

A DSGE model to assess the post crisis regulation of universal banks*

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Abstract

The Great Financial Crisis has led to the introduction of many new banking regulations in different areas (Volcker rule, Vickers and Liikanen proposals, as well as the Basel III new requirements). It is therefore useful to assess their overall consistency and impact on both the financial sector and the real economy. For this purpose, we develop a large scale DSGE model with a real and a financial sector, as well as a distinction between retail and wholesale banking. Banks grant credit but invest also in corporate and sovereign bonds. We introduce heterogeneity among producers in the sense that we distinguish between SMEs and large corporate firms, the latter ones being able to issue bonds.

The main findings of the paper are that: (i) the implementation of liquidity regulation which affects private consumption dynamics has a more persistent effect than solvency regulation that affects loan distribution as well as investment; (ii) the model assesses to what extent the Liquidity Coverage Ratio may induce banks to substitute sovereign bonds to business loans; (iii) implementing simultaneously liquidity and solvency regulations has compounded effects; (iv) the model allows to quantify to what extent a more progressive implementation of the regulatory changes affects the mix between deleveraging and increasing profit margins in favour of the latter strategy.

Keywords: Basel III, LCR, multi-period assets, Firms heterogeneity.

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1 Introduction

Following the Great Financial Crisis that started in 2007 a general consensus emerged to conclude that the previous regulatory framework had largely failed to detect and prevent the build-up of excessive risk-taking in the financial sector. As a consequence a new regulatory agenda has been put in place including several dimensions, regarding banks' solvency and -substantial innovation- liquidity, as well on banks' business models. The regulatory agenda is still very dense and while the contours of solvency regulation in Basel III are broadly defined, the overall calibration is still under discussion. This includes that of the Net Stable Funding Ratio (NSFR) and the leverage ratios, as well as the relative risk weights of the different portfolios in the standardised approach for credit risk. However, at the same time, economists as well as the Basel Committee question the overall consistency of the approach and its impact on credit distribution notably to SMEs. In addition, regarding the Liquidity Coverage Ratio (LCR), under article 509 (1) of the Capital Requirement Regulation, that applied to the European Union, the EBA is requested to investigate annually whether "the general liquidity coverage regulation [...] is likely to have a material detrimental [...] on the economy and the stability of the supply of credit, with a particular focus on lending to SMEs [...]".

While in the long run, a tighter solvency and liquidity regulation helps increase the resilience of the banking sector, hence the financing of the economy, policy makers face a dilemma in the short run, as on the one hand restraining banks' leveraging and increasing liquidity helps reduce banking instability, but on the other hand, it may hamper the continuous flow of credit to the real economy.

State-of-the-art macroeconomic models, namely DSGE models including a fully fledged banking sector should be the appropriate tool to answer such a question, more generally to assess the consistency of the regulatory changes and their effects on the real economy, as well as to point out to the relevant tradeoffs.

However, while major progress has been made towards that goal, available macro models are still unsatisfactory and provide divergent answers, with significant larger impacts of regulation in the more recent models, maybe due to an overstated impact of financial frictions (De Nicolo, 2015).

Indeed, the new Basel III requirements triggered a large set of studies that mainly focused on the overall impact of the new regulatory constraints on the real economy. The Macroeconomic Assessment Group (MAG (2010b) and MAG (2010a)) conducted in this regard two studies on the economic benefits and costs of stronger capital and liquidity regulation in terms of their impact on output. Angelini et al. (2011) implemented 13 different models in order to analyze the long-term economic costs of the new rules putting forward the potential increase in banks margins as well as the subsequent drop in production, however most of the models were not fully consistent general equilibrium models. On the other hand, Gerali et al. (2010) as well Darracq Pariès et al. (2011) build DSGE models with a detailed banking sector including a wholesale and a retail branch. However, they concentrate on the effect of the solvency ratio, without considering liquidity regulation, although with the few exceptions of De Nicolo and Lucchetta (2014), Adrian and Boyarchenko (2014) and Covas and Driscoll (2014) with simplified models of the real economy. In addition, the phasing in of the regulation is not investigated while it seems quite crucial for the effect on lending. Indeed, most of these studies ignore the role of the shape of the implementation process (e.g. linear, concave or convex increase in regulatory ratios) making the underlying assumption of neutrality, or at least negligible effects, of the implementation process. In its final report, the MAG (2010b) contends that even if "the transition schedules agreed by the Basel Committee do not mandate a perfectly linear increase in capital requirements, the assumption of a linear increase was considered to be appropriate". One of the aims of this paper is to check how relevant this assumption is.

For this purpose, we develop a large scale DSGE model of the euro area with a banking sector and credit frictions a la Iacoviello (2005) and Gerali et al. (2010). However, the European banking system is dominated by the universal banking model, as in many European countries, where few banks represent a very large part of total assets in the system as well as of provision of financial services. Therefore, we propose to model both investment and retail branches of a bank unlike what is common in the literature, which focuses instead on the distinction between wholesale and retail branches, hence omitting a possible link with the real economy.

Investment banking in our model comes with the introduction of a (corporate) bond market. We find it relevant to match the increasing share of securities issuance in Europe. Debt issuance can be seen as a substitute to bank loans for large corporations. In that respect Europe is getting closer to the US. This is also a way of to investigate further the role of investment banking in the crisis, as its failure (in particular Bear Sterns and Lehman Brothers) played a crucial role. We thus introduce a corporate bond market where large firms are able to issue bonds to fund a part of their expenses. Such a source of borrowing is not available to small and medium sized enterprises (SMEs hereafter). We introduce this heterogeneity in the production sector in line with studies by Gertler and Gilchrist (1994), Gilchrist et al. (2010) among many others. Indeed, one key feature in the study of financial interaction with the real economy relies on the ability of borrowers to have access to different alternative sources of borrowing, or more specifically, to the degree of substitutability between (private) bank credit and market funding. Still, the fixed costs of issuance of bonds as well as the disclosure requirements are, among other reasons, behind the fact that only large firms have access to the corporate market. Thus, conditions in financial and credit markets would have different impacts depending on the economy structure. Giesecke et al. (2012) argue that "the Great Depression collapse of credit hit small and medium sized firms particularly hard since they did not have the same access to alternative forms of credit that a larger firm might". This result is consistent with the findings of Gertler and Gilchrist (1994) as well as Chari and Kehoe (2007), although during the Great Financial Crisis, corporate banking catering the needs of large companies was the most severely hit (see notably Vinas (2015)).

Moreover and to assess the macroeconomic effects of the new banking regulatory constraints, we mainly focus on the Basel Committee's proposed capital and liquidity reforms that are incarnated in the capital to weighted assets ratio as well as the new liquidity ratios (Liquidity Coverage Ratio (LCR) and the Net Stable funding Ratio (NSFR)). However, if the last financial turmoil led to a wide range of studies on macroprudential regulation, only a few of them have investigated the issue of liquidity requirements. Indeed, liquidity presents more data and modeling challenges than capital, so that its impact is addressed by fewer models. The main contributions are, to our knowledge, those mentioned above namely both MAG studies as well as Angelini et al. (2011). Still, not all of the models used in those studies feature bank liquidity. Moreover, even those that incorporate liquidity requirements adopt very simple definitions of the liquidity constraint which mainly takes the form of a liquid to total assets ratio, the former being generally represented by sovereign bonds, a definition that is "quite distant from the complex measures introduced by the new rules" as attested by Angelini et al. (2011). More recently, Adrian and Boyarchenko (2014) present a representative agent model with endogenous risk, where the LCR is always welfare improving. On the other hand, De Nicolo and Lucchetta (2014) show that liquidity requirements hampers maturity transformation, forcing banks to use retained earnings to increase bond holding rather than lending. Our conclusions are close to those of Covas and Driscoll (2014) but we

introduce a somewhat richer model with households and firms over the business cycle. Indeed, liquidity matters come along with asset maturity concerns. Yet, standard General Equilibrium Models, which represent the main framework used to assess the effects of macroprudential regulation effects, rely on the standard one period maturity assumption. An hypothesis that is consistent neither with the economic concept of liquidity, nor with its Basel III definitions. Thus, neglecting the maturity mismatches in the liquidity constraints definition, one may run the risk of omitting a large part of the dynamics of macroeconomic variables. For this reason, we made the choice to develop an economy where most of the assets have more than a one period maturity, using for this purpose the Benes and Lees (2010) framework which incorporate differences in assets maturity at the cost of few additional state variables.

The main finding of the paper is that the impact of the capital ratio differs from what will induce the implementation of the new LCR requirement. First, the implementation of liquidity regulation, which rather affects private consumption dynamics, has a more persistent effect than solvency regulation which affects loan distribution as well as investment. Second, implementing both regulations simultaneously has compounded macroeconomic effects. Third, the model allows to quantify to what extent a more progressive implementation of the regulatory changes affects the mix between deleveraging and increasing profit margins in favour of the latter strategy. A more progressive implementation also has less adverse effects on SMEs that would suffer much less from the new regulatory requirements.

The paper is structured as follows. Section 2 provides an overview of the theoretical model where we mainly present each agent's objective function and the corresponding constraints when we develop the details in the technical appendix. Section 3 deals with the calibration matter of the model when Section 4 presents simulation results, drawing comparisons between the different types of Basel III implementation shapes. Section 5 concludes and describes several directions for future research.

2 The model

The economy¹ is mainly populated by households and two types of entrepreneurs². Households consume, work and accumulate saving in the form of banking deposits, while entrepreneurs produce intermediate good using capital bought from specific capital-good producers and labor supplied by households. Entrepreneurs differ regarding their ability to have access to the bond market, large firms can issue corporate bonds, along with banking loans, to finance their activity when SMEs are limited to the banking loans.

As it is standard in the DSGE literature, there is a monopolistic competition at the workers' and unions' level. But firms use an homogeneous labor input. More formally, workers supply their differentiated labor services through a set of unions which operates in a monopolistic competitive market. Unions differentiate the aggregated level of labor issued by households and sell their services to a competitive labor packer which supplies a single labor input to firms.

The intermediate goods produced by entrepreneurs are aggregated by a perfectly competitive retailer to transform them to an homogeneous good which will be offered to final consumers through distributors. The latter

¹The chart in the annex of the paper sums up the model and the main interactions between the different agents.

²Thereafter, the variables and parameters corresponding to households are indexed with 'w' (for workers), when those for entrepreneurs are indexed with 'e', for some variables and parameters we add a 'p' for SMEs and a 'g' for large firms. Finally, 'f' is used for final goods producers and distributors.

evolve in a monopolistic competitive market.

The economy is also characterized by the presence of a financial intermediary represented by a continuum of universal banks. Each bank collects households' deposits and interbank funds which form, together with its accumulated own capital, the total liabilities. On the asset side, banks supply loans to both kinds of entrepreneurs and purchase corporate bonds. The banking system faces three classes of frictions. First, banks face quadratic adjustment costs when changing their nominal interest rates. This degree of nominal rigidity generates some imperfect pass-through of policy rate to bank deposit, lending and bond interest rates. Second, they operate in a monopolistic competitive market which can amplify/attenuate the impact of some of their decisions. Third, banks face capital requirements as well as liquidity ones represented by the Basel III LCR.

The question of the implementation of the new Basel III requirements has been recently investigated in the literature (Roger (2000), Gambacorta (2010) among others). However, as indicated by Angelini et al. (2011), most of the model featuring bank liquidity generally "adopt very simple definitions (e.g. the ratio of cash and government bonds to total assets) for the bank liquidity, that are quite distant from the complex measures introduced by the new rules". One reason behind this simplification is the use of DSGE models standards that are all based on one period maturity assets when the notion of liquidity - and more specifically both Basel III liquidity constraints (NSFR and LCR) - intrinsically presupposes a maturity mismatch between and within assets. One key feature of our model is that we develop an economy where most of the assets have more than a one period maturity. This allows us to assess much better the impact of the new Basel III liquidity constraints (and more specifically the LCR) taking into account the maturity mismatch between the assets coupled with the heterogeneity in the productive sector as well as the different frictions in the model.

Households

There is a continuum $h \in [0, 1]$ of infinitely-lived households, each representative household h maximizes its intertemporal utility function which is assumed to be of the form :

$$W_t^{w,h} = \mathbb{E}_t \left[\sum_{i=0}^{\infty} \beta^i \left(\frac{1 - \eta^w}{1 - \sigma_c^w} \left(\frac{C_{t+i}^{w,h} - \eta^w \bar{C}_{t+i-1}^w}{1 - \eta^w} \right)^{1 - \sigma_c^w} - \frac{(N_{t+i}^h)^{1 - \sigma_n}}{1 - \sigma_n} \right) \right]$$

This utility function depends on consumption $C_t^{w,h}$ and hours worked N_t^h . The parameter σ_c represents the intertemporal elasticity of substitution and η^w measures the degree of external habit formation in consumption³. Each period, the representative household has to optimize his utility function under the following budget constraint (in real terms):

$$C_t^{w,h} + D_t^{w,h} + T_t^{w,h} (1 - \mu_t^w) = \frac{W_t^h}{P_t} N_t^h + \frac{J_{t-1}^{D,w,h}}{\pi_t} + \frac{J_{t-1}^{T,w,h}}{\pi_t} - B C_t^{w,h} + \mathcal{D}_t^{w,h}, \quad (1)$$

with $\pi_t = P_t/P_{t-1}$. The flow of expenses includes current consumption $C_t^{w,h}$ and the new deposit flow $D_t^{w,h}$. Resources include wage earnings $\frac{W_t^h}{P_t} N_t^h$, dividends $\mathcal{D}_t^{w,h}$ from the different types of firms that all belong to households and gross interest income on last periods deposits $\frac{J_{t-1}^{D,w,h}}{\pi_t}$ as well as on their financial investment in sovereign bonds $\frac{J_{t-1}^{T,w,h}}{\pi_t}$. Indeed, households have access to the sovereign bond market through financial interme-

³Since C_t^w is the aggregate level consumption at period t

diaries facing transaction costs $T_t^{w,h} \mu_t^w$.

we consider a multi-period assets framework as in Benes and Lees (2010). The letter J_t^X refers to interests and (partial) principal repayments on all the assets X_{t-k} in which the household invested k periods ago ($k \geq 0$). Thus, at time t , household "h" holds a stock of deposits and spvereign bonds noted SD_t^h and $ST_t^{w,h}$ respectively. Adopting the Benes and Lees (2010) multi-period fixed-rate assets framework, we assume that the capital repayment required at each period is a constant propotion $(1 - \delta^X) \in [0, 1]$ of the residual outstanding amount SX_t of the asset X . Moreover, the interest payments are also due on this residual outstanding amount of the debt. This two assumptions involve a geometric repayments scheme that has two major practical advantages : First, the geometric distribution allows for simple recursive equations for most of the variables of interests. Second, the average maturity of an asset can be calibrated using only one parameter, namely the parameter δ^X . For example, we can easily show that according to the Macaulay's duration definition, the average maturity " d^X " of the asset X is (at the steady-state) of the form $d^X = \frac{R}{R - \delta^X}$ where R is the discounting interest rate. Thus, choosing the adequate calibration for the parameters " R " and " δ^X ", we can set different maturities values for the different assets in the economy.

More practically, the sum of all repayments (in real terms) related to $X = (D, T^w)$ due at time 't' can be assessed as :

$$J_{t-1} = \sum_{k=1}^{\infty} \left(\underbrace{1 - \delta^X}_{\text{capital repayment part}} + \underbrace{R_{t-k}^X}_{\text{interest repayment part}} \right) \underbrace{(\delta^X)^{k-1} X_{t-k}}_{\text{Residual amount in 't' of the asset bought in 't-k'}} \frac{P_{t-k}}{P_{t-1}}$$

which can be rewritten recursively as :

$$J_t^X = \frac{\delta^X}{\pi_t} J_{t-1}^X + (1 - \delta^X + R_t^X) X_t$$

As well, the stock of assets hold at time t is of the form :

$$SX_t = \sum_{k=0}^{\infty} (\delta^X)^k X_{t-k} \frac{P_{t-k}}{P_t} \iff SX_t = \frac{\delta^X}{\pi_t} SX_{t-1} + X_t$$

According to this framework, one saving unit will afford resources not only in the next period but in the periods that come afterwards. Furthermore, the optimality condition states that the current period marginal utility of consumption (noted Λ_t , see the left hand of equation (2)) must equal the discounted values of one unit saving benefits (the right hand). We can thus write :

$$\begin{aligned} \Lambda_t &= \mathbb{E}_t \left\{ \beta_w \Lambda_{t+1} (1 - \delta^D + R_t^D) + \beta_w^2 \Lambda_{t+2} (1 - \delta^D + R_t^D) \delta^D + \beta_w^2 \Lambda_{t+2} (1 - \delta^D + R_t^D) (\delta^D)^2 + \dots \right\} \\ &= \beta_w (1 - \delta^D + R_t^D) \underbrace{\mathbb{E}_t \sum_{j=1}^{\infty} \left[\Lambda_{t+j} (\beta_w \delta^D)^{j-1} \right]}_{=K_t} \end{aligned} \quad (2)$$

K_t can be written recursively as $K_t = \Lambda_{t+1} + \beta_w \delta^D K_{t+1}$.

Also, and using the optimality condition equation (2), we know that $\Lambda_{t+1} = \beta_w (1 - \delta^D + R_{t+1}^D) K_{t+1}$.

Merging the two equations gives :

$$\mathbb{E}_t \left(\frac{\Lambda_t}{\Lambda_{t+1}} \frac{1}{\beta_w} \right) = (1 - \delta^D + R_t^D) \mathbb{E}_t \left(1 + \frac{\delta^D}{1 - \delta^D + R_{t+1}^D} \right)$$

The last equation represent modified version of the standard Euler equation which indicates that the consumption growth path depends not only on the current period deposit rate but also on the next period expected value.

Labor Market

In the labor market, there is a continuum of unions $\iota \in [0, 1]$, each of which represents a certain type of labor. Unions differentiate the aggregated level of labor issued by households ($N_t^H = \int_0^1 N_t^h dh$) and sell its services in a monopolistically competitive market to a perfectly competitive firm which transforms it into an aggregate labor input using a CES technology function :

$$N_t = \left(\int_0^1 (N_t^\iota)^{\frac{\nu_w - 1}{\nu_w}} d\iota \right)^{\frac{\nu_w}{\nu_w - 1}}$$

where ν_w is the elasticity of substitution between differentiated labor services.

As a consequence, the unions face a labor demand curve with constant elasticity of substitution which is in the form :

$$N_t^\iota = \left(\frac{W_t^{e,\iota}}{W_t^e} \right)^{-\nu_w} N_t \quad (3)$$

$W_t^e = \left(\int_0^1 (W_t^{e,\iota})^{1-\nu_w} d\iota \right)^{\frac{1}{1-\nu_w}}$ is the aggregate wage the entrepreneurs have to pay.

In addition, unions set their wages on a staggered basis a la Rotemberg (1982) in the sense that, at each period, every union faces quadratic adjustment costs with indexation to a weighted average of lagged and steady-state inflation.

Each union thus maximizes :

$$\max_{N_t^\iota, W_t^{e,\iota}} \mathbb{E}_t \sum_{k=0}^{\infty} \beta^k \lambda_{t+k}^w \left\{ \frac{W_{t+k}^{e,\iota}}{P_{t+k}} N_{t+k}^\iota - \frac{\kappa_w}{2} \left(\frac{W_{t+k}^{e,\iota}}{W_{t+k-1}^{e,\iota}} - \pi_{t+k-1}^{\gamma_w} \bar{\pi}^{1-\gamma_w} \right)^2 \frac{W_{t+k}^e}{P_{t+k}} N_{t+k} - \frac{W_{t+k}^\iota}{P_{t+k}} N_{t+k}^\iota \right\}$$

subject to the demand constraint (3).

In a symmetric equilibrium, the labor choice for each single union in the economy will be given by the (non-linear) wage-Phillips curve (lower case variables are expressed in real terms):

$$\begin{aligned} \kappa_w \left(\frac{w_t^e}{w_{t-1}^e} \pi_t - \pi_{t-1}^{\gamma_w} \bar{\pi}^{1-\gamma_w} \right) \frac{w_t^e}{w_{t-1}^e} \pi_t \\ = 1 - \nu_w \left(1 - \frac{w_t}{w_t^e} \right) + \beta_w \frac{\lambda_{t+1}^w}{\lambda_t^w} \kappa_w \left(\frac{w_{t+1}^e}{w_t^e} \pi_{t+1} - \pi_t^{\gamma_w} \bar{\pi}^{1-\gamma_w} \right) \frac{w_{t+1}^e}{w_t^e} \pi_{t+1} \frac{N_{t+1}}{N_t} \end{aligned} \quad (4)$$

With $w_t = \frac{W_t}{P_t}$ the wage received by households in real terms.

Since we make the assumption that workers have the ability to choose costlessly to work for small or large

companies, the aggregate labor rate faced by each of these companies is unique (equal to w_t^e).

Production

Small Entrepreneurs (SMEs)

In the economy there is a continuum $i \in [0, 1]$ of small entrepreneurs (indexed by "p") that have to maximize their specific consumption $C_t^{i,p}$ according to the following utility function :

$$\max \mathbb{E}_t \left\{ \sum_{j=0}^{\infty} \beta_p^j \frac{1 - \eta^p}{1 - \sigma_c^p} \left[\frac{C_{t+j}^{i,p} - \eta^p \bar{C}_{t+j-1}^i}{1 - \eta^p} \right]^{1 - \sigma_c^p} \right\} \quad (5)$$

Since small entrepreneurs are net borrowers in the model, the correspondent discount factor β_p is assumed to be strictly lower than β_w .

Each small entrepreneur chooses the optimal stock of physical capital $K_t^{i,p}$ and the desired amount of labor input $N_t^{i,p}$ that are combined to produce an intermediate output $Y_t^{i,e,p}$ according to a Cobb-Douglas production function.

$$Y_t^{i,e,p} = A_t A_t^p (K_t^{i,p})^\alpha (N_t^{i,p})^{1-\alpha} \quad (6)$$

A_t and A_t^p represent total factor productivity shocks, the first is supposed to be common to both small and large companies when the second is specific to the small ones. Both of the shocks are supposed to be AR(1) processes.

Moreover, small entrepreneurs maximize their own utility functions subject to an infinite sequence of real budget constraints :

$$C_t^{i,p} + \frac{J_{t-1}^{L^p,i}}{\pi_t} + w_t^e N_t^{i,p} + q_t^K K_t^{i,p} = (1 - \delta) q_t^K K_{t-1}^{i,p} + p_t^{i,e,p} Y_t^{i,e,p} + L_t^{i,p} \quad (7)$$

δ is the capital depreciation rate while $L_t^{i,p}$ represents the amounts of new loans that the whole banking sector is willing to lend to small entrepreneur i at a nominal interest rate $R^{L,p}$ assumed to be common to all small entrepreneurs.

The debt service charges the representative SME has to pay can thus be written recursively as :

$$J_t^{L^p,i} = \frac{\delta^{L^p}}{\pi_t} J_{t-1}^{L^p,i} + \left(1 - \delta^{L^p} + R_t^{L^p} \right) L_t^{p,i} \quad (8)$$

In addition, the entrepreneur faces a borrowing constraint in the sense that the expected value of its collateralizable (physical) capital stock at period t must be sufficient to guarantee lenders of debt repayment. Indeed, in order to insure themselves against a potential credit event, banks require a part of borrowers' resalable capital as a collateral. Moreover, they also require that this collateral has to be large enough to cover not only the amount of debt services of the current time t but also all of those of the next periods. Doing so, banks ensure the repayment of both contracted interests and principal.

The collateral constraint is then written as :

$$F J_t^{L^p,i} \leq \theta_t^p \left(q_{t+1}^{K,p} \pi_{t+1} l^p K_t^{i,p} (1 - \delta) \right) \quad (9)$$

Upon default, bankers would take over all the resalable bankrupted firm's capital at a proportional cost, this

coefficient of proportionality is here represented by $(1 - \theta_t^p)$. θ_t^p is also called the loan-to-value ratio (LTV). The variations in the LTV can be interpreted as outright shocks to bank's loan standards and, ceteris paribus, loan supply.

ι^p is the part of the SMEs' capital that can be considered as resalable. One can consider it as the value of bankrupted firm's building and heavy machinery that could find a buyer in the second hand market.

$FJ_t^{L^p, i}$ represents the residual value of interests and principal that the SME has to pay on the bank credit borrowed until time t . $FJ_t^{L^p, i}$ can be written recursively as :

$$FJ_t^{L^p, i} = \frac{\delta^{L^p}}{\pi_t} FJ_{t-1}^{L^p, i} + \left(1 + \frac{R_t^{L^p}}{1 - \delta^{L^p}}\right) L_t^{p, i} \quad (10)$$

Corporate Firms

Symmetrically with respect to small entrepreneurs, large entrepreneurs (indexed by "g") form a continuum $i \in [0, 1]$ where each member has to optimize its specific utility function facing similar production and loan constraints than small entrepreneurs.

On top of differences in terms of parameter calibration, large firms differ also from the small ones in their ability to rely on a second type of debt contract. Indeed, large firms can enter the financial market and issue bonds which offer to them an alternative source of financing when small and medium sized firms are still bank dependant because of the relatively high fixed costs of issuance as well as the disclosure costs.

Indeed, to finance investment projects and their running expenditures, large firms use a combination of internal and external funds and we assume here that the latter refers exclusively to direct debt security that they issue in the bond market. This external funds are however costly to issue because of the agency costs associated with default. To draw the bond pricing program, we follow the Gilchrist et al. (2010)'s framework based on the presence of idiosyncratic shocks hitting firms' production that are, if to low, able to make firm's manager decide to default.

From an investor point of view, the net-worth of a large firm is defined as :

$$\begin{aligned} \mathcal{W} = & z_t [p_t^{e, g} Y_t^{e, g}] + T_t^g + L_t^g + (1 - \delta) q_t^K K_{t-1}^G - q_t^K K_t^G - w_t N_t^g - \frac{J_{t-1}^{L^g}}{\pi_t} - \frac{J_{t-1}^{T^g}}{\pi_t} \\ & + \iota^g (1 - \theta^g) q_t^K K_{t-1}^G (1 - \delta) - FJ_t^{T^g} \end{aligned} \quad (11)$$

where $\iota^g (1 - \theta^g) q_t^K K_{t-1}^G (1 - \delta)$ is the resale value of installed capital. We note that the resale capital for a bond buyer represents the value of the defaulted firm's capital net of the collateralized part that would belong to the bank in case of a credit event, the bank loans being of a higher degree of seniority than bonds. This would also induce a potential substitution effect between banking loans and market financing, which is also consistent with the results found by Gertler and Gilchrist (1994) and Chari and Kehoe (2007) among many others. Note also that since both current period as future loans banks repayments are entirely collateralized, banks are insured against any eventual default that could occur at the end of the period. They are thus not affected by the realizations of the shock z_t^i .

The firm purchases capital using this debt-financing coupled with other source of funds. In the next period, after observing the realization of shocks, the firm decides whether or not to fulfill the debt obligation. If the firm

decides not to default, it pays the time t interests and principal parts on all the previous issued bonds (namely $J_t^{T^g}$) as it has been contracted and optimizes its program for the next period and the process continues. If the firm does default, it enters a debt renegotiation process with the bond market investors that would ultimately try to get the residual value of the bankrupted firm's net worth. For the structure of the renegotiation process, we adopt Gilchrist et al. (2010) framework by assuming that there is a lower bound to the net-worth of the firm, $\overline{\mathcal{W}}$, below which the firm cannot guarantee the repayment of its debt obligation.

Thus, given the price of capital, the amounts of capital and debt, the firm defaults if and only if the realized production shock is lower than the threshold level, which is defined as the level that makes the firm's net-worth equal to the default boundary⁴ :

$$\begin{aligned} \overline{\mathcal{W}} = & \overline{z}_t [p_t^{\epsilon, g} Y_t^{\epsilon, g}] + T_t^g + L_t^g + (1 - \delta) q_t^K K_{t-1}^G - q_t^K K_t^G - w_t^e N_t^g \\ & - \frac{J_{t-1}^{L^g}}{\pi_t} - \frac{J_{t-1}^{T^g}}{\pi_t} + \iota^g (1 - \theta^g) q_t^K K_{t-1}^G (1 - \delta) - F J_t^{T^g} \end{aligned} \quad (12)$$

Moreover, we assume a costly state verification framework a la Townsend (1979), where investors have to pay an irreversible disclosure cost in order to eliminate losses from the moral hazard of the bond issuer. We assume this cost to be proportional to the net worth value of the firm with μ being the factor of proportionality.

Thus, in the investor point of view, the average profit made on the credit allocation is given by :

$$\begin{aligned} \mathbb{P}_t = & \int_{-\infty}^{\overline{\epsilon}_z} (1 - \mu) \left[z_t (p_t^{\epsilon, g} Y_t^{\epsilon, g}) + T_t^g + L_t^g + (1 - \delta) q_t^K K_{t-1}^G - q_t^K K_t^G - w_t^e N_t^g \right. \\ & \left. - \frac{J_{t-1}^{L^g}}{\pi_t} - \frac{J_{t-1}^{T^g}}{\pi_t} + \iota^g (1 - \theta_{t+1}^g) q_{t+1}^K K_t^G (1 - \delta) \right] dF(\epsilon_z) + \int_{\overline{\epsilon}_z}^{+\infty} \frac{J_t^G}{\pi_{t+1}} dF(\epsilon_z) \end{aligned} \quad (13)$$

\mathcal{F} representing the cumulative distribution function of normal distribution.

The investor has also access to a riskless debt security that is characterized by a larger maturity and also lower interest rates payments than a corporate bond.

The trade-off equation for the investor can be written as :

$$\mathbb{P}_t = \frac{J_t^S (1 - \Delta^s)}{\pi_{t+1}} \quad (14)$$

J_t^S represents the sum of all repayments the investor is expected to receive from sovereign debtors at time t and Δ^s is the default rate on sovereign bonds which is supposed to be different from zero. J_t^S is written as :

$$J_t^S = \frac{\delta^S}{\pi_t} J_{t-1}^S + (1 - \delta^S + R_t) T_t^S$$

Furthermore and in order to be able to use a representative agent framework while maintaining the intuition of the default rule above, we adopt the Darracq Pariès et al. (2011) framework by assuming that borrowers belong to a large family that can pool their assets and diversify away the risk related to large firms after bond repayments are made. By pooling the large firms' resources, the representative family has the following

⁴Hereafter and for a matter of simplicity, we assume $\overline{\mathcal{W}} = 0$.

aggregate repayments and defaults, hence expected gain on its outstanding bonds :

$$\begin{aligned} \mathbb{H}_t = \int_{-\infty}^{\bar{\epsilon}_z} & \left[z_t (p_t^{e,g} Y_t^{e,g}) + T_t^g + L_t^g + (1 - \delta) q_t^K K_{t-1}^G - q_t^K K_t^G - w_t N_t^g \right. \\ & \left. - \frac{J_{t-1}^{L^g}}{\pi_t} - \frac{J_{t-1}^{T^g}}{\pi_t} + \iota^g (1 - \theta_{t+1}^g) q_{t+1}^K K_t^G (1 - \delta) \right] dF(\epsilon_z) + \int_{\bar{\epsilon}_z}^{+\infty} \frac{J_t^G}{\pi_{t+1}} dF(\epsilon_z) \end{aligned} \quad (15)$$

Overall, each large entrepreneur optimizes its utility function :

$$\max \mathbb{E}_t \left\{ \sum_{j=0}^{\infty} \beta^j \frac{1 - \eta^g}{1 - \sigma_c^g} \left[\frac{C_{t+j}^{i,g} - \eta^g \bar{C}_{t+j-1}^i}{1 - \eta^g} \right]^{1 - \sigma_c^g} \right\} \quad (16)$$

subject to an infinite sequence of real budget constraints ⁵:

$$\begin{aligned} C_t^{i,g} + \frac{J_{t-1}^{L^g,i}}{\pi_t} + q_t K_t^{i,g} + w_t N_t^{g,i} + \left[1 - \mathcal{F} \left(\frac{\bar{\epsilon}_{z,t} + \sigma^2/2}{\sigma} \right) \right] \frac{J_{t-1}^{T^g,i}}{\pi_t} \\ + \mathcal{F} \left(\frac{\bar{\epsilon}_{z,t} + \sigma^2/2}{\sigma} \right) \left[\iota^g (1 - \theta_{t+1}^g) q_{t+1}^K \pi_{t+1} K_t^G (1 - \delta) - F J_t^{i,G} \right] = p_t^{e,g} Y_t^{e,g} + T_t^g + L_t^g + (1 - \delta) q_t^K K_{t-1}^G \end{aligned} \quad (17)$$

and the investor trad-off equation discussed above as well as the production function and collateral constraint that are similar to those of their small counterpart (namely eq. (6) and (9)).

Capital Producers

At the beginning of each period, capital producers buy back the undepreciated capital stocks $(K_{t-1}^p + K_{t-1}^g) (1 - \delta) = K_{t-1} (1 - \delta)$ at real prices (in terms of consumption goods) q_t^K . Then they augment this stock using investment goods and facing adjustment costs. The augmented stock is sold back to entrepreneurs at the end of the period at the same price. The decision problem of capital stock producers is given by :

$$\max_{K_t, I_t} \mathbb{E}_t \left\{ \sum_{j=0}^{\infty} \beta^j \lambda_{1,t+j}^p \left[(K_t - K_{t-1} (1 - \delta)) q_t^K - I_t \right] \right\} \quad (18)$$

under the production function technology :

$$K_t = K_{t-1} (1 - \delta) + \left(1 - \frac{\phi^p}{2} \left(\frac{I_t}{I_{t-1}} - 1 \right)^2 \right) I_t \quad (19)$$

⁵Using the probability density function of normal a normal distribution, we can easily show that,

$$\int_a^b z_t dF(\epsilon_z) = z_{t-1}^{\rho^z} \left[\mathcal{F} \left(\frac{b - \sigma^2}{\sigma} \right) - \mathcal{F} \left(\frac{a - \sigma^2}{\sigma} \right) \right]$$

\mathcal{F} stands for the normal cumulative distribution, centered and standardized.

The first order conditions determine the capital producers' optimal real price of capital q_t^K which is as :

$$q_t^K \left(1 - \frac{\phi^p}{2} \left(\frac{I_t}{I_{t-1}} - 1 \right)^2 - \phi^p \left(\frac{I_t}{I_{t-1}} - 1 \right) \frac{I_t}{I_{t-1}} \right) + \frac{\lambda_{1,t+1}^p}{\lambda_{1,t}^p} \beta_p q_{t+1}^K \left[\phi^p \left(\frac{I_{t+1}}{I_t} - 1 \right) \left(\frac{I_{t+1}}{I_t} \right)^2 \right] = 1 \quad (20)$$

Retailer

There is a representative retailer who acts under perfect competition. First, the retailer aggregates intermediate goods from both small and large firms using a CES technology function⁶. Afterward, it sells its output to a monopolistic competitive distribution sector which is in charge to make the different goods accessible to final consumers.

The decision problem of the representative retailer is :

$$\max_{Y_t^e, Y_t^{e,p}, Y_t^{e,g}} [p^e Y_t^e - p^{e,p} Y_t^{e,p} - p^{e,g} Y_t^{e,g}] \quad (21)$$

subject the aggregation technology function :

$$Y_t^e = \left(\nu_t^y \xi^y Y_t^{e,p^{1-\xi^y}} + (1 - \nu_t^y \xi^y) Y_t^{e,g^{1-\xi^y}} \right)^{\frac{1}{1-\xi^y}} \quad (22)$$

The first order conditions determines the optimal demand addressed to each of intermediate goods' produces.

$$Y_t^{e,p} = \nu_t^y Y_t^e \left(\frac{p^{e,p}}{p^e} \right)^{\frac{1}{\xi^y}} \quad (23)$$

$$Y_t^{e,g} = (1 - \nu_t^y) Y_t^e \left(\frac{p^{e,g}}{p^e} \right)^{\frac{1}{\xi^y}} \quad (24)$$

where the aggregate intermediate price (in terms of consumption price) can be set using the previous FOCs and the aggregation technology function (22) :

$$P_t^e = \left(\nu_t^y (Y_t^{e,p})^{\frac{\xi^y-1}{\xi^y}} + (1 - \nu_t^y) (Y_t^{e,g})^{\frac{\xi^y-1}{\xi^y}} \right)^{\frac{\xi^y}{\xi^y-1}} \quad (25)$$

Distribution Sector

The distribution market is assumed to be monopolistically competitive. Distributors' prices are sticky and are indexed to a combination of past and steady-state inflation, with relative weights parameterized by γ^p . In addition, if retailers want to change their price beyond what indexation allows, they face a quadratic adjustment cost parameterized by κ^p .

Each firm f choose its sell price p_t^f (in terms of consumption goods) so as to maximize its market value :

$$\max_{p_{f,t}} \mathbb{E}_t \sum_{i=0}^{\infty} \beta_w^i \lambda_{w,t+i} \left\{ \left(p_{t+i}^f - p_{t+i}^e \right) Y_{t+i}^f - \frac{\kappa^f}{2} \left(\frac{p_t^f}{p_{t-1}^f} \frac{1}{\pi_t} - \pi_{t-1}^{\gamma^p} \bar{\pi}^{1-\gamma^p} \right)^2 Y_{t+i} \right\} \quad (26)$$

⁶The fact that intermediate goods are not perfect substitutes allows for defining different levels of intermediate goods' prices according to whether they are produced by small or large firms.

subject to the demand derived from consumers' maximization :

$$Y_t^f = (p^f)^{-\nu^f} Y_t \quad (27)$$

ν^f is the demand price elasticity which is supposed to be constant.

Banking Sector

The banking sector is represented by a continuum $n \in [0, 1]$ of universal banks evolving in a monopolistic competition framework. We enrich our banking sector modeling by assuming different types of assets and liabilities. Indeed, each bank n has three types of liabilities : its own capital ($K_t^{b,n}$), savers-deposits (D_t^n) and interbank funds (IB_t^n). On the assets side, it can invest on four types of assets : loans to SMEs ($L_t^{p,n}$), loans to corporate firms ($L_t^{g,n}$), corporate bonds ($T_t^{Bg,n}$) and sovereign bonds ($T_t^{Bs,n}$).

Assets	Liabilities
Loans to Small Firms ($SL_t^{p,n}$)	Bank Equity (K_t^n)
Loans to Large Firms ($SL_t^{g,n}$)	Households deposits (SD_t^n)
Large Corporate Bonds ($ST_t^{Bg,n}$)	Interbank Funds (IB_t^n)
Sovereign Bonds ($ST_t^{Bs,n}$)	

Like the universal banks model, each bank n is composed of two main branches, namely retail branch and investment branch. The retail branch of bank n optimizes the discounted value of its contemporaneous and future flow of funds. For this purpose, it sets the optimal amount of the different types of liabilities and assets (except for its capital) as well as their correspondent interest rates (except for the interbank interest rate which is supposed to be equal to the policy rate R_t).

The investment branch of the bank is in charge of dealing with assets in the bond market and choose the optimal amount of corporate and sovereign bonds holding according to the relative yield of such assets as well as the regulatory constraints.

Indeed, each bank faces two kinds of costs descending from the Basel III macroprudential requirements. The first cost is related to the bank's capital position whenever its solvency - measured by its capital-to-weighted assets ratio - moves away from a target value ν^K ; the second one has more to do with its balance-sheet liquidity standard and more specifically its short term liquidity coverage ratio (LCR).

Since we use multi-period assets, we are able to model the LCR in a more suitable way than what it is usually done in the literature. In our paper, we enrich the LCR modeling through different perspectives. First, contrary to a one period asset's maturity, we can make a distinction between short term and long term incoming and outgoing cash flows and, second, using different kind of assets, we are able to take into account different weight of liquidity of each type of assets following the Basel III implementation.

The optimization program for the universal bank n , which maximizes its cash flow, is then of the form :

$$\begin{aligned} \max \mathbb{E}_0 \sum_{t=0}^{\infty} \beta_w^i \lambda_{w,t} \{ & \frac{J_{t-1}^{L^P,n}}{\pi_t} + \frac{J_{t-1}^{L^G,n}}{\pi_t} + \frac{J_{t-1}^{T^{B^g},n}}{\pi_t} + \frac{J_{t-1}^{T^{B^s},n}}{\pi_t} - L_t^P - L_t^G - T_t^{B^g,n} - T_t^{B^s,n} \\ & - \frac{J_{t-1}^{D,n}}{\pi_t} - \frac{1+R_{t-1}}{\pi_t} IB_{t-1}^n + D_t^n + IB_t^n - \text{INTCOST}_t^{T^{B^g},n} - \text{INTCOST}_t^{T^{B^s},n} \\ & - \frac{\kappa^p}{2} \left(\frac{R_t^{P,n}}{R_{t-1}^{P,n}} - 1 \right)^2 R_t^P L_t^P - \frac{\kappa^g}{2} \left(\frac{R_t^{G,n}}{R_{t-1}^{G,n}} - 1 \right)^2 R_t^G L_t^G - \frac{\kappa^d}{2} \left(\frac{R_t^{D,n}}{R_{t-1}^{D,n}} - 1 \right)^2 R_t^D L_t^D \\ & \left. - \frac{\kappa^K}{2} (BCAP_t^n - RCAP_t)^2 SK_t^B - \frac{\kappa^L}{2} (BLCR_t^n - RLCR_t)^2 SK_t^B \right\} \end{aligned} \quad (28)$$

Where $\text{INTCOST}_t^{T^{B^g}}$ and $\text{INTCOST}_t^{T^{B^s}}$ represent the cost of intermediation in the bond market that are composed of transaction and adjustment costs on corporate and sovereign bonds respectively. for $x \in (g, s)$ we have :

$$\text{INTCOST}_t^{T^{B^x},n} = \mu_t^{bg} T_t^{B^x,n} + \frac{\kappa^{B^x}}{2} \left(\frac{ST_t^{B^x,n}}{ST_{t-1}^{B^x,n}} - 1 \right)^2 ST_t^{B^x} \quad (29)$$

$BCAP_t^n$ and $RCAP_t$ stand for the capital to risk weighted assets ratio for bank n as well as its regulatory level. $BLCR_t^n$ and $RLCR_t$ are the equivalent for the liquidity to assets ratio.

$$BCAP_t^n = \frac{SK_t^{B,n}}{\gamma_t^{L^P} SL_t^{L^P,n} + \gamma_t^{L^G} SL_t^{L^G,n} + \gamma_t^{T^g} ST_t^{G,n} + \gamma_t^{T^s} ST_t^{S,n}} \quad (30)$$

$$BLCR_t^n = \frac{\mu^{NT^G} ST_t^{T^G,n} + \mu^{NT^S} ST_t^{T^S,n}}{\underbrace{\mu^D SD_t^n + \mu^{JD} J_t^D + \mu^{IB} (1+R_t) IB_t^n - (\mu^{L^P} J^{L^P,n} + \mu^{L^g} J^{L^G,n} + \mu^{T^g} J^{T^G,n} + \mu^{T^s} J^{T^S,n})}_{BLCRD}} \quad (31)$$

Which represent respectively the capital and the liquidity regulatory costs. γ_t^x and μ_t^x are the weights used when defining the Basel regulatory ratios.

Evolving in a monopolistic competitive framework, each bank n faces the following new borrowing (deposit) demand (supply) equations, namely for deposits and the banking loans :

$$D_t^n = \left(\frac{R_t^{D,n}}{R_t^D} \right)^{-\nu^D} D_t \quad (32)$$

$$L_t^{G,n} = \left(\frac{R_t^{L^P,n}}{R_t^{L^P}} \right)^{-\nu^{L^P}} L_t^P \quad (33)$$

$$L_t^{G,n} = \left(\frac{R_t^{L^G,n}}{R_t^{L^G}} \right)^{-\nu^{L^G}} L_t^G \quad (34)$$

The previous equations derive from an optimization program similar to the one described in the labor market. For a matter of simplicity, we assume in what follows that $\nu^{L,P} = \infty$ (perfect competitive framework) and $\kappa^P = 0$ (flexible rates). In this case, the maximization of banks profits function with respect to the default threshold $J_t^{L,P}$, L_t^P , SL_t^P and IB_t results in the following first order conditions⁷ :

$$\lambda_{1,t} + \kappa^L (BLCR_t - RLCR_t) BLCR \frac{SK_t^B}{BLCRD_t} \mu^{L,P} = \frac{\lambda_{w,t+1}}{\lambda_{w,t}} \frac{\beta_w}{\pi_{t+1}} (1 + \lambda_{1,t+1} \delta^{L,P}) \quad (35)$$

$$-1 + \lambda_{1,t} (1 - \delta^{L,P} + R_t^{L,P}) + \lambda_{2,t} = 0 \quad (36)$$

$$\kappa^K (BCAP_t - RCAP_t) BCAP_t^2 \gamma^{L,P} - \lambda_{3,t} - \lambda_{2,t} + \frac{\lambda_{w,t+1}}{\lambda_{w,t}} \frac{\beta_w}{\pi_{t+1}} \lambda_{2,t+1} \delta^{L,P} = 0 \quad (37)$$

$$-\lambda_{3,t} = 1 - (1 + R_t) \left[\frac{\lambda_{w,t+1}}{\lambda_{w,t}} \frac{\beta_w}{\pi_{t+1}} - \kappa^L (BLCR_t - RLCR_t) BLCR \frac{SK_t^B}{BLCRD_t} \mu^{IB} \right] \quad (38)$$

By putting $\delta^{L,P} = 0$ and κ^L also equal to zero, one finds the standard FOCs in a one period maturity framework, namely:

$$R_t^{L,P} = R_t + \frac{\lambda_{w,t}}{\lambda_{w,t+1}} \frac{\pi_{t+1}}{\beta_w} \kappa^K (BCAP_t - RCAP_t) BCAP_t^2 \gamma^{L,P} \quad (39)$$

We can thus identify $-\lambda_{2,t}$ as the marginal cost for a bank that considers lending to SMEs. Indeed, our banking sector modelling differs slightly from Gerali et al. (2010) in that we allow for different marginal costs for the bank depending on the identity of borrower since the regulatory constraints take into account the heterogeneity of borrowers. However, with $\delta^{L,P} = 0$, we find similar result to Gerali et al. (2010) with regulatory constraints increasing the marginal cost $-\lambda_{2,t}$ when the Banks ratios are below the regulatory ones and decreasing it when they above the thresholds. Moreover, eq. (36) refers to the standard equilibrium equation linking the marginal cost $-\lambda_{2,t}$ to the "selling price" $R_t^{L,P}$.

Still, the introduction of long term maturities modifies the values of the marginal costs and prices as considered at time t . Since, the lending decision matters for all the future periods, the marginal costs have to take into account next periods values of the interbank rate R_t when the future marginal profits induced by the lending decision in the current period have to be discounted by a specific discount factor $\lambda_{1,t}$ which would be equal to the households discount factor in the absence of the liquidity constraint. However, the LCR as it has been defined depends among others on the bank lending rates, this liquidity constraint enters thus the banks's optimal decision by affecting their discount factor. This is a key feature that a standard representation of the LCR constraints lacks. To assess the impact of the liquidity constraints, the MAG examined the impact of a 25% increase in the ratio of liquid assets to total assets, Gambacorta (2010) in a VECM framework considers the liquidity as the sum of cash and government bonds, a very crude assumption as argued by Angelini et al. (2011). We can then legitimately wonder whether these studies on the impact of the LCR on bank lending spreads may create biased results as the liquidity constraint has an ambiguous impact on bank lending rates as they reinforce the banks' marginal cost and at the same time may lessen the banks' lending rate if banks collect more funding, (see section 4.1.2).

⁷ $\lambda_{i=1..4}$ are lagrangian coefficients related to the accounting equation for the banks as well as for the definitions of $J_t^{L,P}$ and SL_t^P .

Government

The Government is able to fund its public spending by levying taxes \mathcal{T}_t or by issuing sovereign bonds T_t^S at an interest rate R_t^S . The budget constraint for the government can thus be addressed as follow :

$$G_t + \frac{J_{t-1}^{TS}}{\pi_t} = \mathcal{T}_t + T_t^S \quad (40)$$

In order to avoid any multiplier effect from public spending, we suppose the latter exogenous.

The purchase for taxes is set to reach a target public debt to GDP level, the later being its steady-state value.

Thus, the law of motion of taxes is as follow :

$$\frac{\mathcal{T}_t}{Y_t} = \frac{\mathcal{T}_{t-1}}{Y_{t-1}} + \gamma^{\mathcal{T}} \left(\frac{ST_t^S}{Y_t} - \overline{ST_y} \right) \quad (41)$$

Where ST_t^S is the outstanding amount of public debt.

Monetary Policy

Monetary policy is specified in terms of an interest rate rule targeting inflation, its first difference as well as the first difference in output. The Taylor interest rate rule used has the following form :

$$R_t = R_{t-1}^{\rho_R} \left[R^* \left(\frac{\pi_t}{\bar{\pi}} \right)^{r_\pi} \left(\frac{\pi_t}{\pi_{t-1}} \right)^{r_{\Delta\pi}} \left(\frac{Y_t}{Y_{t-1}} \right)^{r_{\Delta Y}} \right]^{1-\rho_R} \varepsilon_{R,t} \quad (42)$$

where r_π is the weight assigned to inflation and $\Delta\pi$ and ΔY those assigned to inflation and output growth. R^* is the steady-state policy rate, and $\varepsilon_{R,t}$ is the white noise monetary policy shock.

Market clearing conditions

Aggregating the entrepreneurs' budget constraints (7) and (17) and using the zero-profit conditions for competitive capital producers we can set the following aggregated entrepreneurs' budget constraints :

$$C_t^p + \frac{1 + R_{t-1}^{L,p}}{\pi_t} L_{t-1}^p + w_t N_t^p + I_t^p = p_t^{e,p} Y_t^{e,p} + L_t^p \quad (43)$$

$$\begin{aligned} C_t^g + \frac{1 + R_{t-1}^{L,g}}{\pi_t} L_{t-1}^g + \frac{1 + R_{t-1}^{T,g}}{\pi_t} T_{t-1}^g + w_t N_t^g + I_t^g + \left[1 - \mathcal{F} \left(\frac{\bar{\varepsilon}_{z,t} + \sigma^2/2}{\sigma} \right) \right] \frac{J_{t-1}^{TG}}{\pi_t} \\ + \mathcal{F} \left(\frac{\bar{\varepsilon}_{z,t} + \sigma^2/2}{\sigma} \right) [l^g (1 - \theta_{t+1}^g) q_{t+1}^K \pi_{t+1} K_t^G (1 - \delta) - F J_t^G] = p_t^{e,g} Y_t^{e,g} + L_t^g + T_t^g \end{aligned} \quad (44)$$

Aggregating the workers' budget constraint and using the financial market equilibrium (aggregate accounting equality of the banking system⁸) as well as the previous equations, we can set the following market clearing

⁸Note that the aggregate level of interbank funds is equal to zero, $\int_0^1 IB^n dn = 0$.

condition in goods market :

$$C_t^w + C_t^g + C_t^p + I_t^p + I_t^g + G_t + \mathcal{F} \left(\frac{\overline{\epsilon_{z,t}} + \sigma^2/2}{\sigma} \right) \left[\iota^g (1 - \theta_{t+1}^g) q_{t+1}^K \pi_{t+1} K_t^G (1 - \delta) - F J_t^G - \frac{J_{t-1}^{TG}}{\pi_t} \right] + CapRegCost(t) + LiqRegCost(t) + Adj_t = Y_t \quad (45)$$

Where Adj_t includes all adjustment costs (in both good and banking sectors) when $CapRegCost(t)$ and $LiqRegCost(t)$ stand for the costs related to the capitalization and liquidity constraints.

3 Calibration

We fix several parameters to values in the range suggested by mainly the euro area data⁹ from 1999 (creation of the euro zone) to the mid of 2007 (the beginning of the subprime crisis) and if it is not available, we refer to the literature. Thus, relatively to the interest rates, we set the steady-state nominal interest rate value at 0.75% (in quarterly term) according to Euro Area data. That with an elasticity of deposit supply at -2.5 induce an annual deposit rate about 1.8% which corresponds to a households' discount factor of 0.9995. Relatively to bank lending rates, we calibrate the demand of elasticities at 2.5 and 4.2 for respectively small and large firms which corresponds to a spread SME's loan rate - Corporate Loan rate about 100 bp.

With regard to volumes, we calibrate the LTV parameters θ^p and θ^g to 0.47 and 0.7 when we calibrate the resalable part of capital ι at 0.45. All of these parameters ensure a steady-state values of SMEs (resp. corporate firms) banks loans to GDP about 10% (resp. 30%).

Furthermore, we calibrate the parameters δ^X in a way to get Macaulay's maturities about 4, 5, 7, 10 and 15 years for respectively SMEs bank loans, large firms bank loans, large firms bonds, risk-less (sovereign) bond and households deposits.

Moreover, we calibrate the steady-state value of the corporate firms default rate about 0.7% which with the risk-less bond maturity and yield induce a corporate bond yield about 3.3%.

We set the steady state SME's part in the global production volume ν^y equal to 0.33 in line with official studies on the French economy¹⁰ with SMEs referring particularly to independent SMEs.

Turning to the Basel constraints parameters, we first set the coefficient κ^K at 11 in line with the range of values estimated by Geralli et al.(2010). The calibration of parameter κ^L is more problematic since there is no benchmark model to use. We however choose to set κ^L in a way that, in a partial equilibrium model, a 10% increase in the liquidity constraint induces a similar impact on the bank lending rate to SMEs than a 10% increase in the capitalization ratio. This implies to set κ^L at a value about 0.2.

Second, and in order to set the Basel III weighting coefficients, we mainly use French data to calibrate most of the parameters, and particularly the capital/RWA ratio.

In this order we set γ^{L^P} at 0.81, when γ^{L^G} is set at 0.46 and γ^{T^G} 0.33 and finally γ^{T^S} is set 0.04.

⁹In the case when euro area data are not available when French data are, we make the choice to use the French data as a benchmark for calibration.

¹⁰"Les chiffres-cles des TPE-PME", Ministere de l'economie, de l'industrie et de l'emploi - DGCIS - October 2009.

The rest of the parameters are calibrated as :

$$\begin{aligned}
 \mu_t^{NT^G} &= 0.45 & \mu_t^{NT^S} &= 0.65 \\
 \mu_t^{T^G} &= 0.25/3 & \mu_t^{T^S} &= 0.15/3 \\
 \mu^D &= 0.2 & \mu^{JD} &= 0.03 \\
 \mu^{L^G} &= 0.5/3 & \mu^{L^P} &= 0.5/3 \\
 \mu^{IB} &= \frac{1}{3}
 \end{aligned}$$

We divide most of the outflows parameters by 3 since the regulation is applied to 30 days outflows while we use quarterly data.

The rest of parameters were calibrated at estimated values found in Gerali et al. (2010) paper. Table (1) in the appendix reports the values of the calibrated parameters.

4 The implementation of Basel III Constraints

4.1 Basel III Constraints

4.1.1 Liquidity vs Capital Requirements

In this sub-section, we model the scenario of a steady increase in banking capitalization and liquidity constraints separately. To disentangle the effects of the liquidity constraint from the capitalization one, we set the parameter related to the capitalization constraint κ^K close to 0 in the model when the liquidity is still active, and inversely for the capitalization shock.

With regard to the capitalization ratio, we implement a scenario similar to the MAG (2010) by assuming a linear increase in the capitalization ratio of 1% through 16 quarters. For the liquidity constraints, we choose to implement a scenario of an increase in the LCR by +25% in 4 years (i.e. from 60% to 85%), also with a linear implementation process.

The results are shown in Figure 1. They indicate that GDP decreases by 0.05% as a result of the capital constraint and 0.15% for the liquidity constraint (see cell (1,3), i.e. row 1, column 3 in Figure 1), and -0.05% at a longer horizon, with a slightly more significant effect for the capital constraint. The liquidity constraint affects consumption more (see cell (2,2)), and the capital constraint affects private investment more (see cell (2,3)).

Loans are reduced, but more from the solvency than the liquidity constraint, and more for SMEs (-1% see cell (3,4)) than for large corporates (-0.5%, see cell (4,2)). Interest margins, measured as the difference from the monetary policy rate, increase more from the liquidity than the capital constraint (see cell (4,1) and (4,3)). Banks increase their purchase of sovereign and corporate bonds in order to meet the liquidity constraint, but hardly change their holdings as the consequence of the capital constraint (see cell (4,4) and (5,2)). Banks increase the size of their balance sheet as a consequence of the liquidity constraint while the capital constraint leads to deleveraging (cell (3, 1)).

All in all, the share of large corporates' production increases at the expense of SMEs (cell (2,4)) but the effect is reached in the short run.

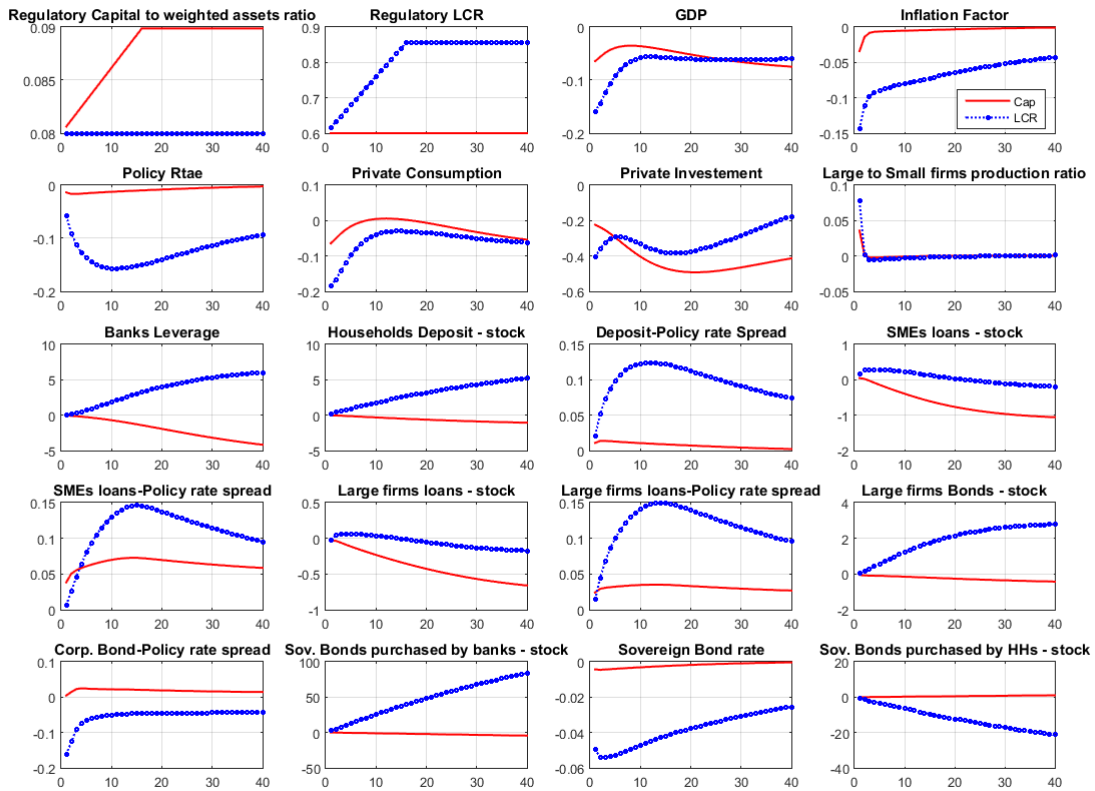


Figure 1: The impact of the Basel III new Capitalization (red curve) and Liquidity (blue curve) thresholds. The regulatory ratios are in level. All rates are shown as absolute deviations from steady state, expressed in percentage points. All other variables are percentage deviations from steady state.

4.1.2 Liquidity Constraints

With respect to the liquidity constraint, an increase in the regulatory ratio has a direct impact on the bank lending rate as suggested by equations (35) to (38) in section 2. However, the impact of an increase in the regulatory liquidity ratio has two opposite effects on the bank lending rates. On the one hand, any increase in interbank borrowing represents additional future cash outflows which reinforces the burden of the liquidity constraint while, on the other hand, any lending opportunity will loosen it, as it will create future inflows. Figure 1 shows that both the lending rates spreads (to SMEs and corporate firms) increase when the policy rate decreases reflecting a relatively sharp increase in the bank lending rate. By increasing their lending rates, banks also generate future cash inflows with larger yields and in shorter time comparatively to corporate or sovereign bonds which are characterized by long maturity and low yields.

Indeed, the increase in the LCR requirements has initially recessionary effects which are largely the consequence of the sharp decrease in private consumption. The latter is mainly due to a second order effect of the LCR, namely the increase in deposits. Indeed, on the one hand, deposits create more outflows, while more deposits is a way to increase future liquid assets, i. e. to purchase bonds in our model. The increase in deposits has a negative impact on the LCR, although less than an increase in interbank borrowing. Accordingly, in its scenario of development of the LCR, the Basel committee considers the scenario of partial retail deposit run-off which implies that the outstanding amount of households deposits increase outflows in the denominator of the LCR. Moreover, the LCR denominator should also contain deposit repayments as they are considered as agreed future cash outflows. For this double reasons, we expect that banks would restrain their willingness of holding deposits by decreasing their demand for deposits as well as their remuneration rate. Nevertheless, we note that according to our simulation exercise, both deposits volumes and interest rates spreads increase. This simultaneous increase indicates that it comes from the demand side, namely the banking sector. This effect originates in the definition of the LCR. Indeed, the LCR implementation stresses the necessary accumulation of Highly Liquid Assets (HLQ) - containing notably sovereign and corporate bonds - that materializes with a high weighting factor in the LCR expression (from 50% to 100%). As compared to the weight of retail deposits volume (between 3% for the most stable funds to 10% for the less stable ones), it can happen that the marginal benefit of holding liquid securities outpaces the marginal cost of holding deposits. Banks will then rather prefer to loosen their accounting constraint by increasing their liabilities (their demand of retail deposits) in order to purchase more liquid assets than limiting their leverage ratio. The LCR can, if it is implemented alone, not necessarily trigger a deleveraging process. This increase in deposit rate combined with the rise in corporate bonds spread leads to an increase in the saving rates of households, who then cut in their consumption expenses.

Note also that private investment tends to increase 15 quarters after the rise in the LCR regulatory constraint. This result corresponds actually to the slight increase in large firms' investment since the existence of an alternative source of funding combined with the absence of a any restriction in the bank loan supply, allows large firms to handle the new Basel III constraint in a more favorable way than SMEs as indicated by the ratio of large firms to small firms production.

The increase in investment suffers, however, from a crowding out effect from public debt. Indeed, one of the expected effects of the new LCR is the search for highly rated sovereign debt as it can be shown in Figure 1 and 2.

Figure 2 investigates further the impact of the LCR associated with the purchase of sovereign bonds. The solid line is the response of variables when introducing the LCR and is the same as in Figure 1, while the dotted line depicts the same analysis when banks cannot invest in sovereign bonds. We notice that in the latter case, when sovereign bond purchase are not allowed, meeting the regulatory LCR threshold is achieved, as expected, through an increase in all other assets and more particularly in corporate bonds. The rise in firms' funding puts downward pressure on prices and help investment recovering. The short-term losses in GDP will then be offset in about 5 years and, more importantly, GDP growth remains positive at a longer horizon. Neglecting the sovereign bonds channel may therefore underestimate the negative effect of the LCR on real variables that can not be adjusted using different calibration of the LCR parameters.

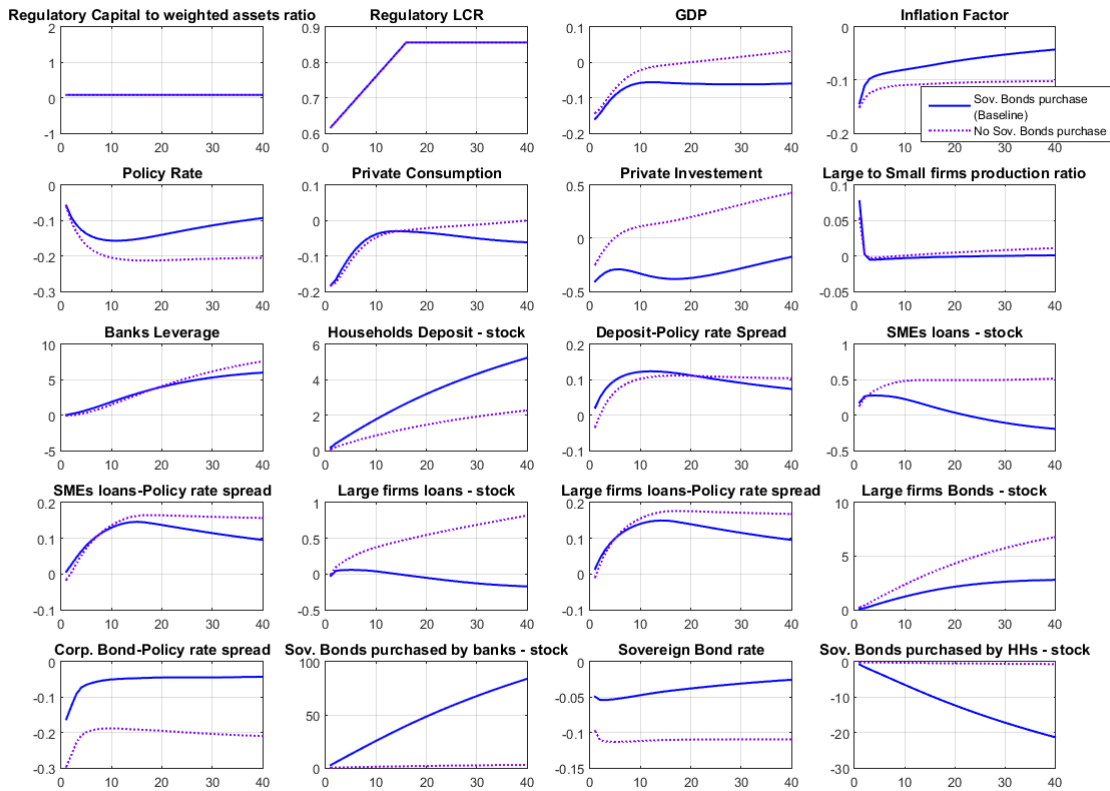


Figure 2: The effect of sovereign bonds purchase in the Basel III new Coverage Liquidity Ratio. The solid line depicts the impact of the LCR when sovereign bonds are available for banks' investment, while this is excluded for the dotted line. The regulatory ratios are in level. All rates are shown as absolute deviations from steady state, expressed in percentage points. All other variables are percentage deviations from steady state.

4.1.3 Capital Requirements

Turning to the other Basel III constraint, a first result to be addressed is the more lasting recessive effect of the capitalization constraint comparing to the LCR effect.

The capital ratio aims among others to limit any surge in leverage from credit institutions. It is then not surprising to expect a deleveraging process from banking sector in the absence of any additional incentives to rise their assets. Thus, in a scenario with no additional shocks, the rise in the regulatory capitalization threshold induces a deleveraging process from the banking sector as well as a simultaneous rise in banks' lending rates. An increase in the interest rate on new bank loans would probably not be sufficient to match the regulatory constraint especially in the case of a large share of long maturities fixed rate loans. Banks resort to a cut in their bank loans, and more particularly the riskier ones (namely SMEs loans here).

The low supply of credit combined with the decrease in the demand for corporate bonds (see cell (4,4)) induces a sharp reduction in the demand for investment goods, magnified by the presence of financial frictions and more precisely the collateral constraint as emphasized in Gertler and Kiyotaki (2009). This also explains differences in the impact of regulatory constraints between large and small companies. Our simulations indicate that the impact of the Basel III constraints favors large firms' assets at the expense of small firms. A larger share of loanable funds as well as labor force moves towards large companies, what in turn amplifies the recessionary effect on small firms as shown in Fig. 1.

4.1.4 Simultaneous Shocks

In the following figure (3), we show the overall impact of the simultaneous implementation of both of the Basel III constraints. The main results that can be assessed is that, surprisingly, the global impact of both shocks is close to the sum of the impacts of each shock.¹¹ In other words, it seems there is no strong positive externalities between liquidity and capitalization constraints which makes them complementary.

When we consider the full implementation of Basel III, with the LCR ratio moving to 100%, GDP decreases by 0.3% at longer horizon, with private consumption reduced by 0.2% and private investment by 1%. SME loans are reduced by 3% (cell (3,4) and corporate loans by 2% (cell (4,2)), partially offset by an increase in corporate bonds. Indeed, in our modeling framework, banks are not able to decrease their leverage and simultaneously increase their spreads in order to meet the LCR target since the latter is positively correlated with future assets repayments. As seen before, the liquidity shock induces a significant rise in the bank leverage, in contrast with the effects of the capital-to-weighted assets ratio shock. As a consequence and in order to reach the new regulatory threshold, banks have to make larger effort, in comparison to what they would do in the absence of the LCR shock. As a result, the simultaneous regulatory shocks trigger a transitory dampening in the aggregate demand components. Such results contrast with De Nicolo and Lucchetta (2014) who conclude to the substitutability of the requirements, focusing on the effect of retained earnings, while the main channel comes from households' deposits in our model. However, both models conclude to the more significant effect of liquidity requirements.

¹¹Note that the results related to the capitalization and the liquidity constraints differ for some variables from what has been shown in the previous section since in this exercise, we do not shut down the other constraint when we implement one.

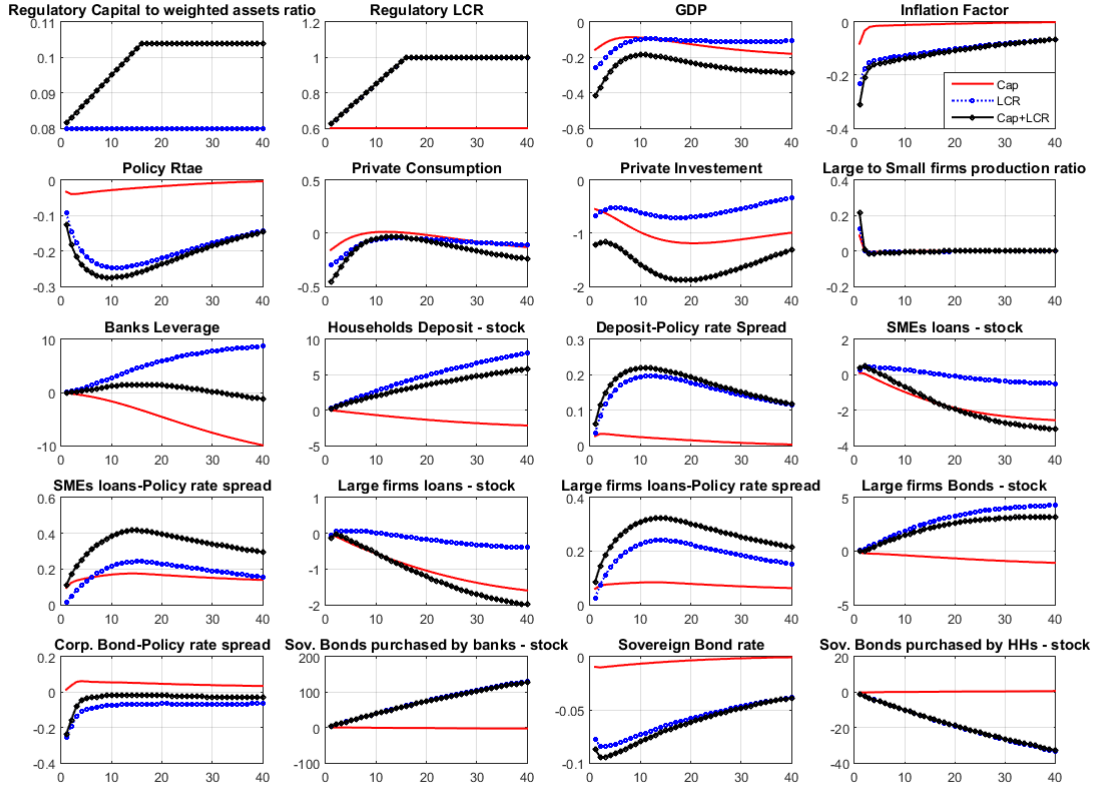


Figure 3: The overall impact of Basel III capitalization and liquidity constraints.

4.2 Basel III phase-in periods

In this section, we proceed with an exercise similar to the MAG(2010-2012) reports which consists in examining the period of time during which banks would need to implement the new regulatory requirements. Indeed, banks, under the pressure of financial markets, would eventually have an incentive to implement the new requirements more rapidly than what has been set by the regulators. However, within a counter-factual scenario, regulators would extend the timeframe of the implementation in order to smooth the impact of the new regulations and soften the cost of the transition to the new regime. For this purpose, we imagine three scenarios where the implementation process takes 2, 5 and 8 years. We also chose the use a linear implementation process in order to avoid additional hypothesis and notably those relative to the curvature that could influence the results.

Figure (4) shows the results for the three scenarios. As we would have expected, a short period implementation process triggers a sharp dampening in overall activity with a drop in production as well as the other key macro variables. We note also that it is the impact on banks behavior that differs across the three scenarios while we only find slight differences in the real economy. The differences in the banking sector side mainly result from the trade-off credit institutions have to make between increasing their profit margins and lowering their leverage in order to meet the capitalization ratio. The origin of this effect depends on what we can call the "degree of urgency" of meeting the constraint. Indeed, since our model takes into account differences in assets maturities, the latter play a relevant role in the banks decisions in the sense that loan decisions have on average

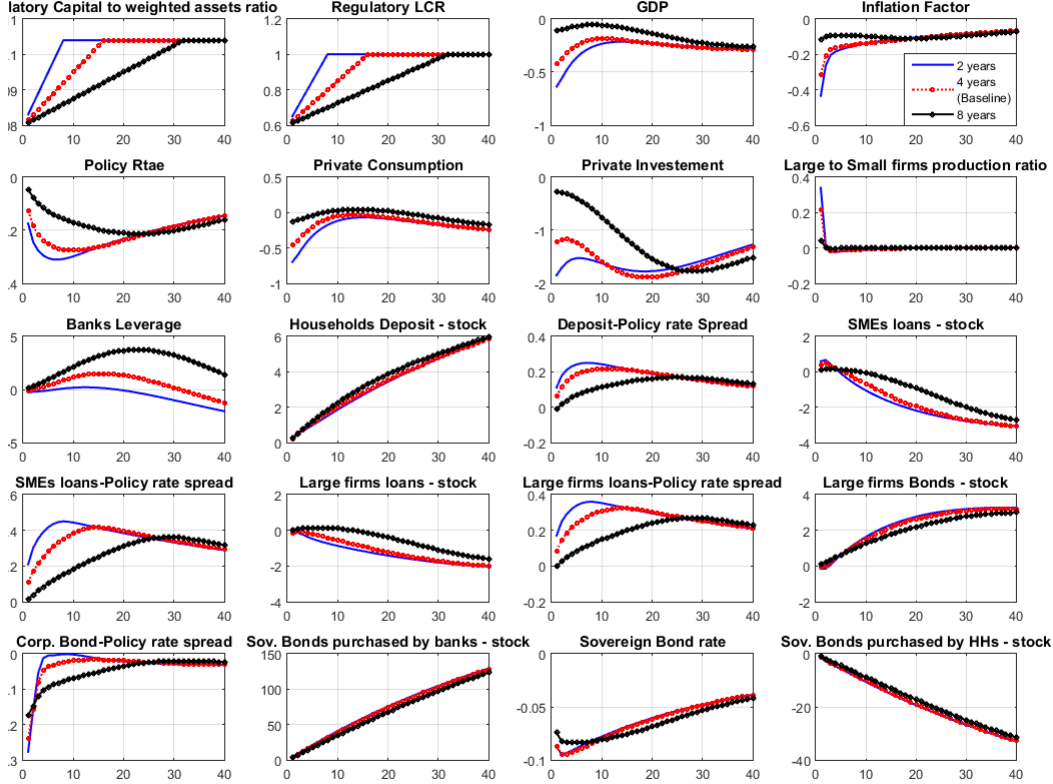


Figure 4: Simultaneous banks capital and Liquidity shocks - The phase-in period.

The Basel III regulatory variables are expressed in level. All rates are shown as absolute deviations from steady state, expressed in percentage points. All other variables are percentage deviations from steady state.

a longer lasting effect on banks' balance sheet as loans are assets with a maturity longer than one period. As a consequence, when banks have little lead-time to meet the regulatory constraint, they will probably make the choice of deleveraging rather than increasing margins. Thus, we simulate different scenarios when we multiply both solvency ratio and LCR deviations costs (namely κ^K and κ^L) by a coefficient $RegCons$ representing different levels of more or less aggressive behavior from the regulator. We found that with high values of $RegCons$, the banks prefer to cut their loans while increasing their purchase of corporate and sovereign bonds in order to increase their capital-to-weighted assets ratio and thus meet the regulatory constraint. When the implementation horizon is longer (low $RegCons$), banks increase their margins without necessarily deleveraging or even reducing their weighted assets. The same results can be observed for banks under stress that are generally small or medium sized banks. Indeed, a weakly capitalized bank, for example, has to make greater efforts to meet the constraints. Consequently, they will probably have stronger incentives to cut their credit supply relatively to well capitalized banks. This would probably, at least in the short and medium term, enlarge the discrepancies between the two types of banks.

Note also that since sovereign bonds benefit from favorable weights in both regulatory constraints, the easiest way for banks to reach quite easily and quickly the constraints is to increase their purchase of sovereign bonds. With a less aggressive constraints (low $RegCons$) or a very large implementation period (8 years), banks are able

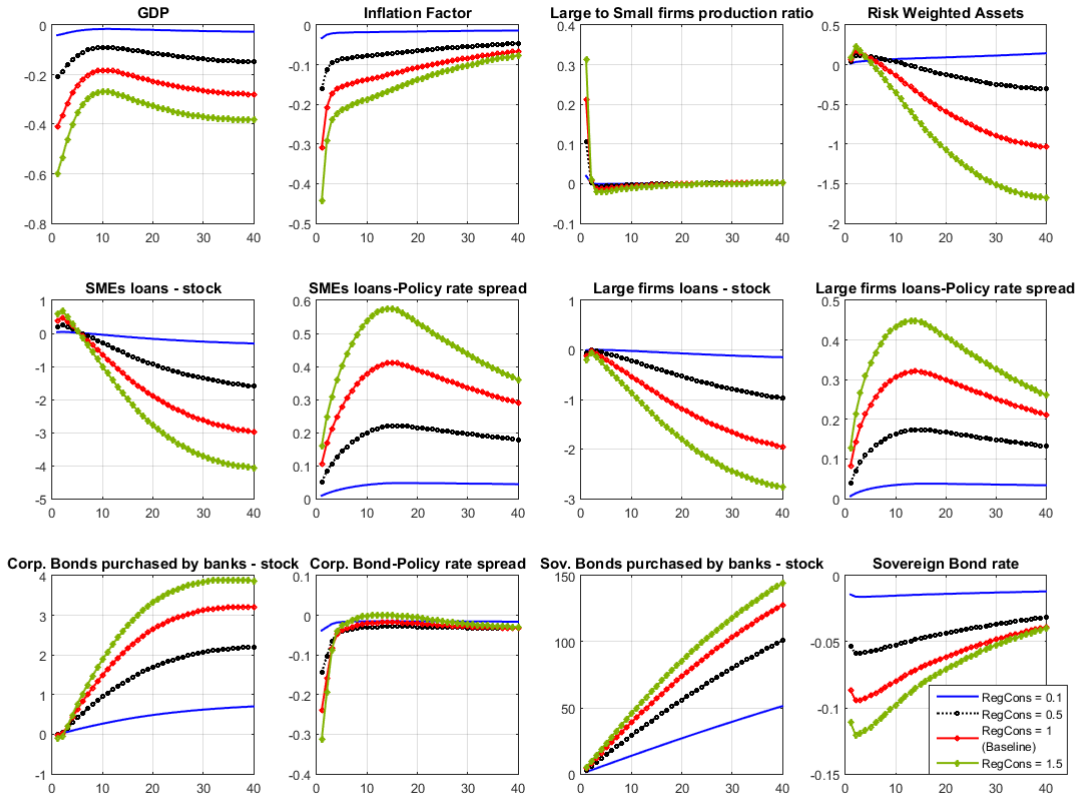


Figure 5: The impact of the weight of Basel III Capitalization and Liquidity constraints. All rates are shown as absolute deviations from steady state, expressed in percentage points. All other variables are percentage deviations from steady state.

to satisfy the (low) one-period regulatory requirements without deleveraging. It will maintain SMEs production level relatively high, as compared to what we observed in the short-term implementation. Thus, the discrepancy between SMEs and large firms production levels remains much more stable with the longer implementation period. The latter together with banks smoothing increases in their profit margins limit the contractionary impact of Basel III constraints and therefore induce a low variability in most of real sector aggregates. The dynamics of most of the variables are in general smoother.

5 Conclusion

In this paper, we extend the results of the numerous studies on the Basel III new requirements implementation and notably those of the (MAG (2010b) and MAG (2010a)). Focusing on the impact of the new banking regulation in presence of firms' heterogeneity, we find that both capital and liquidity requirements widen the discrepancy between small and large companies in favor of the latter. This result is moreover amplified when we implement both constraints simultaneously. Indeed, we find that there is no potential positive spill-over effects between the implementation of the new capitalization ratio and the liquidity coverage ratio as their effects are compounded when the two regulations are implemented jointly. The model sheds some light on the channel of accumulation of sovereign bonds, and partial substitution away from loans to companies, notably SMEs.

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Appendix

Table 1: Calibration

Parameter	Description	Value
Households		
σ_c^w	Inter-temporal elasticity of substitution of workers' consumption	1
η^w	Habit in workers' consumption coefficient	0.87
σ_n	Inverse of the Frisch elasticity	1
ν_w	$\frac{\nu_w}{\nu_w-1}$ is the mark-up in the labor market	5
γ_w	Wage indexation	0.28
κ_w	Wage adjustment cost	100
Production		
σ_c^p	Inter-temporal elasticity of substitution of small entrepreneurs' consumption	1
η^p	Habit in small entrepreneurs' consumption coefficient	η^w
α	Capital share in the production function	0.25
δ	Capital depreciation rate	0.025
σ_c^g	Inter-temporal elasticity of substitution of large entrepreneurs' consumption	1
η^g	Habit in large entrepreneurs' consumption coefficient	η^w
ϕ	Capital producers' investment adjustment cost	10
ξ^y	Inverse of Elasticity of substitution between SMEs and large corporate	0.1
ν^y	SME's share in the production	1/3
ν^f	$\frac{\nu^f}{\nu^f-1}$ is the mark-up in the good market	3.86
γ_f	Price indexation	0.16
κ_f	Price adjustment cost	30
Banking Sector		
κ^{LP}	SMEs' loans interest rate adjustment cost	13
κ^{LG}	Large firms' loans interest rate adjustment cost	7
κ^D	Savers' deposits interest rate adjustment cost	20
ν^{LP}	$\frac{\nu^{LP}}{\nu^{LP}-1}$ is the mark-up on rate on loans to SMEs	2.5
ν^{LG}	$\frac{\nu^{LG}}{\nu^{LG}-1}$ is the mark-up on rate on loans to large corporate	4.2
ν^D	$\frac{\nu^D}{\nu^D-1}$ is the mark-down on rate on deposits	-2.5
κ^K	"Leverage" deviations cost	11
κ^L	"Liquidity" deviations cost	0.20
δ^{LP}	$(1 - \delta^{LP})$ The principal repayment part of the loans to SMEs residual outstanding amount	0.9446
δ^{LG}	$(1 - \delta^{LG})$ The principal repayment part of the loans to large firms residual outstanding amount	0.9571
δ^{TG}	$(1 - \delta^{TG})$ The principal repayment part of the large firms bonds residual outstanding amount	0.9715
δ^{TS}	$(1 - \delta^{TS})$ The principal repayment part of the risk-less bonds residual outstanding amount	0.9823
δ^D	$(1 - \delta^D)$ The principal repayment part of the households deposits	0.9907
Monetary Policy		
r_π	Taylor rule coefficient on inflation	2
$r_{\Delta\pi}$	Taylor rule coefficient on inflation growth	0
$r_{\Delta Y}$	Taylor rule coefficient on output growth	0
\bar{R}	Nominal policy rate in %(ssv)	0.75
$\bar{\pi}$	The long term Inflation rate in %(ssv)	0.49
Shocks		
$\sigma_{\nu\kappa}$	The SD coefficient of the solvency ratio	0.0170
$\sigma_{\nu L}$	The SD coefficient of the LCR	0.0319