Credit Allocation, Capital Requirements and Procyclicality

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Abstract

Although beneficial allocational effects have been a central motivator for the Basel II capital adequacy reform, the interaction of these effects with Basel II's procyclical impact has been less discussed. In this paper, we investigate the effect of risk-based capital requirements on the allocation of credit. We consider competitive credit markets where entrepreneurs can apply for loans for investments with different risk profiles. In this setting, excessive risk taking typically arises because higher-type borrowers cross-subsidize lower-type borrowers through a pricing regime that is based on average success rates. We find that while flat-rate capital requirements (such as Basel I) increase overinvestment in risky projects, risk-based capital requirements alleviate the cross-subsidization effect and improve allocational efficiency. This suggests that Basel II need not lead to exacerbation of macroeconomic cycles because the ensuing reduction in the proportion of high-risk investments will mitigate the procyclical effect of bank lending over the business cycle. Moreover, the level of optimal risk-based capital requirements should increase in the level of interest rates.

Keywords: Basel II, bank regulation, capital requirements, credit risk, procyclicality

JEL-codes: D41, D82, G14, G21, G28

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1 Introduction

Minimum capital requirements on banks are a central element of the regulatory construction which aims at containing systemic risk in the banking sector. Capital requirements are commonly seen as a complement to deposit insurance in preventing bank runs. They can curb banks' risk taking incentives and aim at enforcing a minimum level of solvency for banks (Pennacchi, 2005, provides a recent discussion on the role of capital requirements). To be successful in achieving these aims capital requirements should be proportioned with the actual risks banks take[1]. This is what the new set of minimum capital requirements, known as Basel II, tries to achieve. In the new framework the amount of capital a bank is required to hold at the minimum against a given credit asset explicitly depends on the credit risk of that asset[2]. This contrasts sharply with the previous regulatory framework (Basel I, refering to the Basel Capital Accord of 1988) under which banks faced a flat 8% minimum capital requirement against any asset in their corporate loan portfolio.

'Flat-rate' capital requirements pose an obvious problem. As the cost of holding capital comes over to loan prices, the flat-rate requirement effectively means that low risk customers cross-subsidize high risk borrowers[3]. This increases the attractiveness of high risk loans and thus raises the average credit risk in a bank's loan portfolio. An advantage of risk-based capital requirements is that they can alleviate these potential allocational distortions across different loan risk categories (see also the motivation provided for Basel II by the Basel Committee, 2001). At the same time, however, it has been argued that a potentially serious drawback of risk-based capital requirements is that they may exacerbate 'procyclicality' of capital requirements. In an economic downturn, credit losses typically erode banks' capital base and default probabilities of the surviving customers increase, which implies that banks' risk-based capital requirements also increase. Since raising new capital during bad times may be difficult or very costly, banks may be forced to scale back their lending activity, thereby exacerbating the recession (see e.g. Kashyap and Stein, 2004, Gordy and Howells, 2006, and Pennacchi, 2005).

Although the beneficial allocational effects of risk-based capital requirements have

[1] The importance of this prerequisite is highlighted e.g. by the following quote from The Economist (2007), commenting on the subprime crisis which started in the latter half of 2007: "...the banks now facing up to these contingent liabilities (via conduits or implicit reputational concerns) have not had to set aside capital in case of trouble - that gap in regulations was precisely what made it so attractive to get their investments off balance sheets in the first place".

[2] The main techical innovation in Basel II to implement risk-based minimum capital requirements is called the internal-ratings-based (IRB) approach. More precisely, a bank is required to use a scale of internal ratings in which each credit customer is categorized. The bank further estimates the average probability of default in each rating category. This along with other credit risk parameters determines the minimum capital requirement based on a mathematical formula provided in the Basel II framework (for details see Basel Committee on Banking Supervision, 2006). The IRB approach is applicable also in credit asset categories other than corporate credits although in this paper we focus on the corporate credit assets. Throughout this paper it is implicitly assumed that there is no moral hazard in banks' determining the internal ratings and hence their own capital requirement. The consequences of relaxing this assumption are studied in Blum (2007).

[3] The discussion on why capital requirements impose an additional cost on banks is deferred to section 2.

been a central motivation for the Basel II reform, their interaction with Basel II's alleged procyclical impact has been discussed only a little. Namely, intensity of procyclicality could depend on the risk-profile of banks' loan portfolios. If the relative share of risky assets is high, then the need to collect fresh capital after a negative macroeconomic shock may be significant due to large credit losses and the substantial increase in the default probability and hence capital requirement of the remaining borrowers. Since risk-based capital requirements unravel the cross-subsidization mechanism related to the flat-rate regime, the new requirements could induce a general shift towards less risky portfolios. Hence, the portfolio shift could constitute an attenuating effect on procyclicality of the new regime. Moreover, this counterbalancing effect may be coupled with a more efficient allocation of credit obtained with the risk-based capital requirements.

In this paper our objective is to analyse in a simplified model the efficiency of resource allocation in the credit market under the flat-rate and the risk-based capital requirements. We then discuss the model's implications for procyclicality under the two capital regimes. We construct a model where 'entrepreneurs' can choose between investments of different risk characteristics (as in Vesala, 2007), or they can decide not to take up a risky investment at all. More specifically, we consider two uncertain investment opportunities, a 'high-risk' and a 'low-risk' investment, as well as an outside option that produces a fixed payoff with certainty. Following De Meza and Webb (1987), entrepreneurs' intrinsic and unobservable 'types' determine their success rates in risky investments. High-risk projects are more sensitive to entrepreneurs' types than low-risk investments while the payoff of the outside option is independent of the intrinsic type. Efficient resource allocation is obtained when entrepreneurs with the highest types invest in high-risk projects which also offer the best payoff when successful, while entrepreneurs at the bottom end of the type distribution do not invest at all but stick to the safe outside option. Types located in the middle should invest in low-risk projects. In equilibrium there are two unique threshold types indicating the division of the investment choices of the various types. Banks cannot observe the explicit success rate of an individual entrepreneur but they rationally expect the equilibrium average success probabilities within each investment class. Banks are assumed to operate in competitive credit markets where loan prices for high-risk and low-risk investments are determined by banks' posterior beliefs about average success rates within each investment category. The competitive loan prices, in turn, govern entrepreneurs' self-selection among different investment opportunities. The entrepreneurs in the model could perhaps best be understood as representing the small and medium-size corporate loan customers of banks. Such firms still typically rely on bank finance and, therefore, we do not consider capital markets as an alternative source of finance.

The conventional result in this kind of setting is that there is too much risk-taking because low risk borrowers cross-subsidize high risk borrowers through the price system that is based on average success rates (De Meza and Webb, 1987).[4] We find that

[4] Our choice of the De Meza and Webb (1987) type of framework which produces overinvestment in high-risk assets even in the absence of bank capital requirements is of course a crucial starting point to our analysis. It is often argued that the alternative framework based on Stiglitz and Weiss (1981) type of assumptions which produce credit rationing may be empirically more relevant. Nonetheless,

the flat-rate regime exacerbates this overinvestment problem by allocating even more resources to high-risk projects. We also observe that the flat-rate capital requirements induce a trade-off between optimal composition of loans and the efficiency of overall bank lending volume. By contrast, risk-based capital requirements alleviate the cross-subsidization effect in high-risk investments and thereby reduce overinvestment in these projects. Moreover, the lower capital requirement against low-risk loans increases entrepreneurs' general participation in the credit market, so that the overall lending volume is higher under the risk-based capital requirements than under the flat-rate regime. In actuality, we show that there exists a risk-based capital requirement schedule that implements both the first-best loan composition and the first-best lending volume. This central result obtains because capital requirements which are differentiated according to projects' risks provide a sufficient number of instruments, unlike a constant capital requirement, to implement the first-best allocation. In effect, the project-specific loan prices can be individually adjusted so that it is not optimal for intermediate types to pool with the best types or for the worst types to pool with intermediate types. Reminiscent of Repullo (2004), our model also implies that the introduction of risk-based capital requirements would allow for a reduction in the overall level of regulatory capital.[5]

Regarding discussion on Basel II and procyclicality of risk-based capital requirements, our finding on the alleviation of overinvestment in the high-risk projects suggests that Basel II does not necessarily lead to exacerbation of macroeconomic cycles (cf. Gordy and Howells, 2006).[6] This is based on the plausible assumption that the high-risk projects would be more prone to fail and thus to cause more credit losses in a downturn than the low-risk projects. At the least, the allocational effects should be taken into account in assessing the overall procyclical impact of a capital adequacy regime. Moreover, we also find that the overall level of the optimal risk-based capital requirements depends on the level of interest rates. The standard result in many macroeconomic models is that the real interest rate is higher in booms and lower in downturns. Therefore, our result is consistent with the view that the overall level of

several arguments can be provided to justify our starting point. First, there are papers that argue that risks in the banking sector may build up during economic upturns (see Borio et al., 2001, and Rajan, 1994). Several recent crisis episodes such as those in Japan, Scandinavia and Asia seem to have ex post verified the possibility of such excessive investment in booms. Overinvestment financed by commercial banks has been a central issue also in the credit market turmoil that started in the second half of 2007 from the US subprime mortgage market. The second argument relates to the construction of prudential policies. Given that periodic overinvestment is possible, even if not necessarily the prevailing condition in credit markets, it seems more important from the financial stability viewpoint to analyse and design capital requirements that work well in curbing banks' risk-taking under circumstances of inherent overinvestment rather than underinvestment. Finally, as De Meza and Webb (1987) have shown, debt is the optimal contract in their type of framework whereas in the Stiglitz and Weiss (1981) setting equity would be optimal. Therefore the overinvestment framework may be more consistent with credit markets analysed in this paper.

[5] Interestingly, this is not the objective of Basel II. According to the Basel Committee (2001), the goal of Basel II is "neither to produce a net increase nor a net reduction - on average - in minimum regulatory capital."

[6] Also the Basel Committee (2001) has pointed out that "(Basel I) which does not adequately reflect changes in risk creates incentives for banks to make high-risk investments that may contribute to cyclicality over the business cycle".

risk-based capital requirements should vary in accordance with the business cycle, being relatively higher in booms and lower in downturns. This view has been expresssed in some studies and recent policy discussions (see e.g. Goodhart, 2008, Gordy and Howells, 2006, Kashyap and Stein, 2004, and Risk, 2007).

So far, there are only a handful of papers focusing on the portfolio effects of risk-based capital requirements. Repullo and Suarez (2004) investigate loan pricing implications of Basel II capital requirements. They consider both the 'standardized' approach based on external ratings as well as the more risk-sensitive internal-ratings-based (IRB) approach.[7] In their model, banks can differentiate by choosing either the standardized approach or the IRB approach. Repullo and Suarez (2004) conclude that low risk borrowers achieve reductions in loan rates as they do business with banks using the IRB approach. However, the prospects of high-risk borrowers may not be weakened as they may borrow from banks adopting the standardized approach. Other related studies focus on procyclicality (e.g. Gordy and Howells, 2006, and Kashyap and Stein, 2004), the justifications of 'excess' capital buffers (Allen, Carletti and Marquez, 2005), or empirical evidence of the cyclical fluctuations of these buffers (Ayuso, Pérez and Saurina, 2003; Jokipii and Milne, 2007). It has also been argued (see eg Peura and Jokivuolle, 2004) that banks can hold extra buffers of capital in excess of the minimum capital requirement and thereby alleviate procyclical effects. Repullo and Suarez (2007) show in a dynamic model that banks under Basel II may, indeed, raise their capital buffers in booms but that that alone may not suffice to avoid a credit crunch if a recession hits. In Heid's (2007) model endogenous buffers also have a mitigating role. Further related studies are Zicchino (2006) and Zhu (2007). Some studies have investigated how Basel II type of regulation could be improved to reduce the procyclical effects. Kashyap and Stein (2004) and Gordy and Howells (2006) suggest and consider time-varying capital requirements. However, Pennacchi (2005) argues these studies do not take into account implications for deposit insurance losses and suggests instead integration of risk-based deposit insurance with risk-based capital requirements to reduce the procyclical impact. Lastly, we refer to the paper by Repullo (2004) where the role of capital requirements in preventing 'gambling' in bank lending is stressed in a setting with bank market power. He finds that both the flat-rate and the risk-based capital regime can be successful in this objective, albeit under the risk-based system the prevention of gambling is implemented with lower overall level of regulatory capital. Our results suggest, however, that flat-rate capital requirements may actually increase 'gambling' (in the sense of overinvestment in the riskiest projects by the entrepreneurs) whereas moving from flat-rate capital requirements to the risk-based system may significantly reduce 'gambling' as overinvestment in the riskiest projects is reduced.

The paper is organized as follows. Section 2 prescribes the general modelling environment, and section 3 presents equilibrium analysis containing the main results. Implications for the procyclicality are discussed in section 4 along with consistency of the model's implications in the context of the previous Basel I reform. Section 4 ends

[7] In Basel II banks have the option to use either the simpler and less risk-sensitive standardized approach or the more sophisticated and risk-sensitive IRB approach, subject to supervisory approval. In practice it is expected that large and sophisticated banks opt for the latter. In the US, the largest banks will only have the choice of the IRB approach.

with some robustness considerations. Finally, section 5 concludes.

2 The model

We consider a risk-neutral economy with a continuum of entrepreneurs and a competitive banking market. Entrepreneurs have access to either an 'high-risk' or a 'low-risk' investment. When successful, a high-risk project produces v while the output of a low-risk investment is of worth $s < v$. If a project fails it produces nothing, regardless of the type of the investment. Entrepreneurs differ in their 'intrinsic types'. The type parameter θ is distributed over $\Theta = [0, 1]$ according to a strictly increasing function $G(\theta)$. $G(\theta)$ is common knowledge but the actual realization of θ is entrepreneur's private information. The success probability of an investment depends on entrepreneur's type θ. The type dependent success rates of a high-risk and a low-risk investment are denoted by $p(\theta)$ and $q(\theta)$ respectively, so that the expected outputs are $p(\theta)v$ and $q(\theta)s$. We assume

$$p'(\theta) > q'(\theta) > 0, \forall \theta \in \Theta. \tag{1}$$

Hence, while both success rates are strictly increasing in θ, a high-risk investment is riskier than a low-risk one as it is more sensitive to entrepreneur's intrinsic type.

Instead of making an investment, entrepreneurs may also choose an outside option (e.g. participation in the labor market) which produces an exogenously given payoff w. The magnitude of this fixed payoff is independent of θ. Moreover, we assume

$$p(1)v > q(1)s > w \text{ but } p(0)v < q(0)s < w, \tag{2}$$

i.e., a high-risk investment has the greatest expected output for entrepreneurs at the upper end of the type distribution while entrepreneurs at the bottom end of the distribution should choose the outside option.

The implementation of any new investment requires external finance equal to a constant amount, I, which we normalise to one without loss of generality. These external resources can be obtained from competitive credit markets where banks deliver standard debt contracts. If I units of financial capital were invested elsewhere in the financial markets, banks could earn $\bar{R}$. $\bar{R}$ thus serves as the opportunity cost of finance. Moreover, the regulator requires the banks to raise equity capital K. Under the flat rate regime, the requirement is to hold at least a minimum capital $K = \bar{k}$ per unit of loans, regardless of the risk status of the asset. Under the risk-based regime, however, the requirement is to hold $K = k_v$ per unit of high-risk loans and $K = k_s$ per unit of low-risk loans.

In what follows we assume that the minimum capital requirement constitutes an additional financing cost to banks. Starting from Myers and Majluf (1984) there is a large literature justifying that for reasons of asymmetric information external equity capital is the most costly form of finance for firms and financial institutions. Moreover, for banks in particular equity can be costly because banks earn part of their income from the interest rate margin on their deposit base. E.g. Repullo and Suarez (2004) show how a competitive bank would always choose the minimum amount of equity allowed by the regulator (see also Diamond and Rajan, 2000). Finally, although it

may not generally be the case that regulatory minimum capital requirements are a binding constraint on banks, evidence that banks hold more capital than the regulatory minimum may merely indicate that in imperfect capital markets banks need internal capital buffers to avoid the adverse consequences from violating the minimum requirement (see e.g. Elizalde and Repullo, 2006, and Gropp and Heider, 2007 and the references therein). Anecdotal evidence of the motives of banks' securitisations also suggests that banks do consider regulatory capital requirements costly and may thus have alleviated these costs partly via securitisations.

The timing of events is as follows[8]:

Stage 1 Nature draws entrepreneurs' types from the distribution $G(\theta)$ with support $\Theta = [0, 1]$.

Stage 2 Entrepreneurs choose whether to invest in an uncertain project or stick to the safe outside option. If they choose to invest, they need external finance in order to implement the project. Before entering the credit market, entrepreneurs have to fix the business plan for which they are seeking finance. Banks can observe whether the chosen project is high-risk or low-risk, and they are able to monitor the implementation of the chosen project.

Stage 3 Entrepreneurs and banks trade in a competitive credit market. Upon a trading opportunity, loan contracts can only be conditioned on the observable project characteristics but not on the unobservable entrepreneur type.

Stage 4 Outputs are realized. If the project has been successful, the bank receives the repayment and the entrepreneur keeps the residual. A failure incurs a credit loss to the bank.

From assumptions (1) and (2) it follows that there are two unique cut-offs $\overline{\theta}^{fb}$ and $\underline{\theta}^{fb}$ s.t.

$$p(\overline{\theta}^{fb})v = q(\overline{\theta}^{fb})s \text{ and } q(\underline{\theta}^{fb})s - \bar{R} = w. \tag{3}$$

The upper index in these thresholds stands for 'first-best' as efficient resource allocation is obtained when types $\theta \in [\overline{\theta}^{fb}, 1]$ choose high-risk investments, types $\theta \in [\underline{\theta}^{fb}, \overline{\theta}^{fb})$ stick to low-risk projects and types $\theta \in [0, \underline{\theta}^{fb})$ choose the fixed outside option.

In the market solution, the marginal type that is indifferent between a high-risk and a low-risk investment is denoted by $\overline{\theta}$. Since any type above this cut-off has a greater success probability (and thereby greater expected payoff) in a high-risk project than the type $\overline{\theta}$, it must hold that types $\theta > \overline{\theta}$ strictly prefer high-risk investments over low-risk ones. Correspondingly, types $\theta < \overline{\theta}$ strictly prefer low-risk projects over high-risk investments. As an application of Bayes' rule, the expected success probability of

[8] The sequence of events adopted here draws on the model by Vesala (2007).

an entrepreneur with a high-risk investment is given by

$$p(\hat{\theta}_v) = \frac{\int_{\overline{\theta}}^{1} p(\theta) dG(\theta)}{1 - G(\overline{\theta})}. \tag{4}$$

Similarly, the type that is indifferent between a low-risk investment and the outside option is denoted by $\underline{\theta}$. Again we must have that types $\underline{\theta} < \theta < \overline{\theta}$ strictly prefer a low-risk investment and types $\theta < \underline{\theta}$ strictly prefer choosing the fixed payoff. The expected success probability of an entrepreneur with a low-risk investment is thus given by

$$q(\hat{\theta}_s) = \frac{\int_{\underline{\theta}}^{\overline{\theta}} q(\theta) dG(\theta)}{G(\overline{\theta}) - G(\underline{\theta})}. \tag{5}$$

In competitive credit markets, banks make on average zero profits in their lending business. In other words, the expected repayment just covers the opportunity cost of finance $\bar{R}$ plus the cost of the regulatory equity capital K; i.e., $p(\hat{\theta}_v)R_v = \bar{R} + K$ and $q(\hat{\theta}_s)R_s = \bar{R} + K$ where R_v and R_s denote the competitive loan rates for high-risk and low-risk investments respectively. Note that for simplicity we treat the capital requirement K directly as the extra financing cost incurred of this requirement by the bank.

Solving for R_v and R_s yields

$$R_v = \frac{\bar{R} + K}{p(\hat{\theta}_v)} \text{ and } R_s = \frac{\bar{R} + K}{q(\hat{\theta}_s)}.$$

Entrepreneurial payoffs from high-risk and low-risk investments are given by

$$\pi_v(\theta, \hat{\theta}_v) = p(\theta)(v - R_v) = p(\theta)v - \frac{p(\theta)}{p(\hat{\theta}_v)}(\bar{R} + K), \tag{6}$$

$$\pi_s(\theta, \hat{\theta}_s) = q(\theta)(s - R_s) = q(\theta)s - \frac{q(\theta)}{q(\hat{\theta}_s)}(\bar{R} + K). \tag{7}$$

3 Equilibrium analysis

Entrepreneurs choose their projects by comparing the expected payoffs from high-risk and low-risk investments, and from the fixed outside option. The marginal type $\overline{\theta}$ is indifferent between the two investment options and $\underline{\theta}$ between a low-risk investment and the safe payoff. Banks, who observe entrepreneurs' investment choices but not their explicit types, use the Bayes' rules in (4) and (5) to update their posterior beliefs about the average success probabilities of a high-risk and a low-risk investment. As a formal definition, we have:

Definition 1 *A perfect Bayesian equilibrium specifies a pair* $(\overline{\theta}^*, \underline{\theta}^*)$ *which is a solution to the following system of equations (note that* $(\hat{\theta}_v^*, \hat{\theta}_s^*)$ *follow directly from the equilibrium marginal types):*

$$(i)\ \pi_v\left(\overline{\theta}^*, \hat{\theta}_v^*\right) = \pi_s\left(\overline{\theta}^*, \hat{\theta}_s^*\right),$$

$$(ii)\ \pi_s\left(\underline{\theta}^*, \hat{\theta}_s^*\right) = w,$$

3.1 Flat-rate capital requirements

Under flat-rate capital requirements, $K = \bar{k}$ regardless of the type of the investment. First, the equilibrium condition (i) implies:

$$\begin{aligned} p(\overline{\theta}^{FR})v - \frac{p(\overline{\theta}^{FR})}{p(\hat{\theta}_v^{FR})}(\bar{R}+\bar{k}) &= q(\overline{\theta}^{FR})s - \frac{q(\overline{\theta}^{FR})}{q(\hat{\theta}_s^{FR})}(\bar{R}+\bar{k}) \Leftrightarrow \\ p(\overline{\theta}^{FR})v - q(\overline{\theta}^{FR})s &= (\frac{p(\overline{\theta}^{FR})}{p(\hat{\theta}_v^{FR})} - \frac{q(\overline{\theta}^{FR})}{q(\hat{\theta}_s^{FR})})(\bar{R}+\bar{k}), \end{aligned} \tag{8}$$

where $\overline{\theta}^{FR}$ and $\hat{\theta}_v^{FR}$ denote the equilibrium values of $\overline{\theta}$ and $\hat{\theta}_v$ under the flat-rate regime.

Proposition 1 *Given the flat-rate capital requirements, there is overinvestment in high-risk projects as entrepreneurs with inefficiently low success rates choose this investment opportunity; i.e.,* $\overline{\theta}^{FR} < \overline{\theta}^{fb}$ *and* $\hat{\theta}_v^{FR} < \hat{\theta}_v^{fb}$.

Proof: Follows from the observation that the RHS of (8) is strictly negative, which directly implies that $\overline{\theta}^{FR} < \overline{\theta}^{fb}$ and thereby $\hat{\theta}_v^{FR} < \hat{\theta}_v^{fb}$.■

By equation (8) it is obvious that the overinvestment problem would exist also without any extra capital requirement, i.e., when $\bar{k} = 0$. This is the conventional DeMeza-Webb (1987) overinvestment result and it stems from the effect that the high types investing in high-risk projects cross-subsidize the low types investing in similar projects through the price system that is based on average success rates. Fundamentally, the overinvestment mechanism is based on positive levels of 'interest-rate' $\bar{R}$ which causes a limited liability effect on entrepreneurs, which spurs risk-taking. Indeed, note from equation (8) that for $\bar{R}$ and $\bar{k}$ both equal to zero the first-best equilibrium would obtain. A flat-rate capital requirement, which indiscriminately comes over to all loan prices regardless of the average risk level of the loan, amplifies overinvestment in high-risk projects because the marginal type becomes cross-subsidized for this extra cost in the market for high-risk loans while in the category of low-risk loans she would be the one who would cross-subsidize entrepreneurs with lower success rates. Hence, the higher is the flat-rate requirement $\bar{k}$ the greater is the distortion towards high-risk investments.

Second, from the equilibrium condition (ii) it follows that

$$q(\underline{\theta}^{FR})s - \bar{R} - w = \frac{q(\underline{\theta}^{FR})}{q(\hat{\theta}_s^{FR})}\bar{k} - \frac{q(\hat{\theta}_s^{FR}) - q(\underline{\theta}^{FR})}{q(\hat{\theta}_s^{FR})}\bar{R}. \tag{9}$$

Remark 1 *The cut-off* $\underline{\theta}^{FR}$*, which determines the division of entrepreneurs between investment and the safe outside option, is efficient if the flat-rate capital requirement satisfies*

$$\bar{k} = (\frac{q(\hat{\theta}_s^{fb})}{q(\underline{\theta}^{fb})} - 1)\bar{R} \equiv \bar{k}^{fb}.$$

If $\bar{k} < \bar{k}^{fb}$ entrepreneurs with inefficiently low success rates choose to invest in low-risk projects. On the other hand, if $\bar{k} > \bar{k}^{fb}$, too many entrepreneurs opt to choose the fixed payoff.

Proof: Follows directly from (3) and (9) .■

Since the extra capital requirement does not hit the payoff from the fixed outside option, $\bar{k}$ can be used to limit market participation. At the margin where entrepreneurs are indifferent between taking up a low-risk investment and opting the safe payoff the capital requirement reduces the incentive to invest and thus alleviates the excess market entry due to the cross-subsidizatione effect. $\bar{k}^{fb}$ is exactly the level of regulatory capital that implements the first-best division. If the capital requirement is greater than this, there will be underinvestment. Also observe that as the distortion in the high-risk investment margin is minimized when $\bar{k} = 0$ the introduction of a flat-rate capital adequacy regime necessarily induces a trade-off between optimal composition of loans and the efficiency of the overall bank lending volume. Obviously, the flat-rate capital requirement which minimizes the overall distortions is somewhere in between 0 and $\bar{k}^{fb}$; i.e. there will be both overinvestment in expansionay projects and excess market entry by entrepreneurs.

3.2 Risk-based capital requirements

Under the risk-based capital requirements, $K = k_v$ for high-risk investments and $K = k_s$ for low-risk investments. The equilibrium condition (i) then implies:

$$p(\overline{\theta}^{RB})v - q(\overline{\theta}^{RB})s = (\frac{p(\overline{\theta}^{RB})}{p(\hat{\theta}_v^{RB})} - \frac{q(\overline{\theta}^{RB})}{q(\hat{\theta}_s^{RB})})(\bar{R} + k_s) + \frac{p(\overline{\theta}^{RB})}{p(\hat{\theta}_v^{RB})}(k_v - k_s) \qquad (10)$$

Similarly, the condition (ii) now reads as

$$q(\underline{\theta}^{RB})s - \bar{R} - w = \frac{q(\underline{\theta}^{RB})}{q(\hat{\theta}_s^{RB})}k_s - \frac{q(\hat{\theta}_s^{RB}) - q(\underline{\theta}^{RB})}{q(\hat{\theta}_s^{RB})}\bar{R}. \qquad (11)$$

Remark 2 *The cut-offs $\overline{\theta}^{RB}$ and $\underline{\theta}^{RB}$ are efficient, if*

$$\begin{aligned} k_s &= (\frac{q(\hat{\theta}_s^{fb})}{q(\underline{\theta}^{fb})} - 1)\bar{R} \equiv k_s^{fb} \\ k_v &= (\frac{p(\hat{\theta}_v^{fb})}{p(\overline{\theta}^{fb})}\frac{q(\overline{\theta}^{fb})}{q(\underline{\theta}^{fb})} - 1)\bar{R} \equiv k_v^{fb} \end{aligned}$$

Proof: Follows directly from (3), (10) and (11).■

Remark 2 states that, contrary to the flat-rate regime, there exists a risk-based capital requirement schedule that implements both the first-best loan composition and the first-best lending volume. This follows from the fact that the risk-based system

offers as many independent instruments to affect allocational efficiency as there are different loan categories. This is not the case under the fixed capital requirement where there is only one instrument and efficiency can be obtained only at the margin where entrepreneurs are indifferent between investment and the safe outside option. Since the indifference condition between a low-risk investment and the safe outside option is essentially the same under both regimes, the efficient overall lending volume is implemented when the risk-based capital requirement for low-risk investments coincides with the flat-rate requirement given in Remark 1; i.e., $\bar{k}^{fb} = k_s^{fb}$. In turn, as $p(\hat{\theta}_v^{fb}) > p(\overline{\theta}^{fb})$ and $q(\overline{\theta}^{fb}) > q(\hat{\theta}_s^{fb})$, the risk-based capital requirement against high-risk investments that implements the efficient loan composition must be strictly greater than the capital requirement against low-risk loans; i.e., it must hold that $k_v^{fb} > k_s^{fb} = \bar{k}^{fb}$.

Note also that the optimal risk-based capital requirements depend positively on the level of interest rate, $\bar{R}$. If the standard macroeconomic view holds that the real interest rate increases with the business cycle, this implies that the optimal level of risk-based capital requirements should be increased in economic upturns and be lowered in downturns. This supports the view of Gordy and Howells (2006) that the overall level of capital requirements should be tied to the state of the business cycle. If, however, k_s and k_v were kept constant as $\bar{R}$ rises, then from equations (10) and (11) we can deduce that there would be overinvestment in the risky project and too little participation in the labour market. We will briefly return to this issue also in section 4.

In practice, fostering allocational efficiency is hardly the only - nor even the most important - objective of bank capital regulation. The primary goal of a regulator is to ensure that the capital holdings suffice to cover the potential credit losses incurred in the case when the economy is hit by an unexpected negative shock[9]. Here we assume that such a negative shock causes a downward shift in the success probability functions $p(\theta)$ and $q(\theta)$, and that the shock has greater impact on prospects of high-risk investments. Hence, the amount of credit losses incurred by the shock are decreasing in the average success rates $p(\hat{\theta}_v)$ and $q(\hat{\theta}_s)$, and it should hold for the required capital holdings that $k_v(\hat{\theta}_v) > k_s(\hat{\theta}_s)$. What we are still missing is the linkage between these risk-based capital requirements and the flat-rate measure $\bar{k}$. In a long run equilibrium, it is plausible to assume that the relationship between the flat-rate and the risk-based capital requirement is such that the flat-rate requirement is roughly equal to a 'weighted average' of the hypothetical risk-based schedule with the given equilibrium loan composition; i.e.,

$$\bar{k} \approx \frac{[1 - G(\overline{\theta}^{FR})]k_v(\hat{\theta}_v) + [G(\overline{\theta}^{FR}) - G(\underline{\theta}^{FR})]k_s(\hat{\theta}_s)}{1 - G(\underline{\theta}^{FR})}. \tag{12}$$

As an immediate consequence of this we have $k_s(\hat{\theta}_s) < \bar{k} < k_v(\hat{\theta}_v)$, and

Proposition 2 *Given that $k_s(\hat{\theta}_s) < \bar{k} < k_v(\hat{\theta}_v)$, it holds that*

$$\overline{\theta}^{RB} \geq \overline{\theta}^{FR} \text{ and } \underline{\theta}^{RB} < \underline{\theta}^{FR}.$$

[9] I.e. a shock that entails a realization of risks which are not fully internalized in the competitive loan prices.

Hence, there is less investment in high-risk projects under the risk-based capital requirements than under the flat-rate capital requirements but the overall lending volume under the risk-based regime is greater than under the flat-rate regime.

Proof: Follows from the observations that the RHS of equation (10) is strictly larger than the RHS of equation (8) , while the RHS of equation (11) is strictly smaller than that of equation (9).■

Compared to the flat-rate regime, the risk-based capital adequacy regime alleviates overinvestment in high-risk projects because it counterbalances the cross-subsidization effect at the margin where entrepreneurs are indifferent between high-risk and low-risk projects. On the other hand, lower capital requirement against low-risk loans increases entrepreneurs' participation to the credit market, so that the overall lending volume is higher under the risk-based system than under the flat-rate regime. Moreover, from (12) and Proposition 2 it follows that the average capital holding against a risky asset, i.e. either a low-risk or a high-risk loan, is larger under the flat-rate regime than under the risk-based system because the allocation of financial resources is less efficient with the flat-rate requirements.

4 Discussion

4.1 Implications for procyclicality

Since the allocational effect analysed in this paper potentially has a bearing on the vulnerability of the economy to shocks, it should be taken into account in assessing the overall impact of a capital adequacy regime on procyclicality. The alleged procyclical impact of the Basel II type regime may turn out to be less pronounced if attenuation of overinvestment in high-risk projects softens the cyclicality of bank lending over the business cycle. This argument is in line with the view of Gordy and Howells (2006) who note that the endogenous response by banks to Basel II does not necessarily lead to exacerbation of macroeconomic cycles. In this section we provide a discussion of procyclicality under Basel I flat-rate capital requirements versus Basel II risk-based capital requirements. The argumentation is heuristic in nature but makes use of the results of our analytical model.

We start with repeating the following assumption:

Assumption 1 *The high-risk projects fail more easily than the low-risk projects in an economic downturn.*[10]

[10]This assumption appears quite natural and can be given a few interpretations. We may think of the high-risk projects as investments into new products to be introduced to the market. Such investments often take place in economic upturns but might easily turn unprofitable if the aggregate demand turns down. Low-risk projects in turn could represent investments in already existing products which are less sensitive to overall demand fluctuations. More generally, almost by definition the 'beta' of a high-risk project is high, indicating high exposure to market wide factors, often strongly correlated with the business cycle.

Let us also assume to begin with that the overall amount of lending is efficient under both the flat-rate and risk-based capital requirement regimes. Under former there is overinvestment in high-risk projects whereas under the latter the efficient allocation between high-risk and low-risk projects can be implemented. Now consider a negative shock to the economy in the current period, which leads to a materialization of loan losses particularly from the risky investment projects[11]. By the previous assumption total losses are higher under the flat-rate regime than under the risk-based regime because of the overinvestment in high-risk projects. How is lending in the next period affected? If banks' are capital constrained in that their capital buffers are insufficient to absorb the losses and external capital is costly or simply difficult to get at short notice, banks will have to cut lending in order to absorb the losses and not to violate the minimum capital requirement, which could be very costly. The lending cut may then fuel the economic downturn. This is the procyclical effect. Because losses are higher under the flat-rate regime, the procyclical effect is, ceteris paribus, also more severe. Now consider that if Proposition 2 holds, a changeover to risk-based regime would increase the overall volume of lending which, other things equal, would expose the economy to more credit losses and hence more procyclicality[12]. Nonetheless, as the increase in lending volume would result from the increase in the number of low-risk projects which are less prone to losses in economic downturns, we would conjecture that the risk-based regime's dampening effect on procyclicality through correcting the overinvestment in high-risk projects would dominate.

On the other hand, a negative shock to the economy would also raise the probability of default of the non-defaulted risky assets which hence are subject to a higher capital requirement under Basel II than under Basel I. Hence, the procyclical effect resulting directly from capital requirements is bigger under Basel II. This is the standard view why Basel II is considered to be the more procyclical capital regime. The net of the above effects remains an open issue: we can not say which of the two capital regimes is the more procyclical one. Nonetheless, our analysis of the portfolio effects and the efficiency of the two different regulatory capital regimes does suggest that Basel II may be less procyclical than hitherto understood. The uncertain overall effect on procyclicality of the two regimes also implies that we can not say for sure which of the regimes produces a higher social welfare. We conjecture, however, that Basel II is a stronger candidate for being better for the social welfare because, in the light of our model, it can correct the fundamental overinvestment problem stemming from asymmetric information, which Basel I only makes worse.[13]

[11] Note that our analytical model has been static. However, when discussing procyclicality we essentially need to consider dynamic effects. We may think of an economy which starts in a boom in the first period and is then hit by a negative aggregate shock in the second period.

[12] For the corporate credit portfolio the lowest risk-weights of the Internal Ratings Based Approach of Basel II are clearly lower than the 8% flat-rate requirement of Basel I. Moreover, the goal of Basel II has been to calibrate the IRB risk-weights in such a way that the overall amount of capital in the banking sector does not change much. In this respect it is plausible to assume that Proposition 2 does actually hold.

[13] Elizalde and Repullo (2006) state that "In principle, regulatory capital should be derived from the maximization of a social welfare function that takes into account the costs (eg increase in the cost of credit) and the benefits (eg reduction in the probability of bank failure) of capital regulation." In terms of Elizalde and Repullo (2006), the efficiency aspect of our model apparently relates to the cost

Gordy and Howells (2006) argue that in order to curb the procyclical effect of Basel II the overall level of risk-based capital requirements should be set higher in booms and lower in downturns. This view gets support from our model as already pointed out in connection with Remark 2 which shows that optimal risk-based capital requirements are increasing in the level of interest rate. The level of real interest rate would increase with the business cycle e.g. in an economy in which the central bank follows the Taylor rule of monetary policy.

4.2 Consistency with Basel I changeover

The central motivation for introducing the common international capital standards in 1988 was to put a stop on banks' eroding capital bases and rapidly expanding lending as a result of tightening international bank competition. Furfine (2001) provides evidence that Basel I was successful in curbing lending growth. In the context of our model the changeover to Basel I could be interpreted as moving from the absence of capital requirements to a flat-rate capital regime. According to our Remark 1, such a change results in a reduction in the overall volume of lending. At the same time, Remark I also predicts that in such a change overinvestment in the high-risk projects increases. Concern about this latter possibility has indeed been a central motivator of the Basel Committee to launch the Basel II reform (see the discussion in the introduction). Flanery and Rangan (2004) argue that market discipline on banks has been fortified during the 1990's and that although banks' risk-taking may have increased it has been matched by banks' increased voluntary capital buffers. Nonetheless, the subprime debacle which started 2007 suggests that regulators' concern over excessive risk-taking was not unjustified. In sum, our model produces results which appear consistent with experiences also from the previous major change in international bank capital regulation.

4.3 Some robustness considerations

It is possible that the allocation in the credit markets could also be improved by other means than risk-based capital requirements, such as collateral arrangements between banks and the entrepreneurs. E.g. Besanko and Thakor's (1987) results indicate that in competitive banking markets, which we also study, collateral can be a meaningful sorting device. Nonetheless, collateral may not be available to small firms, especially if they are new and high-risk enterprises. Requiring a sufficient stake of self-financing from the entrepreneurs, which might be another way of improving the resource allocation, might not be feasible for the same reason as sufficient collateral requirements.

Finally, it is possible that overinvestment results depend on market structure; i.e., in our case on the degree of banking competition. The results of Koskinen et al. (2006) provide an example in this regard. They find in their study of venture capital financing that an original overinvestment problem may vanish when the relative bargaining

of credit; that is, socially optimal capital regulation should also, if possible, ensure efficient credit allocation through the price system. Of course, there could also be a trade-off between efficiency and financial stability.

power of the venture capitalist is improved. Nonetheless, we believe it is important to study competitive credit markets as a potential setting for credit distortions and hence as a threat to financial stability, as we have done in this paper. Indeed, intensified international banking competition has often been acknowledged as one potential source of the relatively more frequent periods of financial turmoil experienced globally in the last decades.

5 Concluding remarks

In this paper, we have investigated the effect of risk-based capital adequacy regulation, such as Basel II, on the efficiency of resource allocation in credit markets. Allocational efficiency is driven by entrepreneurs' self-selection among investments of different risk categories. The conventional result (e.g. De Meza and Webb, 1987) in this kind of setting is that there is too much risk-taking because high-type borrowers cross-subsidize low-type borrowers through the price system that is based on average success rates. We find that a flat-rate capital requirement regime (such as Basel I) exacerbates this problem and it allocates too much investment in high-risk projects. The risk-based capital requirements, in turn, alleviate the cross-subsidization effect, improving allocational efficiency in the credit market. The ability of Basel II type of capital requirements to improve allocational efficiency, formalized in this paper, is important also in the light of the view that excessive risks may tend to build up during good times (see eg Borio et al., 2001, and Rajan, 1994). Moreover, lower capital requirement against less risky loans increases entrepreneurs' general participation in the credit market, so that the overall lending volume is higher under the risk-based capital requirements than under the flat-rate regime. It is also shown that there exists a risk-based capital requirement schedule that implements both the first-best loan composition and the first-best lending volume. We argue that Basel II does not necessarily lead to exacerbation of macroeconomic cycles because the reduction in the suboptimally high proportion of high-risk investments, which may have resulted under Basel I, should mitigate the cyclicality of bank lending over the business cycle. Moreover, in our model the optimal overall level of risk-based capital requirements depend on the level of interest rates. If the real interest rate rises in economic upturns, which can be justified as a standard outcome from many macroeconomic models, then our result can be taken as support for recent arguments that the Basel II capital requirements should be refined by tying their overall level to the state of the business cycle; tightening in upturns and easing in downturns.

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