Discussion Paper Series

Supply Shocks and the Cyclical Behaviour of Bank Lending Rates under the Basel Accords

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January 2012
Number 161

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Abstract

This paper examines the cyclical effects of bank capital requirements in a simple macro model with credit market frictions. A bank capital channel is introduced through a monitoring incentive effect of bank capital buffers on the repayment probability and hence the loan rate. We also identify a collateral channel, which mitigates moral hazard behaviour by firms, and therefore raises their repayment probability. Basel I and Basel II regulatory regimes are then defined, with a distinction made between the Standardized and Foundation Internal Ratings Based (IRB) approaches of Basel II. We analyze the role of the bank capital and collateral channels in the transmission of supply shocks, and show that depending on the strength of these channels, the loan rate can either amplify or mitigate the effects of the shock. Finally, the relative impact of the two channels also determines which of the regulatory regimes is most procyclical.

JEL Classification Numbers: E44, E30, G28

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1 Introduction

Banking regulation in form of bank capital requirements has gained further attention following the global financial crisis of 2007-2009, triggered by the collapse of the U.S. subprime mortgage market and fuelled by complex financial innovations that have made it difficult for market operators to assess risk. The standards of banking regulation, associated with the Basel Accords, state that banks must meet risk based capital requirements such that the ratio of bank capital to risk adjusted assets is at least 8%.

Since the adoption of the first Basel accord (Basel I) in 1988, many concerns have been raised concerning the possible procyclical effects caused by such type of banking regulation.[1] For example, during an economic recession accompanied with credit losses incurred by financial intermediaries, the bank capital-loan ratio falls, which forces banks to raise new capital or decrease lending to firms. Assuming that raising capital is very costly during economic downturns, bank capital requirements may therefore lead to a credit crunch and to a further exacerbation of a financial or economic crisis.[2]

In 2004, the Basel Committee on Banking Supervision released the current Basel Accord (Basel II) in order to address the main shortcomings of Basel I (Basel Committee on Banking Supervision (BCBS) 2004). Most importantly, in Basel I, the risk weight on loans applied to all loans in the same particular category and therefore the risk associated with a particular borrower could not be detected by the banks nor the regulators. This, in turn, led banks to engage in regulatory capital arbitrage that undermined the effectiveness of Basel I (Jones 2000). The main difference between Basel I and Basel II is that under the latter regime the risk weights on loans are endogenous, and depend on either the probability of default (The Foundation Internal Rating Based (IRB) Approach) or on ratings provided by external rating agencies (The Standardized approach). These ratings tend to be procyclical and consequently the Standardized approach is often linked with the nature of the business

[1] In the literature of banking regulation, procyclicality refers to the amplification of a variable following various shocks (see Agénor and Pereira da Silva 2012, Drumond 2009 and Repullo and Suarez 2009 for instance) and not necessarily to a positive correlation between two variables.

[2] On the credit crunch that may have occurred in the U.S. in the early 1990's following the implementation of Basel I see Bernanke and Lown (1991) and Peek and Rosengran (1995) for instance.

cycle or the output gap in macroeconomic models (see for example Zicchino 2006).[3]

The introduction of increased sensitive risk weights on loans, which may change throughout the business cycle, has led to a broader debate on the procyclical effects of bank capital regulation. In Basel II, the amount of bank capital held by the bank not only depends on the institutional nature of the borrowers but also on the risk imposed by each particular borrower. Moreover, if lending becomes riskier following a negative supply shock for example, banks may be required to hold more capital- or, failing that, to reduce their lending capacity in order to satisfy the more risk sensitive capital requirements. Hence, the increased volatility of the risk weights on loans during an economic recession may result in a more intensified credit crunch, thereby amplifying the economic downturn and making capital requirements more procyclical. The possible increased procyclical effects of the Basel II accord is supported by the models of Aguiar and Drumond (2009), Zicchino (2006) and Tanaka (2002), to name a few.

However, in a recent contribution, Agénor and Pereira da Silva (2012) and Agénor, Alper and Pereira da Silva (2012) argue that much of the literature examining the effects of Basel II compared to Basel I is based on the analysis of industrialized countries and not middle-income countries, which face more extreme financial market imperfections. These include severe asymmetric information problems fostering collateralized lending, underdeveloped capital markets, limited competition among banks, greater vulnerability to shocks, weak supervision and a limited ability to enforce bank capital regulation (see Agénor and Pereira da Silva 2012 for more details). Both of these models demonstrate that within a general equilibrium framework and accounting for some of the abovementioned credit market imperfections, Basel II may actually be less procyclical than Basel I, as opposed to what partial equilibrium results would suggest.

Specifically, by extending the static macroeconomic model of Agénor and Montiel (2008), Agénor and Pereira da Silva (2012) introduce a bank capital channel through a signaling effect of bank capital buffers on the deposit rate, which, in turn, impacts directly households' consumption. This analysis demonstrates that such type of bank capital chan-

[3] The risk weighting scheme remains essentially the same under the new proposed regulatory framework - Basel III.

nel has sizable effects on the economy. More precisely, with a signalling effect of bank capital buffers on the deposit rate, both Basel I and Basel II magnify the procyclical effects of the risk premium following supply shocks, with Basel II inducing less procyclicality compared to Basel I under non-binding capital requirements (the more relevant case in practice, as discussed later).

Furthermore, Agénor, Alper and Pereira da Silva (2012), by employing a Dynamic Stochastic General Equilibrium (DSGE) model, show that it cannot be ascertained a-priori whether Basel II is always more procyclical than Basel I. The bank capital channel in their model assumes that holding more bank capital relative to loans induces banks to screen and monitor borrowers more carefully, which raises the repayment probability and consequently lowers the lending rate. Embedding this channel through the impact of the bank capital-loan ratio together with the collateral-debt ratio (which mitigates moral hazard behaviour by the borrowers) on the repayment probability, their analysis shows that Basel I may be more procyclical than Basel II following various shocks.

The goal of this paper is to examine the cyclical effects of Basel I, the Standardized approach of Basel II and the foundation IRB approach of Basel II in a simple static macroeconomic model, which is related to the analysis of Agénor and Pereira da Silva (2012). However, instead of embedding the bank capital channel through the impact of bank capital buffers on the deposit rate, we employ this channel by positively relating bank capital buffers to the repayment probability and consequently the loan rate. Our model is therefore complementary to their paper, exploring how bank capital buffers are transmitted through their direct impact on the financial system rather than their effect on consumption and the real economy. The hypothesis of such a bank capital channel is supported by recent evidence which suggests that banks holding capital buffers charge lower interest spreads on their loans (Fonseca, Gonzalez and Pereira da Silva 2010).

Because total bank capital is fixed given the short run nature of our model, the bank capital channel is incorporated in the form of bank capital *buffers* rather than *total* bank capital relative to outstanding loans (which is the case in Agénor, Alper and Pereira da Silva 2012). Moreover, the role of this type of bank capital channel in the transmission of supply shocks is studied under both Basel I and Basel II, with a distinction made between the foundation IRB and the Standardized approaches. We also analyze the link between bank capital requirements, firms collateral, the repayment probability and the cyclical behaviour of the loan rate. Finally, this model compares between the cyclical effects on the loan rate caused by a negative supply shock under Basel I and the different variants of Basel II.

The rest of the paper continues as follows. Section 2 presents the model, with a detailed examination of the agents behaviour, the different bank capital regulatory regimes, and the market clearing conditions. Section 3 provides the solution of the model under non binding capital requirements, and studies the impact of a negative supply shock on the macroeconomic equilibrium and the degree of cyclicality of the loan rate. Finally, section 4 summarizes the main results with possible extensions of the analysis.

2 The Model

This model follows the static framework proposed by Agénor and Pereira da Silva (2012), but with the incorporation of a bank capital channel similar in spirit to Agénor, Alper and Pereira da Silva (2012). The economy consists of four types of agents: firms, households, a commercial bank and a central bank (which also acts as a regulator) and we now turn to describe their behaviour.

2.1 Firms

Firms produce a single, homogenous good using beginning of period capital (which is therefore predetermined) and labour. Firms borrow from the commercial bank in order to finance both their working capital needs, consisting only of labour costs, and investment. Thus, the total costs of firms in producing output comes from paying wages and interest on loans given for employing labour. Financing working capital needs is fully collateralized by the firms' capital stock and thus bears no risk.[4] Consequently, such loans are provided by the commercial bank at a fixed mark up (normalized to unity) on the cost of borrowing

[4] Loans contracted for working capital needs are short-term in nature, and can be easily monitored by the bank as they are readily observable *ex post* (Besanko and Thakor 1987).

from the central bank, denoted by the refinance rate i^R. In contrast, loans provided for investment financing do carry risk and are priced at a loan rate i^L, set as a mark up over the refinance rate (as shown later in the text).

After the homogeneous goods are produced and sold, the firms repay their loans to the commercial bank, with interest, so the loans are single period debt contracts. Finally, the end of period profits are transferred to households, who act as the firms owners.

The firm's total demand for loans (L^F) is given by,

$$L^F = WN + PI, \tag{1}$$

where W denotes the nominal wage for employing labour, N the amount of labour employed, P the price of the homogeneous good and I the level of real investment.

The real investment (I) is inversely related to the lending rate (i^L) charged by the commercial bank,

$$I = I(i^L - \pi^e), \tag{2}$$

where π^e is the expected (exogenous) rate of inflation and $\frac{dI}{di^L} < 0$.

The production function is assumed to take a typical Cobb-Douglas form,

$$Y = AN^\alpha K_0^{1-\alpha}, \tag{3}$$

where $A > 0$ is a shift technology parameter, and K_0 is the predetermined stock of physical capital. The total costs faced by firms when borrowing for working capital needs from the commercial bank are given by WN. Thus, the firm's maximization problem can be written as,

$$\max_N \left[PY - (1 + i^R)WN - (1 + i^L)PI\right],$$

subject to,

$$Y = AN^\alpha K_0^{1-\alpha}.$$

Deriving the first order condition with respect to N (the only choice variable) and taking i^R, P, W and I as given yields the labour demand function,[5]

$$N^d = \left[\frac{\alpha A}{(1 + i^R)(W/P)}\right]^{\frac{1}{1-\alpha}} K_0. \tag{4}$$

[5] The investment level is not a choice variable in the profit maximization.

By substituting (4) in (3), the total output supply is,

$$Y^s = \left[\frac{\alpha A}{(1+i^R)(W/P)}\right]^{\frac{\alpha}{1-\alpha}} K_0. \tag{5}$$

Equations (4) and (5) show that the demand for labour and the output supply are negatively related to the effective cost of labour, denoted by the term $(1+i^R)\frac{W}{P}$.

Because the model is short run in nature, the nominal wage is assumed to be fixed at $\bar{W}$. Thus, the labour demand and output supply equations can be represented as functions of prices, the refinance rate and the technology parameter,

$$N^d = N^d(P, i^R, A), \tag{6}$$

$$Y^s = Y^s(P, i^R, A), \tag{7}$$

with $N^d_P, Y^d_P > 0$, $N^d_{i_R}, Y^d_{i_R} < 0$ and $N^d_A, Y^d_A > 0$. That is, an increase in prices, lower interest rates (both of which reduce the effective cost of labour) or an upward shift in the technology parameter have an expansionary effect on the labour demand and output supply.

Finally, substituting $\bar{W}$, (2) and (6) in (1) results in the firms total demand for credit,

$$L^F = \bar{W} N^d(P, i^R, A) + PI(i^L - \pi^e), \tag{8}$$

where L^F is negatively related to the lending rate (i^L) for a given price level (P), which is endogenous in the model.

2.2 Households

Households consume goods and supply labour inelastically to firms. Furthermore, there are three types of assets available to the households: currency (which bears no interest), bank deposits and equity capital. These three assets are imperfect substitutes and the households hold bank capital as they are assumed to own the bank. Thus, the household's financial wealth (F^H) is defined as,

$$F^H = BILL^H + D + P^E \bar{E}, \tag{9}$$

where $BILL^H$ denotes the nominal value of currency holdings, D the nominal quantity of bank deposits and $P^E\bar{E}$ the nominal value of bank capital held by households, with $\bar{E}$ representing the fixed amount of equity capital. As in Agénor and Pereira da Silva (2012), equity prices (P^E) are taken as given because they are determined by the expected value of future dividends, which is exogenous.

The relative demand for currency is assumed to be negatively related to the interest rate on bank deposits (i^D), thus inversely related to its opportunity cost,

$$\frac{BILL^H}{D} = v(i^D), \tag{10}$$

where $v^{'} < 0$. Using (9), equation (10) can be written as,

$$\frac{D}{F^H - P^E E} = h_D(i^D), \tag{11}$$

with $h_D = \frac{1}{1+v(i_D)}$ and $h_D^{'} > 0$. Therefore,

$$\frac{BILL^H}{F^H - P^E\bar{E}} = \frac{v(i^D)}{1+v(i^D)} = h_B(i^D), \tag{12}$$

where $h_B^{'} < 0$.

The real consumption expenditure function (C) depends positively on the real labour income $\left(\frac{\bar{W}}{P}N\right)$ and on the beginning of period real value of financial wealth $\left(F_0^H/P\right)$, while being negatively related to the deposit rate. Because profits and interest on deposits are assumed to be distributed at the end of the period, the consumption function is related to the current income composed of wages. Hence,

$$C = \alpha_0 + \alpha_1\frac{\bar{W}}{P}N - \alpha_2(i^D - \pi^e) + \alpha_3\frac{F_0^H}{P}, \tag{13}$$

with $\alpha_1 \in (0,1)$ denoting the marginal propensity to consume out of disposable income, and $\alpha_0, \alpha_2, \alpha_3 > 0$.

2.3 Commercial Bank

The liabilities of the commercial bank consists of deposits held by households (D), borrowing from the central bank (L^B), and the nominal value of equity capital ($P^E\bar{E}$). The bank's assets are given by the mandatory reserves held at the central bank (RR) and the credit supplied to firms (L^F). Therefore, the bank's balance sheet is,

$$L^F + RR = P^E \bar{E} + D + L^B, \tag{14}$$

where the total nominal value of bank capital ($P^E \bar{E}$) is composed of the required regulatory capital ($P^E E^R$) and the capital buffer ($P^E E^E$), which is measured by the ratio of total bank capital to required bank capital. Formally, the bank capital buffer is equal to $\frac{\bar{E}}{E^R}$ (as in Agénor and Pereira da Silva 2012). Moreover, to avoid prohibitive penalties or reputational costs, the bank is assumed to hold a positive capital buffer such that $\bar{E} \geq E^R$ (also consistent with empirical evidence as shown by Pereira da Silva 2009).

The reserves held at the central bank pay no interest and are set proportionally to the level of deposits,

$$RR = \mu D, \tag{15}$$

with $\mu \in (0, 1)$. The total borrowing from the central bank is therefore obtained by combining (14) and (15),

$$L^B = L^F - (1 - \mu) D - P^E \bar{E}. \tag{16}$$

Moreover, the bank must satisfy risk based capital requirements such that bank equity covers at least a given percentage of its loans provided for investment purposes. This capital adequacy requirement, also known as the *Cooke Ratio*, does not apply to loans given for paying working capital needs (which bear no risk) but only to risky loans supplied to firms for investment purposes. Thus, denoting $\sigma > 0$ as the risk weight on investment loans, the capital requirement constraint is,

$$P^E E^R = \rho \sigma P I, \tag{17}$$

where $\rho \in (0, 1)$ is the capital adequacy requirement, set at a floor value of 8% under both Basel I and Basel II. Under Basel I, the same risk weight (σ) applied to all loans in the same particular category and therefore σ was set exogenously to a value equal or less than unity (depending on the type / category of loans). Hence, under the old regime, it was not possible to distinguish between risks imposed by different borrowers in the same particular category. On the other hand, under the foundation IRB approach of Basel II, the risk weight is a function of the repayment probability estimated by the bank because it can be related to the credit default risk;

$$\sigma = (q)^{-\phi_q}\,, \tag{18}$$

where $q \in (0,1)$ denotes the repayment probability and $\phi_q > 0$.

This specification is similar to Heid (2007) and Tanaka (2002) who relate the risk weight to the probability of default, and to Agénor and Pereira da Silva (2012). In the latter, the risk weight is determined by the risk premium, which, in turn, is negatively related to the repayment probability. Under the IRB approach of Basel II, banks calculate the estimated risk weight and consequently can shape the capital requirements according to their own private information.

Alternatively, the risk weight under Basel II can be determined by the Standardized approach, where σ is calculated by external rating agencies. Thus, similar to Zicchino (2006), this approach can be modeled by relating the risk weight to the macroeconomic conditions or the total supply of output relative to its potential value, under the assumption that ratings are procyclical.[6] Specifically,

$$\sigma = \left(\frac{Y^S}{\bar{Y}}\right)^{-\phi_{Y^S}}, \tag{19}$$

where $\phi_{Y^S} > 0$, such that $\frac{\partial \sigma}{\partial \left(Y^S/\bar{Y}\right)} < 0$. The term $\bar{Y}$ denotes potential output, which is taken as given and normalized to unity in what follows.

2.3.1 The Bank's Optimization Problem

The bank decides on the deposit rate and the lending rate so as to maximize the following real expected profits function $\left(\Pi^B\right)$ subject to the investment function (20), the loan demand function (21), the total lending from the central bank (22) and the capital

[6] Drumond (2009) shows that these external ratings are indeed procyclical.

requirement constraint (23),[7]

$$\max_{i^D,i^L} E\left(\Pi^B\right) = \left(1+i^R\right)\frac{W}{P}N + q(1+i^L)I + (1-q)\kappa Y^s + \mu d$$
$$-(1+i^D)d - (1+i^R)\left(\frac{L^B}{P}\right),$$

subject to,

$$I = I(i^L - \pi^e), \tag{20}$$

$$L^F = WN^d(P, i^R, A) + PI(i^L - \pi^e), \tag{21}$$

$$L^B = L^F - (1-\mu)D - P^E\bar{E}, \tag{22}$$

$$P^E E^R = \rho\sigma PI, \tag{23}$$

where $\kappa \in (0,1)$ and $d = \frac{D}{P}$ representing the real level of deposits. The first element on the right hand side, $(1+i^R)\frac{W}{P}N$, denotes the returns of the commercial bank from supplying non-risky loans to finance the firms' working capital needs. The second element, $q(1+i^L)I$, denotes the expected repayment if there is no default on loans supplied for investment purposes while the third expression, $(1-q)\kappa Y^s$, is the expected return for the bank if firms default. In case of default the bank collects collateral pledged by the borrowers, denoted by the term κY^s. Therefore, as pointed out by Agénor and Montiel (2008), κ measures the degree of credit market imperfections. The fourth term, μd, represents the reserve requirements held at the central bank. Because the bank lasts only for one period, μd is given back to the bank at the end of the period and as a result enters positively in the profit maximizing problem. Turning to the bank's costs, the term $(1+i^D)d$ represents the gross deposit repayment of the bank to households, while $(1+i^R)\left(\frac{L^B}{P}\right)$ is the gross repayment of central bank loans.

The first order condition of the above bank's maximization problem with respect to i^D is,

$$1 + \frac{i^D}{d}\frac{\partial d}{\partial i^D} = (1-\mu)i^R\frac{\partial d}{\partial i^D}\frac{i^D}{i^D}\frac{1}{d}. \tag{24}$$

[7] Although E^R depends on i^L through the capital constraint, we do not exploit this relationship in the bank's maximization problem. Because total bank capital is fixed in this model, any changes in E^R would be fully offset by a change in the capital buffer, which is implausible given the short run nature of the model.

Defining the elasticity of the supply of deposits to households as $\eta^D = \frac{i^D}{d}\frac{\partial d}{\partial i^D}$, treating it as a constant, and rearranging (24) results in the rate of return on bank deposits,

$$i^D = \frac{1}{\left(1+\frac{1}{\eta^D}\right)}(1-\mu)i^R. \tag{25}$$

Hence, the interest rate on bank deposits is set as a constant markup over the refinance rate, adjusted downwards due the implicit costs of holding reserve requirements.

The first order condition with respect to i^L (with q taken as given) yields,

$$qI + \left[q(1+i^L) - (1+i^R)\right]\frac{\partial I}{\partial i^L} = 0.$$

Defining the interest elasticity of the demand for loans given for investment purposes as $\eta^I = \frac{\partial I}{\partial i^L}\frac{i^L}{I}$ and treating it as constant, then the above equation reduces to,

$$i^L = \frac{1}{\left(1+\frac{1}{\eta^I}\right)}\left[\frac{1}{q}(1+i^R) - 1\right]. \tag{26}$$

Therefore, the loan rate is set as a mark up over the refinance rate, with the value of the mark up determined by the risk premium. The risk premium, in turn, is negatively related to the repayment probability.

2.3.2 The Repayment Probability, Collateral and Bank Capital

The repayment probability is now related to two main factors: First, to the firm's collateral relative to (risky) loans given for investment purposes. Following Boot, Thakor and Udell (1991), Bester (1994) and Hainz (2003), collateral reduces borrowers' incentives to engage in risky investments and mitigates moral hazard behaviour. As a result, effective collateral has a positive impact on the repayment probability. Second, the repayment probability depends positively also on the bank capital buffer through a monitoring incentive effect (similar in spirit to Agénor, Alper and Pereira da Silva 2012).[8]

[8] In Agénor, Alper and Pereira da Silva (2012) the *total* amount of bank capital relative to outstanding loans induces the positive impact on the repayment probability. However, given that total capital ($\bar{E}$) in our model is fixed and constant, this type of bank capital channel will not have substantive implications to our results and will not allow a comparison between the different regulatory regimes. The bank capital channel in our model implies that banks only care about the excess capital held *above* the regulatory minimum.

Micro foundations for this monitoring incentive effect are provided by the models of Allen, Carletti and Marquez (2011) and Mehran and Thakor (2009). In the static model of Allen, Carletti and Marquez (2011), excess bank capital held by a monopolistic bank increases its incentives to monitor borrowers, which raises the borrowers' success probability and therefore improves their expected payoff. Mehran and Thakor (2009) show within a dynamic setting that holding bank capital enhances the incentives to monitor borrowers as it raises the future survival probability of the bank. Empirically, the relationship between bank capital and the lending rate is supported by the study of Hubbard, Kuttner and Palia (2002), where the capital structure of the bank determines the rate of return on loans. More specifically, well capitalized banks tend to charge lower lending rates compared to low capitalized banks. Moreover, this effect of an inverse relationship between holding bank capital and loan rates is also highlighted in Coleman, Esho and Sharpe (2006), wherein capital constrained banks charge a higher spread on their loans.

An alternative explanations stems from the idea that banks holding capital buffers are expected to face lower bankruptcy cost, thus allowing them to expand lending by reducing the interest rate charged on loans. In addition, higher capital buffers increase incentives for banks to screen and monitor their borrowers more carefully, thus enabling them to lower the lending rate, which, in turn, leads to an expansionary effect on the economic activity. This idea is supported by Fonseca, Gonzalez and Pereira da Silva (2010), who, by examining the pricing behaviour of more than 2,300 banks in 92 countries over the period 1990-2007, show that bank capital buffers affect the bank lending spreads (or the risk of default). In our model, the bank capital channel is embedded into the repayment probability, which ultimately impacts the lending rate (see equation 26). This contributes to the model of Agénor and Pereira da Silva (2012), who incorporate this type of bank capital channel through its impact on the deposit rate.

The abovementioned effects on the repayment probability are captured by the following separable linearized equation,

$$q = \varphi_1 \left(\frac{\kappa P Y^s}{PI} \right) + \varphi_2 \left(\frac{\bar{E}}{E^R} \right), \tag{27}$$

where $\varphi_i > 0 \ \forall i$, and φ_1, φ_2 denote the elasticities of the repayment probability with respect to the borrowers effective collateral and the bank capital buffer, respectively.

2.4 Central Bank

The central bank's liabilities consists of the monetary base (MB) while its liabilities consists of loans provided to the commercial bank (L^B). The balance sheet of the central bank is therefore given by,

$$L^B = MB, \tag{28}$$

where the monetary base is defined as the sum of the total currency in circulation ($BILL$), and reserves (RR),

$$MB = BILL + RR. \tag{29}$$

The central bank supplies liquidity through a standing facility and sets its monetary policy through the refinance rate, given by a constant rate (i^R). Thus, substituting (15) and (28) in equation (29) results in the total supply of currency,

$$BILL^s = L^B - \mu D. \tag{30}$$

2.5 Market Clearing Conditions

The market clearing conditions requires the four financial markets (deposits, loans, central bank credit and cash) and the goods market to clear by equating supply and demand. The market for central bank credit is always in equilibrium given the assumption that the central bank fixes the policy rate i^R and inelastically supplies all credit to the commercial bank at that rate. The markets for deposits and loans adjust through quantities, with the commercial bank setting both the deposit rate and the lending rate. The cash market is cleared through equations (10) and (30) but this market automatically clears given Walras' law and thus can be ignored.

The equilibrium in the goods market, which determines the price of the domestic good (P), is represented by the following market clearing condition,

$$Y^s = C + I. \tag{31}$$

3 Model Solution under Non-Binding Capital Requirements

3.1 Financial Market Equilibrium

The first step to solve the model under nonbinding capital requirement ($\bar{E} > E^R$) is to find the financial equilibrium condition, obtained by substituting output supply (7), the demand for investments (2) and the capital requirement constraint (17) into the repayment probability (given by 27). Setting $\pi^e = 0$ for simplicity, this yields,

$$q = \varphi_1 \left(\frac{\kappa Y^s(P, i^R, A)}{I\left(i^L\right)} \right) + \varphi_2 \left(\frac{P^E \bar{E}}{\rho\sigma P I\left(i^L\right)} \right). \tag{32}$$

Substituting (32) in the lending rate equation (26) and normalizing $P^E = 1$ results in the following expression,

$$i^L = \frac{1}{\left(1 + \frac{1}{\eta^I}\right)} \left\{ \frac{(1 + i^R)}{\left[\varphi_1 \left(\frac{\kappa Y^s(P, i^R, A)}{I(i^L)} \right) + \varphi_2 \left(\frac{\bar{E}}{\rho\sigma P I(i^L)} \right)\right]} - 1 \right\}. \tag{33}$$

That is, the financial equilibrium condition is related to σ, which implies that the cyclicality of the lending rate depends on the nature of the regulatory regime. Solving equation (33) gives,

$$i^L = FF^j(P, A, i^R), \tag{34}$$

where FF denotes the financial equilibrium function and j stands for the different regulatory regimes ($j = I$ for Basel I, $j = II$ for Basel II, $j = IRB$ for the foundation IRB approach of Basel II and $j = ST$ for the Standardized approach of Basel II). The total derivative of equation (33) with respect to P and A is now calculated in order to find how these variables affect the cyclicality of the lending rate under Basel I, the foundation IRB approach of Basel II and the Standardized approach of Basel II.

Under Basel I, where σ is exogenous, the effect of P on i^L is (see Appendix A for a complete derivation),

$$FF_P^I = \left(\frac{di^L}{dP} \right)_{FF}^{Basel\ I} = \Delta^{Basel\ I} \left[\varphi_1 \frac{\kappa Y_P^s}{I} - \varphi_2 \frac{\bar{E}}{P^2 \sigma\rho I} \right] \lesseqgtr 0, \tag{35}$$

where,

$$\Delta^{Basel\ I} = -\frac{\frac{(1+i^R)}{\left(1+\frac{1}{\eta^I}\right)}}{\left\{\left[\varphi_1\left(\frac{\kappa Y^s}{I}\right)+\varphi_2\left(\frac{\bar{E}}{\rho\sigma PI}\right)\right]^2 - \frac{(1+i^R)}{\left(1+\frac{1}{\eta^I}\right)}\left[\varphi_1\frac{\kappa Y^s I'}{I^2}+\varphi_2\frac{I'\bar{E}}{\rho\sigma PI^2}\right]\right\}} < 0.$$

Similarly, the effect of A on i^L is (see Appendix B),

$$FF_A^I = \left(\frac{di^L}{dA}\right)_{FF}^{Basel\ I} = \Delta^{Basel\ I}\varphi_1\frac{\kappa Y_A^s}{I} < 0. \tag{36}$$

A rise in prices under Basel I has an *ambiguous* effect on the lending rate, as long as $\varphi_2 > 0$. On the one hand, an increase in P stimulates real output (by reducing real wages), which increases the effective value of firms collateral relative to risky loans. This, in turn, raises the repayment probability and lowers the loan rate. On the other hand, a rise in P leads to an increase in the nominal value of risky loans and thus to a rise in bank capital requirements, thereby resulting in a lower bank capital buffer. The deterioration in the bank capital buffer reduces the repayment probability and increases the lending rate charged by the commercial bank. In the absence of the bank capital channel ($\varphi_2 = 0$), the loan rate falls unambiguously, which is also the case if the elasticity of the repayment probability with respect to firm's collateral dominates the strength of the bank capital channel. Therefore, the bank capital channel *mitigates* the initial fall in the lending rate following the improvement in firms' collateral (caused by a rise in prices in this example).

A positive supply shock raises output and the value of collateral, without having a direct effect on the level of investment. As a result, a rise in A leads to an *unambiguous* rise in the repayment probability, thereby reducing the loan rate. When examining the effect of productivity shocks under Basel I, the bank capital channel has only a quantitative effect (in terms of the magnitude of the impact), and not a qualitative effect. More precisely, $\Delta^{Basel\ I}$ is lower (in absolute value) if $\varphi_2 > 0$, so the lending rate falls by *less* in the presence of the bank capital channel.

Under Basel II, where σ is endogenous, the effect of prices on the lending rate is,

$$\frac{di^L}{dP} = \frac{\left(1+i^R\right)}{\left(1+\frac{1}{\eta^I}\right)} \left\{ \frac{-\varphi_1 \left(\frac{\kappa Y_P^s I - \kappa Y^s I' \frac{di^L}{dP}}{I^2} \right) - \varphi_2 \left(\frac{-\left[(\sigma_P P + \sigma)\rho I + I' \frac{di^L}{dP} \rho\sigma P \right] \bar{E}}{(\rho\sigma P I)^2} \right)}{\left[\varphi_1 \left(\frac{\kappa Y^s}{I} \right) + \varphi_2 \left(\frac{\bar{E}}{\rho\sigma P I} \right) \right]^2} \right\},$$

where $\sigma_P = \frac{d\sigma}{dP}$. The risk weight ($\sigma$) depends either on output supply or the repayment probability, which, in turn, is related to both prices and output. Solving the above equation for $\frac{di^L}{dP}$ and using some algebraic manipulations yields (see Appendix C),

$$FF_P^{II} = \left(\frac{di^L}{dP}\right)_{FF}^{Basel\ II} = \Delta^{Basel\ II} \left\{ \varphi_1 \frac{\kappa Y_P^s}{I} - \varphi_2 \frac{\sigma_P \bar{E}}{\rho P I \sigma^2} - \varphi_2 \frac{\bar{E}}{\rho I \sigma P^2} \right\}, \tag{37}$$

where $\Delta^{Basel\ II} = \Delta^{Basel\ I}$ under the assumption that the initial value of the risk weight under Basel II is equal to the risk weight under Basel I. Substituting (37) in (35) results in,

$$\left(\frac{di^L}{dP}\right)_{FF}^{Basel\ II} = \left(\frac{di^L}{dP}\right)_{FF}^{Basel\ I} - \Delta^{Basel\ II} \varphi_2 \frac{\sigma_P \bar{E}}{\rho P I \sigma^2}. \tag{38}$$

Similarly, the effect of A on i^L under Basel II is (see Appendix D),

$$FF_A^{II} = \left(\frac{di^L}{dA}\right)_{FF}^{Basel\ II} = \Delta^{Basel\ II} \left\{ \varphi_1 \frac{\kappa Y_A^s}{I} - \varphi_2 \frac{\sigma_A \bar{E}}{\sigma^2 \rho P I} \right\}. \tag{39}$$

Again, under the assumption that $\Delta^{Basel\ I} = \Delta^{Basel\ II}$, equation (39) reduces to,

$$\left(\frac{di^L}{dA}\right)_{FF}^{Basel\ II} = \left(\frac{di^L}{dA}\right)_{FF}^{Basel\ I} - \Delta^{Basel\ II} \varphi_2 \frac{\sigma_A \bar{E}}{\sigma^2 \rho P I}. \tag{40}$$

The total effect of prices under Basel II can be decomposed to three effects as implied by equation (38). The first two effects are the same as in Basel I, where on the one hand an increase in P stimulates output and lowers the lending rate, while on the other, a rise in P increases the capital requirements, which tends to raise the loan rate. However, under Basel II there is an additional effect of P on the lending rate, stemming from the impact of prices on the (endogenous) risk weight. Under both the foundation IRB and Standardized approaches of Basel II, the risk weight (σ) depends on the price level.

Similarly, from equation (40), supply shocks under Basel II have an additional effect on the lending rate when compared to Basel I, captured through the impact of A on σ.

We now turn to discuss the implications of changes in prices and productivity on the risk weight and the lending rate under the Standardized and the foundation IRB approaches of Basel II, and examine the role of the bank capital channel following such changes.

Under the Standardized approach of Basel II, where $\sigma = (Y^s)^{-\phi_{Y^S}}$, the effect of prices on the risk weight is,

$$\left(\frac{d\sigma}{dP}\right)^{ST} = -\phi_{Y^S} (Y^s)^{-\phi_{Y^s}-1} Y_P^s < 0. \tag{41}$$

That is, higher prices increase the supply of output and thus lead to a lower risk weight. Substituting (41) in (37),

$$FF_P^{ST} = \left(\frac{di^L}{dP}\right)_{FF}^{ST} = \Delta^{Basel\ II} \left\{ \begin{array}{c} \varphi_1 \frac{\kappa Y_P^s}{I} + \varphi_2 \frac{\bar{E}}{\rho I P \sigma^2} \phi_{Y^S} (Y^s)^{-\phi_{Y^s}-1} Y_P^s - \\ -\varphi_2 \frac{\bar{E}}{\rho I \sigma P^2} \end{array} \right\} \lesseqgtr 0. \tag{42}$$

Examining equation (42), the strength of the bank capital channel (φ_2) has an *ambiguous* impact on the lending rate following changes in prices. Similar to the previous cases, the initial rise in prices results in a higher value of nominal loans and a lower bank capital buffer, thereby leading to a higher lending rate. However, this price increase raises the output supply (by lowering real wages), which directly lowers the risk weight under the Standardized approach. The fall in the risk weight then results in a higher repayment probability and a lower loan rate. Therefore, the increase in output impacts the lending rate through the *collateral channel* (as explained earlier) and via the *bank capital channel*, which operates differently under Basel I and the Standardized approach of Basel II due to the additional impact of prices on the risk weight.

The Standardized approach of Basel II induces a further decrease in the loan rate following a rise in prices compared to Basel I if the sensitivity of the repayment probability to the effective collateral dominates the strength of the bank capital channel relative to the bank capital buffer, $\varphi_1 \frac{\kappa Y_P^s}{I} > \varphi_2 \frac{\bar{E}}{\rho I \sigma P^2}$. Under this condition, the lending rate *falls unambiguously* under Basel I, so the term

$$\Delta^{Basel\ II} \varphi_2 \frac{\bar{E}}{\rho I P \sigma^2} \phi_{Y^S} (Y^s)^{-\phi_{Y^s}-1} Y_P^s < 0 \tag{43}$$

(the additional effect of changes in the repayment probability, resulting from changes in output, on the risk weight) *amplifies* the drop in the lending rate in the Standardized approach. If, by contrast, $\varphi_2 \frac{\bar{E}}{\rho I \sigma P^2} > \varphi_1 \frac{\kappa Y_P^s}{I}$, then the lending rate *rises unambiguously* under Basel I, such that the above term (43) *mitigates* the initial rise in the lending rate following an increase in prices under the Standardized approach. If the bank capital channel does not operate ($\varphi_2 = 0$), then following a price increase, the lending rate drops unambiguously via the collateral channel only. Moreover, because of the ambiguous effect of the strength of the bank capital channel on the lending rate, it cannot be concluded whether the bank capital channel amplifies or mitigates the initial fall in the loan rate caused by the rise in prices and the improvement in firms' collateral.

The effect of A on the risk weight under the **Standardized approach** of Basel II, can be directly calculated as follows,

$$\left(\frac{d\sigma}{dA}\right)^{ST} = -\phi_{Y^S} \left(Y^s\right)^{-\phi_{Y^s}-1} Y_A^s < 0. \tag{44}$$

Substituting (44) in equation (39) yields,

$$FF_A^{ST} = \left(\frac{di^L}{dA}\right)_{FF}^{ST} = \Delta^{Basel\ II} \left\{\varphi_1 \frac{\kappa Y_A^s}{I} + \varphi_2 \frac{\bar{E}}{\sigma^2 \rho P I} \phi_{Y^S} \left(Y^s\right)^{-\phi_{Y^s}-1} Y_A^s\right\} < 0, \tag{45}$$

or,

$$\left(\frac{di^L}{dA}\right)_{FF,\ \varphi_2>0}^{ST} = \left(\frac{di^L}{dA}\right)_{FF,\ \varphi_2=0}^{ST} + \Delta^{ST} < 0, \tag{46}$$

where $\left(\frac{di^L}{dA}\right)_{FF,\ \varphi_2=0}^{ST} < 0$ and $\Delta^{ST} = \Delta^{Basel\ II} \varphi_2 \frac{\bar{E}}{\sigma^2 \rho P I} \phi_{Y^S} \left(Y^s\right)^{-\phi_{Y^s}-1} Y_A^s < 0$. Thus, positive supply shocks lead to an *unambiguous fall* in the loan rate. The effect of A on the repayment probability and the lending rate is captured by two channels influencing directly the cost of borrowing. Specifically, a rise in A increases the effective collateral and directly lowers the risk weight on loans (caused by the output stimulation), both resulting in a lower lending rate. Because of the additional effect of the productivity shock on the risk weight, the Standardized approach induces *additional procyclicality* in the loan rate compared to Basel I.

Without the transmission of the bank capital channel on the repayment probability and the risk weight ($\varphi_2 = 0$), the lending rate falls by *less* when compared to an active bank capital channel. Thus, the bank capital channel, through its impact on the risk weight, *amplifies* the response of the lending rate following supply shocks, as implied from equation (46).

To calculate the effects of prices on the risk weight under the **foundation IRB approach** of Basel II, it is first necessary to determine the impact of prices on the repayment probability. Calculating the derivative of q with respect to P in equation (32) with $P^E = 1$, yields,

$$\frac{dq}{dP} = \varphi_1 \frac{\kappa Y_P^s}{I} - \varphi_2 \frac{\bar{E}}{P^2 \rho \sigma I} \lesseqgtr 0.$$

Consequently, under the IRB approach of Basel II, where $\sigma = (q)^{-\phi_q}$, the effect of prices on the risk weight is given by,

$$\left(\frac{d\sigma}{dP}\right)^{IRB} = -\phi_q q^{-\phi_q - 1} \left\{ \varphi_1 \frac{\kappa Y_P^s}{I} - \varphi_2 \frac{\bar{E}}{P^2 \rho \sigma I} \right\} \lesseqgtr 0. \qquad (47)$$

Thus, in contrast to the Standardized approach, prices have an *ambiguous* effect on the risk weight under the IRB approach. The initial increase in prices tends to raise the effective collateral pledged by firms, increase the repayment probability and thus lower the risk weight on loans. However, this rise in prices raises the value of nominal investments, increases the capital requirements, lowers the bank capital buffer and reduces the repayment probability, which, in turn, translates into a higher risk weight. In the absence of the bank capital channel ($\varphi_2 = 0$), the rise in prices results unambiguously in a lower risk weight, similar to the Standardized approach.

The total effect of prices on the lending rate is obtained by substituting (47) in (37),

$$FF_P^{IRB} = \left(\frac{di^L}{dP}\right)_{FF}^{IRB} = \Delta^{Basel\ II} \left\{ \begin{array}{c} \left(1 + \varphi_2 \phi_q q^{-\phi_q - 1} \frac{\bar{E}}{\rho I P \sigma^2}\right) * \\ \left(\varphi_1 \frac{\kappa Y_P^s}{I} - \varphi_2 \frac{\bar{E}}{\rho I \sigma P^2}\right) \end{array} \right\} \lesseqgtr 0. \qquad (48)$$

Dividing equation (48) by equation (35) and using $\Delta^{Basel\ I} = \Delta^{Basel\ II}$,

$$\frac{FF_P^{IRB}}{FF_P^I} = \left(1 + \varphi_2 \phi_q q^{-\phi_q - 1} \frac{\bar{E}}{\rho I P \sigma^2}\right) > 1,$$

implying that,

$$\left(\frac{di^L}{dP}\right)_{FF}^{IRB} > \left(\frac{di^L}{dP}\right)_{FF}^{I}. \qquad (49)$$

Therefore, the additional impact of prices on the risk weight under the foundation IRB approach leads to increased procyclicality in the loan rate behaviour when compared to Basel I.

The role of the bank capital channel following a rise in prices cannot be determined unambiguously under the foundation IRB approach. On the one hand, a rise in prices lowers the bank capital buffer, which reduces the repayment probability and increases the risk weight on loans. These two effects create an upward pressure on the lending rate. On the other hand, the increase in the price level directly increases the repayment probability (through the collateral channel), which directly lowers the risk weight. These two effects result in a downward pressure on the loan rate. Of course, when the bank capital channel is not active ($\varphi_2 = 0$), then the lending rate falls unambiguously, similar to Basel I and the Standardized approach of Basel II.

To examine the total effect of a productivity shock on the lending rate under the **foundation IRB approach**, we first calculate the derivative of q with respect to A in equation (32),

$$\frac{dq}{dA} = \varphi_1 \frac{\kappa Y_A^s}{I}. \tag{50}$$

Thus, the impact of A on σ is,

$$\left(\frac{d\sigma}{dA}\right)^{IRB} = -\phi_q q^{-\phi_q - 1} \varphi_1 \frac{\kappa Y_A^s}{I} < 0. \tag{51}$$

Substituting (51) in (39) yields,

$$FF_A^{IRB} = \left(\frac{di^L}{dA}\right)_{FF}^{IRB} = \Delta^{Basel\ II} \left\{ \varphi_1 \frac{\kappa Y_A^s}{I} + \varphi_2 \frac{\bar{E}}{\sigma^2 \rho P I} \phi_q q^{-\phi_q - 1} \varphi_1 \frac{\kappa Y_A^s}{I} \right\} < 0, \tag{52}$$

or,

$$\left(\frac{di^L}{dA}\right)_{FF,\ \varphi_2 > 0}^{IRB} = \left(\frac{di^L}{dA}\right)_{FF,\ \varphi_2 = 0}^{IRB} + \Delta^{IRB} < 0, \tag{53}$$

where $\left(\frac{di^L}{dA}\right)_{FF,\ \varphi_2 = 0}^{IRB} < 0$ and $\Delta^{IRB} = \Delta^{Basel\ II} \varphi_2 \frac{\bar{E}}{\sigma^2 \rho P I} \phi_q q^{-\phi_q - 1} \varphi_1 \frac{\kappa Y_A^s}{I} < 0$. Positive productivity shocks result *unambiguously* in a *lower* lending rate. The impact of A on the loan rate is captured now through two channels: First, higher productivity raises output, increases firms' effective collateral, both which result in a lower loan rate. Second, the rise in the repayment probability, associated with the higher collateral pledged by firms, reduces the risk weight, creating an additional downward pressure on the lending rate. Consequently, both of these channels strengthen one another and lead to a decrease in the loan rate following positive supply shocks. Further, the lending rate reaction is *amplified* under the IRB approach when compared to Basel I due to the additional effect of collateral on the repayment probability and thus on the risk weight.

Similar to the Standardized approach, in the foundation IRB approach the bank capital channel *magnifies* the initial fall in the lending rate caused by positive supply shocks.

Comparing between supply shocks under the foundation IRB approach and the Standardized approach, one should note that supply shocks in the latter *directly* impact the risk weight and thus the lending rate through the direct relationship between the risk weight and the output supply. In the IRB approach, on the other hand, supply shocks affect the risk weight through the impact of effective collateral on the repayment probability. Therefore, under this approach, productivity shocks *indirectly* impact the risk weight and the lending rate, in contrast to the Standardized approach. Consequently, by subtracting equation (52) from equation (45), then the Standardized approach induces more procyclicality in the lending rate if $\phi_{Y^S} (Y^s)^{-\phi_{Y^s}-1} Y_A^s > \phi_q q^{-\phi_q - 1} \varphi_1 \frac{\kappa Y_A^s}{I}$. This implies that the sensitivity of the risk weight with respect to changes in output supply is greater than the sensitivity of the risk weight with respect to changes in the repayment probability, caused by shifts in the firms' effective collateral. We assume that this is indeed the case in what follows.

Table 1 summarizes the results presented above and indicates whether the cyclicality in the loan rate is amplified or mitigated with an active bank capital channel following a rise in prices and a positive supply shock.

Following a rise in prices, the bank capital channel mitigates the initial fall in the loan rate under Basel I, whereas it cannot be concluded whether the bank capital channel magnifies or dampens the drop in the loan rate (caused by the improvement in effective collateral) under both variants of Basel II. Following positive supply shocks and with an active bank capital channel, the impact on the lending rate is mitigated under Basel I

Table 1: Response of the Loan Rate to an Increase in Prices and a Positive Supply Shock under Alternative Regulatory Regimes

	Basel I	**Standardized Approach**	**IRB Approach**
Price Effect			
$FF_P^{\varphi_2=0}$	unambiguous fall	unambiguous fall	unambiguous fall
$FF_P^{\varphi_2>0}$	mitigated	ambiguous	ambiguous
Supply Shock Effect			
$FF_A^{\varphi_2=0}$	unambiguous fall	unambiguous fall	unambiguous fall
$FF_A^{\varphi_2>0}$	mitigated	amplified	amplified

(through the quantitative effect on $\Delta^{Basel\ I}$). However, positive productivity shocks have similar qualitative amplifying effects on the loan rate under both variants of Basel II with an active bank capital channel.

3.2 Goods Market Equilibrium

The second step to find the general equilibrium is to solve for the goods market equilibrium. Using equations (2),(6),(7),(13),(25), (26) and setting $\bar{W} = 1$, $\pi^e = 0$, $\alpha_0 = 0$ for simplicity, condition (31) can be written as,

$$\begin{aligned} Y^s(P, i^R, A) \quad &= \quad \alpha_1 \frac{N^d(P, i^R, A)}{P} - \alpha_2 \left[\frac{1}{\left(1 + \frac{1}{\eta^D}\right)} (1-\mu) i^R \right] + \\ &+\alpha_3 \left(\frac{F_0^H}{P} \right) + I(i^L). \end{aligned} \tag{54}$$

The above expression *does not* directly depend on the regulatory regime and the risk weight (σ), and therefore the equilibrium condition in the goods market is the same under Basel I and both the IRB and Standardized approaches of Basel II. Solving for i^L yields,

$$i^L = GG(P, i^R, A), \tag{55}$$

where GG denotes the goods market equilibrium curve under all regulatory regimes. The impact of P on i^L is,

$$GG_P = \left(\frac{di^L}{dP} \right)_{GG} = \Omega \left(Y_P^s + \alpha_1 \frac{N^d - N_P^d P}{P^2} + \alpha_3 \frac{F_0^H}{P^2} \right) < 0, \tag{56}$$

where $\Omega = \frac{1}{I'} < 0$. Studying the effect of A on i^L yields the following,

$$GG_A = \left(\frac{di^L}{dA}\right)_{GG} = \Omega\left(Y_A^s - \alpha_1 \frac{N_A^d}{P}\right) < 0. \tag{57}$$

The effect of an increase in prices on the lending rate can be decomposed as follows: First, a rise in prices lowers the real wage, stimulates output, increases labour demand and distributed wage income, which all result in higher consumption. Second, the rise in prices creates a downward pressure on aggregate demand through a negative wealth effect on consumption. As in Agénor and Pereira da Silva (2012), the net effect on consumption depends on the movement of the output supply relative to aggregate demand. Their analysis shows that the effect on the output supply *always* dominates the wage income effect. Therefore, an increase in prices creates excess supply at the initial level of investment, which implies that the lending rate must fall in order to raise investment and restore equilibrium in the goods market. As a result, *higher* prices lead to a *lower* lending rate in the goods market ($\left(\frac{di^L}{dP}\right)_{GG} < 0$).

Following a positive productivity shock, the supply side is assumed to dominate the demand side effects ($Y_A^s > \alpha_1 \frac{N_A^d}{P}$). Therefore, in order to eliminate the excess supply in the goods market (given the initial level of investment), the lending rate must fall such that the investment level increases. In this way the equilibrium in the goods market is restored. Consequently, *positive* productivity shocks tend to *lower* the loan rate in the goods market ($\left(\frac{di^L}{dA}\right)_{GG} < 0$).

In the next sections we study the general equilibrium effects of a negative supply shock, with an intuitive graphical solution, and make a distinction between **two cases**: First, the case where the "pure" bank capital channel ($\varphi_2 \frac{\bar{E}}{\rho I \sigma P^2}$) is "strong" and dominates the elasticity of the repayment probability with respect to the collateral pledged by firms ($\varphi_1 \frac{\kappa Y_A^s}{I}$). Second, the scenario where the collateral channel dominates the "pure" bank channel such that $\varphi_1 \frac{\kappa Y_A^s}{I} - \varphi_2 \frac{\bar{E}}{\rho I \sigma P^2} > 0$.[9]

[9] The "pure" bank capital channel refers *solely* to the effect of the bank capital buffers on the repayment probability and the lending rate. The other channel associated with bank capital is the impact of the risk weight on the capital buffers and consequently on the financial market equilibrium (observed only in Basel II).

3.3 General Equilibrium - The Bank Capital Channel Dominating The Collateral Channel

3.3.1 Macroeconomic Equilibrium

In this section we focus on the case where the "pure" bank capital channel ($\varphi_2 \frac{\bar{E}}{\rho I \sigma P^2}$) dominates the collateral channel ($\varphi_1 \frac{\kappa Y_A^s}{I}$). This assumption, in turn, results in the following: First, the effect of prices on the risk weight under the IRB approach is positive ($\left(\frac{d\sigma}{dP}\right)^{IRB} > 0$), while an inverse relationship exists between the risk weight and prices under the Standardized approach ($\left(\frac{d\sigma}{dP}\right)^{ST} < 0$). Second, from equations (35) and (48) it can be concluded that a positive relationship exists between the lending rate and the price level under both Basel I and the foundation IRB approach (FF_P^I, $FF_P^{IRB} > 0$). In the Standardized approach, it is assumed that the strength of the "pure" bank capital channel dominates *both* the collateral channel, and the additional alternation of the risk weight resulting from changes in prices and consequently output supply ($\varphi_2 \frac{\bar{E}}{\rho I P \sigma^2} \phi_{Y^S} \left(Y^s\right)^{-\phi_{Y^s}-1} Y_P^s$). That is, $FF_P^{ST} > 0$. As a result, $FF_P^j = \left(\frac{di^L}{dP}\right)^j > 0$ for $j = I, ST, IRB$.

The contribution of this analysis compared to Agénor and Pereira da Silva (2012) is that the financial equilibrium curve can indeed be *upward sloping* if the bank capital channel is dominant. This, of course, is obtained by the way the bank capital channel is incorporated in our model, through the impact of bank capital buffers on the repayment probability and consequently on the lending rate. In Agénor and Pereira da Silva (2012), the financial equilibrium *does not* depend on the bank capital channel nor the regulatory regime and hence is *always downward sloping*.

To determine the general equilibrium effects of shocks under **Basel I**, equations (34) (for $j = I$) and (55) are solved simultaneously for i^L and P. The total effect of prices and productivity shocks on the lending rate in the financial market and goods market can be respectively written as follows,

$$di^L = FF_P^I dP + FF_A^I dA,$$

$$di^L = GG_P dP + GG_A dA.$$

The solution of a shock to A is obtained by solving the following matrix equation,

$$\begin{bmatrix} 1 & -FF_P^I \\ 1 & -GG_P \end{bmatrix} \begin{bmatrix} di^L \\ dP \end{bmatrix} = \begin{bmatrix} FF_A^I \\ GG_A \end{bmatrix} dA,$$

which gives,

$$\left(\frac{di^L}{dA}\right)^{Basel\ I} = \frac{GG_A FF_P^I - FF_A^I GG_P}{FF_P^I - GG_P} < 0,$$

$$\left(\frac{dP}{dA}\right)^{Basel\ I} = \frac{GG_A - FF_A^I}{FF_P^I - GG_P} \lesseqgtr 0.$$

An active and "strong" bank capital channel implies $FF_P^I > 0$. In addition, $GG_P < 0$, $GG_A < 0$ and $FF_A^I < 0$ so $FF_P^I - GG_P > 0$ and $GG_A FF_P^I - FF_A^I GG_P < 0$, which ensures that $\left(\frac{di^L}{dA}\right)^{Basel\ I} < 0$. In other words, the lending rate falls unambiguously following positive supply shocks, meaning that the change in the loan rate is procyclical. On the other hand, the impact of a supply shock on prices is ambiguous, $\left(\frac{dP}{dA}\right)^{Basel\ I} \lesseqgtr 0$, because $GG_A - FF_A^I \lesseqgtr 0$. In the absence of the bank capital channel, or even when this channel is not "too strong" such that $FF_P^I < 0$, then an ambiguous result is obtained for both $\left(\frac{di^L}{dA}\right)^{Basel\ I}$ and $\left(\frac{dP}{dA}\right)^{Basel\ I}$ (see next section for a detailed examination of this case).

Similarly, under the **Standardized approach of Basel II**, solving equations (34) for $j = ST$ and (55) simultaneously for i^L and P yields,

$$\left(\frac{di^L}{dA}\right)^{ST} = \frac{GG_A FF_P^{ST} - FF_A^{ST} GG_P}{FF_P^{ST} - GG_P} < 0,$$

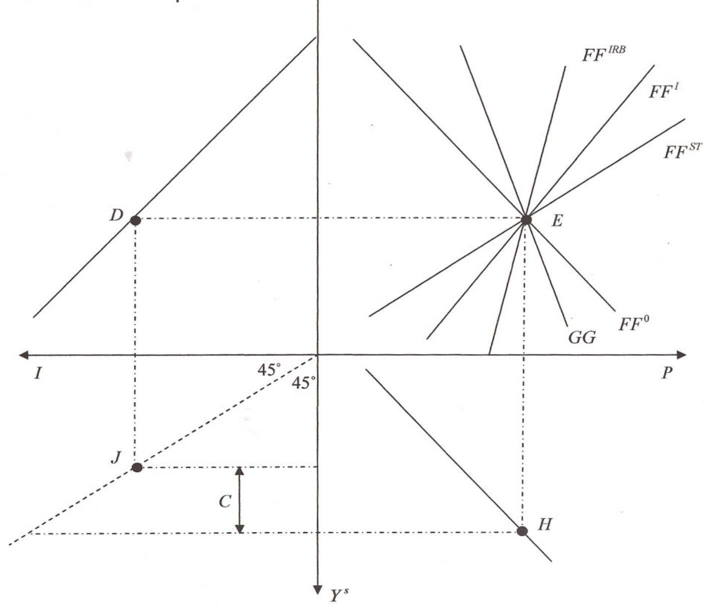
$$\left(\frac{dP}{dA}\right)^{ST} = \frac{GG_A - FF_A^{ST}}{FF_P^{ST} - GG_P} \lesseqgtr 0.$$

Again, with $FF_P^{ST} > 0$ and $FF_A^{ST} < 0$, then $\left(\frac{di^L}{dA}\right)^{ST} < 0$ and $\left(\frac{dP}{dA}\right)^{ST} \lesseqgtr 0$. Similar qualitative results are obtained for the **foundation IRB approach of Basel II**.

To conclude, the lending rate behaviour is *always procyclical* following supply shocks while the impact on prices is *ambiguous*. The difference across the three regulatory regimes is only in terms of magnitudes and not in terms of directions.

Figure 1 depicts a graphical representation of the general equilibrium under Basel I, the Standardized approach of Basel II and the foundation IRB approach.

Figure 1 -
Macroeconomic Equilibrium



The slope of the financial equilibrium curve under Basel I, the Standardized approach and the IRB approach are denoted respectively by equations (35), (42) and (48), which are rewritten here for convenience,

$$FF_P^I = \left(\frac{di^L}{dP}\right)_{FF}^{Basel\ I} = \Delta^{Basel\ I}\left[\varphi_1 \frac{\kappa Y_P^s}{I} - \varphi_2 \frac{\bar{E}}{\rho I \sigma P^2}\right],$$

$$FF_P^{ST} = \left(\frac{di^L}{dP}\right)_{FF}^{ST} = \Delta^{Basel\ II}\left\{\varphi_1 \frac{\kappa Y_P^s}{I} + \varphi_2 \frac{\bar{E}}{\rho I P \sigma^2}\phi_{Y^S}\left(Y^s\right)^{-\phi_{Y^s}-1} Y_P^s - \varphi_2 \frac{\bar{E}}{\rho I \sigma P^2}\right\},$$

$$FF_P^{IRB} = \left(\frac{di^L}{dP}\right)_{FF}^{IRB} = \Delta^{Basel\ II}\left\{\left(1 + \varphi_2 \phi_q q^{-\phi_q - 1}\frac{\bar{E}}{\rho I P \sigma^2}\right)\left(\varphi_1 \frac{\kappa Y_P^s}{I} - \varphi_2 \frac{\bar{E}}{\rho I \sigma P^2}\right)\right\}.$$

Assuming that the strength of the bank capital channel dominates the collateral channel, then the slopes of FF^j for $j = I, ST, IRB$ are *positive*, as noted earlier.[10] Moreover, a comparison of (35), (42) and (48) implies that FF^{ST} is *flatter* than FF^I, while FF^{IRB} is *steeper* than FF^I. Intuitively, under Basel II there is an additional effect captured through the relationship between prices and the risk weight. Specifically, under the Standardized

[10] Recall that for FF_P^{ST} to be positive it is also assumed that the change in the risk weight, followed by a change in output supply and consequently the repayment probability, is not strong enough to offset the (positive) impact of the "pure" bank capital channel on the lending rate.

approach a rise in prices stimulates output and directly *lowers* the risk weight (as implied from equation 41). The fall in the risk weight, in turn, mitigates the initial drop in the bank capital buffer, which *moderates* the increase in the lending rate (at the initial level of investment). As a result, following a rise in prices, the loan rate rises by *less* under the Standardized approach of Basel II compared to Basel I.

By contrast, under the IRB approach, a rise in prices tends to *increase* the risk weight on loans when the bank capital channel dominates the collateral channel (see equation 47). The increase in the risk weight amplifies the fall in the bank capital buffer and leads to a *further* increase in the lending rate, at the initial level of investment. Consequently, the loan rate increases by *more* under the foundation IRB approach of Basel II compared to Basel I following a hike in prices.

Finally, inspection of equations (35), (42) and (48) shows that in the absence of the bank capital channel the slopes are all equal and downward sloping. More precisely, the lending rate *falls unambiguously* following a rise in prices such that $FF_P^I = FF_P^{ST} = FF_P^{IRB} = \Delta^{Basel\ I}\left[\varphi_1 \frac{\kappa Y_P^s}{I}\right] < 0$. The curve corresponding with the financial equilibrium curve with a non active bank capital channel is denoted by FF^0 in Figure 1.[11]

As shown in the previous section, the goods market equilibrium, labeled as GG, does not depend on the regulatory regime, and its (negative) slope is given by equation (56),

$$GG_P = \left(\frac{di^L}{dP}\right)_{GG}^{I,II} = \Omega\left(Y_P^s + \alpha_1 \frac{N^d - N_P^d P}{P^2} + \alpha_3 \frac{F_0^H}{P^2}\right) < 0.$$

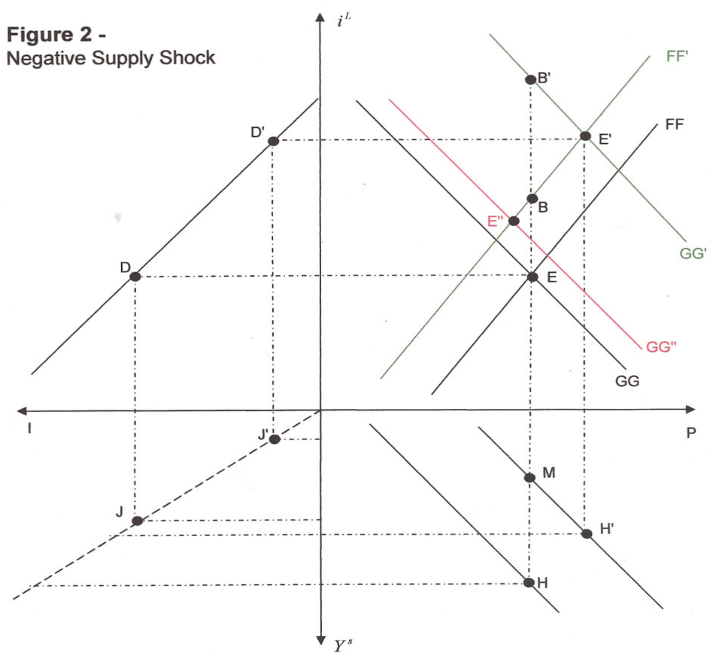
The northeast quadrant exhibits the relationships between the lending rate and the price level in the financial market equilibrium and the goods market equilibrium. The negative relationship between investment and the lending rate is shown in the northwest quadrant, whereas the positive relationship between output supply and the price level is displayed in the southeast quadrant. Using the 45−degree line to report Y^s and I in the southwest quadrant results in the household's consumption (C). The economy's equilibrium is determined at points E, D, H and J.[12]

[11] The financial equilibrium curve will also be downward sloping if the *collateral channel* dominates the *bank capital channel*, as examined in the next section.

[12] Naturally, FF^j for $j = I, ST, IRB$ would not normally intersect GG at the same point E. This is used for convenience.

3.3.2 Negative Supply Shock

A negative supply shock to output, that is, a fall in A, is now examined. The outcomes of such a shock are presented in Figure 2; the differences between the three regulatory regimes are only in terms of the slope of the curve FF and therefore only the Basel I regime is considered in order not to complicate and clutter the graph unnecessarily. The differences between the regulatory regimes are pointed out throughout the discussion.



The first effect of a negative supply shock is a drop in output, shown in the southeast quadrant. The supply curve shifts to the right and at the initial level of prices, output falls from point H to point M. As a result, the value of effective collateral pledged by firms decreases (at the initial level of investments), which results in a lower repayment probability. Ultimately, in order to account for the fact that lending is riskier, the FF curve shifts to the left and the lending rate rises from E to B. The fall in output also creates excess demand in the goods market at the initial level of prices. Consequently, from (54) the lending rate would need to increase further to bring investments down and restore equilibrium in the goods market. In Figure 2, this is shown by the upward movement of the GG curve, such that the loan rate would hypothetically need to rise from point B to point $B^{'}$.

However, this "overshooting" effect in the behaviour of the lending rate (point B') is not feasible, so the initial rise in the loan rate is not sufficient to eliminate excess demand in the goods market through a fall in investment only. Hence, prices must increase, which (through a negative wealth effect) lower the level of consumption. The higher price level also tends to lower real wages, thus dampening the initial decrease in output; after output falls from H to M, it gradually recovers from M to $H^{'}$. This rise in output raises effective collateral, thereby mitigating the increase in the lending rate. However, this improvement in effective collateral is not strong enough to offset the impact of the bank capital channel on the lending rate, which has sizable effects in this case. More specifically, the abovementioned rise in the price level (which raises the nominal value of bank loans) lowers the bank capital buffer and reduces the repayment probability, thereby resulting in a *higher* lending rate (from B to $E^{'}$). The new general equilibrium point therefore corresponds to point $E^{'}$, where the lending rate is *higher,* investments are *lower,* output is *lower*, and prices are *higher* (compared to the initial equilibrium point E).

Nevertheless, the new general equilibrium can also be characterized by a *higher* lending rate and *lower* prices following a negative productivity shock. This scenario may occur if the FF curve shifts by a large amount (such that the repayment probability and thus the lending rate adjust quickly to changes in the effective collateral, that is φ_1 is high), while the GG curve shifts by a small amount (which happens if the sensitivity of investment to the loan rate is relatively high). Suppose the FF curve shifts to the left by the same amount as before to $FF^{'}$, but the curve GG moves to the right by a small amount to GG''. In this case, the new general equilibrium point is characterized by point $E^{''}$, where the lending rate is still *higher* (compared to point E) but the price level is *lower*. In sum, in both the abovementioned cases, the loan rate *rises unambiguously* following a negative supply shock ($\frac{di^L}{dA} < 0$), while the impact of such a shock on the price level is *ambiguous* ($\frac{dP}{dA} \lesseqgtr 0$).

The behaviour of the loan rate is therefore said to be procyclical with respect to supply shocks, such that the lending rate falls during economic upswings and rises during economic recession, thereby exacerbating the initial movement in output. This *unambiguous* result is evident in this model in Basel I and both variants of Basel II. In the absence of a strong bank capital channel (or when the FF curve is *downward* sloping), the lending rate can either increase or decrease following a negative supply shock (as in the case of Agénor and Pereira da Silva 2012). This depends on the movement of the FF curve relative to the change in the GG curve (see next section for a detailed examination of this case).

With non binding capital requirements and an active bank capital channel, Basel I, the Standardized approach and the foundation IRB approach all amplify unambiguously the procyclical effects of a negative supply shock in the lending rate. In addition, a negative supply shock under Basel II affects the (endogenous) risk weights in both the Standardized approach and the foundation IRB approach. The negative supply shock raises the risk weight on loans, increases the bank capital requirements and lowers the bank capital buffer. The deterioration in the bank capital buffer then translates into a lower repayment probability, resulting in an amplified increase in the loan rate compared to Basel I (where the risk weight is constant under a specific loan category).

However, to restore equilibrium in the goods market (following the drop in output), prices must increase (such that $\frac{dP}{dA} < 0$), which, in turn, leads to a further rise in the lending rate through the bank capital channel. Given that $FF_P^{IRB} > FF_P^{I} > FF_P^{ST} > 0$, then this *additional* rise in the loan rate (followed by the increase in the price level) is the highest under the foundation IRB approach and the lowest under the Standardized approach. Therefore, combining the effects of A and consequently P on i^L, the following results are obtained: *i)* The foundation IRB approach is always more procyclical than Basel I following a negative supply shock. *ii)* It cannot be ascertained whether the foundation IRB approach is more procyclical than the Standardized approach (because $\phi_{Y^S} (Y^s)^{-\phi_{Y^s}-1} Y_A^s > \phi_q q^{-\phi_q - 1} \varphi_1 \frac{\kappa Y_A^s}{I}$, so, all else equal, $FF_A^{ST} > FF_A^{IRB}$). *iii)* Whether a supply shock entails more procyclicality under the Standardized approach compared to Basel I cannot be determined unambiguously either.

Alternatively, if $\frac{dP}{dA} > 0$, then following (only) the drop in prices, the loan rate falls by the largest amount under the foundation IRB approach and by the smallest amount under the Standardized approach. Taking into account the effects of A and thus P on i^L (as before), results in the following: *i)* The Standardized is always more procyclical than the foundation IRB approach and Basel I following a supply shock. *ii)* Whether the foundation IRB approach is more procyclical than Basel I cannot be ascertained.

3.4 General Equilibrium - The Collateral Channel Dominating The Bank Capital Channel

3.4.1 Macroeconomic Equilibrium

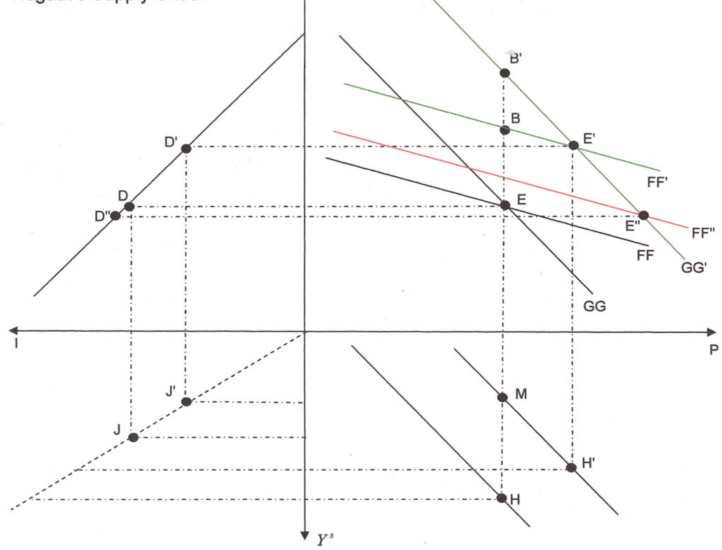
Assuming now that the elasticity of the repayment probability with respect to the borrowers' effective collateral dominates the strength of the bank capital channel, then the slopes of FF^j for $j = I, ST, IRB$ are *negative.* Moreover, a comparison of (35), (42) and (48) implies that FF^I is *steeper* than FF^{ST} and FF^{IRB}, while the ranking between the slopes of FF^{ST} and FF^{IRB} cannot be determined. The goods market equilibrium curve (GG) remains the same and downward sloping under all regulatory regimes as it does not directly depend on the bank capital channel. Finally, because the slopes of the financial equilibrium curves under the Standardized approach and the IRB approach cannot be ranked, the rest of the discussion focuses on the differences between Basel II (in general) and Basel I.

3.4.2 Negative Supply Shock

A negative supply shock to output is now examined when the collateral channel dominates the bank capital channel. The outcomes of such a shock are presented in Figure 3; the difference between Basel I and Basel II is only in terms of the slope of the FF curve and therefore, and as in the previous section, only the Basel I regime is considered in order not to clutter and complicate the graph unnecessarily. The differences between Basel I and Basel II are pointed out throughout the discussion.

As shown in Agénor and Montiel (2008), under standard dynamic assumptions, local stability requires the GG curve to be steeper than the FF curve.

Figure 3 -
Negative Supply Shock



The first effect of a negative supply shock is a movement of the supply curve (in the southeast quadrant) to the right such that at the initial level of prices, output falls from point H to point M. Thus, the value of collateral is lower, which implies that at the initial level of investment, the curve FF shifts upwards from point E to B. This results in a lower repayment probability and a higher loan rate. As in the previous case, the drop in output leads to excess demand in the goods market (at the initial level of prices) and therefore the lending rate must increase further to bring investment down and restore equilibrium in the goods market. Nonetheless, because a rise to point B' is not feasible, the price level must increase which, in turn, lowers the level of consumption (through a negative wealth effect), but leads to a gradual recovery of output from point M to H'. The rise in output raises the effective collateral pledged by firms and consequently mitigates the rise in the loan rate. Ultimately, the new equilibrium point is characterized by a *higher* lending rate (point E'), *lower* investments, *higher* level of prices and a *lower* level of output (compared to the initial equilibrium point H).

However, it is also possible for the new equilibrium to be characterized by a *lower* loan rate and *higher* prices following a negative productivity shock. This scenario may occur if the GG curve shifts by a large amount (such that investments are not very sensitive to changes in the loan rate), while the FF curve shifts by a small amount (which happens if the lending rate adjusts slowly to changes in effective collateral). Suppose the GG curve shifts to the right by the same amount to GG', but the FF curve shifts only slightly to FF''. As shown on the graph, the new equilibrium point in this case corresponds with point E'', where the price level is still *higher* but the loan rate is *lower*. Hence, when the collateral channel dominates the bank capital channel, the lending rate may be either procyclical or countercyclical with respect to productivity shocks ($\frac{di^L}{dA} \lesseqgtr 0$). In other words, the lending rate may amplify the initial movement in output (procyclicality case when $\frac{di^L}{dA} < 0$), or may mitigate the initial drop in output (contercyclicality case when $\frac{di^L}{dA} > 0$).[13]

To make things clearer, note that a negative productivity shock and a higher level of prices have contradicting effects on the lending rate. On the one hand, a negative supply shock leads to a *deterioration* in effective collateral, *lowers* the repayment probability and *increases* the lending rate. On the other hand, the rise in prices associated with the negative productivity shock *improves* the effective collateral pledged by firms, *increases* the repayment probability and thus *lowers* the loan rate. This ambiguity exists regardless of the regulatory regime as it depends solely on the collateral channel, which dominates the bank capital channel in this section.

To investigate how the bank capital channel operates in this setting, the focus again is on how changes in the productivity level and prices impact the nominal value of risky loans and the risk weight. As shown in the financial market equilibrium section, *following (only) a negative supply shock*, Basel II always leads to a further rise in the loan rate compared to Basel I ($\left|FF_A^{II}\right| > \left|FF_A^{I}\right|$). This occurs due to the negative relationship between supply shocks and the risk weight under Basel II, as explained earlier.

However, it is important to note that prices play a crucial role in determining which regulatory regime is more procyclical than the other when examining the general equilib-

[13] Although not shown and examined in Figure 3, it is also possible for the new equilibrium point to exhibit a *higher* lending rate and a *lower* price level (north-west to point E). This happens when the FF curve shifts by a large amount while the GG curve shifts only by a small amount. We, however, focus solely on the cases where prices *increase* following a negative supply shock under this section.

rium effects. More specifically, prices must rise to restore equilibrium in the goods market (following the drop in output). The higher prices increase the nominal value of risky loans, reduce the bank capital buffer, lower the repayment probability and raise the loan rate. This is evident in both Basel I and Basel II. Nevertheless, in Basel II, this rise in prices stimulates output, raises effective collateral pledged by firms, increases the repayment probability, which translates into a lower risk weight on loans. The fall in the risk weight mitigates the fall in the bank capital buffer, thereby dampening the initial increase in the lending rate (at the initial level of investment). Consequently, when examining *only* the effects of the bank capital channel on the lending rate *following a rise in prices*, Basel I may be more procyclical than Basel II.

Taking into account both the collateral channel and the bank capital channel, recall that the lending rate may either *rise* or *fall* following a negative supply shock. In the first scenario where the loan rate is procyclical with respect to supply shocks ($\frac{di^L}{dA} < 0$), both Basel I and Basel II *magnify* the initial rise in the loan rate (caused by the impact of the collateral channel). Nevertheless, when combining the effects of A and consequently P on i^L, it cannot be ascertained whether Basel II is always more procyclical than Basel I in a general equilibrium setup.

Alternatively, if the loan rate is countercyclical with respect to supply shocks ($\frac{di^L}{dA} > 0$), both regulatory regimes *mitigate* the initial drop in the loan rate (led by the improvement in effective collateral), as the increase in prices tends to raise the lending rate through the bank capital channel. Once again, taking into account both the effects of A and consequently P on i^L, it cannot be concluded which regulatory regime is more procyclical than the other when the impact of a negative supply shock is examined in a general equilibrium context.

The results under this section are very similar to the Agénor and Pereira da Silva (2012) paper, but what our model shows is that even with a bank capital channel transmitted through the impact of bank capital buffers on the loan rate, Basel I may be more procyclical than Basel II. This comes in contrast to what partial equilibrium results would suggest.

4 Concluding Remarks

This paper studies the procyclical effects of bank capital regulation using a simple static macroeconomic model with credit market imperfections. The model combines elements from Agénor and Montiel (2008), Agénor and Pereira da Silva (2012) and Agénor, Alper and Pereira da Silva (2012) and defines the Basel I and Basel II regulatory regimes, with a distinction made between the Standardized and the foundation IRB approaches of Basel II. Under the Standardized approach the risk weight on loans is related to the output supply, while under the foundation IRB approach, the risk weight is a function of the repayment probability, which, in turn, is embedded in the lending rate charged by the commercial bank. Thus, in contrast to Basel I, the risk weights on loans under both variants of Basel II are endogenous, and are affected by changes in output and prices.

The *bank capital channel* in this model assumes that bank capital buffers induces the commercial bank to screen and monitor its borrowers more carefully, thus raising the repayment probability and allowing the bank to set a lower loan rate. Empirically, this idea is supported by Fonseca, Gonzalez and Pereira da Silva (2010) and theoretically by the micro founded models of Allen, Carletti and Marquez (2011) and Mehran and Thakor (2009). In our model, and similar in spirit to Agénor, Alper and Pereira da Silva (2012), a reduced form formula relating the repayment probability to the bank capital buffer is used as a helpful and convenient shortcut to conduct the macroeconomic analysis of this paper.

This model also illustrates the differences in the transmission processes of the bank capital channel under the various regulatory regimes. Specifically, under both variants of Basel II, a supply shock is not only transmitted through the impact of effective collateral on the loan rate (*the collateral channel*), but also through its effect on the endogenous risk weights. Moreover, changes in the price level (associated with productivity shocks) have a substantial impact on the bank capital channel and the degree of procyclicality of the different regulatory regimes.

Examining the general equilibrium effects, it is shown that when the *bank capital channel dominates the collateral channel,* then the lending rate is *always procyclical* following supply shocks. Under this scenario, it is crucial to know the direction in which prices fluctuate in order to rank between the procyclical effects of the different regulatory regimes. Nevertheless, when the *collateral channel is stronger than the bank capital channel*, the loan rate may be either *procyclical or countercyclical* following supply shocks. In this case the conclusion is that it *cannot* be ascertained whether Basel II is more procyclical than Basel I.

This analysis can be extended in the following main directions: First, as noted above, the relationship between bank capital buffers, monitoring scrutiny and the repayment probability is of a reduced form and not endogenously derived. A useful and important extension would be to implement micro foundations to derive the bank capital channel in our macroeconomic model, which may build upon the micro foundations of Allen, Carletti and Marquez (2011) and Mehran and Thakor (2009), as already mentioned. Furthermore, holding bank capital buffers can also be motivated by Repullo and Suarez's (2009) model, where banks build capital buffers during good times in order to avoid a significant contraction in lending during a recession. However, this idea can only be implemented in a dynamic setting which leads us to the second useful extension to our model; extending our static framework to a dynamic stochastic general equilibrium (DSGE) model. Extending our model to a DSGE framework with an explicit endogenous derivation of the relationship between bank capital buffers and incentives to monitor and/or the linkage between capital buffers and anticipation of bad times will provide, in our opinion, an original contribution to this line of research.

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