# 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 capital requirements on the allocation of credit and its interaction with procyclicality, and compare Basel I and Basel II type capital requirements. We consider competitive credit markets where entrepreneurs of varying ability can apply for loans for one-period investment projects of two different risk types. The risk of a project further depends on the state of the economy, modelled as a two-state Markov process. In this type of 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 risk-based capital requirements (such as Basel II) alleviate the cross-subsidization effect and can be chosen so as to implement first-best allocation. This implies that the ensuing reduction in the proportion of high-risk investments may mitigate the procyclical effect of Basel II on economic activity. Moreover, we find that optimal risk-based capital requirements should be set lower in recessions than in normal times. Our simulations show that when measured either with cumulative output or output variation, Basel II type capital requirements may in actuality be slightly less procyclical than flat capital requirements. The biggest reduction in procyclicality is achieved, however, with optimal risk-based capital requirements which are adjusted downwards in recession periods.

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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 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 is incorporated into 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. The Basel Committee (2001) has itself used a similar motivation for the reform. At the same time, however, it has been argued that a potentially serious drawback of risk-based

[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 3.

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 hard 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 been a central motivation for the Basel II reform, their potential interaction with Basel II's alleged procyclical impact has been less discussed. 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 probabilities and hence capital requirements 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. As a result, there would be less defaults and more moderate increase in capital requirements during a recession. Hence, the portfolio shift could constitute an attenuating effect on procyclicality of the new regime[4]. Moreover, this counterbalancing effect may be coupled with a more efficient allocation of credit obtained with the risk-based capital requirements.

In this paper we analyse in a simplified model the efficiency of resource allocation in the credit market under the flat-rate and the risk-based capital requirements. The model economy can be in one of two Markov states in each period, normal or recession, which evolve according to exogenously given transition probabilities. An adverse selection type of setup and the dynamic structure of the model enables us to analyze the different effects of capital requirements on economic activity and thus compare the procyclicality of the flat-rate and risk-based capital requirements. We construct a model where long-lived 'entrepreneurs' can in each period choose between investment projects of different risk characteristics, which last for one period, or they can decide not to take up a project at all. The macro state is unknown when investment and labor decisions are made. More specifically, we consider two uncertain investment opportunities, a 'high-risk' and a 'low-risk' investment, as well as an outside option (call it labor market) that produces a fixed payoff with certainty. Following De Meza and Webb (1987) and Vesala (2007), entrepreneurs' intrinsic and unobservable 'types' determine their success rates in the investment projects. High-risk projects are more sensitive to the entrepreneurial type than low-risk investments while the payoff in the labor market is independent of the intrinsic type. The success probabilities of the projects also depend on the macro state of the economy: in a recesssion, the success probabilities decline, and the success probability of a high-risk project declines more than the success probability of a low-risk project. If a project fails, the entrepreneur can start again with a new project, or choose the outside option, in the next period.

[4] 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".

However, aggregate economic activity in each period will be reduced by the lost output of the failed projects.

Let us consider the credit allocation problem of the economy in any single period. Efficient resource allocation is obtained when entrepreneurs with the highest types invest in high-risk projects which also offer the best payoff when successful. 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 entrepreneur 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. It is also important to note that our model differs from the models of relationship lending in which banks possess private information of the borrowers. However, we believe that our model of competitive banks with no private information of their borrowers is quite relevant especially in the context of lending booms when typically many new potential borrowers may seek bank financing. It is important to understand the effects of capital requirements on banks' risk taking in lending booms which have often been critical times in accumulating threats to banks' long-term stability.

The conventional result in this kind of setting is that there is too much risk-taking because higher-type borrowers cross-subsidize lower-type borrowers through the price system that is based on average success rates (De Meza and Webb, 1987).[5] 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 in-

[5] 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, 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, Asia and, indeed, the subprime crisis, appear to verify 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.

vestments 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.[6]It is also worth noting that at one level our paper provides a mechanism, i.e., risk-based capital requirements, to unwind the over-investment equilibrium which is a policy problem discussed already since the original work of De Meza and Webb (1987).

Importantly, we also find that the optimal risk-based capital requirements are decreasing in a recesssion. This results from the fact that in a recession the profitability of all projects declines as success probabilities decline. In order to implement the first-best number of projects as well as their first-best allocation to high and low-risk projects, risk-based capital requirements need to be set lower than in normal times. Moreover, optimal risk-based capital requirements should also decline in response to a potential increase in the banks' cost of equity capital in a recession (see also Kashyap and Stein, 2004). These results are consistent with the view that the overall level of 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 recent studies and policy discussions (see e.g. Goodhart, 2008, Gordy and Howells, 2006, Kashyap and Stein, 2004, Repullo and Suarez, 2008, and Risk, 2007).

The favorable allocational effects of risk-based capital requirements have implications for the procyclicality of risk-based capital requirements in comparison with flat-rate requirements. We illustrate these effects by simulating the economy over a business cycle which we define as a two-period recession before turning to normal. We investigate procyclicality of flat-rate capital requirements and Basel II type capital requirements in terms of output. Ouput is measured as labor income plus payoffs from successful projects minus the banks' opportunity cost. We assume that in normal times the average Basel II capital requirement is the same (eight percent) as in the flat-rate regime. Finally, we compare the two 'real-world' capital regimes, Basel I and Basel II, with the optimal risk-based capital requirements which are adjusted downwards in recessions.

The simulation results verify our conjecture that because risk-based capital requirements allocate less resources to high-risk projects, there are fewer unsuccessful projects when a recession hits than under the flat-rate regime. This effect contributes

[6] 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."

to a smaller output decline under risk-based capital requirements in the recesssion. As the recession continues we find that output still falls less under risk-based capital requirements than under the flat-rate regime. This is because two favorable allocational effects dominate the traditional procyclical effect that the number of projects that get financed in a recesssion declines *more* under risk-based capital requirements as a result of an increase in project failure probabilities which results in an increase in capital requirements. Overall, the Basel II regime appears slightly less procyclical than Basel I, both in terms of cumulative output and output variation. However, in our simulations, the optimal risk-based capital requirements which are adjusted downwards in recessions are clearly the least procyclical of all the capital requirement regimes considered.

So far, there have not been many papers which focus on the portfolio effects of risk-based capital requirements. The paper closest related to ours is the one by Boissay and Sorenssen (2009). Their main result is similar to ours in that a favorable allocational effect may attenuate procyclicality of bank lending and, ultimately, its effect on economic activity. They also build on the basic model of DeMeza and Webb (1987). However, unlike us, they do not consider capital requirements but banks' own capital management rules; either time-invariant or risk-sensitive. This allows them to use data on US banks which have arguably followed various capital management rules, in order to test their model.[7] 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.[8] 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. The difference between our paper and Repullo and Suarez (2004) is that while they focus on the division of high- and low-risk borrowers between different kind of banks using different options of Basel II, we focus on the allocation of high- and low-risk

[7] More precisely, Boissay and Sørensen (2009) consider a model in which all investment projects are similar but the capital requirements of the entrepreneurs can nevertheless differ, because some banks use loan rating and others do not. In the model the more competent entrepreneurs choose a bank which uses a costly rating technology and the less competent entrepreneurs opt for unrated loans. The authors point out an interesting effect, to which we shall refer as the *Boissay -Sørensen effect*, which reduces the procyclicality of rating-based capital requirements: if the rated loans become less attractive during recessions, the quality of the entrepreneurs who opt for unrated loans improves, and this reduces the interest rates for unrated loans (ibid., p. 8). It turns out that the Boissay -Sørensen effect has an analogy also in the current model.

Since the investment projects do not inherently differ from one another in the Boissay -Sørensen model, all entrepreneurs in their model could be induced to make the socially optimal choices with a Basel I type decision rule if the profitability of their projects did not change as a function of time. In this case a Basel II type requirement would always yield a lower welfare level than the optimal Basel I type requirement, since the use of a Basel II type requirement causes an extra cost of screening.

[8] 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.

projects among identical banks which all use the IRB approach. As in many countries a few large and sophisticated banks dominate the market share and are likely users of the IRB approach, we believe our focus is also relevant. 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 that banks can hold extra buffers of capital in excess of the minimum capital requirement and thereby alleviate procyclical effects. Repullo and Suarez (2008) 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). Studies have have investigated how Basel II type of regulation could be improved to reduce the procyclical effects. Kashyap and Stein (2004), Gordy and Howells (2006) and Repullo and Suarez (2008) suggest and consider time-varying capital requirements as a cure. Pennacchi (2005) argues that implications for deposit insurance losses should also be taken into account and suggests 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 describes the basic model and section 3 introduces banks to it. Secions 4 and 5 analyze the effects of flat-rate and risk-based capital requirements on the model equilibrium, respectively. Section 6 presents our simulation results, and section 7 concludes.

# 2 The model

We consider a discrete time model with periods $t = 0, 1, 2, ...$ in which the state of the economy is in each period either $N$ (normal) or $R$ (recession). During each period $t$, the probability that the economy is during the next period $t+1$ in the state $\sigma'$ (where $\sigma' \in \{N, R\}$) is determined by its state $\sigma$ ($\sigma \in \{N, R\}$) in the current period. This probability will below be denoted by $\gamma_{\sigma\sigma'}$ , and it will be assumed that $\gamma_{NN} > \gamma_{RN}$ and $\gamma_{RR} > \gamma_{NR}$ so that, the piece of information that the economy is in a state $\sigma$ in a given period increases the probability that the economy is in the same state also in the following period.

There is a continuum of entrepreneurs, indexed by $\theta$. The distribution of the parameter $\theta$ is given by a density function $g(\theta)$ which is non-zero only on $[0, 1]$. During each period $t$, the entrepreneur can be involved in a high-risk ($H$) or in a low-risk ($L$)

project, or in a riskless outside option. High-risk projects and low-risk projects both require investments, which must be financed by a bank. The entrepreneur must make a choice between these three options and the bank makes its financing decisions at the end of the previous period $t-1$, before the state of the economy in period $t$ is known.

The riskless outside option produces the wealth $w > 0$. The value $w$ is, for simplicity, assumed to be independent of the type $\theta$ of the entrepreneur and the state ($N$ or $R$) of the economy. The high-risk and the low-risk projects can either succeed or fail. The success probability of a project depends on *1)* the type $\eta \in \{H, L\}$ of the project, *2)* the current state $\sigma \in \{N, R\}$ of the economy, and *3)* the type $\theta$ of the enterpreneneur. The functions $\widetilde{p}_{\sigma\eta}(\theta)$ express the success probability of a project as a function of $\theta$ for each combination of the state of the economy (which is either $N$ or $R$) in the period in which the project is realized, and the type $\eta$ of the project (which is either $H$ or $L$).

Intuitively, the $\theta$ value of an entrepreneur has been meant to represent her competence, and in what follows it will be assumed that competence increases the chances of success of both kinds of projects, but that it is more crucial for the success of a high-risk project. Accordingly, we shall assume that both when $\sigma = N$ and when $\sigma = R$ (i.e. both when the state of the economy is normal and when it is recession)

$$\widetilde{p}\,'_{\sigma H}(\theta) > \widetilde{p}\,'_{\sigma L}(\theta) > 0 \tag{1}$$

The intuitive idea that high-risk projects have smaller chances of success than low-risk projects is captured by the assumption that[9]

$$0 < \widetilde{p}_{\sigma H}(\theta) \leq \widetilde{p}_{\sigma L}(\theta) \tag{2}$$

When an entrepreneur decides whether to start a project in the next period, she does not know the state of the economy in the next period, but only its current state. Accordingly, when the current state is normal ($N$), the success probability of a new project of type $\eta$ (where $\eta = L$ or $\eta = H$) is for the entrepreneur $\theta$

$$p_{N\eta}(\theta) = \gamma_{NN}\widetilde{p}_{N\eta}(\theta) + \gamma_{NR}\widetilde{p}_{R\eta}(\theta) \tag{3}$$

and when the current state is recession ($R$), the success probability of a new project is

$$p_{R\eta}(\theta) = \gamma_{RR}\widetilde{p}_{R\eta}(\theta) + \gamma_{RN}\widetilde{p}_{N\eta}(\theta) \tag{4}$$

If the entrepreneur $\theta$ has at the end of period $t-1$ chosen a project of type $\eta$ (where $\eta = L$ or $\eta = H$), the project produces $v_{\eta}(\theta)$ in period $t$ if it succeeds and nothing if it fails. The competence of an entrepreneur $\theta$ increases also the revenue $v_{\eta}(\theta)$ from a project either kind, and by assumption, its effects will be stronger in the case of a high-risk project. We shall not formulate these assumptions by stating

[9]To be more precise, the assumptions (1) and (2) imply that high-risk projects have a smaller chance of success than low-risk projects for all entrepreneurs, with the possible exception of the entrepreneur $\theta = 1$.

simply that $v'_H(\theta) > v'_L(\theta) > 0$; rather, we make the slightly stronger assumption that both when $\sigma = N$ and when $\sigma = R$

$$v'_H(\theta)\, p_{\sigma H}(\theta) > v'_L(\theta)\, p_{\sigma L}(\theta) > 0 \tag{5}$$

Below we shall restrict attention to the economically plausible equilibria in which in each period $t$ the least competent agents (agents in some interval $[0, \underline{\theta})$) choose the outside option, the most competent agents (agents in some interval $[\bar{\theta}, 1])$ choose the high-risk project, and there are also some agents in between who choose the low-risk project (i.e., $\underline{\theta} < \bar{\theta}$ and all agents in the interval $[\underline{\theta}, \bar{\theta})$ choose the low-risk project). Suppose now that the cut-off values which correspond to the projects that have been chosen at the end of some period $t-1$ are $\underline{\theta}$ and $\bar{\theta}$. As it will be explained in a more detailed manner in the next section, in the current model each successful entrepreneur $\theta$ with a project of type $\eta$ ($\eta = L, H$) will have to pay a sum $\rho_\eta$ to the bank in return for her investment. Here $\rho_\eta$ may depend on the cut-off values $\underline{\theta}$ and $\bar{\theta}$, but not on the $\theta$.value of the entrepreneur. Accordingly, if the project of an entrepreneur $\theta \in [\underline{\theta}, \bar{\theta})$ succeeds, her profit will be

$$\pi_L(\theta) = v_L(\theta) - \rho_L \tag{6}$$

and if the project of an entrepreneur $\theta \in [\bar{\theta}, 1]$ succeeds, her profit will be

$$\pi_H(\theta) = v_H(\theta) - \rho_H \tag{7}$$

By assumption, the utility function which each entrepreneur is maximizing while choosing between projects at the end of a period $t-1$ is given by her expected revenue in period $t$. Accordingly, the cut-off value $\underline{\theta}$ is the value for which the expected profit from a low-risk project is identical with the revenue from the outside option, and if in period $t-1$ the state of the economy is $\sigma$ ($\sigma \in \{N, R\}$), it satisfies the condition

$$p_{\sigma L}(\underline{\theta})\,(v_L(\theta) - \rho_L) = w \tag{E1}$$

Similarly, the cut-off value $\bar{\theta}$ is the value for which the expected profit from a low-risk project and a high-risk project are identical, and it is characterized by

$$p_{\sigma L}(\bar{\theta})\,(v_L(\theta) - \rho_L) = p_{\sigma H}(\bar{\theta})\,(v_H(\theta) - \rho_H) \tag{E2}$$

According to the following lemma, the assumptions (1), (2), and (5) suffice to guarantee that a combination of cut-off values $\underline{\theta}$ and $\bar{\theta}$ which satisfies (E1) and (E2) corresponds to the kind of Nash equilibrium that we are considering.

**Lemma 1** *Suppose that the probability functions $p_{\sigma\eta}(\theta)$ and the revenue functions $v_\eta(\theta)$ satisfy the conditions* (1) (2), *and* (5). *If the equilibrium conditions (E1) and (E2) are valid and $\underline{\theta} < \bar{\theta}$, the cut-off values $\underline{\theta}$ and $\bar{\theta}$ corresponds to a Nash equilibrium: in this case each entrepreneur $\theta < \underline{\theta}$ will maximize her revenue by choosing the outside option, each entrepreneur $\theta \in (\underline{\theta}, \bar{\theta})$ will maximize her revenue by choosing a low-risk* *project, and each entrepreneur $\theta > \bar{\theta}$ will maximize her revenue by choosing a high-risk project.*

**Proof.** See Appendix 1.

# 3 Banks

By assumption, the implementation of a new project requires an external finance of size $I$. This external funding can be obtained from competitive credit markets in which banks deliver standard debt contracts. When a bank makes its financing decision, it can by assumpion observe the current state (normal or recession) of the economy $\sigma$ and also the type $\eta$ (high-risk or low-risk) of the project, but not the type of the entrepreneur $\theta$.

Introducing the notation

$$p_{\sigma\eta,AV}\left(\theta_1,\theta_2\right) = \left(\int_{\theta_1}^{\theta_2} g\left(\theta\right) p_{\sigma\eta}\left(\theta\right) d\theta\right) / \left(\int_{\theta_1}^{\theta_2} g\left(\theta\right) d\theta\right) \tag{8}$$

for the average success probability that the entrepreneurs in the interval $[\theta_1, \theta_2]$ have in a project of type $\eta$ in the state of the economy $\sigma$, the success probability of a low-risk project is from the perspective of a bank given by

$$\hat{p}_{\sigma L} = p_{\sigma L,AV}\left(\underline{\theta}, \bar{\theta}\right) \tag{9}$$

and the success probabilty of a high-risk project is from the perspective of a bank given by

$$\hat{p}_{\sigma H} = p_{\sigma H,AV}\left(\bar{\theta}, 1\right) \tag{10}$$

If a bank invested $I$ units of financial capital elsewhere in the financial markets, it could by assumption earn $\bar{R}$, so that $\bar{R}$ represents the opportunity cost of finance. In addition, the regulator requires banks to raise costly equity capital. We normalize the riskless interest rate to zero, so that $\bar{R} = I$.

By assumption, banks are subject to a minimum capital requirement which is proportional to the size of the investment $I$. We shall assume that the 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 a 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.

We postulate that a bank can raise arbitrary amounts of deposits at the rate 0, whereas an excess return of $\delta > 0$ is required on each unit of equity capital. By assumption, there is a capital requirement according to which for each unit of the loans that are given, a part $b$ must be funded by equity, and only a part $1 - b$ may be funded by deposits. Under flat-rate capital requirement, $b$ has the same value for all projects, but under risk-based capital requirements $b = b\left(\hat{p}_{\sigma\eta}\right)$ is a function of the probability of success $\hat{p}_{\sigma\eta}$ that the bank perceives the project to have.

By assumption, the banks receive nothing in repayment from the customers who go bankrupt, so that the repayment $\rho_\eta$ from the non-bankrupt entrepreneurs who have chosen a project of type $\eta$ must satisfy the condition

$$\widehat{p}_{\sigma\eta}\rho_\eta = (1-b)\,\bar{R} + b\,(1+\delta)\,\bar{R} \tag{11}$$

Hence, the repayment $\rho_\eta$ is given by

$$\rho_\eta = \frac{(1-b)\,\bar{R} + b\,(1+\delta)\,\bar{R}}{\widehat{p}_{\sigma\eta}} = \frac{(1+b\delta)\,\bar{R}}{\widehat{p}_{\sigma\eta}} \tag{12}$$

Now the equilibrium conditions (E1) and (E2) can be rewritten as follows:

$$p_{\sigma L}\left(\underline{\theta}\right)\left(v_L\left(\underline{\theta}\right) - \frac{\left(1 + b\left(\hat{p}_{\sigma L}\right)\delta\right)\bar{R}}{\widehat{p}_{\sigma L}}\right) = w \tag{E1'}$$

$$p_{\sigma L}\left(\bar{\theta}\right)\left(v_L\left(\bar{\theta}\right) - \frac{\left(1 + b\left(\hat{p}_{\sigma L}\right)\delta\right)\bar{R}}{\widehat{p}_{\sigma L}}\right) = p_{\sigma H}\left(\bar{\theta}\right)\left(v_H\left(\bar{\theta}\right) - \frac{\left(1 + b\left(\hat{p}_{\sigma H}\right)\delta\right)\bar{R}}{\widehat{p}_{\sigma H}}\right) \tag{E2'}$$

As our next step, we define the concept of a *first-best capital requirement*, and constrast it with a flat-rate (Basel I type) capital requirement for which $b$ is a constant.

# 4 Flat-Rate Capital Requirements and the First-Best Equilibrium

By definition, a capital requirement is *first-best* if it yields an allocation of resources which corresponds to the maximal expected welfare gain relative to the information which is available when the projects are launched. More precisely, the expected welfare gain which results from the agent $\theta$ getting involved in a project of type $\eta$ when the current state of the economy is $\sigma$ is by definition

$p_{\sigma\eta}\left(\theta\right) v_\eta\left(\theta\right) - \bar{R}$

and the welfare gain from the outside option is by definition $w$, so that the socially optimal cut-off values $\underline{\theta}^{fb}$ and $\bar{\theta}^{fb}$ can be defined as

$$p_{\sigma L}\left(\underline{\theta}^{fb}\right) v_L\left(\underline{\theta}^{fb}\right) - \bar{R} = w \tag{13}$$

and

$$p_{\sigma L}\left(\bar{\theta}^{fb}\right) v_L\left(\bar{\theta}^{fb}\right) = p_{\sigma H}\left(\bar{\theta}^{fb}\right) v_H\left(\bar{\theta}^{fb}\right) \tag{14}$$

If such cut-off values exist in the first-best allocation, it is socially optimal for the most competent entrepreneurs to choose the high-risk project, so that

$$w < p_{\sigma L}(\theta) v_L(\theta) - \bar{R} < p_{\sigma H}(\theta) v_H(\theta) - \bar{R}, \quad \text{when } \theta > \bar{\theta}^{fb} \tag{15}$$

whereas for the least competent entrepreneurs it is socially optimal to choose the outside option, so that

$$p_{\sigma H}(\theta) v_H(\theta) - \bar{R} < p_{\sigma L}(\theta) v_L(\theta) - \bar{R} < w, \text{ when } \theta < \underline{\theta}^{fb}. \tag{16}$$

Under a flat-rate capital requirement $b$ is a constant regardless of the type of the investment. Denoting the cut-off values which correspond to a flat-rate capital requirement by $\underline{\theta}^{FR}$ and $\bar{\theta}^{FR}$, the equilibrium condition (E2' ) is seen to be in this case equivalent with

$$p_{\sigma H}\left(\bar{\theta}^{FR}\right) v_H\left(\bar{\theta}^{FR}\right) - p_{\sigma L}\left(\bar{\theta}^{FR}\right) v_L\left(\bar{\theta}^{FR}\right) = \left(\frac{p_{\sigma H}\left(\bar{\theta}^{FR}\right)}{\hat{p}_{\sigma H}} - \frac{p_{\sigma L}\left(\bar{\theta}^{FR}\right)}{\hat{p}_{\sigma L}}\right)(1 + b\delta)\bar{R} \tag{17}$$

**Proposition 1** *Under a flat-rate capital requirement, there is overinvestment in high-risk projects as entrepreneurs with inefficiently low success rates choose them; i.e.,* $\overline{\theta}^{FR} < \overline{\theta}^{fb}$.

**Proof**: When $\underline{\theta} = \underline{\theta}^{FR}$ and $\bar{\theta} = \bar{\theta}^{FR}$, the definitions (8), (9), and (10) imply that

$p_{\sigma L}\left(\bar{\theta}^{FR}\right) > \widehat{p}_{\sigma L}$ and $p_{\sigma H}\left(\bar{\theta}^{FR}\right) < \widehat{p}_{\sigma H}$

and further that

$\frac{p_{\sigma H}\left(\bar{\theta}^{FR}\right)}{\widehat{p}_{\sigma H}} - \frac{p_{\sigma L}\left(\bar{\theta}^{FR}\right)}{\widehat{p}_{\sigma L}} < 0$

Together with (17) this result implies that

$p_{\sigma H}\left(\bar{\theta}^{FR}\right) v_H\left(\bar{\theta}^{FR}\right) < p_{\sigma L}\left(\bar{\theta}^{FR}\right) v_L\left(\bar{\theta}^{FR}\right)$

Hence, $\bar{\theta}^{FR}$ lies in the region in which it would be socially optimal to choose the low-risk project, and $\bar{\theta}^{FR} < \bar{\theta}^{fb}$.■

The equation (17) shows that the overinvestment problem would exist also without any extra capital requirement, i.e., in the laissez-faire situation in which $b = 0$. This is the conventional DeMeza-Webb (1987) overinvestment result, and it stems from the fact that the more competent entrepreneurs investing in high-risk projects cross-subsidize the less competent ones who invest in similar projects, since the interest rates reflect average success rates. The overinvestment mechanism is based on positive levels of the altervative cost $\bar{R}$, which causes a limited liability effect on the entrepreneurs and spurs risk-taking. Indeed, note from equation (17) that if $\bar{R}$ was zero, the first-best equilibrium would obtain.

An increase in a flat-rate capital requirement $b$ has a two-fold effect on the equilibrium cut-off values $\bar{\theta}^{FR}$. Firstly, it has the direct effect of decreasing the profitability of both low-risk and high-risk projects. According to the proof of Proposition 1,

$\frac{p_{\sigma H}\left(\bar{\theta}^{FR}\right)}{\widehat{p}_{\sigma H}} - \frac{p_{\sigma L}\left(\bar{\theta}^{FR}\right)}{\widehat{p}_{\sigma L}} < 0$

so that the direct effect tends to decrease the left-hand side of (17). This effect corresponds to a decrease in $\bar{\theta}^{FR}$, and it makes a high-risk project seem more attractive.

On the other hand, an increase of $b$ tends to increase also $\underline{\theta}^{FR}$ which shows up as an increase of $\widehat{p}_{\sigma L}$ and of the left-hand side of $(E2')$. Intuitively, this means that as the lowest-quality entrepreneurs turn to the outside option, the quality of the remaining entrepreneurs rises and this lowers the interest rates for the low-risk projects. In this way, the low-risk projects become more attractive for the more competent entrepreneurs, which tends to increase $\bar{\theta}^{FR}$. This interconnection between $\underline{\theta}^{FB}$ and $\bar{\theta}^{FR}$ constitutes an analogy of the Boissay - Sørensen effect in the current model (see footnote 7 above).

There seem to be no general and elegant theorems concerning the relative magnitudes of these two effects. In the simulations whose results we report in Section 6.2 the two effects cancel each other out almost exactly, but in other simulations it has turned out that an increase in $b$ causes a slight increase in the cut-off value $\bar{\theta}^{FR}$.

The equilibrium condition $(E1')$, which characterizes the lower cut-off value, receives in the context of a flat-rate capital requirement the form

$$p_{\sigma L}\left(\underline{\theta}^{FR}\right) v_L\left(\underline{\theta}^{FR}\right) - w - \bar{R} = \frac{p_{\sigma L}\left(\underline{\theta}^{FR}\right)}{\hat{p}_{\sigma L}} b\delta\bar{R} - \left(\frac{\hat{p}_{\sigma L} - p_{\sigma L}\left(\underline{\theta}^{FR}\right)}{\hat{p}_{\sigma L}}\right)\bar{R} \tag{18}$$

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

$b = \frac{1}{\delta}\left(\frac{\hat{p}_{\sigma L}}{p_{\sigma L}\left(\underline{\theta}^{fb}\right)} - 1\right) \equiv b^{fb}$

If $b < b^{fb}$, entrepreneurs with inefficiently low success rates choose to invest in low-risk projects. On the other hand, if $b > b^{fb}$, too many entrepreneurs opt to choose the fixed payoff. Since the extra capital requirement does not hit the payoff from the fixed outside option, $b$ can be used to limit market participation. At the margin in which the entrepreneurs are indifferent between taking up a low-risk investment and opting for the safe payoff the capital requirement reduces the incentive to invest and thus alleviates the excess market entry due to the cross-subsidization effect. The value $b^{fb}$ is exactly the level of regulatory capital that implements the first-best division.

# 5 Risk-based capital requirements

Under the risk-based capital requirements $b = b\left(\widehat{p}_{\sigma\eta}\right)$, so that the value of the capital requirement is different for the high-risk ($\eta = H$) and the low-risk ($\eta = L$) investments. Introducing the notations $b_H = b\left(\widehat{p}_{\sigma H}\right)$ and $b_L = b\left(\widehat{p}_{\sigma L}\right)$ for the two capital requirements which are in use simulaneously, the equilibrium condition $(E2')$ can be written in the form

$$\begin{aligned} & p_{\sigma H}\left(\bar{\theta}\right) v_H\left(\bar{\theta}\right) - p_{\sigma L}\left(\bar{\theta}\right) v_L\left(\bar{\theta}\right) \qquad (19) \\ = & \left(\frac{p_{\sigma H}\left(\bar{\theta}\right)}{\widehat{p}_{\sigma H}} - \frac{p_{\sigma L}\left(\bar{\theta}\right)}{\widehat{p}_{\sigma L}}\right)\left(1 + b_L\delta\right)\bar{R} + \frac{p_{\sigma H}\left(\bar{\theta}\right)}{\widehat{p}_{\sigma H}}\delta\bar{R}\left(b_H - b_L\right) \end{aligned}$$

Similarly, the condition $(E1')$ can be put into the form

$$p_{\sigma L}\left(\underline{\theta}\right) v_L\left(\underline{\theta}\right) - \bar{R} - w = \left(\frac{p_{\sigma L}\left(\underline{\theta}\right)}{\widehat{p}_{\sigma L}}\delta\bar{R}\right) b_L - \frac{\widehat{p}_{\sigma L} - p_{\sigma L}\left(\underline{\theta}\right)}{\widehat{p}_{\sigma L}}\bar{R} \qquad (20)$$

**Remark 2** *Risk-based capital requirement yields the efficient cut-offs* $\bar{\theta} = \bar{\theta}^{fb}$ *and* $\underline{\theta} = \underline{\theta}^{fb}$ *if*

$$\begin{aligned} b_L &= \frac{1}{\delta}\frac{\widehat{p}_{\sigma L} - p_{\sigma L}\left(\underline{\theta}\right)}{p_{\sigma L}\left(\underline{\theta}\right)} \\ b_H &= \frac{1}{\delta}\left(\frac{\widehat{p}_{\sigma H}}{p_{\sigma H}\left(\bar{\theta}\right)}\frac{p_{\sigma L}\left(\bar{\theta}\right)}{p_{\sigma L}\left(\underline{\theta}\right)} - 1\right) \end{aligned}$$

Proof: Follows directly from (13),(14), (19)and (20).■

This remark states that, contrary to the flat-rate regime, there exists a risk-based capital requirement schedule which implements both the first-best loan composition and the first-best lending volume. This is because the risk-based system offers as many independent instruments which affect allocational efficiency as there are different loan categories. The differentiation of capital requirements for high-risk and low-risk projects makes it possible to increase the cost of the high-risk project relative to the low-risk project in order to discourage interim type entrepreneurs from taking the high-risk project. This is not the case under a fixed capital requirement, which provides only a single instrument, so that efficiency can be obtained only at the margin where entrepreneurs are indifferent between investment and the safe outside option.

# 6 Simulation results

## 6.1 Specifying the success probabilities and parameter values

In the simulations whose results are discussed below it has been postulated that the density of the $\theta$ values among the entrepreneurs is given by the constant function

$g(\theta) = 1$. The success probabilities of both low-risk and high-risk projects have been specified as linear functions of $\theta$, so that $\widetilde{p}_{\sigma L}{}'(\theta)$ and $\widetilde{p}_{\sigma H}{}'(\theta)$ are constants. We have made the idealizing assumptions that when the state of the economy is normal, the most competent entrepreneur (the one for whom $\theta = 1$) will always succeed in the project that she chooses. Accordingly, it is postulated that in normal times, the success probabilities of both high-risk ($\eta = H$) and low-risk ($\eta = L$) projects have the simple linear specifications

$$\widetilde{p}_{N\eta}(\theta) = 1 - B_\eta (1 - \theta) \tag{21}$$

where $B_L$ and $B_H$ are constants. By assumption, the success probability of a low-risk project is reduced by a factor $\widetilde{\xi}$ and the success probability of a high-risk project is lowered by a factor $\widetilde{\zeta}$ in a recession, so that

$$\widetilde{p}_{RL}(\theta) = \widetilde{\xi}\widetilde{p}_{NL}(\theta) \tag{22}$$

and

$$\widetilde{p}_{RH}(\theta) = \widetilde{\zeta}\widetilde{p}_{NH}(\theta) \tag{23}$$

In the simulations the values of $B_L, B_H, \widetilde{\zeta}$, and $\widetilde{\xi}$ have been chosen so that $B_L\widetilde{\xi} < B_H\widetilde{\zeta}$ and $\widetilde{\zeta} < \widetilde{\xi} < 1$, so that the assumptions (1) and (2) are valid for the chosen functions $\widetilde{p}_{\sigma\eta}$. Intuitively, the assumption $\widetilde{\zeta} < \widetilde{\xi} < 1$ means that the success probabilities of the high-risk projects decline in recessions more than the success probabilities of the low-risk projects[10].

The maximum value of the revenue from a project of type $\eta$ is denoted by $V_{1,\eta}$, so that for both $\eta = L, H$

$v_\eta(1) = V_{1,\eta}$

Also the functions $v_\eta(\theta)$ will be given a linear specification, so that

$$v_\eta(\theta) = V_{1,\eta} - C_\eta (1 - \theta) \tag{24}$$

where $C_H$ and $C_L$ will be chosen so that $C_H/C_L$ is sufficiently large to make the assumption (5)valid for the entrepreneurs who choose high-risk projects.

We normalize the value of the outside option $w$ to 1. Following Repullo-Suarez (2008, p. 20), the excess return of $\delta$ which is required for equity capital has been set to $\delta = 0.04$, and the transition probabilities between the two states of the economy have been given the following values:

$$\begin{cases} \gamma_{NN} = 0.8 \\ \gamma_{NR} = 0.2 \\ \gamma_{RN} = 0.36 \\ \gamma_{RR} = 0.64 \end{cases}$$

We have also postulated that a recession decreases the chances of success of a high-risk project by 5% and those of a low-risk project by 1%, so that $\widetilde{\xi} = 0.99$ and $\widetilde{\zeta} = 0.95$.

[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.

The rest of the parameters of the model are not easily observable. We have calibrated them using estimates for a number of more directly observable features of the economy during a normal state. The features which we have used for calibration include *1)* the ratio between the number $n_H$ of high-risk projects and the number $n_L$ of low projects $n_H/n_L$, *2)* actual success rates (i.e. rates of not going bankrupt) of both low-risk (L) and high-risk (H) firms, $\widetilde{p}_{NL,AV}$ and $\widetilde{p}_{NH,AV}$, 3) the average profits per employee $\pi_{NL,av}$ and $\pi_{NH,av}$ of both low-risk and high-risk non-bankrupt firms, and 4) the average turn-over per employee $\upsilon_{NL,av}$ of non-bankrupt low-risk firms.

Table 1 lists the values of these quantities, together with the parameters whose values have already been fixed above. Since in the intended application of the model there is a relatively large share of potential enterpreneurs who might reasonably choose a low-risk project, whereas an essentially smaller share of the potential enterpreneurs has a realistic chance of succeeding in a high-risk project, we have postulated that $n_H/n_L = 1/3$. We have used various sources of information as well as judgement in order to obtain reasonable values for the rest of the quantities which are listed in Table 1. For instance, in calibrating the average normal time profits of the different project types, we have used tax authorities' recent information from Finland that on the average entrepreneurial income is approximately one third higher than the average salary income.

| $\gamma_{NN}$ | $\gamma_{RN}$ | $w$ | $\widetilde{\xi}$ | $\widetilde{\zeta}$ | $n_H/n_L$ | $\widetilde{p}_{NL,AV}$ | $\widetilde{p}_{NH,AV}$ | $\pi_{NL,av}$ | $\pi_{NH,av}$ | $\upsilon_{NL,av}$ | $\delta$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.8 | 0.36 | 1 | 0.99 | 0.95 | 1/3 | 0.99 | 0.98 | 1.2 | 2 | 6 | 0.04 |

**Table 1**. The observable features of the economy which have been used for calibrating the parameter values.

The task of calibrating the remaing parameter values to the values which appear in Table 1 is made more difficult by the fact that the formulas which connect them contain also the capital requirements whose effects we wish to compare.. Since we just wish to find parameter values which roughly fit the empirical evidence, we deduce the missing values by assuming that the values in Table 1 apply to a laissez-faire case in which there are no capital requirements (i.e., $b = 0$ for both low-risk and high-risk projects), and the state of the economy is normal in both the current period $t$ and the previous period $t - 1$.

In the simulations $B_L$ and $B_H$ have been given values which are sufficiently large to guarantee that the entrepreneur $\theta = 0$ always chooses the outside option, independently of the state of the economy. When this is the case, the value of $B_L$ can be viewed as fixing the limit between the economic agents who are viewed as *potential* entrepreneurs (despite of the fact that they never choose to become actual entrepreneurs, due to their low chances of success), and individuals who are not included in the model, since they are not viewed as entrepreneurs even potentially. This limit may be chosen by convention; below we have chosen $B_L = 0.1$, implying that $\widetilde{p}_{NL}(\theta) = 0.9$ for the least competent individual $\theta = 0$ who still qualifies as a potential entrepreneur.

It turn out that the six parameter values which are still missing after this conventional definition (i.e. $\bar{R}$, $B_H$, $C_L$, $C_H$, $V_{1,L}$, and $V_{1,H}$) are uniquely determined by the six values which appear in Table 1 and which are not parameters of the model (i.e. $n_H/n_L$, $\widetilde{p}_{NH,AV}$, $\widetilde{p}_{NH,AV}$, $\pi_{NL,av}$, $\pi_{NH,av}$, and $\upsilon_{NL,av}$). These values have been listed in

Table 2. The procedure for calculating these values has been outlined in Appendix 2.

| $\bar{R}$ | $B_L$ | $B_H$ | $C_L$ | $C_H$ | $V_{1,L}$ | $V_{1,H}$ |
|---|---|---|---|---|---|---|
| 4.7425 | 0.1 | 1 | 3.0223 | 27.5955 | 6.3019 | 7.4363 |

**Table 2**. The rest of the parameter values that have been used in the simulations

The simulations contrast the laissez-faire situation with three other capital requirement regimes. We have considered a Basel I type flat-rate capital requirement $b = 0.08$, a counterpart of the real-world Basel II type requirement, and the "first-best capital requirement" which has been described in Remark 2. The counterpart of the real world Basel II requirement has been taken to be a requirement which is determined in accordance with the Basel II formula (see Basel Committee on Banking Supervision, 2006), i.e. in accordance with

$$b(p) = \lambda\Phi\left(\frac{\Phi^{-1}(p) + \sqrt{\rho}\Phi^{-1}(0.999)}{\sqrt{1-\rho}}\right) \tag{25}$$

where

$$\rho = 0.12\left(2 - \frac{1-e^{-50p}}{1-e^{-50}}\right) \tag{26}$$

and $p = 1 - \widehat{p}_{\sigma\eta}$ is the perceived probability of default of a project of type $\eta$, when the state of the economy is $\sigma$. For simplicity, the loss given default parameter $\lambda$ has been calibrated so that in a persisting normal state the average capital requirement is identical with the Basel I capital requirement $b = 0.08$. This follows a stated goal of the Basel Committee, according to which the average capital requirement in the banking sector should not change as a result of the changeover from Basel I to Basel II, and which has been implemented by a separate calibration factor in the Basel II framework.

## 6.2 Results

We simulated the model for eight periods and assumed that there is a two-period recession which starts in the third period of the simulation. After that the economy returns to the normal macro state. Figure 1 depicts the evolution of the capital requirements we have used in each of the four regimes. Note that the capital requirement of the high-risk project increases more as a result of the recession than the capital requirement of the low-risk project[11]. This follows directly from our assumption that the success probabilities of the high-risk projects decline more in recessions than the success probabilities of the low-risk projects. It should also be noted that capital requirements rise as a result of the recession first in the second recession period (i.e. in period 4) because capital requirements for projects that are implemented in any given period are determined already in the previous period and are hence conditional on the then prevailing macro state. The most dramatic difference is, however, in the optimal

[11] The Basel II capital requirement for the low-risk project increases from approximately 7 to 8 per cent from normal to a recesssion period and the capital requirement of the high-risk project increases correspondingly from about 10.5 per cent to 13 per cent.

risk-based capital requirements. The capital requirement for both the low-risk and the high-risk project is higher than any other capital requirement and, moreover, the optimal capital requirement of the high-risk project is approximately 76 per cent in normal times (declining to 70 per cent in the recession). Although this seems unrealistic, we have to remember that in our model framework capital requirements have only the role of guiding resource allocation via banks' loan pricing. This allocational effect ultimately stems from the premium paid on equity capital which is 4 per cent in our calibration. If the difference in capital requirements between low-risk and high-risk project is about 60 percentage points, this means that the high-risk project should have 2.4 percentage points (0.6 times 4 per cent) higher loan price margin, which is quite plausible.

Figures 2a and 2b illustrate how the threshold entrepreneur types vary over the business cycle in the different capital requirement regimes. These results are well in line with our theoretical predictions in sections 2-5. Consider figure 2a which depicts the lower threshold type which indicates the sum of entrepreneurs in both low-risk and high-risk projects. Compared to the optimal requirement, the zero capital requirement laissez-faire regime allocates most excess resources to entrepreneurial activity. Basel I and Basel II are very close to one another with Basel II allocating slightly more resourcs to total investment projects. Figure 2b gives the threshold entrepreneur of the high-risk project. The laissez-faire and Basel I regimes are now indistinguishable while Basel II allocates slighty less resources to high-risk projects (its high-risk threshold type is higher). Yet they all clearly allocate excessive resources to high-risk projects compared to the optimal allocation given by the optimal capital requirement regime.

In table 3 and figure 3 we provide evidence of the procyclicality of the various capital requirement regimes. For each simulation period from 1 to 8 we report the output in each regime. Output would equal one hundred (100) if all agents chose the outside option. As we can thus see, normal times' output is about 6 per cent higher in each regime, as a result of entrepreneurial activity, than the benchmark output of 100. Output drops by a bit less than two per cent between period 2 and 3 when the economy falls into recession. This suggests that our model calibration is able to produce a plausible magnitude of business cycle fluctuation.

We summarize the procyclicality of the various capital requirement regimes over the simulation sample with two measures; cumulative output over the eight periods and the standard deviation of output. Both measures result in the same ranking that the laissez-faire regime is the most procyclical, followed by Basel I. Basel II is slightly less procyclical than Basel I while the optimal risk-based capital requirements are the least procyclical.

Quantitative differences between the regimes are very small. The percentual difference between Basel I and Basel II in the drop of output in the first recession period is negligible. The difference between Basel II and optimal capital requirements is 0.12 percentage points. In any case, we believe that it is more essential to focus on the qualitative differences between the regimes. After all, the financial crisis of 2007 and 2008 has shown as some authors have suggested (see e.g. Acharya and Schnabl, 2009) that distorted investment incentives related to capital requirements can under some circumstances lead to very serious misallocations. Then again, the result that the quantitative differences between different capital regimes are only very small could also indicate that in the course of normal business cycle fluctuations, the procyclical effects of capital requirements should not be exaggerated.

Let us take a closer look at Basel I and Basel II regimes in table 3 and figure 3. The results verify our expectation that because risk-based capital requirements allocate less resources to high-risk projects (cf. figure 2), there are fewer unsuccessful projects and hence higher output when a recession hits than under the flat-rate regime. As the recession continues for the second period (period 4), output is still higher under Basel II than under Basel I. This is a result of three different effects. First, consistent with the traditional procyclical effect the number of projects that get financed in a recesssion declines *more* under risk-based capital requirements because project failure probabilities and thus capital requirements increase. However, this effect is dominated by two opposing effects. The first of them is the favorable allocation effect that the share of high-risk projects continues to be smaller in each period under risk-based capital requirements. The second effect is the more subtle Boissay-Sørensen (2009) effect (cf. footnote 7 above). Because in a recession the success probabilities of high-risk projects decline relatively more than those of low-risk projects, the number of high-risk projects is also reduced relatively more under risk-based capital requirements. As a result, more higher-type entrepreneurs choose the low-risk project which improves the average success rate of the low-risk projects. Note that in the fifth period, the first normal period after recession, the output ranking of all regimes is actually reversed for that one period only. The reason for this is that returning to normal is a positive 'surprise' to the economy in the sense that investment decisions in the previous periods were still done in an on-going recession. So in the first period after the recesssion, those capital requirement regimes that allocated resources most excessively, particularly to high-risk investment projects, benefit the most of the higher success rates which materialized in the fifth period.

Taken together, our results may be somewhat surprising in that, in contrast with prior views, capital requirements tend to reduce procyclicality of the economy. This is the case already when moving from no capital requirements to the flat-rate regime. Moreover, the more risk-sensitive Basel II is less procyclical than the flat-rate Basel I. These outcomes result from the better allocational properties of flat-rate capital requirements vis-á-vis no capital requirements as well as the better allocational properties of risk-based capital requirements vis-á-vis flat-rate requirements. What is in line also with prior views is that by adjusting risk-based capital requirements downwards in recessions, as opposed to the current Basel II in which capital requirements increase in recessions, procyclicality is further dampened.

# 7 Conclusion

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. Our model has a simple dynamic setting with two exogenously determined Markov macro states so that we are also able to analyze the effects on procyclicality of the risk-based capital requirements vis-á-vis flat-rate capital requirements. 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. 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 in the light of the view that excessive risks may tend to build up during good times. 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. Such optimal risk-based capital requirements should be set lower in recesssions than in normal times. It is worth emphasizing that optimal capital requirements that are adjusted downwards in recessions are obtained endogenously in our model framework (see also Kashyap and Stein, 2004). In much of the literature the implications of recession-adjusted capital requirements, which is also an important policy question, have been studied by exogenously adding the adjustment rule to capital requirements.

Simulations with the calibrated model support the view that allocational effects of different capital requirement regimes should be taken into account when comparing their procyclical properties. In actuality, Basel II type capital requirements appear slightly less procyclical than the flat-rate Basel I requirements. Moreover, we find strong indications that optimally chosen risk-based capital requirements which, overall, are much higher but which are set relatively lower in recessions, are less procyclical both in terms of cumulative output and output variation over the business cycle. These results support the view that the current Basel II framework could be further improved by making capital requirements a function of the state of the business cycle. This should be done by taking into account how the state of the business cycle has an effect on the profitability of investment projects.

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# Appendix 1. Proof of Lemma 1

If the entrepreneur $\theta$ chooses a project of type $\eta$ in a period in which the state of the economy is $\sigma$, the expected revenue from it is

$E(\pi_\eta(\theta)) = p_{\sigma\eta}(\underline{\theta})\left(v_\eta(\theta) - \rho_\eta\right)$

The definitions (3), and (4) immediately imply that the conditions (1) and (2) are valid also for the probabilities $p_{\sigma\eta}$.

Let $\theta_{\min,\eta}$ be the smallest value of $\theta$ in $[0,1]$ for which the revenue from a successful project of type $\eta$, $v_\eta(\theta) - \rho_\eta$, is non-negative. Assume first that $\theta \geq \theta_{\min,L}$. Clearly, the conditions (1) and (5) imply that

$$\frac{dE(\pi_L(\theta))}{d\theta} = p'_{\sigma L}(\underline{\theta})(v_L(\theta) - \rho_L) + p_{\sigma L}(\underline{\theta})\, v'_L(\theta) > 0 \tag{27}$$

Since $\underline{\theta}$ is the value of $\theta$ for which $E(\pi_\eta(\theta)) = w$,

*a low-risk project is preferable to the outside option for the agent $\theta$ if $\theta > \underline{\theta}$, and the converse is true when $\theta < \underline{\theta}$.*

Assume next that $\theta \geq \theta_{\min,H}$. The conditions (1) and (2) imply that

$\frac{p'_{\sigma H}(\theta)}{p_{\sigma H}(\theta)} > \frac{p'_{\sigma L}(\theta)}{p_{\sigma L}(\theta)}$

which is equivalent with

$\frac{d}{d\theta}\left(\frac{p_{\sigma H}(\theta)}{p_{\sigma L}(\theta)}\right) > 0.$

Hence, when $\theta \geq \theta_{\min,H}$ so that $E(\pi_H(\theta))$ is not negative, (1) and (5) imply that

$$\frac{d}{d\theta}\left(\frac{E(\pi_H(\theta))}{p_{\sigma L}(\theta)}\right) = \frac{d}{d\theta}\left(\frac{p_{\sigma H}(\theta)}{p_{\sigma L}(\theta)}(v_H(\theta) - \rho_H)\right) = \tag{28}$$

$\frac{d}{d\theta}\left(\frac{p_{\sigma H}(\theta)}{p_{\sigma L}(\theta)}\right)(v_H(\theta) - \rho_H) + \frac{p_{\sigma H}(\theta)}{p_{\sigma L}(\theta)} v'_H(\theta) > v'_L(\theta) = \frac{d}{d\theta}\left(\frac{E(\pi_L(\theta))}{p_{\sigma L}(\theta)}\right)$

Hence, when $\theta > \bar{\theta}$, $E\left(\pi_H\left(\bar{\theta}\right)\right)/p_{\sigma L}(\theta) > E\left(\pi_L\left(\bar{\theta}\right)\right)/p_{\sigma L}(\theta)$ and when $\theta < \bar{\theta}$, $E\left(\pi_H\left(\bar{\theta}\right)\right)/p_{\sigma L}(\theta) < E\left(\pi_L\left(\bar{\theta}\right)\right)/p_{\sigma L}(\theta)$. Multiplying each of these results by $p_{\sigma L}(\theta)$, it follows that

*when $\theta > \bar{\theta}$, a high-risk project is preferable to a low-risk project for the entrepreneur $\theta$, whereas when $\theta < \bar{\theta}$ either a low-risk project or the outside option is prefereable to a high-risk project.*

The lemma follows by combining the two italicized conclusions.□

# Appendix 2. The procedure for fixing the parameters of the model.

In what follows we shall ouline the procedure with which one arrives from the observable values in Table 1 to the parameters in Table 2.

First, it is observed that the values $\widetilde{p}_{N\eta,AV}$ which describe the actual success rates of projects suffice to determine the values $\widehat{p}_{N\eta}$ since (3), (22) − (23), and (8) − (10) imply that

$$\widehat{p}_{NL} = \left(\gamma_{NN} + \gamma_{NR}\widetilde{\xi}\right)\widetilde{p}_{NL,AV}$$

and

$$\widehat{p}_{NH} = \left(\gamma_{NN} + \gamma_{NR}\widetilde{\zeta}\right)\widetilde{p}_{NH,AV}$$

By taking averages in (6) and using (12), it follows that

$$\pi_{NL,av} = v_{NL,av} - \frac{\bar{R}}{\widehat{p}_{NL}}$$

after which the value of $\bar{R}$ can be solved as

$$\bar{R} = \widehat{p}_{NL}\left(v_{NL,av} - \pi_{NL,av}\right)$$

In a next step, it is observed that the values $\underline{\theta}$ and $\bar{\theta}$ are connected by the two linear equations

$$\widetilde{p}_{NL,AV} = 1 - B_L\left(1 - \frac{\underline{\theta}+\bar{\theta}}{2}\right)$$

and

$$\left(n_H/n_L\right)\left(\bar{\theta} - \underline{\theta}\right) = 1 - \bar{\theta}$$

from which one may solve $\underline{\theta}$ and $\bar{\theta}$. When both $\bar{\theta}$ and $\bar{R}$ are known, the equilibrium condition $(E1')$, i.e.

$$p_{\sigma L}\left(\underline{\theta}\right)\left(v_L\left(\underline{\theta}\right) - \frac{\bar{R}}{\widehat{p}_{\sigma L}}\right) = w$$

can be solved relative to $v_L\left(\underline{\theta}\right)$.

In what follows the value of $\theta$ for which $v_\eta\left(\theta\right) = v_{N\eta,av}$ (where $\eta = L, H$) will be denoted by $\theta = \widehat{\theta}_\eta$. The value of $\widehat{\theta}_L$ can be determined by observing that

$$v_L\left(\underline{\theta}\right) + C_L\left(\widehat{\theta}_L - \underline{\theta}\right) = v_L\left(\widehat{\theta}_L\right) = v_{NL,av} = \frac{1}{\int_{\underline{\theta}}^{\bar{\theta}}\widetilde{p}_{NL}(\theta)d\theta}\left(\int_{\underline{\theta}}^{\bar{\theta}}\widetilde{p}_{NL}\left(\theta\right)v_L\left(\theta\right)d\theta\right) =$$
$$v_L\left(\underline{\theta}\right) + \frac{C_L}{\int_{\underline{\theta}}^{\bar{\theta}}\widetilde{p}_{NL}(\theta)d\theta}\int_{\underline{\theta}}^{\bar{\theta}}\widetilde{p}_{NL}\left(\theta\right)\left(\theta - \underline{\theta}\right)d\theta$$

implying that $\widehat{\theta}_L$ is given by

$$\widehat{\theta}_L = \underline{\theta} + \frac{1}{\int_{\underline{\theta}}^{\bar{\theta}}\widetilde{p}_{NL}(\theta)d\theta}\int_{\underline{\theta}}^{\bar{\theta}}\widetilde{p}_{NL}\left(\theta\right)\left(\theta - \underline{\theta}\right)d\theta$$

Now the definition (24) implies that

$$v_{NL,av} - v_L\left(\underline{\theta}\right) = v_L\left(\widehat{\theta}_L\right) - v_L\left(\underline{\theta}\right) = C_L\left(\widehat{\theta}_L - \underline{\theta}\right)$$

and the value of $C_L$ is seen to equal

$$C_L = \frac{\left(v_{NL,av} - v_L(\underline{\theta})\right)}{\widehat{\theta}_L - \underline{\theta}}$$

When both $v_L\left(\underline{\theta}\right)$ and $C_L$ have become known, also the value $V_{1,L}$ is determined by (24) , since it implies that

$$V_{1,L} = v_L\left(\underline{\theta}\right) + C_\eta\left(1 - \underline{\theta}\right)$$

Turning to the parameters which characterize the high-risk projects, it is observed that since the probability function $\widetilde{p}_{NH}$ has the linear specification (21),

$\widetilde{p}_{NH,AV} = 1 - B_H \left(1 - \frac{\bar{\theta}}{2}\right)$

and

$B_H = \frac{1-\widetilde{p}_{NH,AV}}{1-\bar{\theta}/2}$

When $B_H$ and accordingly, the functions $\widetilde{p}_{NH}$ and $p_{NH}$ have become known, the equilibrium condition $(E2')$, i.e.

$p_{NL}\left(\bar{\theta}\right)\left(v_L\left(\bar{\theta}\right) - \frac{\bar{R}}{\widehat{p}_{\sigma L}}\right) = p_{NH}\left(\bar{\theta}\right)\left(v_H\left(\bar{\theta}\right) - \frac{\bar{R}}{\widehat{p}_{\sigma H}}\right)$

can be solved with respect to $v_H\left(\bar{\theta}\right)$. On the other hand, the value of $v_{NH,av}$ can be solved by taking averages in (7) and using (12), which yields

$v_{NH,av} = \pi_{NH,av} + \frac{\bar{R}}{\widehat{p}_{NH}}$

The value $\theta = \widehat{\theta}_H$ for which $v_H\left(\widehat{\theta}_H\right) = v_{NH,av}$ can be calculated analogously with the value of $\widehat{\theta}_L$, and its value turns out to be

$\widehat{\theta}_H = \bar{\theta} + \frac{1}{\int_{\bar{\theta}}^1 \widetilde{p}_{NH}(\theta) d\theta} \int_{\bar{\theta}}^1 \widetilde{p}_{NH}\left(\theta\right)\left(\theta - \bar{\theta}\right) d\theta$

Now the definition (24) implies that

$v_{NH,av} - v_{NH}\left(\bar{\theta}\right) = v_H\left(\widehat{\theta}_H\right) - v_{NH}\left(\bar{\theta}\right) = C_H\left(\widehat{\theta}_H - \bar{\theta}\right)$

and when $v_H\left(\bar{\theta}\right)$, $v_{NH,av}$, and $\widehat{\theta}_H$ are known, one can solve this equation with respect to $C_H$ and conclude that

$C_H = \frac{v_{NH,av} - v_{NH}\left(\bar{\theta}\right)}{\widehat{\theta}_H - \bar{\theta}}$

Finally, the definition (24) implies also that

$V_{1,H} = v_H\left(\bar{\theta}\right) + C_H\left(1 - \bar{\theta}\right)$.

In this way, we have fixed all the parameters of the model.

Table 3. Output over the eight simulation periods. Recession in periods 3 and 4. Output would be 100 if all agents chose the outside option.

| period | laissez-faire | Basel I | Basel II | optimal |
|---|---|---|---|---|
| 1 | 106.4017 | 106.4061 | 106.4077 | 106.4099 |
| 2 | 106.4017 | 106.4061 | 106.4077 | 106.4099 |
| **3** | **104.3388** | **104.3699** | **104.3743** | **104.5000** |
| **4** | **104.4930** | **104.5122** | **104.5196** | **104.5800** |
| 5 | 106.4115 | 106.4036 | 106.4017 | 106.3515 |
| 6 | 106.4017 | 106.4061 | 106.4077 | 106.4099 |
| 7 | 106.4017 | 106.4061 | 106.4077 | 106.4099 |
| 8 | 106.4017 | 106.4061 | 106.4077 | 106.4099 |
| Cumulative output | 847.2518 | 847.3162 | 847.3341 | 847.4810 |
| Standard deviation | 0.9209 | 0.9102 | 0.9080 | 0.86160 |

Figure 1. Capital requirements (%) over the eight (8) simulation periods. Recession in periods 3 and 4.

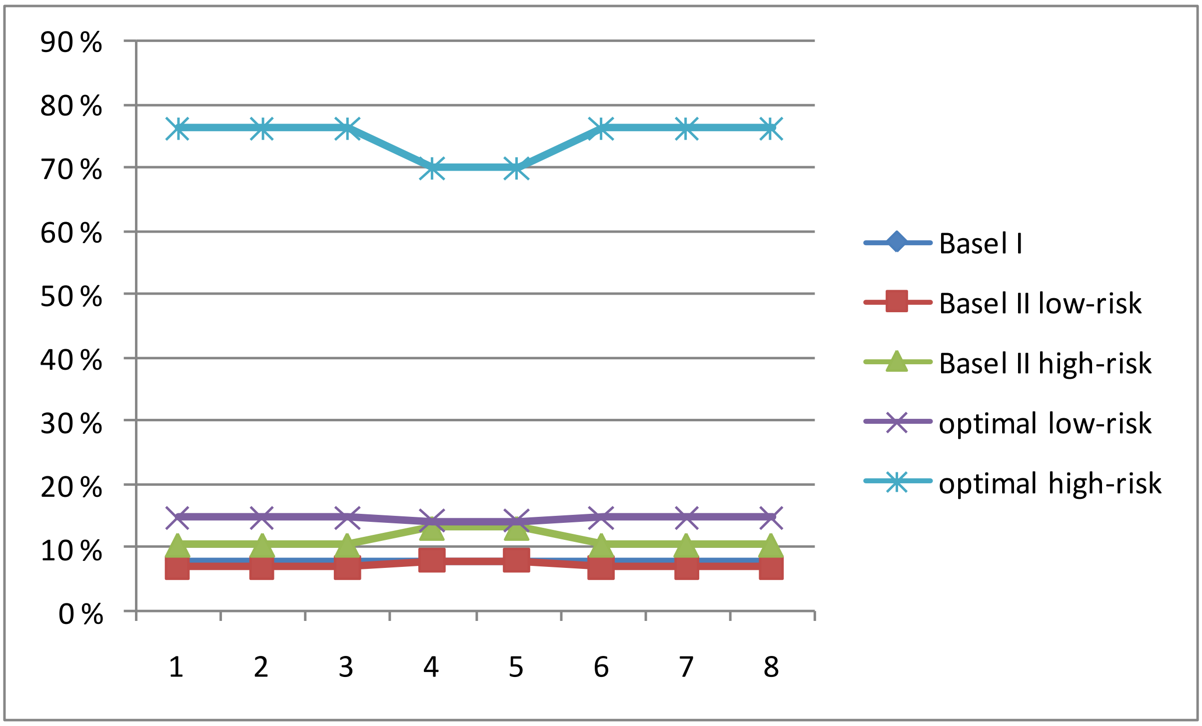


Figure 2a. Threshold type entrepreneurs for low-risk projects, $\underline{\theta}$, (vertical axis) in different capital requirement regimes over the eight simulation periods (horizontal axis). The size of the pool of potential entrepreneurs is normalized to one. Hence 1-$\underline{\theta}$ is the total share of entrepreneurs with high-risk or low-risk projects. Correspondingly, $\underline{\theta}$ indicates the share of labor market participants. Recession in periods 3 and 4.

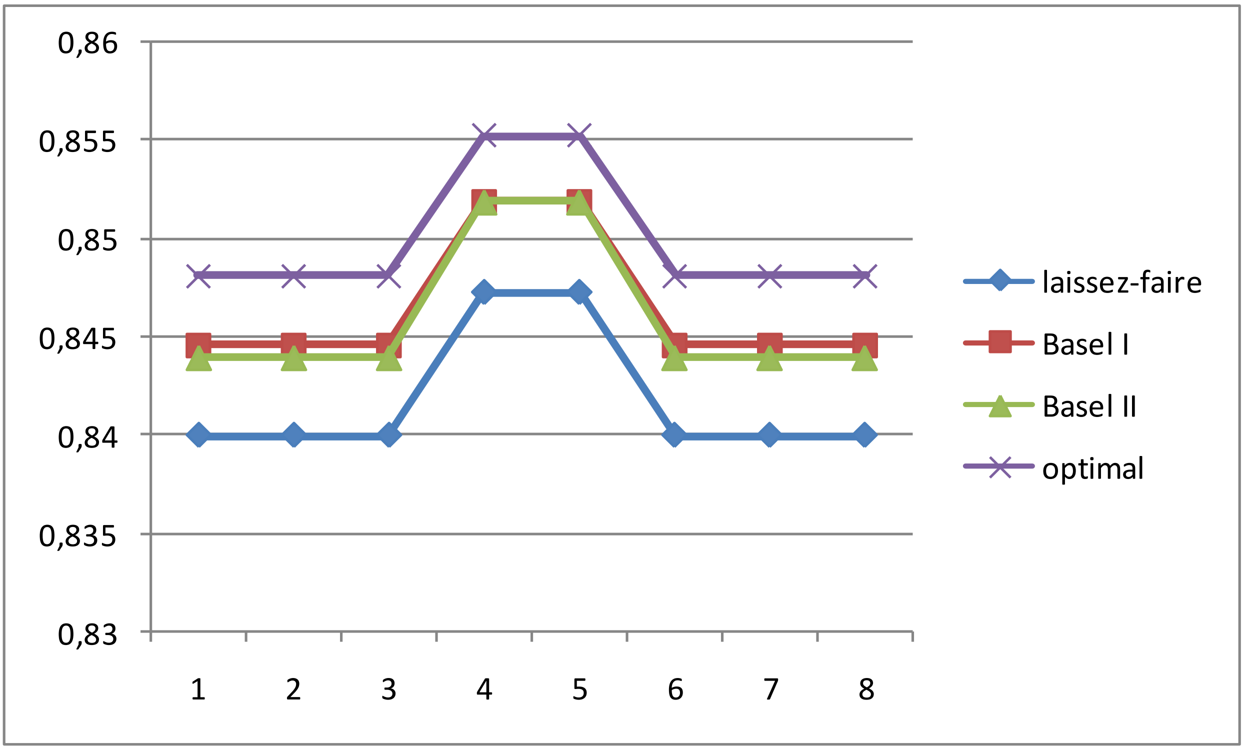
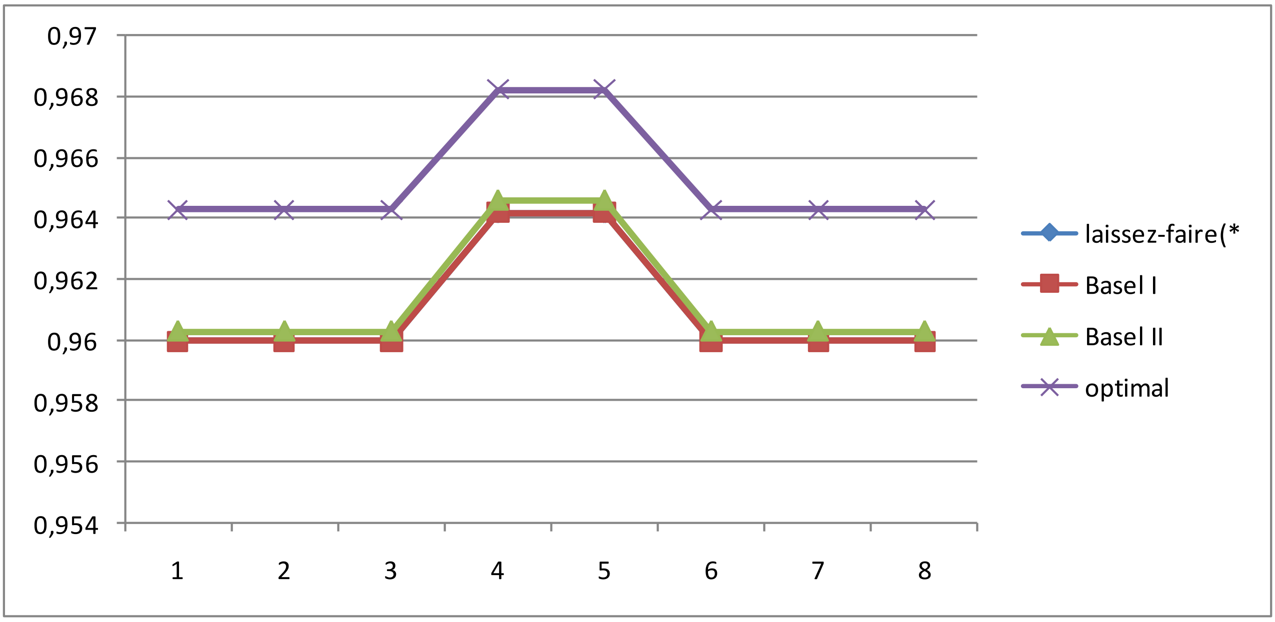


Figure 2b. Threshold type entrepreneurs for high-risk projects, $\overline{\theta}$, (vertical axis) in different capital requirement regimes over the eight simulation periods (horizontal axis). The size of the pool of potential entrepreneurs is normalized to one. 1-$\underline{\theta}$ is the share of entrepreneurs with high-risk projects. Recession in periods 3 and 4.




*) Laissez-faire threshold values virtually coincide with the threshold values of Basel I.

Figure 3. Output over the eight simulation periods. Recession in periods 3 and 4. Output would be 100 if all agents chose the outside option.