

Assessing the Impact of Basel III: Review of Transmission Channels and Insights from Policy Models*

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This paper (i) reviews the different channels of transmission of prudential policy highlighted in the literature and (ii) provides a quantitative assessment of the impact of Basel III reforms using several policy-oriented DSGE models. It shows that the long-term effects on GDP of higher capital requirements are positive when the associated benefits are accounted for in addition to their costs. However, the results crucially depend on assumptions about crisis probability and severity. For liquidity regulations, only models capturing benefits of increased liquidity (e.g., preventing bank runs) show a net benefit.

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1. Introduction

In the aftermath of the 2008 global financial crisis (GFC), the Basel Committee on Banking Supervision (BCBS) developed a set of reforms—the Basel III Accord—aimed at improving regulation, supervision, and risk management within the banking sector. By requiring banks to maintain adequate liquidity ratios and keep certain levels of reserve capital on hand, Basel III addresses a number of shortcomings in the pre-crisis regulatory framework. In order to quantitatively assess the macroeconomic impact of Basel III reforms, quantitative medium-scale models have been developed, essentially by central banks and supervisory agencies that have been at the forefront in their development and application. Are the effects beneficial for the economy according to these models?

In this paper, we address this question by first reviewing the different transmission channels of prudential policy highlighted in the literature in the last 15 years and detailing how they have been introduced in dynamic stochastic general equilibrium (DSGE) models. Second, we provide insights of the effects of Basel III from policy DSGE models routinely used for policy scenarios by central banks such as the European Central Bank, the Board of Governors of the Federal Reserve System, Norges Bank, and the Banque de France. In particular, our quantitative analysis considers how a change in the regulatory environment affects the supply of loans, lending spreads, and ultimately GDP and inflation.

Such considerations were present in the initial development of Basel III, as discussed in the Basel Committee's Long-term Economic Impact (LEI) report (BCBS 2010) and the Macroeconomic Assessment Group (MAG 2010) report, as well as BCBS (2012). However, after a decade it is useful to revisit these issues in order to take stock of the large number of developments in macroeconomic models since then, which include a much more detailed description of the interaction between the financial sector and the rest of the economy, as well as other potential trade-offs.¹ Our analysis also

¹It is worth noting, in contrast to our analysis, that the LEI and MAG rely mostly on real-sector macroeconomic models without a banking sector, and the transmission of regulation was implemented through a calibration of the transmission of higher regulatory requirements on bank lending rates (i.e., prices)

contributes to the regular assessment of the Basel III reforms by the Financial Stability Board (FSB), an international body that monitors and makes recommendations about the global financial system, and the BCBS.

We first show that a very large number of new models have been made available since BCBS (2010, 2012), highlighting various transmission channels. Policy models reflect these channels in a consistent manner, while academic models identify other channels but are not yet sufficiently operational to allow a quantitative assessment of the impact of the regulatory changes. Second, model simulations from five policy models, based on harmonized regulatory scenarios, provide novel estimates of the impacts of Basel III. Specifically, we assess the costs associated with the implementation of Basel III, and highlight potential trade-offs between short-run losses of implementing the reforms in normal times (or when crises are mild) with long-run gains, in particular when a severe crisis occurs. The variety of models and jurisdictions on which the macroeconomic impact of Basel III is assessed helps ensure the robustness of the findings. Some models do not measure the benefits, but these may be inferred by difference from the output of the models that assess both costs and benefits. Evidence on these policy models displayed in Table 1 indicates that the long-run impact of Basel III has the expected positive sign on GDP, although the effect is not large. However, this may be associated with a economic slowdown in the transition to full implementation of Basel III. Whenever the costs and benefits of regulation are both introduced into models, the effects of Basel III are generally positive on GDP.

We find that the long-run gross benefits of the Basel III framework for the euro area could be estimated between 0.6 and 1.6 percent of GDP, as measured by the difference between the net benefits found by the 3D model (Mendicino et al. 2020), 1.2 percent, or by the model by de Bandt and Chahad (2016), 0.2 percent, and the cost found by the Gerali et al. (2010) framework, -0.4 percent. Notice that these estimates are likely underestimated due to non-linear dynamics of crises that are not well captured by the underlying

assuming a full pass-through of a higher cost of capital. Since then, the academic literature has investigated the direct impact of higher requirements on loan supply (in particular, loan quantities). See Birn et al. (2020).

Table 1. Long-Run Impact of a Move from Basel II to Basel III (Solvency) in Several Policy Models

Unit	GDP % Dev.	Bank Probability of Default, % pts. Dev.	Cost of Crisis (% of GDP), % pts. Dev.
Euro Area with 3D Model (Mendicino et al. 2020)	1.2	-7.50	-2.55 ¹
Euro Area with de Bandt and Chahad (2016)	0.2	-0.29	-0.34 ¹
Euro Area with Gerali et al. (2010) Framework (Cost Approach)	-0.4	N/A	N/A
United States (Clerc et al. 2015, with U.S. Calibration)	0.9	-9.21	-3.36 ¹
Norway—Moderate Crisis Prob. and Severity ² (Kockerols, Kravik, and Mimir 2021)	-0.2	-0.16 ⁴	-0.85 ⁵
Norway—High Crisis Prob. and Severity ³ (Kockerols, Kravik, and Mimir 2021)	2.1	-1.63 ⁴	-4.39 ⁵

¹Change in bailout costs. ²Moderate sensitivity of crisis probability and severity to credit growth. ³High sensitivity of crisis probability and severity to credit growth. ⁴Change in the probability of a financial crisis. ⁵Change in the cost of a financial crisis.

Note: The move from Basel II to Basel III is measured by a 5 percentage point increase in capital requirements.

frameworks. In addition, one needs to emphasize that the results crucially depend on the assumptions regarding the magnitude and the sensitivity of bank default probability or of the financial crisis probability to credit growth. For instance, the Markov regime-switching version of the Central Bank of Norway's Norwegian Economy Model (NEMO) (Kockerols, Kravik, and Mimir 2021) indicated that, in the case of moderate sensitivity of crisis probability and severity to credit growth, Basel III implementation reduces GDP. However, when the sensitivity of crisis probability and severity to credit growth almost doubles, Basel III has positive effects on GDP. This is consistent with BCBS (2010) and Birn et al. (2020). Expectations regarding the likely impact of the regulation also play a significant role in the positive assessment of the impact of Basel III regulations.

While significant advances have been made in the modeling of solvency requirements, more research is needed assessing liquidity requirements. Most models concentrate only on the costs of liquidity, and more work is still needed to provide a full assessment of the costs and benefits—in particular, in terms of lower contagion risk. Further modeling improvements such as the inclusion of a shadow banking sector or a more systematic inclusion of non-linear effects would allow to even better assess the impact of both capital and liquidity requirements.

This paper is organized as follows. Section 2 presents the relevant economic channels for the impact of Basel III reforms that are available in the academic literature. Section 3 discusses the contributions and limitations of policy models. Section 4 discusses the results of model-based simulation exercises and compares the outputs of some of the models surveyed in the previous section and in current use by regulators. Section 5 concludes.

2. Channels of Prudential Policy

Since the GFC, macroeconomic models have been expanded to include a more comprehensive financial sector which takes into account banks' balance sheet constraints and additional transmission channels of financial shocks, incorporating the results of models developed in the banking and finance literature. These macroeconomic transmission mechanisms of financial shocks (and thereby also prudential regulation) to the real economy have been widely

discussed in the economic literature and implemented in macroeconomic models. Table 2 sets out these channels and the corresponding contributions of the literature that are summarized in this section. In addition to these channels, it should be noted that all DSGE models are forward-looking models and incorporate a strong role of expectations, whereby agents converge to the final equilibrium, at a speed depending on the existence of nominal and real rigidities and market imperfections.

Policy models or models available in the academic literature are usually built around a core element that we call “bank capital channel,” similar to a collateral channel: increase in capital requirements lead to higher prices of bank capital, leading banks to eventually reduce loan supply and thereby affect the real economy through this price externality (Section 2.1). The notion of “bank capital channel” also appears in the context of monetary policy to denote the extent to which the central bank affects lending through its impact on bank equity when there are capital requirements for banks (see also Van den Heuvel 2006). In Section 2.2 we discuss some other possible transmission channels through banks’ liquidity, differently from bank runs discussed in Section 2.3. The integration of the possibility of bank runs into economic models introduces new trade-offs for regulation, in particular liquidity regulation. Risk-taking behavior of banks (Section 2.4) or interactions with non-bank financing (Section 2.5) combined with other elements such as the bank capital channel are other important building blocks possibly changing the trade-offs of regulation. Empirical macroeconomic models have also been developed but are not discussed here (see BCBS 2021 for more details on these models).

2.1 Bank Capital Channel

Before the 2008 crisis, some models already incorporated a collateral channel for non-financial firms. Two approaches based on different agency problems were generally used. In the first approach, the costly state-verification problem (Townsend 1979) was introduced. Information asymmetry requires lenders to pay a verification cost when borrowers default. Better capitalized borrowers are less likely to default and thus pay a lower external finance premium (Carlstrom and Fuerst 1997; Bernanke, Gertler, and Gilchrist 1999).

Table 2. Selected Contributions to the Literature by Channels of Transmission

Channels	Papers
Bank Capital Channel	Kiyotaki and Moore (1997); Gerali et al. (2010); Meh and Moran (2010); Gertler and Karadi (2011); Clerc et al. (2015); Korinek and Simsek (2016); Walther (2016); Ikeda (2018); Mendicino et al. (2018, 2020); Kravik and Mimir (2019); Jeanne and Korinek (2020); Elenev, Landvoigt, and Van Nieuwerburgh (2021); Schroth (2021); Kockerols, Kravik, and Mimir (2021)
Banks' Liquidity	Covas and Driscoll (2014); De Nicolò, Gamba, and Lucchetta (2014); de Bandt and Chahad (2016); Boissay and Collard (2016); Hoerova et al. (2018); Van den Heuvel (2019); Begenauf (2020); de Bandt, Lecarpentier, and Poinville (2021)
Bank Runs	Angeloni and Faia (2013); Gertler and Kiyotaki (2015); Miller and Soverbutts (2018); Gertler, Kiyotaki, and Prestipino (2020); Kashyap, Tsomocos, and Vardoulakis (2020)
Risk-Taking	Martinez-Miera and Suarez (2014); Boissay, Collard, and Smets (2016); Collard et al. (2017); Martinez-Miera and Repullo (2017); Adrian and Boyarchenko (2018); Swarbrick (2019); Coimbra and Rey (2023); Adrian et al. (2020)
Interactions with Non-bank Financing	Kale and Meneghetti (2011); Fiore and Uhlig (2011, 2015); Plantin (2015); Gertler, Kiyotaki, and Prestipino (2016); Jiménez et al. (2017); Meeks et al. (2017); Crouzet (2018); Ikeda (2018); Fève, Moura, and Pierrard (2019); Martinez-Miera and Repullo (2019); Irani et al. (2021); Begenauf and Landvoigt (2022); Durdu and Zhong (2023)

The second approach builds on the human capital assumption of Hart and Moore (1994). When borrowers cannot pre-commit to work and have the option to repudiate their debt, the value of capital pledged as collateral must match the value of the debt. Thus, better capitalized borrowers can attract more funds to finance their expenditures. Kiyotaki and Moore (1997) find in their seminal paper that the collateral channel has the potential to amplify business cycle fluctuations.² Since agents fail to internalize the feedback mechanism from collateral price changes, this mechanism can also be viewed as a price externality.

The bank capital channel exhibits some parallels to the collateral channel for non-financial firms. The core idea is that a certain amount of bank capital is necessary due to an agency problem between banks and their creditors (similar to the role of collateral described above), or directly due to regulatory capital requirements. Some models combine both approaches by introducing (socially costly) financial frictions based on an agency problem mitigated by bank capital requirements. In this case, regulatory bank capital requirements have both costs and benefits: they impose credit supply constraints, but mitigate risks and lower inefficiencies associated with banks' agency problem.

When the bank capital channel is active, the impact of an adverse shock to bank capital is accompanied by a drop in bank credit supply. The exact transmission mechanism depends on the type of friction considered between banks and their creditors, and on the final use of bank funding: any fall in bank capital can result directly in higher funding costs for banks or limit banks' ability to attract funds (e.g., deposits). In both cases, a decline in credit supply affects business and/or housing investment. Some models also incorporate consumer loans which directly affect consumption. The bank capital channel thus generates interactions between the financial and non-financial sectors: adverse non-financial shocks depress activity and weaken banks' balance sheets and credit supply, exacerbating the impact of the shock on overall economic activity.

²Note that the Kiyotaki and Moore (1997) paper was revisited recently by Urban (2019), who shows that the linear approximation used in the paper reportedly led to biased results and the amplification of business cycle shocks was not quantitatively important after the correct solution method was applied.

In order to extend the collateral channel to financial intermediaries, the state-verification friction was introduced between banks and their creditors, in addition to the usual friction between banks and entrepreneurs. Hence, both banks' and entrepreneurs' capital ratios drive lending spreads (Davis 2010; Hirakata, Sudo, and Ueda 2011). A double moral hazard problem between banks and their creditors, and between banks and entrepreneurs (Holmstrom and Tirole 1997) is another friction that was introduced in DSGE models (Meh and Moran 2010). Banks exert monitoring efforts, which are costly and unobserved but can incentivize entrepreneurs to behave optimally. Higher bank capital acts as a monitoring incentive for banks and determines the amount of funds banks can attract from their creditors to fund entrepreneurs' investment. A different moral hazard problem between banks and creditors arises where banks hold equity stakes in non-financial corporations and have the option to divert a fraction of their assets to these corporations (Gertler and Karadi 2011). Depositors will liquidate the bank to avoid losses where banks divert assets. Consequently, banks hold sufficient capital to assure depositors that they do not have an incentive to divert assets and attract sufficient deposits. In all these models, changes in banks' capital affect banks' credit supply. In the same vein, Clerc et al. (2015) incorporate optimizing financial intermediaries, which allocate their scarce net worth together with funds raised from saving households across two lending activities, mortgage and corporate lending. For all borrowers (households, firms, and banks), external financing takes the form of debt which is subject to default risk. Their three default (3D) model illustrates how the three interconnected net worth channels may cause financial amplification and the distortions due to deposit insurance.

The introduction of capital requirements directly into models with the bank capital channel is crucial for measuring the costs and benefits of capital regulations. Most models capture the costs of tighter capital requirements as a reduction in credit supply. In some models, regulatory capital-to-asset ratios directly affect credit volumes (Clerc et al. 2015). In other models, stricter capital requirements are transmitted through higher bank funding costs. For example, banks deviating from exogenously given capital requirements can incur a cost captured by an ad hoc penalty function (Gerali et al. 2010).

Some models also measure the benefits of capital requirements. There is an incentive for excessive risk-taking by banks where they are protected by limited liability and consumers are protected by deposit guarantees. Higher bank capital requirements reduce bank default rates and the resources lost in the liquidation process. In addition, in Clerc et al. (2015), higher default probability for banks increases the required interest rate on uninsured bank debt and raises the cost of providing loans to the real economy. When the capital ratio is too low, the probability of bank default is high. Conversely, increasing capital from a low level may lower the weighted average cost of bank funding, as the cost of uninsured bank debt decreases, implying higher steady-state bank lending and GDP. Transition effects can also be important. The costs of tighter capital requirements can be higher in the short run (as banks must reduce credit supply) while benefits emerge in the long run as banks accumulate more capital (Mendicino et al. 2020).

The bank capital channel thus opens important interaction with macroprudential policies, but also with monetary policy. The introduction of nominal rigidities and monetary policy allows the central bank to adjust interest rates downwards in the transition phase towards tighter capital requirements to mitigate any economic slowdown caused by a drop in credit supply (Mendicino et al. 2018, 2020). Unconventional monetary policy can also be modeled as central bank credit intermediation, which interacts with the bank capital channel (Gertler and Karadi 2011).

Similar price externalities can also play a role where a liquidity trap may occur at the zero lower bound (ZLB) on interest rates (Korinek and Simsek 2016). Where constrained households deleverage after a financial shock, decreases in interest rates are needed to induce unconstrained households to support aggregate demand. If the interest rate reduction is limited by the ZLB, aggregate demand is insufficient and the economy enters a liquidity trap. In this environment, households' ex ante leverage and insurance decisions are subject to such externalities.

Some three-period models with a banking sector rely on a bank capital channel that can trigger fire sales. They can provide insights into the effect of liquidity policies alongside capital regulation. Where banks' creditors have a preference for liquidity by assumption (Walther 2016) or where the amount of liquidity is not enough in the

case of a bank run (Ikeda 2018), the economy is inefficient without regulation. In these models, both capital and liquidity requirements play a role to counter these inefficiencies. In a similar framework, Jeanne and Korinek (2020) investigate how macroprudential policy should be designed when policymakers also have access to liquidity provision tools to manage crises.

2.2 Banks' Liquidity

The second most important channel of transmission of financial shocks to the real economy concerns banks' liquidity. Similar to changes in capital requirements, changes in liquidity requirements lead to changes in the behavior of banks affecting the real economy. In some models, a role of liquidity regulation is created by directly imposing constraints on the maturity of funding sources, or on the liquidity of assets to avoid bank runs (without explicitly modeling bank runs; see Section 2.3). Models in this part of the literature include De Nicolò, Gamba, and Lucchetta (2014) in partial equilibrium, or Covas and Driscoll (2014) or de Bandt and Chahad (2016), in general equilibrium. In the latter model, liquidity requirements are implemented through multi-period assets and liabilities. Including households with a preference for liquidity, which banks can supply through their mix of liquid and illiquid assets, can allow for an analysis of the interaction between capital and liquidity policies (Van den Heuvel 2019; Begenau 2020). Bank capital requirements directly limit the fraction of assets that can be financed with liquid deposits, while regulation requiring banks to hold more liquid assets increases the required return on bank loans and reduces credit as a consequence. These effects have different implications for the macroeconomic costs of these policies, measured as the welfare cost to households from reduced liquidity, and lost investment and production from higher costs of intermediation.

Hoerova et al. (2018) focus on the costs and benefits of liquidity regulation. The paper demonstrates the positive role that liquidity policy can have on reducing the need for lender of last resort interventions during financial crises. The authors examine the opportunity costs of liquidity policy, providing evidence for the presence of private costs to banks resulting from requirements that force these

banks to hold more liquid assets than their own preferences, which in turn has a negative impact on profitability (see also de Bandt, Lecarpentier, and Pouvelle 2021). One major finding is that the opportunity cost of liquidity regulation is small, and smaller than that of capital regulation.

Finally, the introduction of heterogeneous banks with an interbank market can also create a role for liquidity policy (Boissay and Collard 2016). In the interbank market, borrowing banks divert funds that lending banks cannot easily take back, creating an agency problem. As banks do not fully internalize the effect of their funding decisions, capital and liquidity regulations can address these issues. These policies can be reinforcing where capital requirements reduce risky lending decisions and liquidity requirements encourage the purchase of lower risk liquid assets (government bonds). That said, the latter effect can reduce government bond yields, increasing demand for deposits and bank leverage (and hence risk).

2.3 Bank Runs

Reducing the risk of bank runs is a major objective of prudential policies, which triggers a new channel of transmission. A theoretical approach suitable for studying crisis phenomena (including bank runs) is global coordination games of regime change (see Morris and Shin 2001). Agents take an action (e.g., withdraw deposits from a bank, or refuse to roll over short-term debt) and their incentive to act rises with the proportion of agents taking similar actions (strategic complementarity). This innovation in the global game solution methods has spurred the development of extensions to the classical bank run model by Diamond and Dybvig (1983) (see, for example, Goldstein and Pauzner 2005).

An extension to this approach includes the introduction of safe alternative opportunities for investors to provide deposits that fund bank lending in a three-period model. Investors receive a private signal about a bank's solvency and can decide to withdraw their funding. In this way, runs are predicated on expectations about a bank's solvency. Banks have to offer a risk premium to attract funding, and more liquid banks have lower premiums. Liquidity regulation

reduces the probability of a run and can be demonstrated to reduce the profits of banks to a lesser extent than for other approaches (Miller and Sowerbutts 2018). Similar approaches have been used to examine the complementarity between capital and liquidity regulation (Hoerova et al. 2018; de Bandt, Lecarpentier, and Pouvelle 2021). Another extension of the Diamond and Dybvig framework is to include endogenous funding, with banks and borrowers subject to limited liability. Banks monitor borrowers (when profitable) to ensure that they repay their loans, while depositors may choose to run based on beliefs about both banks' monitoring and resources available for those withdrawing early (Kashyap, Tsomocos, and Vardoulakis 2020).

In a different strand of the literature, authors have started investigating infinite-horizon DSGE models combining financial accelerator effects and bank runs. In this approach, the probability of a run increases with bank leverage. Expansionary shocks increase bank leverage, bank risk, and the probability of runs. A recession that constrains bank lending due to conventional financial accelerator effects raises the possibility of runs due to the associated weakening of balance sheets. When banks optimize over a finite (two-period) horizon, regulatory constraints on leverage (in particular, countercyclical capital requirements) reduce the probability of runs, stabilize the banking system, and reduce fluctuations of the economy (Angeloni and Faia 2013). Furthermore, when banks do not take into account the effect of their leverage on asset fire sales in distressed times, there is excessive leverage in (no regulation) equilibrium (Gertler and Kiyotaki 2015). Capital requirements correct this bias and reduce the probability of runs, although there is a trade-off as tighter capital requirements also reduce the level of financial intermediation. Extending this model further to a more conventional macroeconomic setting including a production sector allows for more quantitative conclusions (Gertler, Kiyotaki, and Prestipino 2020). Compared to the more conventional models discussed in Section 2.2, the models discussed above have the advantage of capturing the highly non-linear nature of bank runs in case of a financial system collapse: when bank balance sheets are strong, negative shocks do not push the financial system to the verge of collapse; when they are weak, a similar negative shock leads the economy into a crisis in which bank runs exist in equilibrium.

2.4 Risk-Taking Channel

The bank-capital, bank-liquidity, and bank-run channels can all account for the fact that credit is depressed during and following a financial crisis. However, empirical studies also find that credit is also often elevated prior to financial crises (Schularick and Taylor 2012), pointing to a causal link between high credit *ex ante* and the occurrence of a financial crisis *ex post*. The literature has thus also explored how risk can endogenously build up over the course of the business cycle through a bank risk-taking channel.

The bank risk-taking channel is often built on bank's limited liability and deposit insurance. Banks enjoying limited liability do not fully internalize the risks of their lending activities, and the deposit insurance implies that banks' creditors do not require a compensation for the excessive risk-taking behavior of the bank. Compared to the social optimum, banks take too much risk, and the financial sector is too fragile. Macroprudential policies can mitigate these inefficiencies by ensuring that banks internalize these risks.

Bank risk-taking can take different forms, from extending too much credit (volume of assets) to overinvesting in risky assets (quality of assets). In Section 2.1., we already described how banks' limited liability and deposit insurance affect their credit volumes and how macroprudential policies can mitigate their risk-taking incentives. In this section, we complement this discussion by focusing on the endogenous buildup of vulnerabilities and on the risk-taking channel operating through the quality of bank assets.

Martinez-Miera and Suarez (2014) develop a DSGE model where banks can invest in safe and risky assets. Risky assets are exposed to a systemic shock affecting all these assets at the same time. When the systemic risk materializes, the equity of banks investing in risky assets is destroyed, credit supply contracts, and investment falls. In their framework, risky assets have a lower expected return on average than safe assets. Investment in the risky asset is thus socially inefficient. However, they offer a higher return when the economy is in the boom phase of the business cycle. Banks thus have an incentive to invest in risky assets, as they benefit from higher returns when the systemic shock does not materialize and are protected by limited liability when it does. When making their investment decisions, banks trade off the extra yield offered by risky assets with the

potential loss of equity. In tranquil times, bank equity becomes abundant, its value declines, and banks' incentive to take risks increases. As a consequence, systemic risk-taking peaks after long duration of normal times.

Regarding the impact of regulation, higher capital ratios (i) discourage investing in the bad asset, i.e., reduce the proportion of resources going into inefficient systemic investments, and (ii) increase the demand for scarce bank capital in each state of the economy, reinforcing bankers' dynamic incentives to guarantee that their wealth (invested in bank capital) survives if a systemic shock occurs.

Collard et al. (2017) introduce a similar framework—where banks can invest in safe or risky assets—into a standard New Keynesian DSGE model to study the interaction between monetary and prudential policies. They show that macroprudential policy is effective at mitigating bank risk-taking behaviors on the quantity and quality of credit. In contrast, monetary policy only directly affects credit volumes, because the policy rate determines the cost of funding of both safe and risky assets.

A series of recent papers have also used “savings glut” (as proposed by Bernanke 2005) to model financial crisis. As a boom progresses, investors (or savers) accumulate savings, coming from higher incomes and a desire to smooth consumption. These extra savings cause a savings glut, lowering interest rates and spreads. These lower rates, in turn, induce more risky lending such that a financial crisis becomes more likely. There is additional feedback because the risks of financial instability created by a savings glut further increase the incentive to save and to bid up asset prices.

Several frictions have been used to model the relation between saving gluts and financial crisis. They explain the endogenous buildup of risk associated with a decline in interest rates and generate boom-and-bust dynamics. They show that a banking crisis can be caused by exceptionally large shocks, or by small negative shocks at the end of a boom cycle. The bust is always associated with a credit crunch, stemming for example from bank failure, interbank market freeze, or credit rationing.

In a first set of papers, the savings glut that develops during certain booms feeds bank risk-taking behavior and culminates in bank failures. Martinez-Miera and Repullo (2017) consider banks'

investment in costly monitoring of loan quality. Banks optimally choose to monitor less in boom periods since monitoring is costly and profit is lower due to lower lending spreads, just as borrowers become riskier and crises (endogenously) more likely. A similar mechanism that is also active, mentioned already in the context of the liquidity channel, is that banks relax credit standards during a boom. Coimbra and Rey (2023) assume that intermediaries differ with respect to risk tolerance (expressed as different value-at-risk constraints). When interest rates are sufficiently low, further drops in the interest rate disproportionately benefit highly leveraged intermediaries, driving out of the market the more prudent ones. Assets then concentrate in a few large and risk-tolerant institutions, which increases financial market fragility. Similarly, Adrian et al. (2020) find that lower interest rates shift conditional output risk via further risk-taking.

In a second set of papers, the intensity of the moral hazard and/or adverse problems worsen during savings gluts, potentially causing freezes in the interbank market or credit rationing for the ultimate borrower. Boissay, Collard, and Smets (2016) introduce moral hazard and asymmetric information on the interbank market with banks that differ with respect to their intermediation skills. In a frictionless interbank market, less efficient banks raise deposits and lend their proceeds to the banks that are more efficient in intermediating funds to firms. The late-cycle savings glut reduces interbank interest rates, exacerbates the moral hazard problem, and leads to a freeze of the interbank market. The interbank market freeze forces less efficient banks to lend directly to firms (instead of delegating the task to the most efficient banks) and leads to a drop in credit. Swarbrick (2019) models asymmetric information on credit risk between firms (which know the risk) and banks (which do not), leading to adverse selection and credit rationing. During a savings glut, the risk of default increases to the point where banks decide not to lend all available funds and restrict credit to safe firms.

2.5 *Interactions with Non-bank Financing*

While our discussion so far has focused on banks, the financial sector is a complex system where banks, non-bank financial intermediaries

(NBFI), and the bond market interact and provide different sources of external funds to borrowers. The ability to include NBFI and direct bond issuances are important modeling features that increase the relevance of macroeconomic models used in policy analysis for economies that rely comparatively less on banking finance.

A number of recent papers try to explicitly include NBFI that are unregulated (or lightly regulated) and not covered by deposit insurance. In these papers, changes in capital requirements (or shocks on regulated banks' capital) lead to substitution effects between regulated bank and NBFI loans. In a quantitative general equilibrium (real business cycle type) setting, increasing capital requirements forces regulated banks to find more expensive equity funding, leading to an expansion of the NBFI sector as it becomes relatively more profitable (Begenau and Landvoigt 2022). A further insight from this class of model is that the broader effect of higher capital requirements in the regulated banking sector on non-financial sector borrowing may be ambiguous, as reduced leverage (and capacity for lending) at regulated banks is absorbed by higher leverage (and lending) at NBFI (Durdu and Zhong 2023). In a more stylized model built on similar assumptions, tighter leverage restrictions also improve the resilience of regulated banks but lead to increased leverage (and, as a result, higher default probability) by NBFI (Ikeda 2018).

The literature also offers insights on the modeling of other NBFI characteristics. NBFI tend to finance their assets with short-term wholesale funds (e.g., Gertler, Kiyotaki, and Prestipino 2016) and have special securitization skills: they issue tradable securities backed with (bank) loans (e.g., Meeks, Nelson, and Alessandri 2017). In such setting, NBFI can be the source of financial shocks that propagate to banks and the macroeconomy. NBFI can also amplify the effect of aggregate shocks leading to a synchronized increase in economic activity and credit demand, because they help to alleviate the constraints faced by regulated banks (Fève, Moura, and Pierrard 2019).

Other papers focused on borrowers' (mostly entrepreneurs) choice between bonds and bank loans. Bond finance is cheap, but banks can mitigate information asymmetry problems through screening and monitoring and have special restructuring skills. In De Fiore and Uhlig (2011, 2015), firms can pay a cost to share

some information on their productivity with the bank. Firms with an intermediate level of productivity find it optimal to pay the information cost and opt for bank loans. The most productive firms are financed with bonds, while the least productive abstain from raising funds. When bank loans can be restructured in times of financial distress (thus avoiding inefficient liquidation of potentially viable firms), riskier firms opt for a mix between bonds and bank loans, while safer firms exclusively rely on the bond market (Crouzet 2018). In this type of model, bonds are substitutes for bank loans. Bond issuance can mitigate the impact of bank credit supply shocks. These models are, however, silent on the effect of a change in capital requirements.

It is also well-known that larger firms are more likely to have access to the bond market (for empirical evidence, see Kale and Meneghetti 2011 and the references therein). de Bandt and Chahad (2016) introduce small and large non-financial corporations when studying the impact of prudential regulations in a policy model. While small firms exclusively rely on bank loans, large firms are financed with a mix of bond and bank loans, which also generates substitution effects between bank and bank loans for the latter.

Martinez-Miera and Repullo (2019) extends this discussion to the choice between bonds, bank loans, and NBFI loans. They build a stylized model where financial intermediaries screening is costly and unobserved but mitigates entrepreneurs default risks. They find that low-risk entrepreneurs borrow from the market. Intermediate and high-risk entrepreneurs borrow from intermediaries. Their choice between bank and NBFI loans depends on the design of prudential regulations. When capital requirements are risk based, intermediate-risk entrepreneurs opt for bank loans while high-risk borrowers are financed by NBFI. Similarly to the aforementioned literature (as well as Plantin 2015), a tightening of capital requirements in the banking sector may lead to substitution effects (see empirical evidence in Jiménez et al. 2017, Irani et al. 2021). As a consequence, the optimal capital ratio may be lower compared to a situation without a shadow banking sector (or financial market). But at the same time, the overall financial system is riskier, due to the existence of an unregulated shadow banking sector. The overall macroeconomic effect of a larger shadow banking sector is still an area for additional research.

3. Contributions and Limitations of Policy Models

We now discuss how policy models used by central banks and supervisory authorities incorporate the channels presented in Section 2 and what are their limitations. In particular, we highlight similarities and differences between models developed in a representative set of jurisdictions: (i) the euro area (3D model by Clerc et al. 2015, complemented by a monetary policy channel, as described by Mendicino et al. 2020; model by de Bandt and Chahad 2016; and a modified version of Gerali et al. 2010, as described by Bennani et al. 2017), (ii) the United States (3D model by Clerc et al. 2015, with a country-specific calibration used by the Board of Governors) and (iii) Norway (Norges Bank, regime-switching version of NEMO; see Kockerols, Kravik, and Mimir 2021). We also consider models developed in other policy institutions. Darracq-Pariès et al. (2022) carry out a similar exercise but only focusing on models at the European Central Bank. We then investigate their performance in light of results highlighted in academic papers. Papers under review in the section are displayed in Table 3.

3.1 Contributions of Policy Models

Policy models are operational macroeconomic models used for policy simulations. They implement in a consistent fashion some of the characteristics of academic models and bring them to the data. Policy models share the following features. First, the models are estimated or calibrated to get a reasonable level of plausibility. This implies in particular that they are cast in a national accounting framework, at a quarterly frequency. They are well adapted to mirror actual economic data and trends. One should not, however, underestimate the challenges in estimating and calibrating these models in the context of setting initial steady-state banks' probability of default (BCBS 2021, Annex 1) or financial crisis probability (BCBS 2021, Annex 6). Although the default probability is endogenous in these models and the elasticity of the default probability depends on structural factors, the initial value of default probability matters. Moreover, in some of these models, financial crisis probability depends on credit growth that is endogenous, but the sensitivity

Table 3. Policy and Academic Literature on the Modeling Challenges Associated with Basel III

Challenge	A Selection of Policy Models	Other Academic References
Detailed Regulatory Policies	Gerali et al. (2010); Covas and Driscoll (2014); De Nicolo, Gamba, and Lucchetta (2014); Clerc et al. (2015); de Bandt and Chahad (2016); Mendicino et al. (2018, 2020); Kravik and Mimir (2019) (Central Bank of Norway's NEMO model); Darracq-Pariès et al. (2022); Kockerols, Kravik, and Mimir (2021)	Brunnermeier and Sannikov (2014); Holden, Levine, and Swarbrick (2019); Lang and Forletta (2020); Dou et al. (2021); Elleney, Landvoigt, and Van Nieuwerburgh (2021); Schroth (2021); Jondeau and Sahuc (2022); Sharez (2022)
Non-linearity	See line 1	Adrian and Boyarchenko (2018); He and Krishnamurthy (2019); Begnau (2020)
Multiplicity of Channels	Kockerols, Kravik, and Mimir (2021)	Gertler, Kiyotaki, and Prestipino (2020)
Endogenous Crisis Heterogeneous Banks		Badarau and Levieuge (2011); Corbae and D'Erasmo (2019); Coimbra and Rey (2023)

of crisis probability to credit growth is estimated based on single-country or cross-country data outside the model.

Second, the models include a quite high level of details, allowing a measurement of actual policy which is clearly not the case in more stylized models. For example, the 3D model includes two types of assets, and two types of liabilities, even if they are one-period debt. In the model by De Nicolò, Gamba, and Lucchetta (2014) banks may invest and issue one-period bonds, besides collecting deposits and granting loans. In the model by de Bandt and Chahad (2016), assets and liabilities are defined for more than one period, allowing a quite accurate modeling of liquidity requirements. In the Central Bank of Norway's model, NEMO, banks extend credit to both households and non-financial firms and finance themselves using household deposits and foreign debt. Household debt is long term, which reflects the long-term nature of mortgage debt.

Third, they integrate many of the channels presented in Section 2, in contrast to stylized academic models that often concentrate on a particular channel of transmission. To be more specific:

- The *bank capital channel* is present in all policy models, as solvency is a central tool of banking regulation. A key benefit of increasing capital in the 3D model—as well as for Kockerols, Kravik, and Mimir (2021) for Norway—is the expected reduction in the probability of bank failure. It also induces a reduction of bank runs for the de Bandt and Chahad (2016) model. The models reviewed by Darracq-Pariès et al. (2022) also include a strong link between bank capital and credit supply. Bank default appears a key factor affecting the response of the economy to higher capital requirements in the medium to long term. In 3D, fewer bank failures imply lower bank failure costs—both public and private. The public costs of deposit insurance and the bailing out (or resolution) of failing banks are ultimately borne (for simplicity) by all households because they are taxpayers. Other deadweight costs also affect households' consumption. The private costs are captured by the spread banks are forced to pay over the risk-free rate in order to attract debt funding. Some bank debt is uninsured and its interest rate decreases when banks are safer because debt holders no longer need to be compensated for the potential

losses. When banks are competitive, as in the 3D model, this cost reduction will be passed on to borrowers (*ceteris paribus*), stimulating economic activity. When they are facing monopolistic competition, like in NEMO, the pass-through is smaller in the short run but is ultimately passed on to borrowers. Nevertheless, when there is an occasional financial crisis, lending spreads in NEMO become higher during crisis episodes due to asymmetrically large credit supply shocks. In this case, a benefit of reducing the crisis probability (by raising capital requirements) is to have lending spreads that are lower in crisis times, at the cost of being higher in normal times.³ An effect that pushes in the opposite direction, and that is a key cost of increasing capital requirements, arises when the required rate of return on equity is higher than the cost of debt (which is usually the case and assumed in the 3D model, in NEMO, and in many other macrofinancial models). The higher return on equity means that higher capital requirements adversely affect banks' profits, which increase the spread of lending rates over deposit rates in order to achieve higher profitability and attract equity investors.

- *Liquidity and bank runs* are introduced in de Bandt and Chahad (2016), while the *liquidity channel* is also introduced in the De Nicolò, Gamba, and Lucchetta (2014) partial equilibrium model, and the Covas and Driscoll (2014) DSGE model. In the latter model, general equilibrium effects matter; notably, the increase in loan spreads following a tightening of regulation softens the initial negative effects on loan supply. But the consideration of both capital and liquidity constraints is not very frequent in the academic literature, and also not prevalent in many policy models. Impacts on bank runs are rarely introduced, except for de Bandt and Chahad (2016). For instance, for De Nicolò, Gamba, and Lucchetta (2014), liquidity requirements reduce banks' liquidity transformation

³Tighter solvency regulation in NEMO reduces the probability of occurrence of crisis periods characterized by a large increase in lending spreads, hence partially reducing the increase in the ergodic mean of lending spreads over the whole business cycle, because higher capital requirements slow down household credit growth upon which the crisis probability depends.

activity, hence lending activity, without consideration of long-run effects on financial stability.

- *Financial crisis* into policy models is introduced through a regime-switching DSGE model, as in Kockerols, Kravik, and Mimir (2021) (as implemented in Norges Bank's main macroeconomic model, NEMO).⁴ This type of policy model allows one to flexibly incorporate different types of non-linearities into large-scale quantitative macro models such as financial crises by combining typical business cycle fluctuations (normal times regime) with crises dynamics (crisis times regime). The evolution of crisis is then calibrated to replicate the dynamics of many macroeconomic and financial variables during actual crisis episodes or those under macroprudential stress-testing scenarios used at central banks. Moreover, the transition from normal times to crisis times depends on endogenous regime-switching probabilities that link credit growth (or leverage) to crisis probability. Crisis probability and severity endogenously fluctuate based on the evolution of credit growth in the model.
- The *risk-taking channel* is introduced in the 3D model through limited liability (see Section 2.4.).

Note, however, that some academic models also include multiple channels through interaction between capital and liquidity requirements. This is the case of the Adrian and Boyarchenko (2018) continuous-time model, which looks at the interaction between liquidity and solvency requirements, and concludes that liquidity requirements reduce systemic risk without impairing consumption growth. This is also the case of the Begenau (2020) model, which includes deposits in households' utility functions. Deposits are cheaper compared to equities, because they offer a convenience yield. Higher equity requirements reduce bank deposits. This is welfare decreasing for households that derive utility from deposits. However, it also decreases the deposit rate (since the marginal convenience yield increases), which lowers banks' financing costs. Higher equity

⁴The Markov regime-switching version of NEMO is solved using the Rationality In Switching Environments (RISE) toolbox developed by Junior Maih. RISE is an object-oriented MATLAB toolbox for solving and estimating non-linear regime-switching DSGE models. The toolbox is freely available for downloading at https://github.com/jmaihs/RISE_toolbox.

requirements also increase banks' incentive to monitor projects, as shareholders have more "skin in the game." This lowers banks' risk and raises their average returns, leading to more credit provision. Overinvestment in low-quality projects decreases. This reduces the volatility of output and consumption and boosts their average levels. Benefits from higher and smoother consumption outweigh the costs of lower deposits. The "deposit rate" channel complements the traditional bank capital channel.

3.2 Limitations of Policy Models

Policy models face, however, some limitations.⁵ First, one criticism of operational models is that they fail to adequately capture observed economic outcomes during crisis periods. Linearized solutions to DSGE models around a steady state disregard underlying non-linear dynamics. While some models explicitly allow for the presence of occasionally binding constraints on bank capital, the simulations are performed assuming that these constraints are always binding. So by assumption there is no financial crisis in the latter models, as only the normal business cycle fluctuations are modeled. As a consequence, these models drift back towards a steady state more quickly than real economic data demonstrate. Bank capital constraints may be binding during crises but not in normal times.

The non-linear financial crisis dynamics integrated into Kockerols, Kravik, and Mimir (2021) are not fully microfounded. The evolution of crisis dynamics are determined using regime-switching structural model parameters and asymmetrically large shocks. Furthermore, in some of these models, the negative externalities that are driven by crisis probability and severity are estimated empirically outside the model. In particular, the sensitivity of crisis probability and severity to credit growth is calibrated to match the empirical estimates of crisis probability and severity from logit-type regressions and local projection models, respectively.

In contrast, several academic papers explicitly introduce non-linear dynamics as discussed in Dou et al. (2021), although they remain stylized. They analyze the full non-linear dynamics leading to uncertainty over the persistence of a crisis. In the paper by

⁵See also BCBS (2012).

Brunnermeier and Sannikov (2014) greater instability is generated once the economy moves sufficiently away from the steady state (crisis times), as equity capital is increasingly misallocated due to the uncertainty, leading to underinvestment and distorted household consumption decisions. Similarly, in He and Krishnamurthy (2019) where the amount of equity raised by an intermediary depends on uncertain equity returns subject to shocks, a negative shock when intermediaries are relatively unconstrained (“normal” times) triggers only a small decline in equity, asset prices, and investment. However, when these equity constraints are binding or likely to be binding in the near future (“crisis” times), a negative funding shock triggers a more substantial decline. In addition, Jondeau and Sahuc (2022) show that non-linearities (fire sales and bank default) in a DSGE model with two types of banks play a fundamental role in the development of a crisis. Occasionally binding constraints on bank debt (as opposed to bank capital) can generate similar non-linear dynamics and outcomes. Under normal circumstances, banks rely on debt finance whereas under financial stress borrowing constraints can bind and banks must eventually raise additional equity finance at a higher cost. This results in occasional episodes with sharp increases in spreads and deeper downturns, helping explain observed macroeconomic asymmetries such as negatively skewed aggregate investment (Holden, Levine, and Swarbrick 2020).

Recently, models including a bank capital channel with occasionally binding constraints were used to analyze the effectiveness of prudential policy. Pre-crisis capital requirements in the United States were found to be close to optimal in terms of the aggregate welfare of savers and borrowers where default and occasionally binding borrowing constraints in both the non-financial and financial sectors are present (Elenev, Landvoigt, and Van Nieuwerburgh 2021). Capital buffers are found to be more effective in restricting bank equity payouts, rather than bank lending over financial cycles, in examining the implementation of the capital conservation buffer and the countercyclical capital buffer (Schroth 2021). Although these models resolve the limitation of many DSGE models concerning the inclusion of non-linear effects, other elements and frictions are not present in these models (e.g., liquidity requirements, nominal frictions), limiting their potential usefulness for policy analysis.

It is also rather clear that, while long-run dynamics are satisfactory, modeling the nexus between real and the financial sector in these models requires further advances to capture the non-linearities associated with large adverse shocks such as financial crises. Using standard grid-based global solutions is challenging due to the curse of dimensionality. However, new techniques using insights from machine learning appear to be a promising way to handle non-linearities also in larger models. This is an important priority for future work.

Furthermore, financial crises are rare events, but when they occur they tend to be associated with heavy losses for banks. Failure to take into account non-linearities, and more particularly tail events, will thus lead to underestimation of the effects of financial crises. For instance, by studying the impact of cyclical systemic risk on future bank profitability for a large representative panel of EU banks between 2005 and 2017, Lang and Forletta (2020) show that the impact of cyclical systemic risk on the left tail of the distribution of future bank returns is an order of magnitude larger than on the median. In addition, Suarez (2022) explains that using wrong estimates of the (non-linear) causal effects of risk and policy variables on the relevant moments (mean and growth-at-risk) of the growth distribution could produce misguided macroprudential policy advice.

A second limitation is related to the level of details present in the models. Bank capital is modeled in a simple fashion. There is only one type of capital, which is accumulated only through retained earnings and, in most cases, there is no distinction between regulatory and voluntary capital buffers. In addition, most policy models are based on a representative bank (or a continuum of identical banks), while heterogenous agent models are currently being developed, with heterogeneous agent New Keynesian (HANK) type models. Note, however, that the 3D and Gerali et al. (2010) models already include two types of households, with patient and impatient households. Patient households are savers who buy housing without a need for financing, while impatient households borrow from banks using their holdings of housing as collateral. With these features, these policy models allow for some degree of heterogeneity, even though they do not feature the rich heterogeneity in the HANK models. In addition, an interesting extension to the representative bank model is the heterogeneous bank framework, such as Badarau

and Levieuge (2011), Corbae and D’Erasmo (2019), or Coimbra and Rey (2023). A growing literature quantitatively investigates the distribution of bank balance sheet items depending on their size and portfolio composition and its interactions with solvency regulation.

Third and finally, most policy models do not include non-bank financial sector, so that, as discussed in Section 2, leakages would not be captured. Note, however, that some policy models reviewed by Darracq-Pariès et al. (2022) indicate that the existence of non-bank funding sources can help dampen the effect of the short-term tightening of loan supply in response to capital requirements.

4. Model-Based Quantitative Illustrations

This section provides the building blocks for future regulation assessments by illustrating the performance of selected policy DSGE models (e.g., the type of response they provide, distinguishing between benefits and costs) in identifying the macroeconomic impact of Basel III reforms. Specifically, we use five of the models discussed in Section 3: (i) the 3D model by Clerc et al. (2015); (ii) the 3D model complemented by a monetary policy channel, as described by Mendicino et al. (2020); (iii) the model by de Bandt and Chahad (2016); (iv) a modified version of Gerali et al. (2010), as described by Bennani et al. (2017); and (v) a regime-switching version of Norwegian Economy Model, NEMO, as described by Kockerols, Kravik, and Mimir (2021).

The calibration of these models is based on the most recent data, in order to capture the current state of the economy and to be able to perform simulations applied to the current context. In the calibration procedure, we thus assume that most of the Basel III regulatory agenda has been implemented, which is true to a large extent, and set out deep structural parameters to match the means and variances of our data in the recent period. With this calibration of deep structural parameters at hand, we can perform various types of experiments by adjusting the values of our “Basel III parameters.”

To study the macroeconomic impact of Basel III reforms, we implement several scenarios, which consider solvency and liquidity regulations. First, we increase capital requirements to capture the increase in the quantity and quality of capital requirements that the Basel III reform imposed. In a second scenario, we also consider

the fact that Basel III imposed an increase in liquidity requirements. In each case, we analyze the impact of Basel III on long-run equilibrium values of important macroeconomic variables, and study the transition to the new regime, from Basel II to Basel III.

In addition, our analysis allows us to distinguish between the costs and benefits of solvency and liquidity regulations, as shown in Tables 4 and 5. The implementation of the 3D model with different calibrations on simulations for the euro area, as well as for the United States, permits an assessment of the contribution of country/area idiosyncrasies. In contrast, the Norges Bank's model offers a different modeling perspective. All in all, Basel III appears to have the effects anticipated, in terms of positive effects on GDP and financial stability (and the exercise offers a useful quantification of these effects), although its contribution to real macroeconomic outcomes appears to be small. In particular, we find that (i) the calibration/measurement of the bank default probability (or financial crisis probability) and its evolution play a crucial role in the assessment and (ii) the expectation channel plays an important role, conditioning the transition path associated with the reforms: if economic agents anticipate that the reforms will effectively reduce the probability of bank failure or the probability of a run, this triggers, beyond the initial supply shock, a positive demand effect on GDP.

4.1 Solvency Scenario

The Basel III reforms increased banks' minimum capital ratio from 4 percent to 6.5 percent. However, there was a recognition that some hybrid forms of capital did not effectively absorb losses in the crisis. Hence Basel III also increased the share of banks' capital which comes from loss-bearing common equity tier 1 (CET1) capital. In this sense, the reforms increased not only the quantity of capital but also its quality due to its greater ability to absorb losses. The models we use do not have such a high degree of granularity. They include risk weights, but there is only one type of bank capital. However, this does not necessarily prevent us from analyzing fully the impact of Basel III regulation that includes requirements in terms of both quality and quantity of capital.

Table 4. Long-Run Impact of a 5 Percent Increase in Capital Requirements

Unit	Expected Benefits of Regulation			Costs of Regulation			Real Macro Variables			Financial Macro Variables	
	Bank Probability of Default	Cost of Crisis	Bailout Cost as % of GDP	Bank Debt Funding Cost Spread over Risk-Free Rate	Lending Spread over Bank Debt Fund. Cost	GDP	Aggregate Investment	Aggregate Cons.	Total Lending	% Dev.	
Euro Area with 3D	-7.50	NaN	-2.55	-0.59	0.34	1.19	0.29	1.45	2.55		
Euro Area with de Bant and Chahad	-0.29	NaN	-0.34	0.08	0.02	0.2	0.56	0.18	1.26		
Euro Area (Cost Approach)	NaN	NaN	NaN	0.17	0.11	-0.4	-1.31	-0.45	-5.85		
United States with 3D	-9.21	NaN	-3.36	-1.43	2.48	0.87	7.53	4.07	8.03		
Norway (NEMO) ¹	-0.16 (*)	-0.85 (**)	NaN	NaN	0.59	-0.18	-2.96	0.57	-3.18		
Norway (NEMO) ²	-1.63 (*)	-4.39 (**)	NaN	NaN	0.59	2.1	12.4	0.28	12.9		

(*) Change in the probability of a financial crisis. (**) Change in the cost of a financial crisis.
Note: 3D-EA; Mendicino et al. (2020); EA-Cost Approach; Gerali et al. (2010); US with 3D; Clerc et al. (2015); Norway-NEMO; Kockeroels, Kravik and Mimir (2021).

¹Under moderate crisis probability and severity. ²Under higher crisis probability and severity.

To make a quantitative assessment, we can think of the lower effectiveness of hybrid instruments in absorbing losses as representing a lower effective capital ratio. This is the reason why we implement solvency regulation in terms of two quanta of additional capital requirements: 2.5 and 5 percentage point increases which take place gradually over 20 quarters. The 5 percentage point scenario is broadly in line with the actual implementation of Basel III when the quality of capital is included and under the assumption that hybrid instruments were completely ineffective at absorbing losses. The 2.5 percentage point scenario corresponds to the view that quality was not important because the original buffers were effective. We do not take a stance on which of the above extreme assumptions represents the truth, but they do encompass the range of possibilities. Possible non-linearities may lead to responses that are not proportional, hence the need to consider both scenarios explicitly.

The Basel III policy is implemented in the following way in the models. We calibrate the models to data in 2016, i.e., focusing on a time when the transition to the new policy regime is over. We match banks' capital ratios, their probability of failure (for those models where this variable is meaningful) as well as other macro and financial variables. We then perform a counterfactual experiment: we ask the question of how the economy and the financial system would have looked if bank minimum capital ratios had not risen 2.5 percent (or 5 percent) as a result of the Basel III reforms. We measure the impact of Basel III by looking at some simple magnitudes that are usually associated with the benefits and costs of regulation. Table 4 exhibits the results for each jurisdiction. Negative numbers indicate that a variable has declined as a result of Basel III (e.g., bank default probability).

Table 4 suggests that Basel III has been a successful policy. There are some differences across models which can be traced back to differences in the scope of the assessment and in the transmission channels of regulation. But in most models, which include both the costs and benefits of regulation, the long-run effects of Basel III are positive on GDP. This is the case for the 3D model applied to the euro area and the United States, as well as the model by de Bandt and Chahad (2016) applied to the euro area.

The versions of the 3D model employed by the ECB and the Board of Governors exhibit a positive effect of Basel III on GDP

in the long run (1.19 percent in the euro area, 0.87 percent in the United States), associated with a slowdown in the short run. Table 4 shows that the implementation of higher capital requirements leads to a significant reduction in the probability of bank failure (-7.5 percentage points in the euro area and -9.21 percentage points in the United States). Lending spreads increase in all countries. It is worth investigating further the channels that drive these results. The 3D model places banks and their solvency at the heart of the model. All credit (to firms and households) is bank intermediated and the state of bank balance sheets matters greatly for the cost of funds for final borrowers. Since banks are competitive in the model, loan interest rates reflect the weighted average of the cost of equity and the real cost of bank debt (including insured and uninsured debt liabilities) where the weight on equity is the bank's capital ratio. This suggests that changing capital requirements affect the supply of loans through two main channels.

First of all, a key cost of higher capital ratios arises due to the assumption that the risk-adjusted expected return on equity (i.e., the cost of equity) is higher than that on short-term deposits due to limited participation in the equity market. So a bank that funds itself more with equity has a higher weighted average cost of funds. The model also assumes that the required returns on equity do not change as banks' capital ratios increase. In other words, we do not have the so-called Modigliani-Miller offset. These assumptions are in line with the approach in much of the literature (Birn et al. 2020). The assumptions are driven by the difficulty of macroeconomic models to match risk premia in financial markets (the so-called equity premium puzzle). In addition, judging from the fact that market-to-book ratios in banking stocks have significantly declined since 2007, it is difficult to believe that banks nowadays face a lower cost of issuing equity compared to the pre-crisis period. However, the impact of assuming costly equity on banks' overall weighted average cost of funds is quantitatively small: with an 8 percent equity premium, a 1 percentage point change in the capital ratio would increase the weighted average cost of funds by 8 basis points. Nevertheless, assuming a lower cost of equity or a Modigliani-Miller offset would reduce the costs of capital measures further.

Second, and going in the opposite direction, a higher capital ratio reduces the weighted average private cost of funds due to its effect

on the cost of uninsured debt. In the 3D model, market discipline from the uninsured debt market is assumed to be weak due to the opacity of bank balance sheets. Strict capital regulation together with effective supervision is therefore a key mechanism, which reassures uninsured debt investors that banks are safe. As regulation limits the scope for bank risk-taking and moral hazard, interest rate on bank debt falls, exerting an expansionary effect on credit supply. This effect is strong when the probability of failure of banks is relatively high, and it can dominate the contractionary effect of shifting the composition of liabilities towards costlier equity. This explains why the 3D model for the euro area and United States produces an increase in lending and GDP. Given the estimated risks faced by banks, the models imply that the banking system would have been in a very weak state if pre-crisis capital ratios had persisted to the present. This would have affected its ability to supply credit to the real economy with negative effects on real economic activity. Making banks safe is therefore not a cost to the economy but a precondition for a well-functioning credit market.

Finally, some of the costs of financial instability are met by taxpayers who provide implicit or explicit safety net guarantees to bank debt or deposit holders. Higher capital ratios reduce also these public costs: this is reported in Table 4 in the column named “Bank Bailout Costs as a % of GDP.” All of the above private and social benefits of capital regulation are quantitatively very large in the 3D model calibrated to the euro area and the United States.

There are two other models calibrated to the euro area in Table 4. First, the model of de Bandt and Chahad (2016) also shows a positive effect on GDP, although the magnitude is smaller. It is both interesting and instructive to think through the mechanisms in the de Bandt and Chahad (2016) framework and why the benefits appear to be smaller. The model features banks which face random exogenous withdrawals in the spirit of Angeloni and Faia (2013). If the liquidation value of the bank’s assets is smaller than the value of demand deposits, there exists a self-fulfilling “run equilibrium” in the spirit of Diamond and Dybvig (1983). The run can be prevented by either choosing to fund with equity which cannot be withdrawn or by investing in a large amount of liquid assets which do not incur liquidation costs. Hence the probability of crisis depends on the bank’s capital ratio as well as its holdings of liquid assets (this is the aim

of the liquidity coverage ratio). What the results in Table 4 show is that the capital ratio has a positive but relatively small effect on the probability of a run on the bank. Indeed, this is intuitive. If the illiquid assets lead to large losses in a run and loan fire-sale scenario, the bank needs extremely large capital buffers in order to survive. A relatively small capital increase like the one we consider helps to some extent but cannot completely remove the inherent fragility of the fractional reserve banking system. This is why Basel III also introduced liquidity requirements which increase the ability of banks to meet withdrawals without having to liquidate illiquid assets at a loss. In subsequent analysis (see Table 5 in Section 4.2) we will use the de Bandt and Chahad (2016) model to show that both capital and liquidity regulation have an important role to play in making banks safer from runs.

Second, the regime-switching version of Norges Bank's main DSGE model (NEMO), is simulated with two different sets of assumptions on the link between household credit growth and financial crises. In the case of moderate sensitivity of crisis probability and severity to five-year real household credit growth, Basel III has a small negative effect on GDP although it reduces both the crisis probability and the severity. The small negative overall effect on GDP occurs because the reduction in real economic activity in normal times slightly outweighs the gain from the reduction in the probability of financial crisis. In this scenario, costs and benefits of Basel III seem finely balanced. However, when the sensitivity of both probability and severity to credit growth is doubled, Basel III has large positive effects on GDP and its net benefits become substantial. In particular, the negative impact on GDP turns into a positive effect as higher requirements help reduce the probability and the severity of a deeper financial crisis (about 10 percent reduction in output during the crisis). In the latter case, the ergodic mean of GDP increases by 2.1 percent in the long run under the higher capital requirements of the Basel III regime. In terms of mechanisms in this framework, the costs of financial regulation are linked to the excess cost of equity relative to debt. Similarly to the 3D model, a higher capital ratio increases the weighted average cost of capital for banks in normal times, hence reducing economic activity since banks need to accumulate larger net worth by charging higher lending rates. The benefits of higher capital requirements arise because

of a reduced frequency and severity of financial crises. When a crisis occurs, the economy switches from a normal times regime to a crisis regime where macroeconomic and financial shocks are asymmetrically large (having higher volatility) and some structural model parameters regarding housing and banking sectors switch.⁶ This leads to amplified adverse financial accelerator effects leading to private sector deleveraging with substantial negative effects on economic activity.

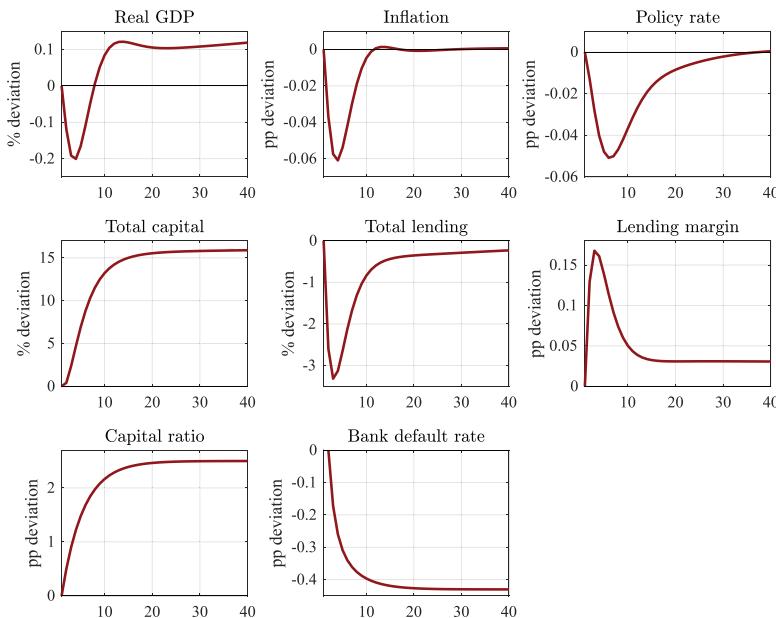
All in all, the results of the models crucially depend on the assumptions regarding the magnitude and the sensitivity of the bank default probability (euro area and United States) or financial crisis probability (Norway) to underlying features of the banking sector. This is consistent with the LEI study (BCBS 2010) and Birn et al. (2020).

In additional exercises, we also assess the opportunity costs related to the implementation of Basel III without separate consideration of benefits. The Gerali et al. (2010) framework for the euro area (“cost approach”), which only identifies the cost of implementation of the regulation, yields a negative effect on GDP, but this result is an obvious consequence of not modeling the benefits of regulation. The long-run net benefits of the Basel III framework could be estimated by comparing the steady-state increase in GDP in the euro-area 3D model (1.2 percent) or in the model by de Bandt and Chahad (2016) (0.2 percent), with the decrease in GDP for the euro area according to the Gerali et al. (2010) model (GDP growth down by 0.4 percent). This yields a long-run net benefit between 0.6 and 1.6 percent of GDP in the euro area.

Finally we investigate the transition dynamics between Basel II and III. The models employed by the European Central Bank and the Board of Governors exhibit a positive long-run effect of Basel III on GDP although there is a temporary slowdown over the transition, as shown in Figure 1 for the 3D euro area model (transitions for the four other models are displayed in the appendix). When capital requirements are increased, the available bank capital can support less lending. Financial institutions therefore contract credit supply

⁶A crisis can occur any point in time in the model given the estimated crisis probability that depends on five-year cumulative real household credit growth in the model.

Figure 1. Transition from 14 Percent Capital Ratio to 16.5 Percent in the Euro Area with 3D Model



Note: Variables are expressed in deviation from initial steady state. “3D Model” refers to the model used by Mendicino et al. (2020).

and lending margins increase. This raises bank profits, and bank capital (“total capital” in the figure) starts to rise. In the long run, total lending recovers as bank capital is accumulated by retained earnings helping to support more loans.

Over the first 10 quarters or so, however, the reduction in lending depresses the investment of bank-dependent firms. This reduces aggregate GDP and leads to a small decline in inflation and a loosening of monetary policy. The monetary accommodation boosts consumption and the investment of firms that do not depend on bank funding (not shown in the figure).⁷ However, the increase in these components of demand is not enough to offset the fall in investment

⁷The 3D model includes a bank-independent sector which funds itself directly from the household sector. Here we have in mind larger firms that can issue equity or corporate bonds.

demand from bank-dependent firms and output declines. In the long run, once capital has fully adjusted, GDP increases.

There are a number of factors which determine the size of the transitional costs from an increase in bank capital requirements. As discussed in Mendicino et al. (2020), the monetary policy reaction is important. When the policy rate is reduced aggressively at the start of the implementation period, this helps to counteract the negative effects on aggregate demand from the squeeze on the credit availability for smaller bank-dependent firms. At the effective lower bound (ELB) on nominal interest rate, this may require the use of non-standard measures to ensure that real economic activity does not suffer too much. When it is difficult to deliver a sizable monetary stimulus, a more gradual implementation period may be optimal. From this perspective, the long time period given to banks to comply with Basel III seems like a good policy which would have significantly smoothed the transitional costs of the increase in bank capital requirements.

Darracq-Pariès et al. (2022) also emphasize several other factors which may affect the size of the transitional costs. First, the presence of large voluntary buffers can help banks smooth the increase in bank capital requirements even when they are imposed without a long implementation period. Second, the ability and willingness of banks to issue equity or cut dividends also reduces the transitional costs. Finally, the ability of non-bank funding sources to expand over the transition is also important.⁸ In the aftermath of the GFC, voluntary buffers were depleted for many banks and the costs of issuing equity were high. Hence, the long implementation period for Basel III was therefore important in ensuring that the transitional costs were manageable for the real economy.

4.2 Liquidity Scenario

There are two liquidity instruments in Basel III—the liquidity coverage ratio (LCR) and the net stable funding ratio (NSFR). The

⁸Non-bank funding sources are of course a double-edged sword. They can reduce the costs of the transition to higher capital requirements but they may also reduce the effectiveness of prudential measures due to “leakages.”

LCR involves the obligation to hold a sufficient quantity of high-quality liquid assets (HQLA) so as to withstand one month of elevated deposit withdrawals. The NSFR involves the obligation to fund long-term assets at least in part with longer-term liabilities (e.g., bank bonds). In practice, both the LCR and NSFR are complex regulations, which aim to increase banks' resilience to funding stress. To make the analysis operational, we concentrate on the LCR and provide the results of two sets of models in Table 5: (i) analysis of the costs of liquidity following the approach in Hoerova et al. (2018); and (ii) a more detailed analysis based on the multi-asset model of de Bandt and Chahad (2016) with bank runs.

Regarding the first approach, most models do not include an analysis of the benefits of the LCR. In this case, the simulations follow Hoerova et al. (2018) and only consider the impact of an LCR scenario through its effect on bank profits, measuring the opportunity cost of raising additional deposits and investing in lower-yielding HQLA. Regulation affects the profit and loss statement, as the return on HQLA is lower than interest and non-interest costs on deposits needed to fund the HQLA holdings. Hoerova et al. (2018) identify the cost of holding a unit of HQLA to be 0.68 percent, meaning that a bank makes a loss of EUR 0.68 on an HQLA holding worth EUR 100, which is fully financed with deposits.⁹ They argue that the move from pre-crisis LCR levels to full compliance with the new Basel III standard (100 percent LCR) involves banks increasing their HQLA holdings by an amount worth 10 percent of total deposits.¹⁰ In equilibrium, loan rates must increase following a negative shock to loan supply in order to restore banks' profitability at least partially. This is how the LCR exerts a negative impact on lending and economic activity.

A crucial caveat is in order. We assume that HQLA are government bonds with a zero capital risk weight. If the HQLA have a non-zero risk weight or if the leverage ratio is the binding constraint,

⁹For the Norwegian banks, the cost of holding a unit of HQLA is calculated to be 0.46 percent.

¹⁰For the Norwegian banks, implementing an LCR of 100 percent is approximated by asking the bank to hold government bonds and covered bonds equal to 11.2 percent of deposits.

the LCR will also directly crowd out lending and will lead to larger costs than those considered here.

The only framework that quantifies the benefits of liquidity regulation is the model by de Bandt and Chahad (2016), where the LCR requirement is explicitly modeled in a multi-asset framework, mimicking the actual regulation, which allows an assessment of the impact of liquidity regulation on the probability of runs.

Table 5 shows the steady-state impact of the LCR regulations.¹¹ For the euro area 3D model, the implementation of the LCR does not affect banks' probability of default (PD), and consequently bailout costs and private lending spreads are also unaffected.¹² As already discussed, the LCR regulation affects bank profitability negatively and, in a partial equilibrium setting, raises the default probabilities of banks. In general equilibrium, however, following a negative shock on loan supply, banks increase their lending rates. Thus, bank solvency does not suffer, but as the fourth column of Table 5 shows, lending spreads over bank funding costs increase by 6 basis points in the case of the LCR for the euro area with the 3D model, and 20 basis points with the model by de Bandt and Chahad (2016). We also notice that the higher cost of funding for borrowing firms and households reduces real economic activity by a moderate amount. The LCR reduces consumption by 0.1 percent, investment by 0.31 percent, and GDP by 0.14 percent in the new steady state. Total lending falls by 0.73 percent. These relatively small costs should be set against the benefits of the regulatory measures.

The model by de Bandt and Chahad (2016) is the only one that finds a positive long-run effect (GDP rises by 0.27 percent), due to a strong expectation channel associated with a lower probability of bank runs which makes banks safer (bank PDs fall by 0.68 percent). When depositors expect a lower probability of a bank run, their expected returns from holding bank deposits increase and they demand a lower interest rate. This increases banks' profitability,

¹¹In the case of the de Bandt and Chahad model, the simulation includes both solvency and liquidity requirements.

¹²There is a very small increase in banks' PDs, but this is less than 1 basis point and is rounded to zero in the table. In the transitional figures, a negative but extremely small effect on bank solvency can be seen.

**Table 5. Long-Run Impact of the Implementation
of a 100 Percent LCR Requirement (in %)**

		Expected Benefits of Regulation		Costs of Regulation		Real Macro Variables		Financial Macro Variables	
Bank PD	Bailout Cost as % of GDP	Bank Debt Funding Cost Spread over Risk-Free Rate	Lending Spread over Bank Debt Fund. Cost	GDP	Aggregate Investment	Aggr. Cons.		Total Lending	
Euro Area 3D (Cost Approach)	0.00	0.00	0.00	0.06	-0.14	-0.31	-0.10	-0.73	
Euro Area de Bandt and Chahad	-0.68	-0.01	-0.61	0.20	0.27	0.28	0.87	1.94	
Norway with NEMO (Cost Approach)	0.00	0.00	0.00	0.05	-0.04	-0.38	0.05	-0.40	
United States with 3D (Cost Approach)	-0.30	0.00	-0.02	0.08	-0.04	-0.30	0.02	-0.50	

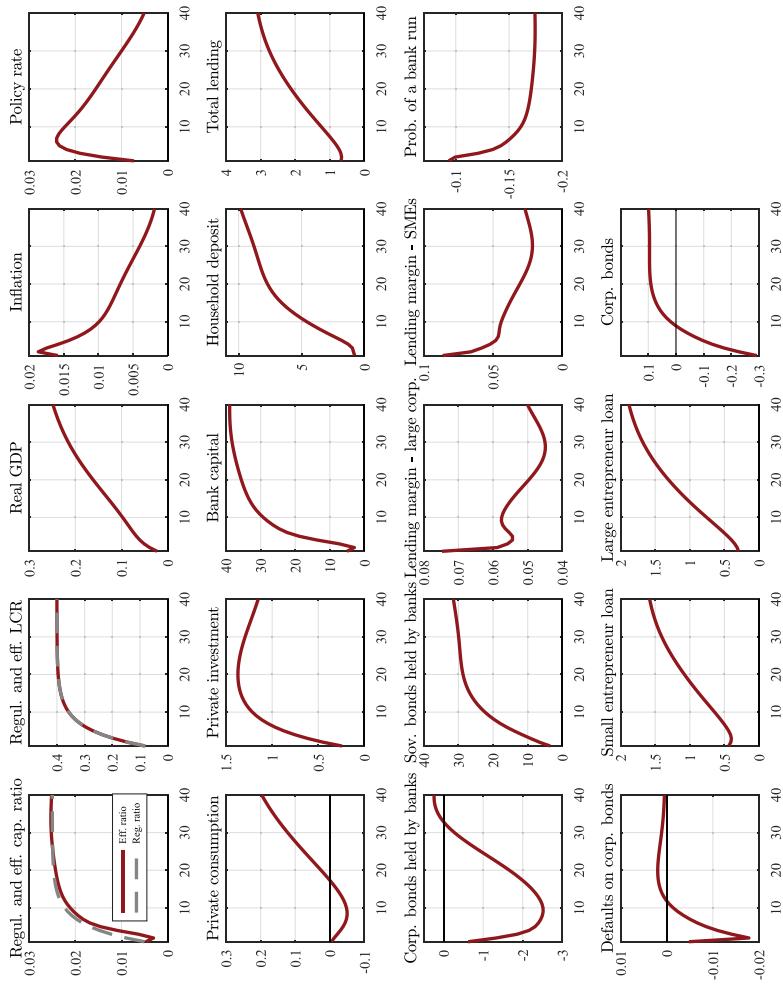
Note: 3D-EA: Mendicino et al. (2020); de Bandt and Chahad (2016); NEMO; Kockerols, Kravik, and Minir (2021); 3D-US: Clerc et al. (2015) with U.S. calibration.

allowing them to accumulate more capital through retained earnings and supporting more lending, which rises by almost 2 percent. It is worth delving with a little more detail into the results from this particular model in Table 5 and comparing them to those in Table 4. Note that for that model the scenario in Table 5 includes an increase in both the solvency and liquidity requirements in order to mimic the actual implementation of Basel III. We see that adding the LCR ratio (in Table 5) generates a further increase in GDP, a bigger increase in consumption (which is arguably a better measure of household welfare), and a bigger decline in banks' probability of failure. This finding confirms the intuition that each risk should be targeted with an appropriate policy tool. The de Bandt and Chahad (2016) model emphasizes that a liquidity policy tool (in this case the LCR) is the most effective way to mitigate liquidity risk. Capital tools also help with liquidity risk, but they are, relatively speaking, less effective. In contrast, as the 3D model results for the euro area and the United States in Table 4 showed, the capital ratio is extremely effective at mitigating solvency risk.

We end our analysis of the impact of the LCR by including the transitional dynamics from a world with no liquidity regulation to a world with full compliance with the LCR. The regulation requires banks to increase the quantity of liquid assets on their balance sheets. In addition, the regulation stimulates banks to increase the quality of their HQLA: this is because the LCR gives a higher weight to government bonds compared to corporate debt. The change in the composition of HQLA carries a small cost because, although government bonds have a lower return than corporate bonds, they have a bigger negative effect on the probability of a bank run.

Figure 2 shows how banks react to the policy: initially they switch the composition, and government debt holdings jump sharply to satisfy the LCR while corporate bond holdings decline. The higher quantity and quality of liquid securities reduce the probability of a bank run. This, in turn, lowers risk premia on bank debt, raises bank profitability, and leads to the accumulation of more capital through retained earnings. As a result, lending, investment, consumption, and GDP gradually increase. As lending rises, banks continue to grow their HQLA (both government and corporate debt) over time in order to continue satisfying the higher LCR. Importantly, lending increases to both small and large firms. In addition, the reduction

Figure 2. Impact of LCR Implementation with the Model by de Bandt and Chahad (2016) for the Euro Area (with regulated and effective capital ratios)



Note: This figure represents the dynamics of several macroeconomic and financial variables to an increase in LCR and capital ratio. The top left two charts exhibit the actual (or effective) ratios contrasted to the regulatory requirements. All variables are expressed as deviations from the initial steady state.

in bank run probability allows an increase in deposits, in contrast to what is observed when only solvency requirements are increased.

Overall, the results in this section suggest that the costs of the imposition of the LCR in the Basel III reforms were very modest while the benefits were significant especially in reducing the liquidity risk faced by the banking system.

5. Conclusion

In this paper, we survey channels of transmission of prudential regulation proposed in the literature since the global financial crisis. We also conduct harmonized simulation exercises examining the effects of Basel III regulation, based on off-the-shelf DSGE models used in various jurisdictions. Our conclusion is that Basel III leads to an increase in GDP, although some models show some negative effects. The increase in GDP is achieved through a reduction in the cost of borrowing, which, in turn, is achieved through a reduction in cost of uninsured debt as higher capital requirement reduces the probability of bank failures, leading to a net increase in credit supply.

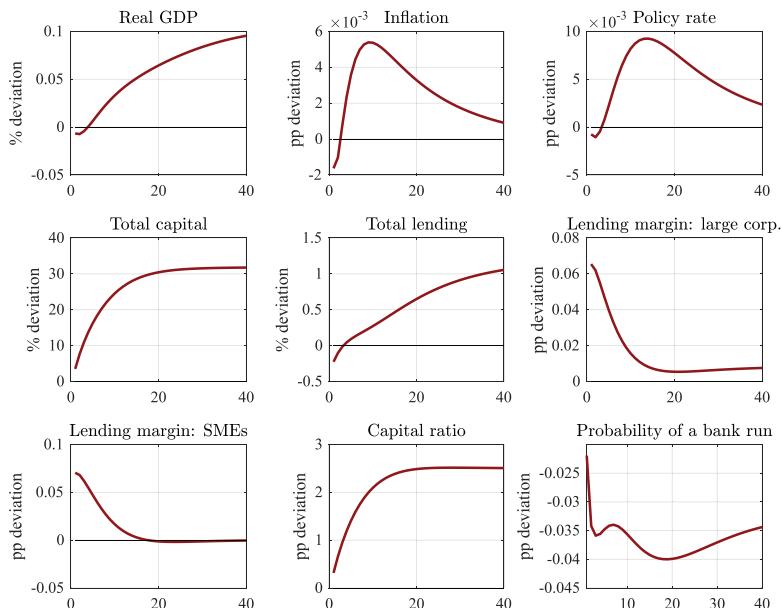
However, the models only offer a partial assessment of the macroeconomic impact of the new regulatory environment. In particular, when assessing the effects of banking regulations, it is crucial to distinguish models that assess both costs and benefits (e.g., the 3D model and NEMO) from models that only assess costs (Gerali et al. 2010). A few limitations have been identified: the models are still quite stylized with only one capital variable, namely aggregate capital; funding liquidity has only been incorporated in a basic way; and liquidity regulation is not fully integrated in most models.

Our study also identifies directions in which policy models should expand. Quantitative DSGE models basically focus on capital requirements, while empirical models lack micro-foundations, which is problematic for policy analysis. More complex issues, such as interactions between multiple regulations, still depend on qualitative models. In addition, these models have only recently started to investigate additional policy issues, and there is scope for further research regarding the role of shadow banking and the interaction between unconventional monetary policy and financial stability policy.

Further research would also include investigating further the micro-foundations of different types of financial crises (bank based, market based, asset price bubbles, etc.), the role of rational versus non-rational expectations, and the distributional effects of financial regulation.

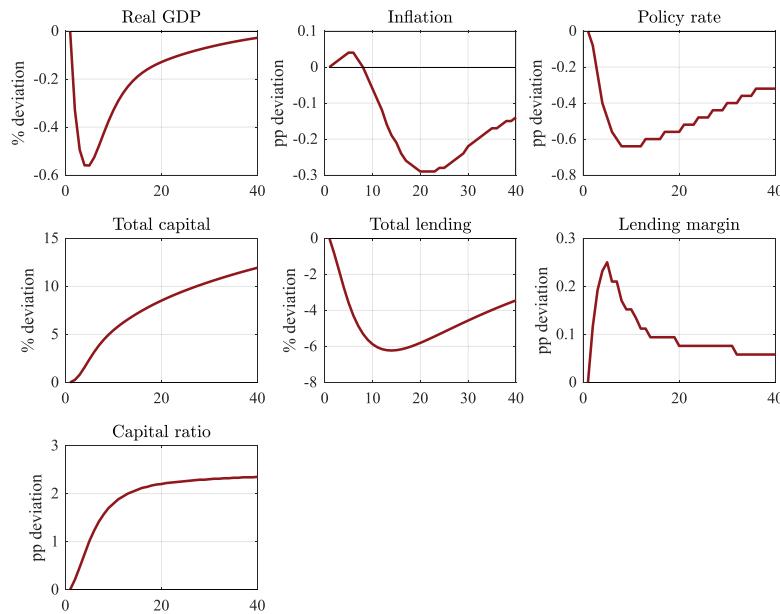
Appendix

Figure A.1. Transition from 14 Percent Capital Ratio to 16.5 Percent in the Euro Area (de Bandt and Chahad)



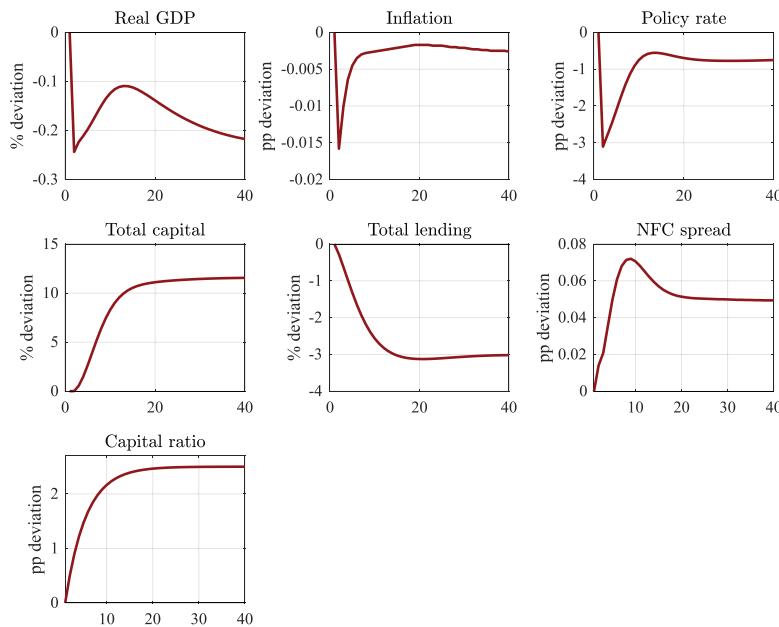
Note: Variables are expressed as deviations from the initial steady state.

Figure A.2. Transition from 14 Percent Capital Ratio to 16.5 Percent in the Euro Area (NEMO)



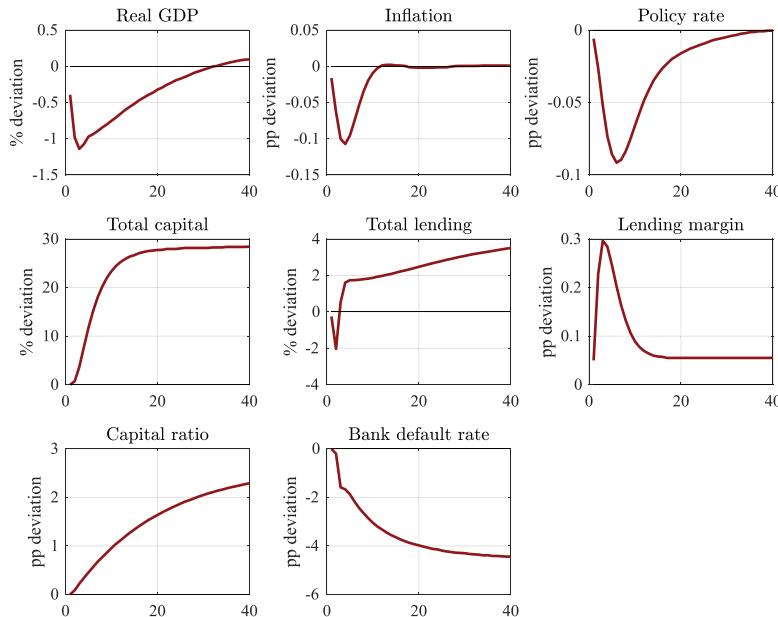
Note: Variables are expressed as deviations from the initial steady state.

Figure A.3. Transition from 14 Percent Capital Ratio to 16.5 Percent in the Euro Area (Gerali et al.)



Note: Variables are expressed as deviations from the initial steady state.

Figure A.4. Transition from 14 Percent Capital Ratio to 16.5 Percent in the United States (3D)



Note: Variables are expressed as deviations from the initial steady state.

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