shock
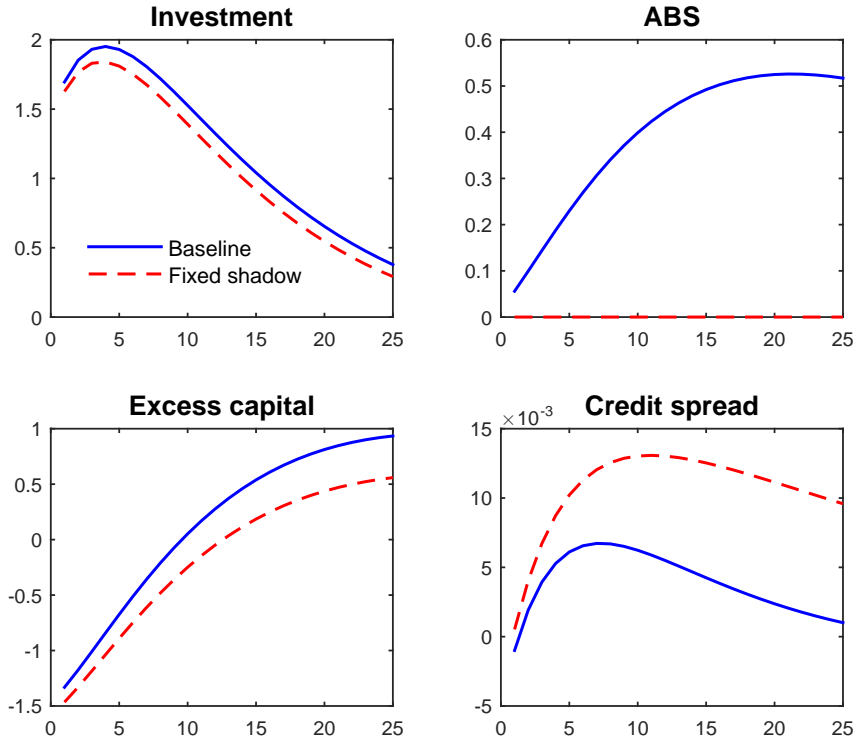
Notes. Deviations from steady states are expressed in percent for investment and ABS, in percent of steady-state regulatory capital for excess bank capital, and in annualized percentage points for the spread.

omy. We compute these standard deviations for each individual shock, as well as for all shocks together.[15] A ratio above (below) 1 means that shadow banking amplifies (dampens) the effects of the shock(s). Globally, it is clear that the presence of shadow banks in the model increases the volatility of the economy: as shown in column 'All,' the standard deviation of GDP in the baseline model is higher by about 5% and that of investment by 4%, compared to the counterfactual with fixed shadow credit. This is explained by the amplification of most individual shocks. In particular, the amplification of the neutral productivity shock u^z, which explains the bulk of the movements in real variables, reaches almost 10% for investment.

To understand how shadow banking generates amplification, we compare the dynamics triggered by a positive neutral productivity shock in the baseline and counterfactual economies. These dynamics are illustrated through impulse-response functions (IRFs) in Figure 1, in blue for the benchmark model and in red for the counterfactual one. To organize the discussion, it is useful to start with the counterfactual economy with fixed shadow credit. After the shock,

[15]The shadow wedge shock does not appear in the table since it is removed from the counterfactual model. Additionally, the table reports the statistics for a regulation shock introduced in Section 4.2. This regulation shock is not present in the estimated model, so that it is not included when computing the results for all shocks.

Figure 2: Impulse Response Functions after a Positive Loan Monitoring Cost Shock
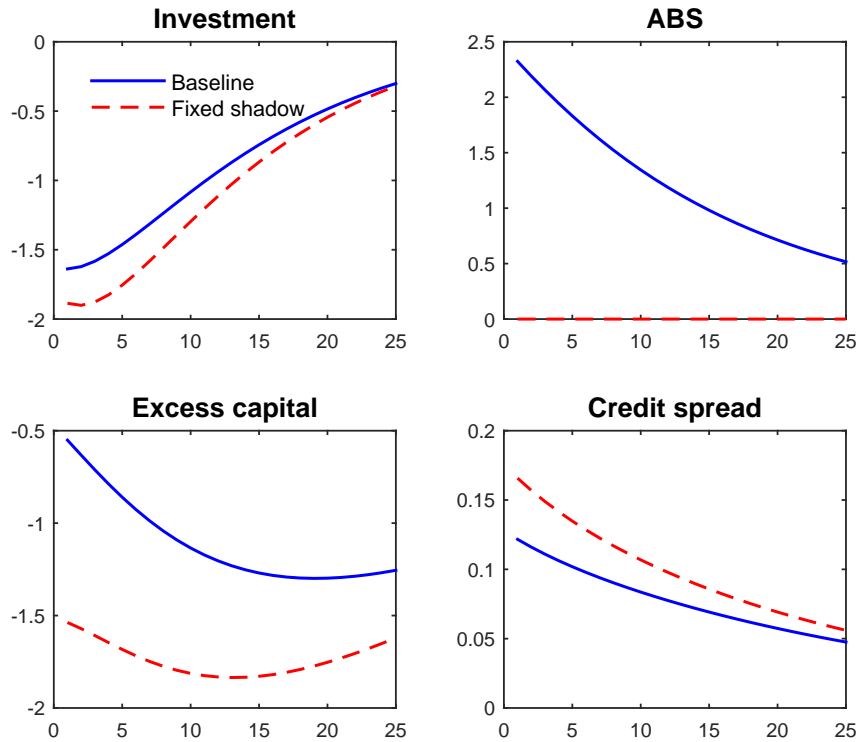
Notes. Deviations from steady states are expressed in percent for investment and ABS, in percent of steady-state regulatory capital for excess bank capital, and in annualized percentage points for the spread.

the traditional bank wants to increase its loan supply because the marginal product of capital is higher. However, the bank simultaneously needs to raise additional capital to comply with macro-prudential regulation. This takes time, so that the bank falls short of its legal requirements during the first 15 quarters. The implied cost forces the bank to increase the credit spread, which raises by about 1.5 basis point in annual terms at its peak.

In the baseline model with flexible shadow credit, the same logic applies but the traditional bank can limit capital costs by substituting regulated standard loans with unregulated ABS holdings. The portfolio cost limits this regulatory arbitrage, but the substitution between traditional and shadow credit is enough to limit the fall in excess bank capital. As a result, credit spreads are lower in the baseline economy and this stimulates GDP and investment. A similar logic — the substitution toward shadow credit keeping intermediation costs small — also explains the amplification of the investment, labor wedge, and deposit shocks.

The story related to the loan monitoring cost shock is slightly different. As shown in Figure 2, a shock raising the cost of loan monitoring makes traditional intermediation more expensive, so that credit spreads increase and the economy enters a recession. The existence of shadow

intermediation helps mitigate this inefficiency, as reallocating credit supply toward shadow banks allows to partly escape from the cost. In this case, credit spreads increase less and the recession is less severe, so that shadow banking dis-amplifies the effects of the shock. A similar intuition applies to the regulation shock, which we present next.

4.2 ... and of regulatory arbitrage

The model also implies that shadow banking activity expands when traditional banks face tighter regulatory constraints. This property, which constitutes in our view a key interaction between traditional and shadow banks, is in line with existing empirical studies. For instance, Buchak et al. (2017) find in the data that shadow banks are more likely to enter markets in which the regulatory burden makes lending more difficult for depository institutions in the US.

The easiest way to emphasize this regulatory arbitrage is to replace the capital adequacy ratio parameter $\overline{\eta}$ by a simple autoregressive stochastic process:

$$\eta_t = \rho_\eta \eta_{t-1} + (1 - \rho_\eta)\overline{\eta} + \sigma_\eta u_{\eta,t},$$

with $|\rho_\eta| < 1$, $\sigma_\eta > 0$, and $u_{\eta,t} \sim i.i.d.N(0,1)$. Following Angelini et al. (2014), we calibrate the persistence parameter ρ_η to 0.90 and we consider a shock triggering an initial increase of 1 pp. in the capital adequacy ratio. Figure 3 reports the IRFs to this shock in our benchmark model, as well as in the counterfactual economy with fixed shadow credit.

As expected, an increase in the capital adequacy ratio has detrimental effects on economic activity. Because it is costly to obtain additional capital in the short run, the bank raises the lending spread by 10 basis points in the counterfactual model with fixed shadow. The bank also cuts its loan supply to decrease leverage, which penalizes investment and output. When shadow banks are free to adjust, the traditional bank exploits the arbitrage between regulated loans and unregulated ABS, so that credit intermediation shifts toward the shadow sector. The equilibrium effect of the regulation shock on the lending spread is smaller and the falls in investment and output are less pronounced. The last column in Table 4 captures this dampening effect, as the presence of shadow banks in the model reduces by 20 to 25% the fluctuations that would be caused by the regulation shock.

This regulatory arbitrage may be a concern for macro-prudential authorities, since it weakens the effectiveness of policy measures targeting only traditional banks. This, together with the

Figure 3: Impulse Response Functions after a Positive Regulation Shock
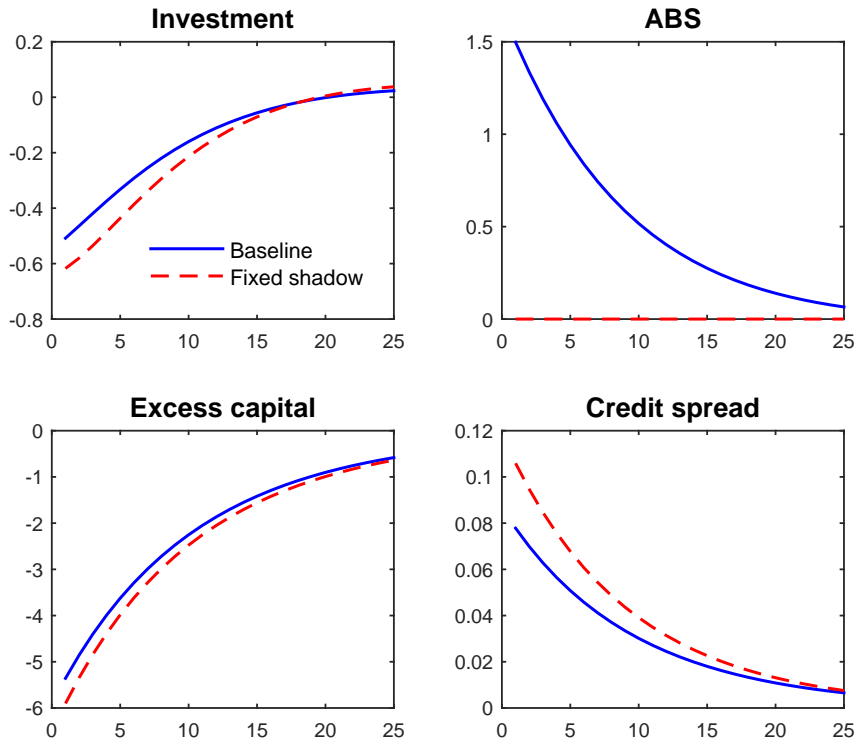
Notes. The shock increases the legal capital adequacy ratio η_t by 1 pp. on impact. Deviations from steady states are expressed in percent for investment and ABS, in percent of steady-state regulatory capital for excess bank capital, and in annualized percentage points for the spread.

amplification role of shadow banks, raises the possibility that regulating both traditional and shadow credit might be a superior strategy. In the next section, we use our model as a simple laboratory to evaluate this possibility.

5 Macro-prudential Regulation with Shadow Banks

During most of our estimation sample, macro-prudential regulation was either limited or based on the 1988 Basel I Accord. After the 2008 financial crisis, a new set of rules named Basel III has been adopted and is currently being implemented. Roughly speaking, Basel III allows for a countercyclical capital buffer and extends regulation beyond traditional loans.[16] In this section, we examine whether these new policy tools would help stabilize aggregate fluctuations in our model with traditional and shadow banks.

We emphasize that our analysis is strictly positive, even if we implicitly assume in our dis-

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[16]The 2004 Basel II Accord had not been fully implemented when the crisis started in 2007-2008. Online Appendix III provides an overview of the successive Basel Accords.

cussions that the macro-prudential authority is concerned with macroeconomic volatility and prefers stable outcomes. Indeed, the Bank of England (2009), the Basel Committee on Banking Supervision (2010), and Angelini et al. (2014) provide theoretical and empirical arguments suggesting that limiting credit volatility may be optimal from a normative perspective.

5.1 Three regulation schemes

Following Angelini et al. (2014), we represent macro-prudential policy with a time-varying capital requirement. This simple instrument allows to capture in a transparent fashion the countercyclical buffer and the extended regulation introduced by the Basel III package. Because the buffer allows national regulators to increase capital requirements in periods of high credit growth, we specify the policy rule for η_t as

$$\eta_t = \overline{\eta} + \kappa_\eta \left(\frac{\Delta b_t}{y_t} - \frac{\overline{\Delta b}}{\overline{y}} \right), \tag{6}$$

where Δb_t is a measure of credit growth (defined below) and $\kappa_\eta \geq 0$ is the responsiveness of capital requirements to credit growth.[17] The latter variable is normalized by GDP, in line with the prescriptions of the Basel III regulation.

In our experiment, we consider three different regulation schemes, that correspond to different calibrations of eq. (6) and different computations of risk-weighted assets. The benchmark case keeps capital requirements constant ($\kappa_\eta = 0$); it broadly captures the Basel I framework. The second case applies a countercyclical buffer ($\kappa_\eta > 0$) to traditional credit only. In that case, (gross) credit growth is measured by $\Delta b_t = q_t l_t - (1-\delta)q_{t-1}l_{t-1}$ and risk-weighted assets are computed with a 100% weight on traditional loans and a 0% weight on ABS. This corresponds to a narrow application of Basel III that leaves shadow banking unregulated. Finally, the third case incorporates both a countercyclical buffer ($\kappa_\eta > 0$) and a regulation of shadow banking. In that case, the policy rule reacts to total credit growth $\Delta b_t = k_t - (1-\delta)k_{t-1}$ and risk-weighted assets are computed with a 100% weight on both traditional loans and ABS. This corresponds to a broad application of Basel III.[18] We fix $\kappa_\eta = 0.80$ for both the narrow and broad regulation

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[17]Remark there is no autoregressive component in our specification of the policy rule. Indeed, capital requirements increase and peak well past the period of rapid credit growth in presence of such a persistence term, which in our view does not capture correctly the logic of Basel III.

[18]The Basel III Accord also recommends to regulate systemically important financial institutions (SIFIs) that are not traditional banks on a case-by-case basis. We could assume that the shadow bank is a SIFI in the model and regulate it. However, this would require important changes to transform the shadow bank into an infinitely-lived agent with capital. Our approach, in which ABS are regulated in the balanced sheet of the traditional bank, corresponds to an indirect regulation of shadow banking since it limits its ability to expand.

Table 5: Economic Volatility under Alternative Regulation Schemes

Variables	Regulation		
	Baseline	Narrow	Broad
GDP	4.40	4.30	4.20
Investment	9.84	9.47	9.12

Notes. Entries are the standard deviations ($\times 100$) of the variables. 'Baseline' corresponds to the first case with constant requirements, 'Narrow' is the second case with a countercyclical buffer applied to traditional credit, and 'Broad' is the third case with a countercyclical buffer applied to both traditional and shadow credit.

cases. This value implies that capital requirements exceed $\overline{\eta} + 0.025 = 0.125$ about once every 8 years.[19]

The third case with broad regulation requires introducing some changes in the model. Because ABS are now regulated, the definition of excess capital becomes $x_t = n_t - \eta_t q_t l_t - \eta_t^a abs_t$, with $\eta_t^a = \eta_t - \overline{\eta}$. This specification ensures that $\overline{\eta}^a = 0$ on average, which keeps the steady state of the model unchanged, while allowing the regulation of ABS to move one-for-one with that of traditional loans in a dynamic setting. In that case, the linearized spread shown in eq. (4) becomes

$$-\Theta'(0)\eta_t^a + \frac{\gamma}{\overline{l}}\left(\widehat{\frac{abs_t}{q_t l_t}}\right) + E_t \epsilon_{t+1}^a = \overline{\Lambda}\left(\hat{r}_t^a - \hat{r}_t^d\right).$$

Since $\Theta'(0) < 0$, this equation shows that an increase in ABS regulation forces the traditional bank to demand higher ABS returns, making shadow intermediation more costly and less attractive.

5.2 Comparing the schemes

We study the stabilization properties of the three regulation schemes — constant capital requirements, countercyclical buffer with narrow regulation, and countercyclical buffer with broad regulation — in different ways. First, we show how they affect the volatility of GDP and investment in equilibrium. Second, to develop the underlying intuition, we consider in more detail how the rules change the behavior of the economy after a productivity shock. Finally, we perform a counterfactual historical exercise asking if the boom-bust cycle in credit associated with the 2007-2008 financial crisis would have been prevented by tighter regulation.

Table 5 reports the standard deviations of GDP and investment implied by the model under

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[19]The Basel Committee on Banking Supervision (2010) limits the capital buffer to be within zero and 2.5% of risk-weighted assets. However, this is not a hard ceiling and the buffer may exceed 2.5% if deemed appropriate in a national context.

the three regulations. In all cases, the shock processes evolve as estimated in Section 3. The entries demonstrate that, while the narrow regulation helps stabilize the economy, the broad regulation scheme is about twice as effective. Indeed, compared to the baseline with constant requirements, the standard deviations of GDP and investment fall by 3 and 4% under the narrow scheme, and by 5% and 8% under the broad rule. This result echoes our earlier discussion about regulatory arbitrage: macro-prudential policy measures that target only traditional credit are likely to be less effective at stabilizing the economy than broader measures if intermediation can be easily redirected toward shadow banks.

To understand how the economy behaves under the alternative schemes, Figure 4 shows the dynamics triggered by a positive neutral productivity shock under each policy. We focus on the productivity shock because, as mentioned above, it is the major driver of real variables in the model. The benchmark case with constant requirements corresponds to the one discussed in Section 4.1: after the shock, loan supply increases because the marginal product of capital is higher and credit partly reallocates toward the shadow sector. With a countercyclical requirement targeting only traditional credit, as in the narrow regulation, shadow credit increases even more as lending costs rise in the traditional sector. This leakage weakens the dampening effect of the regulation and, indeed, the IRF of investment looks very similar to the baseline one. When the countercyclical buffer applies to both traditional and shadow credit, as in the broad scheme, it is not possible anymore to exploit the regulatory arbitrage and the dampening effect on investment is more important, especially so during the first ten periods with fast credit growth. In all cases, the implied increase in the regulatory capital ratio is limited to less than 0.3 percentage points.

Finally, we evaluate the effects of the alternative regulation schemes through a counterfactual historical exercise. We use our estimated model (which corresponds to the baseline regulation scenario with constant requirements for traditional loans) to recover the structural shocks that have hit the economy between 1980 and 2016. Then, we feed these shocks into a counterfactual model in which either the narrow or broad regulation rules applies. Figure 5 reports the counterfactual paths of GDP and investment before, during, and after the financial crisis. A striking result is that the narrow rule is associated with *excess* volatility compared to the benchmark case, so that it would have amplified, rather than reduced, the boom-bust cycle. The behavior of the shadow wedge, whose effects are amplified by the narrow rule, explains this pattern.[20]

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[20]The historical shock decomposition signals that the shadow wedge supported investment during the expansion and penalized it during the crisis. The narrow regulation amplifies the effects of this shock because it increases the traditional bank's incentives to substitute loans with ABS holdings. This explains why the narrow rule would

Figure 4: Impulse Response Functions after a Productivity Shock under Alternative Regulation Schemes
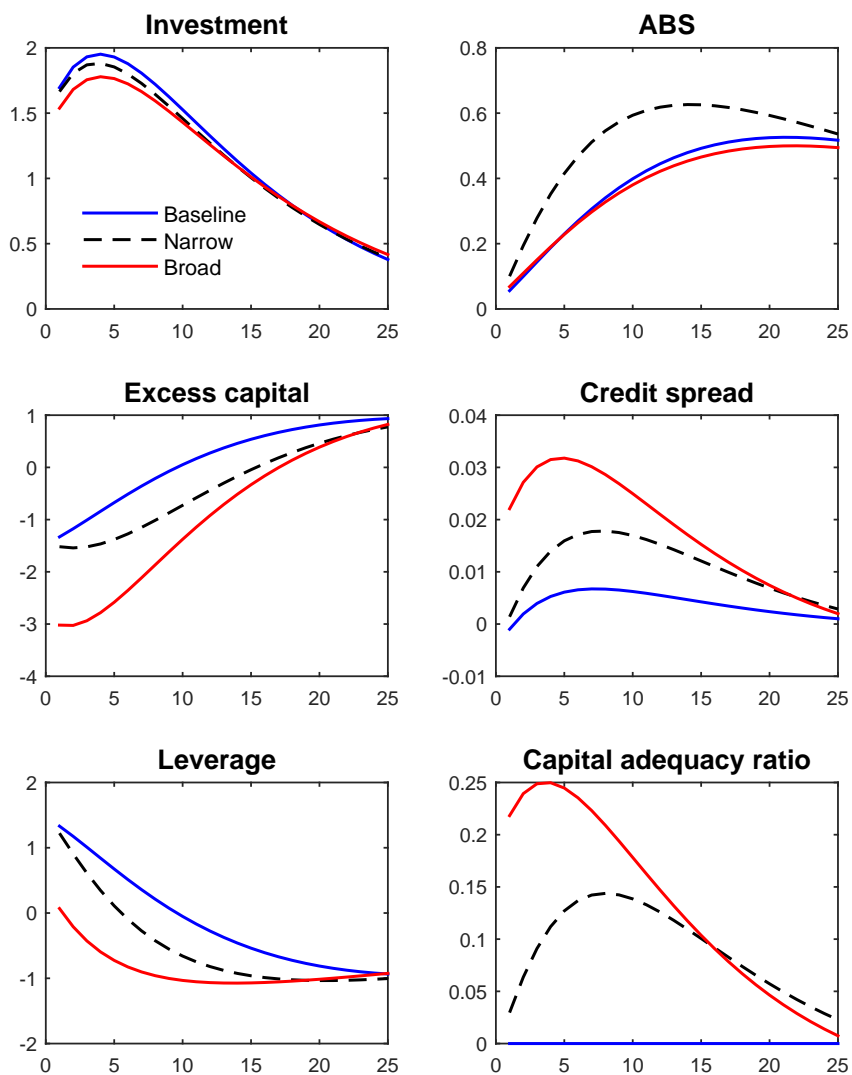
Notes. Deviations from steady states are expressed in percent for investment, ABS, and leverage, in percent of steady-state regulatory capital for excess bank capital, in annualized percentage points for the spread, and in percentage points for the capital adequacy ratio. 'Baseline' corresponds to the first case with constant require-ments, 'Narrow' is the second case with a countercyclical buffer applied to traditional credit, and 'Broad' is the third case with a countercyclical buffer applied to both traditional and shadow credit.

Figure 5: Counterfactual Historical Paths
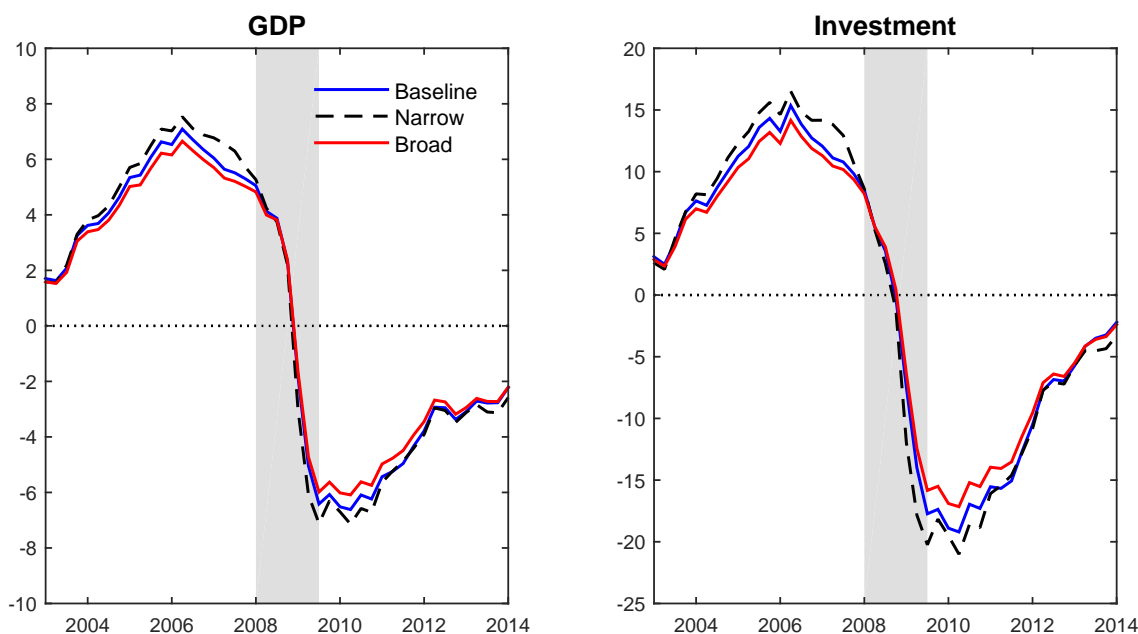
Notes. Deviations from steady states are expressed in percent and shaded areas represent NBER recession dates. 'Baseline' corresponds to the first case with constant requirements (i.e., the observables), 'Narrow' is the second case with a countercyclical buffer applied to traditional credit, and 'Broad' is the third case with a countercyclical buffer applied to both traditional and shadow credit.

On the other hand, the broad rule regulating both traditional and shadow credit would have been more successful in dampening the magnitude of the cycle. For instance, it would have reduced the 2007 peak in investment by 1.5 point and its 2010 through by 2 points, thus limiting the magnitude of the collapse by a non-negligible 3.5 points. The dampening effect on output, while less important, would still have represented about 1 point of GDP.

6 Conclusion

In this paper, we propose and estimate a small-scale DSGE model with interacting traditional and shadow banks. We obtain two main results: (i) Shadow banking is a powerful amplification mechanism because it helps escape important constraints from the traditional sector. (ii) This leakage toward the shadow sector also reduces the effectiveness of macro-prudential policies targeting only traditional banks. Our results even suggest that a countercyclical capital buffer, if applied only to traditional banks, would have amplified the boom-bust cycle associated with

have destabilized the US economy around the Great Recession.

the financial crisis of 2007-2008. On the other hand, a broader regulation scheme also targeting shadow credit would have helped stabilize the economy.

Obviously, our framework remains very stylized. We see at least two interesting extensions. First, it would be useful to extend our model to take into account monetary policy and nominal frictions. Indeed, it would be interesting to see how introducing shadow banks in a medium-scale DSGE model would change its properties. Moreover, monetary policy adds an asymmetry between traditional and shadow banks, as only the former have access to central bank liquidity. Second, it may be worth relaxing the assumption that the representative household owns the whole economy. Indeed, this simplification makes default events irrelevant and potentially prevents capturing some important dynamics of the data during the financial crisis.

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A Data

This appendix describes the sources and the construction of the observables used in estimation.

Consumption. Consumption expenditures on nondurable goods and services (BEA, NIPA Table 1.1.5, lines 5 and 6).

Investment. Sum of consumption expenditures on durable goods and fixed investment (BEA, NIPA Table 1.1.5, lines 4 and 8).

Hours worked. Hours for all workers in the US economy (BLS series downloaded from Valerie Ramey's website).

Traditional credit. Total financial assets of private depository institutions minus their holdings of vault cash, reserves at the Federal Reserve, and holdings of agency- and GSE-backed securities (Z1 release, Table L110, line FL704090005 minus the sum of lines FL703025005, FL713113003, and FL703061705).

Shadow credit. Sum of the total financial assets of ABS issuers (Z1 release, Table L127, line FL674090005) and security brokers and dealers (Z1 release, Table L130, line FL664090005).

Shadow share. Computed as Shadow credit/(Traditional credit + Shadow credit).

Leverage. Computed as Credit/(Assets − Liabilities), where all series pertain to US commercial banks (downloaded from the FRED).

Credit spread. Moody's seasoned Baa corporate bond yield relative to the yield on 10-year treasury bonds, expressed in quarterly terms (downloaded from the FRED).

We seasonally adjust all series extracted from the Financial Accounts Z1 release using the X-12 algorithm implemented in IRIS. We deflate all nominal series by the GDP deflator (BEA, NIPA Table 1.1.4, line 1) to obtain quantity series, which we express in per-capita terms using the population series from the BEA (NIPA, Table 2.1, line 40).

Online Appendix — Not for Publication

I   Traditional and Shadow Banking in the US: A Review

Adrian and Ashcraft (2012) and Pozsar et al. (2013) emphasize three major differences between the traditional and shadow banking sectors in the US. First, intermediaries in each sector finance through different types of liability: traditional banks mostly rely on deposits to extend new loans, whereas shadow banks finance on wholesale markets using tradable credit instruments. Second, traditional banks have access to public sources of liquidity (for instance from the Fed) or insurance (for instance from the FDIC), while shadow banks are excluded from official public enhancements. Third, traditional banks generally perform the whole chain of credit intermediation between borrowers and lenders within a single institution, whereas lender-borrower intermediation is typically performed by a chain of different institutions in the shadow sector. For simplicity, it may be helpful to think of the typical traditional bank as a single institution issuing retail deposits to fund loans, while the typical shadow bank is actually a group of institutions transforming wholesale funding into lending through a complex securitization process.

Because the generic term of shadow banking refers to a wide range of activities, there has been some disagreement about how to properly measure it in the data. In this paper, we follow Meeks et al. (2017) and Gertler et al. (2016) by restrict our definition of shadow banking to security brokers and dealers and issuers of asset-backet securities. These institutions issue tradable securities (wholesale funding) against an underlying pool of securitized assets (loans). They operate about the same economic function as traditional banks, but operate with much less capital and outside the Fed's regulatory framework.

II Variance Decomposition

This appendix provides the unconditional variance decomposition of key variables, as implied by the estimated model.

Table 6: Unconditional Variance Decomposition

Variables	Shocks					
	u^z	u^i	u^m	u^l	u^a	u^d
GDP	62	0	11	19	7	0
Consumption	72	1	5	15	6	1
Investment	47	0	15	28	10	0
Hours worked	26	0	54	11	7	3
Shadow share	0	0	0	22	77	0
Spread	0	67	0	23	11	0
Leverage	5	0	1	9	28	56

Notes. Entries represent percentages. u^z is the neutral productivity shock, u^i is the investment shock, u^m is the labor wedge shock, u^l is the loan monitoring cost shock, u^a is the shadow wedge shock, and u^d is the deposit shock.

The neutral productivity shock explains most of the variability of real variables, but has little effect on financial variables. On the other hand, financial shocks explain a significant share of the variance of real variables. For instance, the loan monitoring cost u^l accounts for 15 to 30 percent of the variance of GDP, consumption, and investment. The shadow wedge also explains 10 percent of investment. Two shocks are more specialized: the investment shock largely explains the spread, whereas the deposit shock accounts mostly for movements in leverage.

III A Review of Financial Regulation in the US and Application to a Simple Model

This appendix reviews the evolution of the Basel regulation, with a special focus on the US economy. It then proposes a simple model with traditional and shadow banks that could capture (part of) this regulation. Within the broad literature about banking regulation, the reader may find more information in Masera (2013), Paskelian and Bell (2013), or Niemeyer (2016).

III.1 From Basel I to Basel III

The Basel Committee develops minimum standards for banking regulation. Countries are therefore free to implement stricter rules, but not rules that are less strict. The Committee has no legislative power, so decisions must be enforced by each country's authority. The successive agreements called Basel I, Basel II, Basel 2.5, and Basel III, are best viewed as gradual refinements of a single regulatory framework, rather than entirely new and independent frameworks. Below, we briefly review each of them.

The Basel I Accord was reached in 1988 and implemented in the following years. It stipulates that traditional banks should have capital equal to at least 8% of their (credit) risk-weighted assets (RWA). The highest weight is 100% (for corporate lending) and the lowest one is 0% (for certain government securities). This agreement evolved over time, notably to take into account market risk on top of credit risk.

The more complex Basel II Accord was concluded in 2004 to refine the computation of the RWA and capital requirements. The agreement embeds 3 pillars. Pillar 1 defines minimum capital requirements covering credit, market, and operational risks. These minimum requirements are based on standardized approaches and/or internal models. Under Pillar 2, the supervisory authority may impose additional capital requirements to individual banks, based on a qualitative assessment of the bank's balance sheet. Pillar 3 contains detailed requirements for the risks and exposures that the bank must make public. When the financial crisis arose in 2007-2008, Basel II was not yet fully implemented in most countries.

The aim of Basel 2.5, agreed in 2009, was to quickly rectify some shortcomings of Basel II that had been revealed during the financial crisis. In particular, banks had grossly underestimated the risk of holding complex securitized assets in their balance sheet. Because Basel 2.5 was only a partial solution, a larger package known as Basel III was adopted between 2010 and 2011 and will be progressively implemented through 2023.

A key element of Basel III is to increase the quantity of capital in the financial system. On top of the 8% of RWA, Basel III adds a 2.5% capital conservation buffer, a 2.5% countercyclical buffer, and a 2.5% extra buffer for globally systemically important banks. With the countercyclical buffer, the Basel Committee has introduced an explicit macroeconomic dimension into prudential regulation. Another key element is to increase the quality of capital, with most of the regulatory capital consisting of Common equity Tier 1 capital (CET1). Basel III also includes,

among other refinements, (i) a strengthening of capital requirements for certain securitization operations, (ii) the possibility for countries to nominate more banks or financial institutions as systematically important (SIFIs), (iii) capital overcharge for loans to SIFIs, (iv) the guarantee that banks have a minimum level of liquid assets, (v) the limitation of the maturity mismatch between assets and liabilities, (vi) the introduction of a complementary leverage ratio requirement, (vii) restriction on the exposure to individual counterparts, and (viii) limitations in accounting practices moving exposures between the trading and banking books.

III.2 Basel III and the Dodd-Frank Act

The Dodd-Frank Act (DFA) was passed in 2010 in the US to prevent the regulatory shortcomings that have been blamed for the 2007-2008 crisis. This legislation creates a top layer of oversight (the Financial Stability Oversight Council, FSOC) for financial institutions and existing regulatory agencies, provides a new resolution procedure for financial companies, and places new regulatory restrictions on derivative assets. The DFA also promotes higher quantitative and qualitative capital requirements and only allows US regulatory agencies to adopt the Basel III guidelines as long as they do not violate the DFA floors. As a result, the US Basel III Final Rule on capital standards has some specificities, as described below:

- The US implementation of Basel III is modulated according to the size of banks: all banks must respect the minimum capital rule, but additional requirements are imposed on the basis of size and complexity. Conversely, the EU has a more 'one-size-fits-all' approach.

- The regulation applies to all depository institutions, but also to systematically important non-bank financial institutions designated by the FSOC.

- The US rule strengthens non-risk-weighted asset capital requirements, which may become binding for large banks.

- Originators of securitized assets must retain at least 5% of the credit risk, a requirement not included in Basel III.

III.3 The Basel/DFA Regulation in a Simple Model of the US Economy

We now propose a simple model capturing some elements of the Basel regulation. We start from the Basel I rule, before turning to the Basel III/DFA rule.[21]

Consider a financial sector composed of traditional and shadow banks intermediating credit between saving households and borrowing firms. The traditional bank finances assets (corporate loans and ABS) through deposits and regulatory capital. Under Basel I, bank capital must be above a constant fraction η^I of RWA, where the weight α^h on corporate loans is relatively high and the weight α^l on ABS (considered as high-quality securities with minimal risk)

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[21]We abstract from Basel II and Basel 2.5, since the former was never fully implemented whereas the later was only a temporary solution.

is relatively low. Hence, capital in the traditional sector must verify

$$\text{capital} \geq \eta^I \text{RWA} = \eta^I(\alpha^h \text{loans} + \alpha^l \text{ABS}).$$

The shadow bank has no access to deposits and finances by issuing ABS in wholesale markets. It is not regulated under Basel I. Figure 6 summarizes this representation of the Basel I rule.

Figure 6: Aggregate Balance Sheets under Basel I

$$\text{capital} \geq \eta^I(\alpha^h \text{loans} + \alpha^l \text{ABS})$$
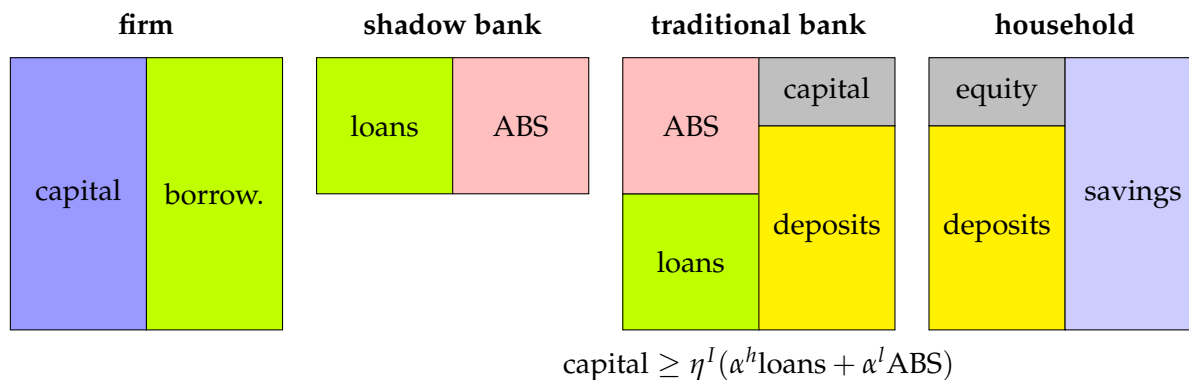
Consider now the same economy under Basel III. Because the new rule requires a higher quantity of capital, the coefficient η has to increase: $\eta^{III} \geq \eta^I$. Moreover, Basel III strengthens capital requirements for certain securities, so we increase the weight on ABS from α^l to α^h. Basel III also introduces an explicit countercyclical buffer, so that η^{III} becomes η_t^{III}, a process that increases in good times and decreases in bad times. Overall, the traditional bank capital must now respect

$$\text{capital} \geq \eta_t^{III} \text{RWA} = \eta_t^{III} \alpha^h (\text{loans} + \text{ABS}).$$

If we view the shadow bank as a SIFI, it would also face capital requirements of the form

$$\text{capital} \geq \eta_t^{III} \text{RWA} = \eta_t^{III} \alpha^h \text{loans}.$$

Figure 7 summarizes this representation of the Basel III regulation.

Obviously, this stylized framework does not take into account other important dimensions of the Basel III/DFA, such as capital quality, liquidity, or maturity mismatch.

Figure 7: Aggregate Balance Sheets under Basel III