# The Color of Finance: Can Bank Capital Requirements Influence Transition to a Green Economy?*

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**Abstract**

Using a general equilibrium model in which brown (polluting) and green (clean-energy) firms compete and seek financing from banks, non-banks, or the capital market, we examine the effects of higher capital requirements on brown bank loans designed to discourage such lending. Higher-quality brown firms leave banks for the market and invest *more*, increasing competition for green firms and causing banks financing them to decrease capital and reduce screening. Lower-quality brown firms leave banks for non-banks and continue to pollute. These "waterbed effects" cause higher capital requirements on brown loans to surprisingly *undermine* bank stability and *increase* pollution.

**JEL:** G10, G21, G28

**Keywords:** Bank capital, Bank stability, Climate finance, Financial system

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# 1 Introduction

There has been much concern about how climate change may threaten financial stability (e.g., Giglio, Kelly, and Stroebel (2021), Hong, Karolyi, and Scheinkman (2020), and Stroebel and Wurgler (2021)). This has spurred discussion about the evolving research in climate finance (e.g., Gasparini and Tufano (2023)), and also about how the banking system may facilitate the transition of the economy to one with more environmentally friendly ("green") investments.[1] One proposal is to lower bank capital requirements on green loans, making them more attractive to banks than loans to carbon-emission-oriented ("brown") firms (Dombrovskis (2017)). Boot and Schoenmaker (2018) criticize this approach because lowering capital requirements on green loans would sacrifice financial stability; they suggest increasing capital requirements on brown loans instead.

The Boot-Schoenmaker proposal reflects the intuitive idea that increasing capital requirements on brown loans makes them less attractive for banks, thus discouraging brown investments without reducing bank capital ratios and jeopardizing stability. It would thus seem that a popular social goal can be achieved through a tweaking of prudential bank regulation, without making banks riskier. Carney (2015), however, cautions against this: "Some have suggested we ought to accelerate the financing of a low carbon economy by adjusting the capital regime for banks and insurers. That is flawed. History shows the danger of attempting to use such changes in prudential rules – designed to protect financial stability – for other ends."[2]

This debate raises an important question – should bank capital requirements on brown loans be increased when green investments ostensibly have higher social benefits?[3] Our answer is: perhaps not. Bank regulators may be unable to have their cake and eat it too – increasing capital require-

[1] For a review of how climate change-related risks may affect banks, see de Bandt et al. (2023).

[2] This is echoed by Sam Woods, Deputy Governor of the Bank of England: "While capital can address the financial consequences of climate change, we don't think it is the best tool to address directly the causes of climate change – for example by reducing capital requirements to subsidise 'green' assets, or increasing them to penalise carbon-intensive ones. How to address the causes of climate change is a decision for governments and parliaments, not financial regulators." See Woods (2022).

[3] We take as given that green investments have higher social benefits. This may stem from factors such as their potential to slow global warming and the economic value generated by the creative destruction associated with green innovation. See Kogan, Papanikolaou, Seru, and Stoffman (2017) for evidence on the economic benefits of such Schumpeterian creative destruction. The general equilibrium model of Kogan, Papanikolaou, and Stoffman (2020) shows that the benefits of technological innovation do not accrue entirely to financial market participants – some accrue to the innovators.

ments on brown loans, even *without* decreasing them on green loans, may also *increase* bank risk. We derive this result with a model in which brown and green firms compete *within* a sector. Think of gasoline-powered carmakers competing with electric vehicle producers in the automobile sector. Investment by a firm's competitor increases the probability that the firm's own investment will be prematurely liquidated. Firms need financing and may borrow from banks, non-bank intermediaries or directly from the capital market. Firms are observationally identical within a sector but unobservably heterogeneous, with good and bad credits in the cross-section. Banks can screen borrowers at a cost to weed out bad investments. Non-banks screen as well, but they differ from banks in the way they screen. While banks use human capital – loan officers, branch managers and other personnel – to engage in personal-interaction-based information collection that involves gathering both soft and hard information whose precision can be controlled at a variable cost, non-banks invest in technology that enables automated (hard) information gathering at a fixed cost (zero marginal cost).[4] In contrast, there is no credit screening in the capital market.[5] Higher bank capital incentivizes more screening (greater information precision), but capital is costly. There is a fixed aggregate supply of bank capital, and the cost of bank capital is endogenously determined. Banks are regulated entities subject to capital requirements, while non-banks are not.

**Results:** We first characterize the laissez-faire equilibrium without bank capital requirements. Banks choose their privately-optimal capital, with its cost determined in general equilibrium by equating the aggregate demand for and supply of bank capital. High-quality firms obtain market finance, intermediate-quality firms take bank loans, low-quality firms borrow from non-banks, and the lowest-quality firms are rationed. Higher firm quality in our model is synonymous with lower risk, and the empirical evidence indicates that larger firms are safer than smaller firms (e.g., Mata and Portugal (1994)). Therefore, we will also refer to higher-quality firms as larger firms.

We then examine the effects of a minimum capital requirement on brown bank loans. We show that this increases each bank's cost of capital via a general equilibrium effect due to the higher

[4]In other words, non-banks focus primarily on hard information and hence transaction lending. For empirical evidence that (relationship) banks rely more on soft information, whereas transaction-oriented banks and non-banks rely more on hard information, see Gropp and Guettler (2018).

[5]All of our results hold qualitatively as long as the capital market screens *relatively* less than banks and non-banks. The notion that banks are screening specialists which distinguishes them from the capital market is familiar from foundational theories of financial intermediation (e.g., Allen (1990) and Ramakrishnan and Thakor (1984)).

capital demanded by banks subject to the requirement. We call this the "cost-of-capital externality" of higher capital requirements. Two prominent effects emerge. First, at the high end of the quality (size) spectrum, both large brown and green firms switch from banks to the capital market, but the migration of brown firms is greater. Thus, in some sectors, while brown firms migrate to the market, green firms remain bank-funded. Due to less stringent credit screening in the market relative to that in banking, investments of these *migrating* brown firms increase relative to the laissez-faire. Moreover, the consequently increased competition that these migrating brown firms exert on (within-sector) green firms that remain bank-funded reduces the quality of these bank loans and increases the odds of their green investments (and hence green loans for these investments) being prematurely terminated; we refer to all such competitive effects as the "competition externality" of higher capital requirements. Premature loan termination erodes bank capital,[6] so banks funding these green firms keep less capital, thereby investing less in screening and making more bad green loans. The overall effect at the high end of the quality (size) spectrum is thus *higher total pollution and lower stability* (*of banks funding green firms*). This surprising result arises from the "waterbed effect" – high-quality (large) firms switch from banks to the market in response to the capital requirement.

Second, at the low end of the quality (size) spectrum, the elevated cost of bank capital due to the imposition of the minimum capital requirement on brown bank loans causes an equal mass of small brown and green firms to switch from banks to non-banks. In the absence of non-banks, these firms would have been denied credit from any source, but the presence of non-banks brings the waterbed effect into play again, enabling not only small green firms to remain funded, but also allowing small brown firms to continue to generate pollution.

Between these two extremes, the spectrum of intermediate firm qualities (sizes) divides into two regions. In the region occupied by the upper end of this quality spectrum, the capital requirement on brown loans forces banks making these loans to keep more capital than in the laissez-faire, so fewer brown loans are expected to be funded. This reduces competition for green firms. Banks making green loans may keep more or less capital than in the laissez-faire, depending on whether the effect of

[6]Empirical evidence that premature loan liquidation erodes bank capital can be found in the literature on zombie lending, wherein banks have incentives to continue lending to borrowers whose loans should be liquidated to avoid the erosion of their capital; see Acharya et al. (2022) for a review. Footnote 17 provides more discussion.

the cost-of-capital externality outweighs that of reduced competition. In the region occupied by the lower end of this quality spectrum, the increased cost of capital induces banks making brown loans as well as those making green loans to keep less capital, leading to more brown and green loans – including more bad loans – being made.[7]

In summary, at the high end of the firm quality/size spectrum, stability *declines* for banks financing green firms, bank lending shrinks, and there is *more* pollution, all due to the minimum capital requirement causing a bank-to-market switch by large brown firms. In the middle of the spectrum, as long as banks lend to firms of sufficiently high quality, pollution declines and bank stability may improve. But for lower-quality firms in this intermediate zone, bank stability declines *and* pollution goes up, as at the high end. At the low end of the spectrum, pollution by small brown firms is not fully eliminated due to the presence of non-banks.

Our analysis may understate the distortions caused by using capital requirements to discourage brown investments. We assume that any decline in brown lending by banks will lead to an immediate reduction in brown investments as firms divest brown assets immediately. However, in reality, as Fuchs, Green, and Papanikolaou (2016) show, adverse selection can delay firms' divestiture decisions. Moreover, we also do not analyze the role of "stranded assets." If non-bank regulators bank certain brown assets (say, coal-fired plants), then the credit risk associated with these assets will go up for banks, forcing bank regulators to increase capital requirements due to the actions of *non-bank* regulators.

**Implications:** Our analysis has numerous policy implications. First, contrary to the seemingly common view that by raising capital requirements on brown loans and not lowering them on green loans, a transition to a green economy can be achieved without sacrificing banking stability, our analysis shows that this may weaken banking stability. Thus, the usual intuition that "punishing" brown loans (with higher capital requirements) is a stability-preserving substitute for rewarding green loans is flawed. Moreover, even the intended climate goals may not be achieved, as pollution may actually *increase* in certain cases.

[7] This also intensifies within-sector competition between brown and green firms, reinforcing banks' propensity to keep lower capital.

Second, if banks are faced with higher capital requirements on brown loans, it does not necessarily mean brown lending will decline. As we saw with other types of securitization, it may encourage banks to originate brown loans and then securitize them.[8]

Third, higher minimum capital requirements on brown loans will not just shrink the brown loans that banks originate and hold on their balance sheets, but *all* bank lending will decline, and the loan demand that banks do not now meet will migrate to less-regulated non-banks.

Fourth, using differential capital requirements on different types of loans to promote the climate agenda will get bank regulators involved in thorny loan classification issues with political overhang.[9]

In terms of how to respond to these challenges, one solution suggested by our analysis is the government provision of subsidized capital to *some* banks. But it is tricky to determine which banks to provide such subsidized capital, and how to link this provision to regulatory capital requirements that vary not only by the type of loans but also which sectors the loans are being made in. Specifically, regulators will need to account for the fact that the effects of higher capital requirements on brown loans are not confined to the "treated" banks, namely those directly experiencing such requirements. Rather, they affect the *entire* financial system due to the cost-of-capital and competition externalities. This should *not* be viewed as a suggestion to diminish the use of bank capital requirements. Instead, it should be viewed as acknowledging capital requirements as a valuable tool of prudential regulation, but offering a word of caution to *limit* their use to prudential bank regulation. We discuss this in some detail in Section 5.

**Literature:** Our paper aims to contribute to the climate finance literature; see Giglio, Kelly, and Stroebel (2021) for a review. Acharya et al. (2023) assess regulators' climate-stress-test scenarios. Recent theories examine the consequences of bank regulations to facilitate green transition. Oehmke and Opp (2022) show that when there is capital scarcity, raising capital requirements on brown loans is a limited regulatory option. Consequently, lowering capital requirements on green loans may be needed, which elevates bank risk. Our paper differs. Rather than relying on a regulatory constraint

[8] If this happens, then even more bad brown loans may be originated than indicated by our analysis, since securitization has been empirically shown to dilute screening incentives at the loan origination stage (e.g., Keys et al. (2010)).

[9] In practice there are plenty of grey areas where brown and green investments may not be clearly distinguished.

in raising capital requirements on brown loans, we explore how firms' access to capital markets shapes the effects of capital requirements. Specifically, some brown firms switch from banks to the market. We examine how this switch feeds back to banking to affect *bank-funded* green firms, impairing stability even when capital requirements on green loans are *not* lowered. These distinctions lead to policy implications that differ from those in Oehmke and Opp (2022).

Empirical evidence indicates that banks price in climate risk (e.g., Ivanov, Kruttli, and Watugala (2022) and Nguyen et al. (2022)). Fuchs et al. (2023) find that climate stress testing is effective in that stress-tested banks charge higher interest rates for brown loans and additional lending is associated with improvements in environmental performance. However, other papers highlight the unintended consequences of climate policies. Altavilla et al. (2023) provide evidence that bank lending policies aimed at achieving climate goals permit banks to engage in "climate risk-taking."[10] Giannetti et al. (2023) document that European banks portraying themselves as environmentally conscious extend more credit to brown industries, and this is more pronounced for lower-capital banks. Kacperczyk and Peydró (2022) find that banks committing to decarbonization reduce lending to brown firms, but there is no improvement in firms' environmental performance. Müller, Nguyen, and Nguyen (2025) show that banks securitize brown loans when they perceive high carbon transition risk and hold these loans on their balance sheets when this risk is perceived to be low.

Several theoretical papers have explored these distortions and proposed possible solutions. Green and Roth (2024) develop social-investing strategies that achieve both higher impact and greater financial returns than common approaches. Interestingly, they find that firms can achieve greater social impact by increasing profitability rather than directly enhancing social value. Inderst and Opp (2025) show that greenwashing in ESG funds marketed to retail investors necessitates a mandatory taxonomy to ensure that sustainable finance achieves meaningful effects. Allen, Barbalau, and Zeni (2023) show that carbon-contingent debt securities can provide incentives for the adoption of non-polluting technologies, but their success requires strong political backing. Hong, Wang, and Yang (2023) model how society adapts to climate-related disaster risks and argue that both capital and

[10]Specifically, Euro-area banks charge higher interest rates to firms exhibiting greater carbon emissions, controlling for their default probabilities, and a tighter monetary policy induces banks to increase both credit risk premia and carbon emission premia.

carbon taxes are needed to achieve the first best. They apply the model to country-level flood control from cyclones and provide empirical evidence.

Our paper is related to the literature on the firm's choice of bank versus market finance and financial system architecture (e.g., Allen and Gale (1997, 1999, 2000), Bolton and Freixas (2000), Boot and Thakor (1997), Holmstrom and Tirole (1997), and Song and Thakor (2010)). The literature on bank capital requirements is also relevant (e.g., Allen, Carletti, and Marquez (2011), Mehran and Thakor (2011), Morrison and White (2005), and Thakor (2014)).

**Structure:** Section 2 describes the model. Section 3 analyzes a benchmark without capital requirements. Section 4 examines the effects of imposing a minimum capital requirement on brown loans. Section 5 discusses policy implications. Section 6 concludes. Proofs are in the Appendix.

## 2 Model

**Setting:** Consider a two-date, $t \in \{0, 1\}$, economy with risk neutrality and no discounting. There are brown and green industries. The brown industry is a traditional industry, less environmentally friendly. Firms in the two industries make competing products. In both industries, a firm has a project that needs a \$1 investment at $t = 0$. The project may be good or bad. The date-1 payoff is $X > 1$ for a good project, and 0 for a bad project. No one, including the firm, knows the type of its project at $t = 0$. This precludes signaling which is unimportant here.

Each firm, brown or green, belongs to a sector indexed by $\lambda$. A sector is defined by product functionality satisfying a set of consumer needs. For instance, "automobile" is a sector, and products in this sector meet consumers' transportation needs. This sector has brown firms (gasoline carmakers) and green firms (electric carmakers). The date-0 common knowledge is that the project of a firm of any color in sector $\lambda$ is good with probability $\lambda$ and bad with probability $1-\lambda$, where $\lambda$ is distributed on support $[0, 1]$ according to a continuous density $f(\lambda)$ for both industries. The mass of firms in each industry is $\int_0^1 f(\lambda)d\lambda = 1$ across all sectors. The total firm mass is thus 2.

Brown and green firms compete within the same sector, but not across sectors: no firm in sector $\lambda_1$ competes with a firm in sector $\lambda_2 \neq \lambda_1$ (e.g., automobile firms do not compete with food companies).

Since we focus on the impact of competition between brown and green firms, we take as fixed the degree of competition among firms of the same color in a sector, so this competition plays no role.[11] Our results are qualitatively unaffected by such competition, but introducing it adds complexity.

We model $\lambda$ as both the sector and the probability of a good investment in that sector for modeling parsimony, but it does have a natural interpretation. Sectors differ in the likelihood of individual firm success due to the nature of the business. A regulated utility with renewable electricity-generation plants is innately less failure prone (higher $\lambda$) than say a new electric-vehicle manufacturer, despite both being green. Thus, the cross-sector heterogeneity in success probabilities leads naturally to an association between a sector and the probability of a good investment in that sector.

For a firm of color $i \in \{\text{brown}, \text{green}\}$ in sector $\lambda$, if the probability that a firm of color $j \in \{\text{brown}, \text{green}\}$, where $i \neq j$, in the same sector is funded is $\gamma(\lambda)$, then firm $i$'s good project will be terminated before $t = 1$ with probability $\alpha\gamma(\lambda)$, where $\alpha \in (0, 1)$ is a scaling factor. A larger $\alpha$ indicates greater brown-green competition, and $\gamma(\lambda)$ is determined in the analysis. This competition has no impact on a bad project, which always returns nothing. We model and analyze the consequences of the (competition-induced) premature termination later. To understand this specification, consider sector $\lambda$. There is an $f(\lambda)$ mass of green firms, and an $f(\lambda)$ mass of brown firms. If a brown firm's project is funded with probability $\gamma(\lambda)$, then the mass of funded brown projects is $\gamma(\lambda)f(\lambda)$. The impact on an average sector-$\lambda$ green firm is $\frac{\gamma(\lambda)f(\lambda)}{f(\lambda)} = \gamma(\lambda)$.

Why is a firm's project termination affected by its competitor's funding? Examples of such a spillover effect abound. When electric-truck maker Nikola made its SPAC debut, it created enormous investor excitement about its technology – investors did not realize the technology was non-existent. This optimism about a non-existent new technology led to excessive pessimism about traditional gasoline-powered vehicles. Funding to good manufacturers of gasoline-powered vehicles thus declined. Another example is in the defense sector. When the Berlin Wall fell, the whole defense sector faced a downturn, so all firms needed to cut investments. If any firm increased investment, it would put downward pressure on the profit margins of all firms.[12]

[11] That is, we focus on competition between say Tesla and Ford (different color), not that between GM and Ford (same color).

[12] William Anders, then CEO of General Dynamics, urged all defense contractors to cut back on capital expenditures.

**Pollution:** A brown firm's project, good or bad, generates a social loss $\omega$ (call it "pollution") if funded; $\omega$ is internalized by regulators, but not by others. Besides that, brown and green firms are modeled with the same project payoffs and firm distributions $f(\lambda)$ over sectors, and equal mass. This symmetry is chosen to delineate the effects of capital requirements on brown loans, ensuring the results are *not* driven by exogenous differences between brown and green firms along those dimensions.

**Financing:** Firms seek funding ($1) from banks, non-bank intermediaries, or the capital market. Bank funding is supplied with uninsured deposits $1-k$ (with a gross deposit rate $r_D$)[13] and equity $k$ (with an expected gross return $r_E > 1$, capturing the cost of bank capital). There is a limited (exogenous) aggregate bank capital supply $K$. We endogenize $k$ and $r_E$. The deposit market is competitive, so $r_D$ is set to yield depositors an expected gross return of 1. The banking sector is also competitive so banks, subject to their participation constraints, maximize borrower surplus. Banks funding brown firms are called "brown banks," and banks funding green firms are called "green banks." For a firm seeking market finance, investors provide the $1 funding via debt, charging a gross interest rate $r_M$. The debt market is also competitive, so all surplus goes to firms.

A non-bank raises the $1 it needs to lend by financing itself with debt.[14] These financiers charge the non-bank a gross interest rate $r_N$, yielding them an expected gross return of 1. Non-banks, subject to their participation constraints, also maximize borrower surplus. It is now more or less standard to distinguish between banks and non-banks based on banks having access to deposits and non-banks lacking such access, with deposits being cheaper than the debt financing raised by non-banks (e.g., Bolton et al. (2023), Donaldson, Piacentino, and Thakor (2021), Merton and Thakor (2019), and Thakor and Merton (2024)). We take a different approach and do *not* assume that banks have a funding cost advantage over non-banks, i.e., deposits are not cheaper than non-bank debt financing.[15] Rather, we distinguish between banks and non-banks based on their screening, as explained below.

**Screening:** Bank screening of loan applicants reduces type-2 errors.[16] A bank perfectly identifies

[13] Our results hold qualitatively as long as deposits are not fully insured.

[14] In our setting, the results would be unchanged if non-banks raise funds via equity.

[15] Incorporating the bank's funding cost advantage in the model does not change any result qualitatively.

[16] Modeling screening to reduce both type-1 and type-2 errors complicates the algebra, with qualitatively similar results. Our specification that screening reduces type-2 errors is consistent with the idea that it is typically easier for credit analysis to identify good projects than to weed out bad ones that are observationally identical to good projects in many dimensions.

good projects and detects bad ones with probability $\theta \in [0,1]$, which is its privately-chosen screening precision, at a cost $\frac{\theta^2}{2}$. There is no screening in market finance; results hold qualitatively as long as the market screens less than banks. Assuming the firm does not know its own project type but the bank can discover this via credit analysis captures the idea that assessing investment prospects may require an interpretation of broad industry conditions that the bank may be better at than the firm.

Non-banks also screen, but their screening differs from banks. Instead of deploying human capital (e.g., loan officers and credit screening committees), a non-bank employs an automated screening technology with a fixed cost $T$ and zero marginal cost. What we have in mind is P2P platforms and other fintech non-depository lenders that use machine-reliant automated screening processes. By investing in such technology, the non-bank lender can perfectly identify a good project, and identify a bad project with probability $\theta_T \in (0,1)$. Both $T$ and $\theta_T$ are exogenous and publicly observable.

The motivation for our modeling the difference between banks and non-banks this way is that banks have branch networks with loan officers and branch managers who engage in interpersonal interactions with borrowers (e.g., Berger, Leusner, and Mingo (1997)). These interpersonal interactions allow loan officers and branch managers to collect borrowers' payoff-relevant "soft" information for credit decisions, with greater effort enabling more soft information to be collected (see, for example, Hattori, Shintani, and Uchida (2015) for evidence). By contrast, non-bank lending tends to be much more technology-reliant, depending predominantly on hard information that is quantitative, impersonal and can be collected via automated mechanisms that do not involve variable-cost human effort (e.g., Liberti and Petersen (2019)). Thus, we view the manner in which borrowers are screened as a useful way to distinguish between banks and non-banks.

**Liquidation:** When a good project is terminated due to competition, it is liquidated before $t = 1$, with a liquidation value of \$1. With bank finance, part of the liquidation value, $1 - k$, is returned to depositors, but the bank recovers only a fraction $1 - \delta$ (with $\delta \in (0,1]$) of the remaining $k$, i.e., $(1-\delta)k$. Since part of bank equity $k$ is eroded upon premature loan liquidation,[17] liquidation is dissipatively costly for the bank and affects how much equity it raises. With non-bank finance and

[17] When a bank must prematurely terminate a loan, it typically will need to write down the loan value, and hence its book equity value. As documented by Peek and Rosengren (2005), this makes banks reluctant to restructure/liquidate loans when their capital ratios are close to the regulatory minimum to avoid equity write-offs.

market finance, the financiers/investors receive the entire \$1 upon liquidation.

Liquidation is observable and contractable – the date-0 deposit contract stipulates that the bank will return $1-k$ (deposit amount) to depositors upon liquidation. Similarly, the date-0 debt contract with market finance stipulates that the firm will return \$1 (debt amount) to investors, and the non-bank's contract with its financiers also stipulates that the \$1 will be returned by the non-bank to financiers. The analysis does not change qualitatively if we model a less-than-\$1 liquidation value, and let fund providers receive less than their funding upon liquidation (i.e., depositors receive less than $1-k$, non-bank financiers and market investors receive less than \$1). The current specification merely helps simplify derivations of interest rates ($r_D$, $r_M$ and $r_N$).

**Timeline:** Events between dates 0 and 1 unfold as follows:

- Banks announce a loan repayment obligation $L$ (which is also the gross loan rate, given the \$1 loan size) if they lend. Non-banks announce a repayment obligation $R$ if they lend.
- Each firm, brown or green, decides whether to approach a bank, a non-bank, or the market for funding.
- If approached by a firm, a bank raises equity $k$, screens the firm's project by privately choosing its screening precision $\theta$, and decides whether to accept or reject. If a non-bank is approached, it invests $T$ in technology with screening precision $\theta_T$ (both $T$ and $\theta_T$ are publicly observed), screens the project, and makes its acceptance/rejection decision. A borrower rejected by either a bank or non-bank is revealed to have a bad project for sure and cannot get financing elsewhere.
- If the bank accepts the borrower, it raises deposits $1-k$, and lends $k+(1-k)=1$. Depositors demand a gross rate $r_D$, based on their updated beliefs about the type of the funded project.
- If the non-bank accepts the borrower, it raises \$1 from financiers and lends it to the borrower. Financiers of the non-bank demand a gross rate $r_N$, based on their updated beliefs about the type of the funded project.
- If a firm approaches the market, investors demand a gross rate $r_M$ for the debt.
- If competition forces a good project to be terminated, its liquidation value is distributed between the bank and depositors (for bank finance) or returned to financiers/investors (for non-bank finance and market finance).

- Project types become public and payoffs are realized. Agents get paid.

**Assumptions:** We impose the following parametric restrictions. First, the within-sector competition between brown and green firms is not too strong:

$$\alpha \in \left(0, \frac{1+\delta-\sqrt{1+2\delta}}{\delta^2}\right). \tag{1}$$

Although a higher-$\lambda$ firm's loan is more likely to be approved by a bank, so is its competitor's loan in the same sector. Since competition-induced premature liquidation erodes bank capital and the associated cost is passed on to the borrower in equilibrium, an $\alpha$ that is too high will make the adverse impact of competition so strong within a high-$\lambda$ sector that a firm's net surplus may decrease with its quality $\lambda$. This is unrealistic, and this possibility is eliminated by (1). The upper bound $\frac{1+\delta-\sqrt{1+2\delta}}{\delta^2}$ is decreasing in $\delta$ (i.e., a tighter constraint on $\alpha$ with greater bank capital erosion $\delta$), since a larger $\delta$ amplifies the adverse impact of competition.

Second, the aggregate supply of bank capital is not too large:

$$K \in (0, \bar{K}), \tag{2}$$

where $\bar{K}$ is determined by (A6) in the Appendix. This ensures that bank capital is scarce, so the equilibrium cost of bank capital $r_E > 1$.

# 3 Laissez-Faire

In a laissez-faire benchmark without capital requirements, banks choose privately-optimal capital. We first take the cost of bank capital, $r_E > 1$, as given and examine banks' privately-optimal choices of capital and screening, as well as firms' financing choices. Lastly, we endogenize $r_E$.

**Definition.** *A laissez-faire equilibrium is characterized by the following conditions:*

1. *Banks and non-banks make decisions to maximize the surplus of a potential borrower, subject to their participation constraints. For a bank, these decisions include the loan repayment obligation $L$, capital $k$, and screening precision $\theta$. A non-bank decides its repayment obligation $R$.*

2. *Firms chooses a funding source (bank, non-bank, or market) to maximize expected surplus.*

3. *The market for bank capital clears.*

**Bank Finance:** Suppose a sector-$\lambda$ firm of any color approaches a bank. Let $\tilde{\theta}$ denote the depositors' belief about the bank's screening precision, and let $\tilde{\gamma}(\lambda)$ be the perceived probability that a different-color firm in sector $\lambda$ is funded. The depositors' participation constraint is

$$\frac{\lambda[1-\alpha\tilde{\gamma}(\lambda)]}{\lambda+(1-\lambda)(1-\tilde{\theta})}r_D(1-k)+\frac{\lambda\alpha\tilde{\gamma}(\lambda)}{\lambda+(1-\lambda)(1-\tilde{\theta})}(1-k)\geq 1-k$$
$$\Rightarrow \quad r_D \geq 1+\frac{(1-\lambda)(1-\tilde{\theta})}{\lambda[1-\alpha\tilde{\gamma}(\lambda)]}. \tag{3}$$

Depositors believe that the bank lends with probability $\lambda+(1-\lambda)(1-\tilde{\theta})$, conditional on which: (i) with probability $\lambda[1-\alpha\tilde{\gamma}(\lambda)]$, the funded project is good and survives competition, so depositors receive $r_D(1-k)$; (ii) with probability $\lambda\alpha\tilde{\gamma}(\lambda)$, the project is good but is prematurely liquidated due to competition, so depositors obtain $1-k$; and (iii) with the remaining probability $(1-\lambda)(1-\tilde{\theta})$, the project is bad, and depositors get nothing.

We analyze the bank's problem using backward induction. For a given capital amount $k$, loan rate $L$, and deposit rate $r_D$ (satisfying (3)), the bank chooses its screening precision $\theta$ to maximize its expected net profit:

$$\lambda[1-\alpha\tilde{\gamma}(\lambda)][L-r_D(1-k)]+\lambda\alpha\tilde{\gamma}(\lambda)(1-\delta)k+(1-\lambda)\theta k+(1-\lambda)(1-\theta)(0)-r_E k-\frac{\theta^2}{2}. \tag{4}$$

The first term is the bank's expected profit when a good project survives competition – it receives the loan repayment $L$ and pays depositors $r_D(1-k)$. This occurs with probability $\lambda[1-\alpha\tilde{\gamma}(\lambda)]$. As for the second term, with probability $\lambda\alpha\tilde{\gamma}(\lambda)$ a good project is prematurely liquidated due to competition and the bank recovers $(1-\delta)k$. As for the third term, if the bank weeds out a bad project (with probability $(1-\lambda)\theta$), it retains capital $k$ instead of lending and losing it. To see the fourth term, note that if a bad project is accepted (with probability $(1-\lambda)(1-\theta)$), it lends and loses $k$, getting nothing in return. The fifth term is the cost of raising $k$. The last term is the screening cost.

The solution is

$$\theta = (1-\lambda)k. \tag{5}$$

The depositors' belief must be correct in equilibrium, i.e., $\tilde{\theta} = \theta$. Therefore, given its capital $k$, the equilibrium bank screening precision is given by (5). A bank with higher capital $k$ has more to lose upon funding a bad project, so its screening investment $\theta$ increases. As shown later, competition affects $k$, and hence *indirectly* affects $\theta$ via (5). A sector-$\lambda$ firm seeking bank finance will be funded with probability $\gamma(\lambda) = \lambda + (1-\lambda)(1-\theta)$.

The bank's problem can now be stated as

$$\max_{k,L} \pi_{\text{bank}}(\lambda) \equiv \lambda[1-\alpha\tilde{\gamma}(\lambda)](X-L) \tag{6}$$

$$\text{s.t. } \lambda[1-\alpha\tilde{\gamma}(\lambda)][L-r_D(1-k)] + [\lambda\alpha\tilde{\gamma}(\lambda)(1-\delta) + (1-\lambda)\theta]k - r_E k - \frac{\theta^2}{2} \geq 0 \tag{7}$$

$$0 \leq k \leq 1 \tag{8}$$

$$\text{and } (3), (5).$$

The bank chooses $k$ (which pins down $\theta$ via (5)) and $L$ to maximize borrower surplus, $\pi_{\text{bank}}(\lambda) \equiv \lambda[1-\alpha\tilde{\gamma}(\lambda)](X-L)$. The absence of type-1 screening errors means that a good project is always funded, but the borrower earns a profit $X-L$ only if the project survives competition, and this occurs with probability $\lambda[1-\alpha\tilde{\gamma}(\lambda)]$. The borrower gets nothing with a bad project (even if funded). The bank faces the depositors' participation constraint (3), its own incentive-compatibility constraint for screening (5) and participation constraint (7), and the constraint on the capital amount (8).

**Lemma 1.** *For a sector-$\lambda$ firm of any color seeking bank finance, if a different-color firm in sector $\lambda$ (competitor) is funded with probability $\tilde{\gamma}(\lambda)$, then the firm is funded by its own bank with probability*

$$\gamma(\lambda) = r_E - (1-\lambda)^2 + \lambda\alpha\delta\tilde{\gamma}(\lambda). \tag{9}$$

When it is easier for a competitor to obtain funding (higher $\tilde{\gamma}(\lambda)$), the firm is also more likely

to be funded by its own bank (higher $\gamma(\lambda)$). Competitor funding causes the firm's good project more likely to be prematurely terminated, increasing the odds of capital loss for the firm's bank. The bank thus raises less capital. The consequent screening reduction (see (5)) increases the bank's likelihood of funding a bad project, increasing $\gamma(\lambda)$. When competition is greater (higher $\alpha$) or the capital erosion upon premature loan liquidation is bigger (higher $\delta$), the adverse competitive impact on screening intensifies. This increases the sensitivity of $\gamma(\lambda)$ with respect to $\tilde{\gamma}(\lambda)$. A higher $r_E$ also lowers bank capital, increasing $\gamma(\lambda)$.

**Non-Bank Finance:** Given a non-bank's screening precision $\theta_T$, a sector-$\lambda$ firm seeking non-bank finance will be funded with probability $\lambda+(1-\lambda)(1-\theta_T) \equiv \gamma_N(\lambda)$. Due to the symmetry in the benchmark, if a firm chooses non-bank finance, so does its competitor in the same sector, implying that the competitor is also funded with probability $\gamma_N(\lambda)$.

The non-bank's problem is

$$\max_R \pi_{\text{n-bank}}(\lambda) \equiv \lambda[1-\alpha\gamma_N(\lambda)](X-R) \tag{10}$$

$$\text{s.t. } \lambda[1-\alpha\gamma_N(\lambda)](R-r_N) - T \geq 0 \tag{11}$$

$$\frac{\lambda[1-\alpha\gamma_N(\lambda)]}{\lambda+(1-\lambda)(1-\theta)} r_N + \frac{\lambda\alpha\gamma_N(\lambda)}{\lambda+(1-\lambda)(1-\theta)} \geq 1. \tag{12}$$

The non-bank maximizes borrower surplus $\pi_{\text{n-bank}}(\lambda)$; its objective function (10) mirrors the bank's objective function (6), except that $\tilde{\gamma}(\lambda)$ and $L$ there are replaced with $\gamma_N(\lambda)$ and $R$, respectively. To understand the non-bank's participation constraint (11), note that it invests $T$ in screening, and makes a profit $R-r_N$ (collecting $R$ from the borrower and repaying $r_N$ to financiers) only when a good project survives competition, which occurs with probability $\lambda[1-\alpha\gamma_N(\lambda)]$. The participation constraint for the non-bank's financiers (12) mirrors the bank depositors' participation constraint (3), except that $\tilde{\gamma}(\lambda)$, $r_D$ and $1-k$ there are replaced with $\gamma_N(\lambda)$, $r_N$ and 1, respectively. Solving the problem in (10) – (12) yields

$$\pi_{\text{n-bank}}(\lambda) = \lambda[1-\alpha\gamma_N(\lambda)](X-1) - (1-\lambda)(1-\theta_T) - T. \tag{13}$$

**Market Finance:** There is no screening in the market, so a sector-$\lambda$ firm seeking market finance always gets funded, with the gross debt rate $r_M$ satisfying

$$\lambda(1-\alpha)r_M + \lambda\alpha(1) + (1-\lambda)(0) \geq 1 \quad \Rightarrow \quad r_M \geq \frac{1-\lambda\alpha}{\lambda(1-\alpha)}. \tag{14}$$

Due to the symmetry in the benchmark, if a firm chooses market finance, so does its competitor and thus is always funded ($\tilde{\gamma}(\lambda) = 1$). So, the probability is $\lambda\alpha\tilde{\gamma}(\lambda) = \lambda\alpha$ that a firm's good project is terminated, and investors receive \$1. With probability $\lambda(1-\alpha)$ a firm's good project survives competition, and investors obtain $r_M$. With probability $1-\lambda$ the project is bad, and investors get nothing. Constraint (14) binds in equilibrium, so a firm's expected surplus from market finance is

$$\pi_{\text{mkt}}(\lambda) = \lambda(1-\alpha)(X - r_M) = \lambda(1-\alpha)X - (1-\lambda\alpha). \tag{15}$$

In the following proposition, which states our first main result, the mathematical expressions for the cutoffs $\lambda_{\text{mkt}}$, $\lambda_{\text{bank}}$ and $\lambda_{\text{n-bank}}$ are given in the proof in the Appendix.[18] We now explicitly express bank capital, $k(\lambda)$, and screening precision, $\theta(\lambda)$, as functions of $\lambda$.

**Proposition 1** (Laissez-Faire)**.** *Given the cost of bank capital $r_E > 1$, a sector-$\lambda$ firm of any color chooses its funding source as follows:*

1. *If $\lambda \geq \lambda_{\text{mkt}}$, the firm borrows from the market and is always funded.*
2. *If $\lambda \in [\lambda_{\text{bank}}, \lambda_{\text{mkt}})$, the firm seeks a bank loan. The bank raises capital*

$$k(\lambda) = \frac{(1-\lambda)^2 - (r_E - 1 + \lambda\alpha\delta)}{(1-\lambda)^2(1-\lambda\alpha\delta)} \in (0,1), \tag{16}$$

*screens with precision*

$$\theta(\lambda) = \frac{(1-\lambda)^2 - (r_E - 1 + \lambda\alpha\delta)}{(1-\lambda)(1-\lambda\alpha\delta)} \in (0,1), \tag{17}$$

[18] $\lambda_{\text{mkt}}$ and $\lambda_{\text{n-bank}}$ are given by (A3) and (A4), respectively, and $\lambda_{\text{bank}}$ is implicitly determined by (A5).

*and approves the loan with probability*

$$\gamma(\lambda) = \frac{r_E - (1-\lambda)^2}{1 - \lambda\alpha\delta} \in (0,1). \tag{18}$$

*Both $k(\lambda)$ and $\theta(\lambda)$ are decreasing in, while $\gamma(\lambda)$ is increasing in, $\lambda$, $\alpha$, $\delta$ and $r_E$.*

3. *If $\lambda \in [\lambda_{\text{n-bank}}, \lambda_{\text{bank}})$, the firm approaches a non-bank and is funded with probability $\gamma_N(\lambda) = \lambda + (1-\lambda)(1-\theta_T)$.*

4. *If $\lambda < \lambda_{\text{n-bank}}$, the firm cannot obtain funding.*

*An increase in $r_E$ leads to a decrease in $\lambda_{\text{mkt}}$, an increase in $\lambda_{\text{bank}}$, and leaves $\lambda_{\text{n-bank}}$ unchanged.*

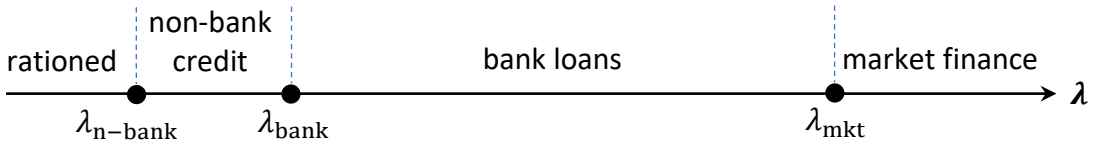



**Figure 1:** *Firm's Choice of Financing Source in Laissez-Faire*

This proposition, illustrated by Figure 1, says that the least risky firms (highest $\lambda$) go to the market, intermediate-risk firms choose banks, high-risk firms opt for non-banks,[19] and the riskiest firms (lowest $\lambda$) are rationed. The basic tradeoff in the laissez-faire equilibrium that generates this pecking order comes from the differences in borrower screening across the three sources of finance. When $\lambda$ is very high, screening adds little value because the borrower pool is of unconditionally high quality, so these borrowers access direct market finance which involves no screening. For intermediate values of $\lambda$, the bank's variable-cost (i.e., $\lambda$-dependent) screening is valuable, and these borrowers choose banks. For low values of $\lambda$, although screening is valuable, a considerable amount of screening is needed, so the bank's variable-cost screening proves to be too expensive relative to the option of accessing non-bank intermediated finance that has a fixed (i.e., zero variable) screening cost. The intuition for why these low-$\lambda$ borrowers prefer non-banks to banks is as follows. The bank's screening precision, $\theta(\lambda) = (1-\lambda)k(\lambda)$ (see (5)), is decreasing in $\lambda$, since $k(\lambda)$ is decreasing in $\lambda$ (Proposition

[19] This result has empirical support; see De Roure, Pelizzon, and Thakor (2022) for evidence that non-banks (P2P lenders) cater to lower-quality borrowers than banks do.

1). This means that $\theta(\lambda)$ will be high for low-$\lambda$ firms, in contrast to the non-bank's fixed screening precision $\theta_T$. To ensure this high screening precision, the bank raises a sufficiently high amount of capital. So the bank incurs two costs in lending to low-$\lambda$ borrowers – the higher variable cost of screening and the higher cost of capital (to incentivize screening). Since these costs are passed on to borrowers in equilibrium, low-$\lambda$ borrowers prefer to borrow from non-banks. Finally, for the lowest values of $\lambda$, the borrower pool is so risky unconditionally that firms are rationed without screening.

An interesting related question is how equilibrium bank screening, $\theta(\lambda)$, compares with the non-bank's, $\theta_T$. Since $\theta(\lambda)$ decreases with $\lambda$ and $\theta_T$ is constant, there is a cutoff $\widehat{\lambda}$ such that $\theta(\widehat{\lambda}) = \theta_T$, $\theta(\lambda) > \theta_T \ \forall \lambda < \widehat{\lambda}$, and $\theta(\lambda) < \theta_T \ \forall \lambda > \widehat{\lambda}$. Whether $\widehat{\lambda}$ lies above or below $\lambda_{\text{bank}}$ depends on the underlying parameters. If $\widehat{\lambda} < \lambda_{\text{bank}}$, then $\theta(\lambda) < \theta_T$ for all bank borrowers. This occurs when bank capital ($K$) is scarce, making its equilibrium cost ($r_E$) too high for banks to raise enough capital to match the screening precision of non-banks. Conversely, if $\widehat{\lambda} > \lambda_{\text{bank}}$, banks screen more precisely than non-banks for borrowers with $\lambda \in [\lambda_{\text{bank}}, \widehat{\lambda})$, but less precisely for those with $\lambda \in (\widehat{\lambda}, \lambda_{\text{mkt}})$.

Our results also have implications for the relationship between the firm's size and its choice of financing source. The documented negative relationship between firm risk and size (e.g., Mata and Portugal (1994)) implies that smaller firms are riskier *ceteris paribus*. When joined with our results above, this implies that the largest firms are market financed, mid-sized firms are bank funded, small firms are financed by non-bank intermediaries, and the smallest firms are rationed.

The result that the least risky firms go to the market and higher-risk firms choose banks is also found in Boot and Thakor (1997) and Holmstrom and Tirole (1997). But there are several differences. First, we include non-bank intermediaries in the menu of financing choices and, as we show later, this has a significant impact on the effects of increasing capital requirements on brown bank loans. Second, in Holmstrom and Tirole (1997) bank capital is the minimum informed capital needed to incentivize bank monitoring – it is not optimally chosen by banks. In contrast, we solve for the bank's privately-optimal capital choice, setting the stage for examining the effects of capital requirements.

The bank's privately-optimal capital, $k(\lambda)$, strikes a balance between the benefit of capital in enabling the bank to *credibly* commit to screening (which lowers the cost of uninsured deposits) and the cost of raising capital. Since the marginal value of screening falls when the likelihood of

encountering bad projects decreases (higher $\lambda$), we have $\frac{\partial k(\lambda)}{\partial \lambda} < 0$. Therefore, if a risk-insensitive ($\lambda$-independent) capital requirement were imposed, it would bind for banks funding high-$\lambda$ sectors, while banks funding low-$\lambda$ sectors would voluntarily raise more capital than the minimum requirement, due to their stronger incentives to control deposit costs. The bank also keeps lower capital when $\alpha$ and $\delta$ are higher, since these connote a more adverse impact of competition and greater bank capital erosion due to premature loan liquidation. A higher capital cost $r_E$ also reduces $k(\lambda)$. The positive monotonic relation between bank capital and screening ((5)) then implies that banks screen less, hence are more likely to approve loans (higher $\gamma(\lambda)$), as $\lambda$, $\alpha$, $\delta$ and $r_E$ increase.

A higher $r_E$ reduces borrower surplus from bank finance, so more large firms switch to the market ($\lambda_{\text{mkt}}$ decreases) and more intermediary-dependent small firms switch from banks to non-banks ($\lambda_{\text{bank}}$ increases). Non-banks are not affected by the cost of bank capital, so $\lambda_{\text{n-bank}}$ is invariant to $r_E$.

Lastly, we characterize $r_E$ by equating aggregate bank capital demand and supply:

$$2\int_{\lambda_{\text{bank}}}^{\lambda_{\text{mkt}}} k(\lambda)f(\lambda)d\lambda = K. \tag{19}$$

Due to symmetry in the benchmark, brown and green banks have equal capital demand, $\int_{\lambda_{\text{bank}}}^{\lambda_{\text{mkt}}} k(\lambda)f(\lambda)d\lambda$, where $k(\lambda)$ is in (16), so the left-hand side (LHS) of (19) is the aggregate capital demand by all banks. The economy's total supply of bank capital is $K$. When $r_E$ rises, $k(\lambda)$ and $\lambda_{\text{mkt}}$ decrease while $\lambda_{\text{bank}}$ increases (Proposition 1), so the LHS strictly falls. Thus, $r_E$ is unique if it exists. If $r_E = \infty$, there will be no demand for bank capital ($k(\lambda) = 0$), so the LHS falls to zero. The existence of $r_E > 1$ is thus guaranteed by letting $K$ be small enough so the LHS exceeds $K$ if $r_E = 1$; a sufficiency condition for this is $K < \bar{K}$ (see (2), with $\bar{K}$ being determined by (A6) in the Appendix). Once $r_E$ is uniquely determined, the other quantities in Proposition 1 are pinned down, as is the laissez-faire equilibrium.

# 4 Effects of Minimum Capital Requirements

In this section, we examine the effects of imposing a minimum capital requirement on brown bank loans. We start with an informal discussion to build intuition (Section 4.1), and then formally characterize the equilibrium with the capital requirement (Section 4.2). Lastly, we analyze the impact

of the capital requirement on pollution and bank stability (Section 4.3).

## 4.1 Informal Discussion

Figure 2 illustrates the effects of a minimum capital requirement on brown bank loans. The black curve $k(\lambda)$ (given by (16)) plots the privately-optimal bank capital in the laissez-faire equilibrium related to brown loans (top) or green loans (bottom). Recall in the laissez-faire equilibrium, regardless of color, firms with $\lambda \geq \lambda_{\text{mkt}}$ obtain market finance, $\lambda \in [\lambda_{\text{bank}}, \lambda_{\text{mkt}})$ take bank loans, $\lambda \in [\lambda_{\text{n-bank}}, \lambda_{\text{bank}})$ borrow from non-bank lenders, whereas those with $\lambda < \lambda_{\text{n-bank}}$ are rationed.

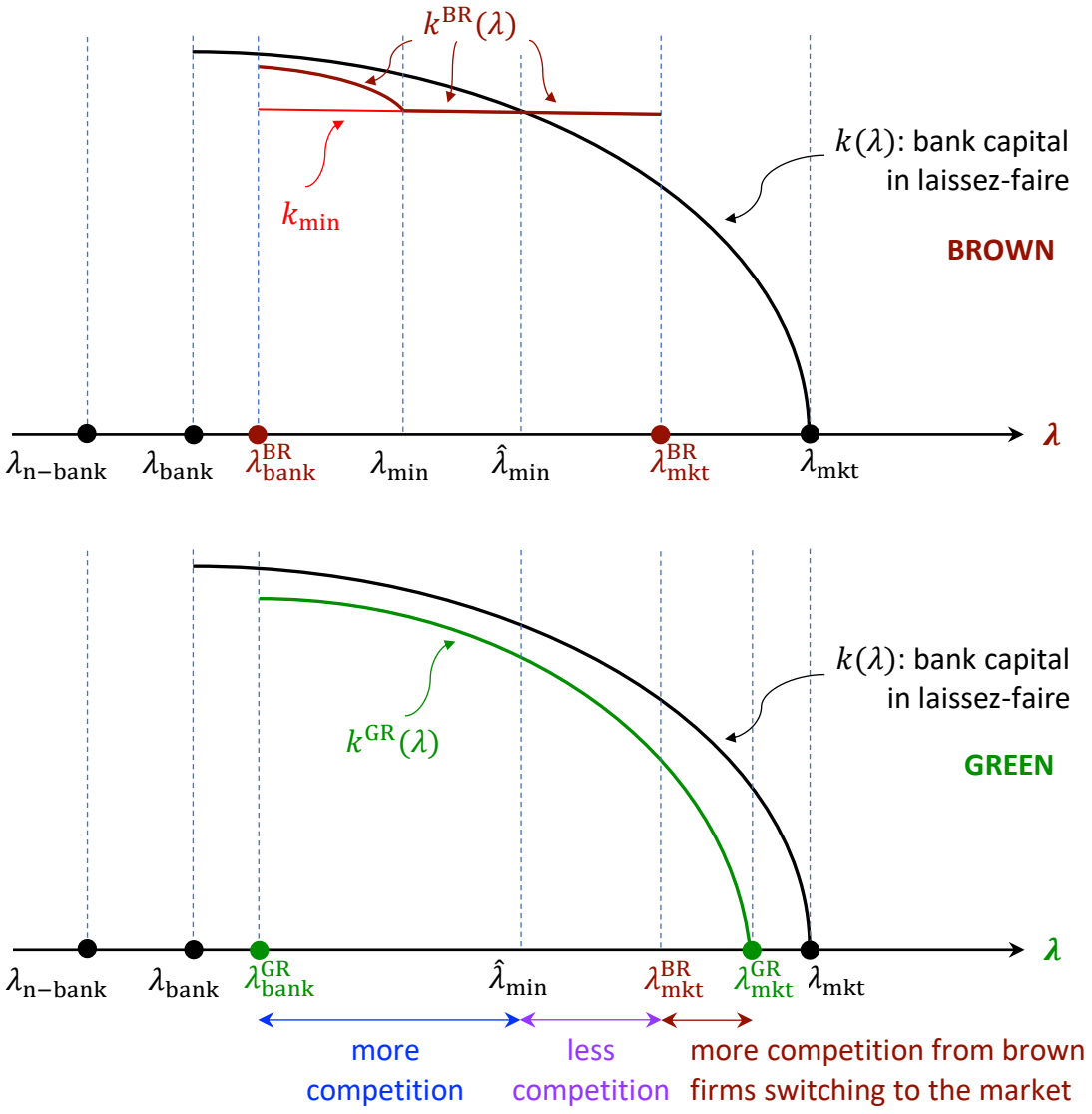



**Figure 2:** *Financial System under a Minimum Capital Requirement on Brown Loans*

Suppose a flat, risk-insensitive minimum capital requirement $k_{\min}$ (red line) is imposed on brown

loans, with $k(\widehat{\lambda}_{\text{min}}) = k_{\text{min}}$. If cutoffs $\lambda_{\text{bank}}$ and $\lambda_{\text{mkt}}$ were unchanged both for brown and green firms, then aggregate bank capital demand would increase and exceed aggregate bank capital supply $K$, since banks funding brown firms with $\lambda \in (\widehat{\lambda}_{\text{min}}, \lambda_{\text{mkt}})$ raise $k_{\text{min}}$ in capital – this is more than their laissez-faire private optimum $k(\lambda)$. Consequently, the capital cost must rise above $r_E$, say to $r_E^{\text{req}}$, to clear the market for bank capital. With a higher capital cost, $\lambda_{\text{bank}}$ rises, while $\lambda_{\text{mkt}}$ falls and $\lambda_{\text{n-bank}}$ remains unchanged (Proposition 1). We use the superscript "BR" (*resp.* "GR") to denote the equilibrium quantities for brown (*resp.* green ) banks/firms with the minimum capital requirement.

**Low-$\lambda$ Firms:** Suppose $\lambda_{\text{bank}}$ rises for brown and green firms to $\lambda_{\text{bank}}^{\text{BR}}$ and $\lambda_{\text{bank}}^{\text{GR}}$, respectively. The elevated capital cost impacts brown and green banks equally in low-$\lambda$ sectors, so $\lambda_{\text{bank}}^{\text{BR}} = \lambda_{\text{bank}}^{\text{GR}}$. Since $\lambda_{\text{n-bank}}$ remains unchanged, this means that imposing $k_{\text{min}}$ on brown loans pushes an equal mass of low-$\lambda$ brown firms (with $\lambda \in [\lambda_{\text{bank}}, \lambda_{\text{bank}}^{\text{BR}})$) and green firms (with $\lambda \in [\lambda_{\text{bank}}, \lambda_{\text{bank}}^{\text{GR}})$) from banks to non-banks.

It is interesting to consider the counterfactual of an economy without non-banks. In this case, the low-$\lambda$ firms that switch from banks to non-banks in our model would be excluded from the financial system. This lack of credit access means that brown firms in these sectors would be stopped from generating pollution. So, from a climate standpoint, the downside of the availability of non-bank credit in our analysis is the higher pollution due to low-$\lambda$ brown firms being able to invest, implying that the presence of non-banks makes the regulatory capital requirement on brown bank loans less effective in achieving its climate objective. But the existence of non-banks also has an upside from a credit access standpoint – low-$\lambda$ green firms that are denied bank loans can still obtain credit.

**High-$\lambda$ Firms:** A higher capital cost causes a bank-to-market switch for both high-$\lambda$ brown and green firms ($\lambda_{\text{mkt}}$ falls to $\lambda_{\text{mkt}}^{\text{BR}}$ and $\lambda_{\text{mkt}}^{\text{GR}}$ for brown and green firms, respectively), but the impact is stronger for brown firms ($\lambda_{\text{mkt}}^{\text{BR}} < \lambda_{\text{mkt}}^{\text{GR}}$). While bank-funded high-$\lambda$ green firms only suffer the higher capital cost,[20] bank-funded high-$\lambda$ brown firms suffer not only this elevated capital cost, but their banks also face binding capital requirements and hence raise more capital than is privately optimal. These two effects reinforce each other, so more brown firms exit banking than green firms.

A region $[\lambda_{\text{mkt}}^{\text{BR}}, \lambda_{\text{mkt}}^{\text{GR}}) \neq \varnothing$ thus exists. Green firms with $\lambda \in [\lambda_{\text{mkt}}^{\text{BR}}, \lambda_{\text{mkt}}^{\text{GR}})$ remain bank-funded, but

[20] The capital requirement targets brown banks exclusively.

now face more competition from brown firms in those sectors that switch to the market and always get funded. Thus, banks serving these green firms reduce capital *beyond* the reduction driven by the elevated capital cost, *further* reducing screening, increasing type-2 errors, and heightening bank risk.

**Mid-$\lambda$ Firms:** With the now higher cost of capital ($r_E^{\text{req}} > r_E$), the privately-optimal capital, $k^{\text{BR}}(\lambda)$, of banks funding brown firms with $\lambda \in [\lambda_{\text{bank}}^{\text{BR}}, \widehat{\lambda}_{\min}]$ is lower than that in the laissez-faire, $k(\lambda)$ (obtained with $r_E$), i.e., $k^{\text{BR}}(\lambda) < k(\lambda)$. So, there is a cutoff $\lambda_{\min} < \widehat{\lambda}_{\min}$, with $k^{\text{BR}}(\lambda_{\min}) = k_{\min} = k(\widehat{\lambda}_{\min})$. For brown firms with $\lambda \in (\lambda_{\min}, \lambda_{\text{mkt}}^{\text{BR}})$, the capital requirement binds – $k_{\min}$ exceeds the $k^{\text{BR}}(\lambda)$ they would raise with $r_E^{\text{req}}$. For brown firms with $\lambda \in [\lambda_{\text{bank}}^{\text{BR}}, \lambda_{\min})$, the capital requirement is not binding – their $k^{\text{BR}}(\lambda)$ with $r_E^{\text{req}}$ already exceeds $k_{\min}$. The brown curve (top) plots brown banks' equilibrium capital with the capital requirement.

Banks lending to green firms with $\lambda \in [\lambda_{\text{bank}}^{\text{GR}}, \lambda_{\text{mkt}}^{\text{GR}})$ are not directly subject to the capital requirement. Nonetheless, they are indirectly affected by the elevated capital cost, which reduces each green bank's privately-optimal capital $k^{\text{GR}}(\lambda)$ *ceteris paribus*, as indicated by the green curve (bottom), relative to $k(\lambda)$ in the laissez-faire. These bank-funded green firms can be grouped into three subsets. The first subset consists of firms with relatively-high qualities $\lambda \in [\lambda_{\text{mkt}}^{\text{BR}}, \lambda_{\text{mkt}}^{\text{GR}})$. As explained earlier, these green firms face greater competition from brown firms switching to the market, which further reduces $k^{\text{GR}}(\lambda)$ beyond that driven by the elevated capital cost. This further reduces bank screening and leads to even more bad bank-funded green projects in these sectors.

The second subset consists of green firms with relatively-low qualities $\lambda \in [\lambda_{\text{bank}}^{\text{GR}}, \widehat{\lambda}_{\min})$. These firms face more competition from brown firms in the corresponding sectors. Banks continue lending to these brown firms, but they raise less capital than in the laissez-faire, so they screen with lower precision and their expected funding of brown loans increases. This competition effect reinforces the elevated-capital-cost effect in *further* reducing the capital of banks funding green firms in these sectors, leading to even more bad bank-funded green projects.

The third subset consists of green firms with intermediate qualities $\lambda \in (\widehat{\lambda}_{\min}, \lambda_{\text{mkt}}^{\text{BR}})$. They now face competing brown firms whose banks raise more capital than in the laissez-faire. This lowers competition for these green firms, inducing their banks to also raise more capital. But the higher capital cost exerts a downward pressure on these green banks' capital demand. The net effect depends

on the strength of the reduced-competition effect relative to the higher-cost-of-capital effect.[21]

**Summary:** The minimum capital requirement on brown loans increases all banks' cost of capital in a general equilibrium. This has a multitude of effects on pollution and bank stability. Pollution increases at the high end of the quality spectrum as high-$\lambda$ brown firms switch from banks to the market. At the low end, low-$\lambda$ brown firms still generate pollution because non-bank credit is available for them. Thus, the market and non-banks represent alternative funding sources for firms, and their presence generates the waterbed effect that reduces the effectiveness of the bank capital requirement in achieving its climate goal.

Pollution also increases in the relatively-low quality sectors $\lambda \in [\lambda^{\text{BR}}_{\text{bank}}, \widehat{\lambda}_{\text{min}})$. Brown firms in these sectors continue borrowing from banks, but their banks keep lower capital than in the laissez-faire (due to the higher cost of capital emanating from the general equilibrium effect of the capital requirement), so brown loans are more likely to be approved in these sectors.

Pollution is reduced in the intermediate-quality sectors $\lambda \in (\widehat{\lambda}_{\text{min}}, \lambda^{\text{BR}}_{\text{mkt}})$. Banks funding brown firms in these sectors face binding capital requirements and keep more capital than in the laissez-faire. This is where the minimum capital requirement achieves its climate objective.

In many sectors, *just as the capital requirement fails to achieve its climate goal, it also fails to foster bank stability.* In the low-quality sectors, $\lambda \in [\lambda^{\text{BR}}_{\text{bank}}, \widehat{\lambda}_{\text{min}})$, stability declines for banks making brown loans and those making green loans, as all banks keep lower capital than in the laissez-faire. In the intermediate-quality sectors, $\lambda \in (\widehat{\lambda}_{\text{min}}, \lambda^{\text{BR}}_{\text{mkt}})$, brown banks experience higher stability due to the binding capital requirement, but the stability of green banks may rise or fall. In the high-quality sectors, $\lambda \in [\lambda^{\text{BR}}_{\text{mkt}}, \lambda^{\text{GR}}_{\text{mkt}})$, stability declines for green banks.

## 4.2 Formal Analysis

We characterize variables in the discussion above, except (exogenous) $k_{\text{min}}$, and hence the equilibrium with the minimum capital requirement on brown loans. We first take the higher capital cost $r_E^{\text{req}}$ induced by the capital requirement as given, and endogenize it later.

[21] Figure 2 assumes that the cost effect dominates for all $\lambda \in (\widehat{\lambda}_{\text{min}}, \lambda^{\text{BR}}_{\text{mkt}})$, so $k^{\text{GR}}(\lambda) < k(\lambda)$. But it is possible that the reduced-competition effect dominates for some $\lambda \in (\widehat{\lambda}_{\text{min}}, \lambda^{\text{BR}}_{\text{mkt}})$, for which $k^{\text{GR}}(\lambda) > k(\lambda)$.

The analysis is conducted in three subsets of sectors, based on differences in the effects of the minimum capital requirement on brown banks/firms: (i) sectors in which the capital requirement is not binding for brown banks (Lemma 2), (ii) sectors in which the capital requirement is binding for brown banks (Lemma 3), and (iii) sectors in which brown firms switch from banks to the market (Lemma 4). All the results below are conditional on the minimum capital requirement, $k_{\min}$, being imposed on brown loans.

**Lemma 2.** *A bank serving a brown firm with* $\lambda \in [\lambda^{\text{BR}}_{\text{bank}}, \lambda_{\min})$ *raises capital*

$$k^{\text{BR}}(\lambda) = \frac{(1-\lambda)^2 - (r_E^{\text{req}} - 1 + \alpha\delta\lambda)}{(1-\lambda)^2(1-\alpha\delta\lambda)} \in \big(k_{\min}, k(\lambda)\big), \tag{20}$$

*and lends with probability*

$$\gamma^{\text{BR}}(\lambda) = \frac{r_E^{\text{req}} - (1-\lambda)^2}{1-\alpha\delta\lambda} > \gamma(\lambda). \tag{21}$$

*A bank serving a green firm with* $\lambda \in [\lambda^{\text{GR}}_{\text{bank}}, \lambda_{\min})$ *raises capital* $k^{\text{GR}}(\lambda) = k^{\text{BR}}(\lambda)$*, and lends with probability* $\gamma^{\text{GR}}(\lambda) = \gamma^{\text{BR}}(\lambda)$*. The cutoffs,* $\lambda^{\text{BR}}_{\text{bank}} = \lambda^{\text{GR}}_{\text{bank}}$*, exceed* $\lambda_{\text{bank}}$*,*[22] *and* $\lambda_{\min}$ *is uniquely determined by* $k^{\text{BR}}(\lambda_{\min}) = k_{\min}$*:*

$$\frac{(1-\lambda_{\min})^2 - (r_E^{\text{req}} - 1 + \alpha\delta\lambda_{\min})}{(1-\lambda_{\min})^2(1-\alpha\delta\lambda_{\min})} = k_{\min}. \tag{22}$$

While banks serving brown firms with $\lambda \in [\lambda^{\text{BR}}_{\text{bank}}, \lambda_{\min})$ do not face binding capital requirements, $k^{\text{BR}}(\lambda) > k_{\min}$, the elevated cost of capital causes them to raise less capital than in the laissez-faire, $k^{\text{BR}}(\lambda) < k(\lambda)$. Consequently, they screen less, approve more brown loans, $\gamma^{\text{BR}}(\lambda) > \gamma(\lambda)$, and make more type-2 errors. The same is true for banks serving green firms with $\lambda \in [\lambda^{\text{GR}}_{\text{bank}}, \lambda_{\min})$ due to the symmetry in these sectors.

The analysis for banks serving brown firms with $\lambda \in [\lambda_{\min}, \lambda^{\text{BR}}_{\text{mkt}})$ and banks serving green firms with $\lambda \in [\lambda_{\min}, \lambda^{\text{GR}}_{\text{mkt}})$ is more involved, due to asymmetry between brown and green banks in these sectors. While brown banks raise the required capital $k_{\min}$, green banks choose their privately-optimal

[22] $\lambda^{\text{BR}}_{\text{bank}}$ and $\lambda^{\text{GR}}_{\text{bank}}$ are (implicitly) determined by (A8) in the Appendix.

capital, which differs from $k_{\min}$. The cutoffs $\lambda_{\text{mkt}}^{\text{BR}}$ and $\lambda_{\text{mkt}}^{\text{GR}}$ also differ (as will be shown in Lemma 5).

Lemma 3, taking $\lambda_{\text{mkt}}^{\text{BR}}$ and $\lambda_{\text{mkt}}^{\text{GR}}$ (also $\lambda_{\text{mkt}}^{\text{BR}} < \lambda_{\text{mkt}}^{\text{GR}}$) as given, examines brown and green banks serving sectors $\lambda \in [\lambda_{\min}, \lambda_{\text{mkt}}^{\text{BR}})$. As explained in Section 4.1, these sectors can be divided into two regions, $[\lambda_{\min}, \widehat{\lambda}_{\min}] \cup (\widehat{\lambda}_{\min}, \lambda_{\text{mkt}}^{\text{BR}})$, where $\widehat{\lambda}_{\min}$ is determined by $k(\widehat{\lambda}_{\min}) = k_{\min}$:

$$\frac{(1-\widehat{\lambda}_{\min})^2 - (r_E - 1 + \alpha\delta\widehat{\lambda}_{\min})}{(1-\widehat{\lambda}_{\min})^2(1-\alpha\delta\widehat{\lambda}_{\min})} = k_{\min}. \tag{23}$$

**Lemma 3.** *A bank serving a brown firm with $\lambda \in [\lambda_{\min}, \lambda_{\text{mkt}}^{\text{BR}})$ raises capital*

$$k^{\text{BR}}(\lambda) = k_{\min} \begin{cases} < k(\lambda) & \text{for } \lambda \in [\lambda_{\min}, \widehat{\lambda}_{\min}) \\ > k(\lambda) & \text{for } \lambda \in (\widehat{\lambda}_{\min}, \lambda_{\text{mkt}}^{\text{BR}}), \end{cases} \tag{24}$$

*and lends with probability*

$$\gamma^{\text{BR}}(\lambda) = 1 - (1-\lambda)^2 k_{\min} \begin{cases} > \gamma(\lambda) & \text{for } \lambda \in [\lambda_{\min}, \widehat{\lambda}_{\min}) \\ < \gamma(\lambda) & \text{for } \lambda \in (\widehat{\lambda}_{\min}, \lambda_{\text{mkt}}^{\text{BR}}). \end{cases} \tag{25}$$

*A bank serving a green firm with $\lambda \in [\lambda_{\min}, \lambda_{\text{mkt}}^{\text{BR}})$ raises capital*

$$k^{\text{GR}}(\lambda) = 1 - \frac{r_E^{\text{req}} - 1 + \lambda\alpha\delta}{(1-\lambda)^2} + \lambda\alpha\delta k_{\min} \begin{cases} < k(\lambda) & \text{for } \lambda \in [\lambda_{\min}, \widehat{\lambda}_{\min}) \\ \lesseqgtr k(\lambda) & \text{for } \lambda \in (\widehat{\lambda}_{\min}, \lambda_{\text{mkt}}^{\text{BR}}), \end{cases} \tag{26}$$

*and lends with probability*

$$\gamma^{\text{GR}}(\lambda) = r_E^{\text{req}} - (1-\lambda)^2(1 + \lambda\alpha\delta k_{\min}) + \lambda\alpha\delta \begin{cases} > \gamma(\lambda) & \text{for } \lambda \in [\lambda_{\min}, \widehat{\lambda}_{\min}) \\ \lesseqgtr \gamma(\lambda) & \text{for } \lambda \in (\widehat{\lambda}_{\min}, \lambda_{\text{mkt}}^{\text{BR}}). \end{cases} \tag{27}$$

Equations (26) and (27) delineate two effects of $k_{\min}$ on green banks. First, the increased cost of bank capital ($r_E^{\text{req}} > r_E$), due to the imposition of $k_{\min}$ on brown loans, directly reduces $k^{\text{GR}}(\lambda)$, which increases $\gamma^{\text{GR}}(\lambda)$. Second, the effect of $k_{\min}$ by itself depends on how it compares with $k(\lambda)$. For $\lambda \in [\lambda_{\min}, \widehat{\lambda}_{\min})$, $k_{\min} < k(\lambda)$: brown banks raise less capital than in the laissez-faire. The

consequently enhanced competition reinforces the cost-of-capital externality to further reduce $k^{\mathrm{GR}}(\lambda)$ and increase $\gamma^{\mathrm{GR}}(\lambda)$. For $\lambda \in (\widehat{\lambda}_{\min}, \lambda^{\mathrm{BR}}_{\mathrm{mkt}})$, $k_{\min} > k(\lambda)$: brown banks raise more capital than in the laissez-faire. This reduces competition from brown firms, which pulls against the cost-of-capital externality, and the net effect on $k^{\mathrm{GR}}(\lambda)$ and $\gamma^{\mathrm{GR}}(\lambda)$ becomes ambiguous.

Next, we analyze bank-funded green firms with $\lambda \in [\lambda^{\mathrm{BR}}_{\mathrm{mkt}}, \lambda^{\mathrm{GR}}_{\mathrm{mkt}})$. As discussed in Section 4.1, these firms face greater competition from within-sector brown firms switching from banks to the market.

**Lemma 4.** *A bank serving a green firm with* $\lambda \in [\lambda^{\mathrm{BR}}_{\mathrm{mkt}}, \lambda^{\mathrm{GR}}_{\mathrm{mkt}})$ *raises capital*

$$k^{\mathrm{GR}}(\lambda) = 1 - \frac{r_E^{\mathrm{req}} - 1 + \lambda\alpha\delta}{(1-\lambda)^2} < k(\lambda), \tag{28}$$

*and lends with probability*

$$\gamma^{\mathrm{GR}}(\lambda) = r_E^{\mathrm{req}} - (1-\lambda)^2 + \lambda\alpha\delta > \gamma(\lambda). \tag{29}$$

The lack of borrower screening in the market means that brown firms switching from banks to the market have a higher probability of obtaining credit. The resulting elevated competition for green firms in sectors $\lambda \in [\lambda^{\mathrm{BR}}_{\mathrm{mkt}}, \lambda^{\mathrm{GR}}_{\mathrm{mkt}})$ causes their banks to raise less capital, screen less, approve more green loans, and commit more type-2 errors. This *competition effect* reinforces the cost-of-capital effect ($r_E^{\mathrm{req}} > r_E$) in reducing capital and screening by green banks serving sectors $\lambda \in [\lambda^{\mathrm{BR}}_{\mathrm{mkt}}, \lambda^{\mathrm{GR}}_{\mathrm{mkt}})$.

We now characterize $\lambda^{\mathrm{BR}}_{\mathrm{mkt}}$ and $\lambda^{\mathrm{GR}}_{\mathrm{mkt}}$.[23]

**Lemma 5.** *More brown firms than green firms switch from banks to the market:* $\lambda^{\mathrm{BR}}_{\mathrm{mkt}} < \lambda^{\mathrm{GR}}_{\mathrm{mkt}} < \lambda_{\mathrm{mkt}}$.

[23] $\lambda^{\mathrm{GR}}_{\mathrm{mkt}}$ is given by (A9), and $\lambda^{\mathrm{BR}}_{\mathrm{mkt}}$ is implicitly determined in the proof of Lemma 5 in the Appendix.

Finally, we determine $r_E^{\text{req}}$ by equating aggregate supply and demand for bank capital:

$$\underbrace{\int_{\lambda_{\text{bank}}^{\text{BR}}}^{\lambda_{\min}} k^{\text{BR}}(\lambda) f(\lambda) d\lambda + \int_{\lambda_{\min}}^{\lambda_{\text{mkt}}^{\text{BR}}} k_{\min} f(\lambda) d\lambda}_{\text{aggregate capital demand by brown banks}}$$
$$+ \underbrace{\int_{\lambda_{\text{bank}}^{\text{GR}}}^{\lambda_{\min}} k^{\text{GR}}(\lambda) f(\lambda) d\lambda + \int_{\lambda_{\min}}^{\lambda_{\text{mkt}}^{\text{BR}}} k^{\text{GR}}(\lambda) f(\lambda) d\lambda + \int_{\lambda_{\text{mkt}}^{\text{BR}}}^{\lambda_{\text{mkt}}^{\text{GR}}} k^{\text{GR}}(\lambda) f(\lambda) d\lambda}_{\text{aggregate capital demand by green banks}} = K. \tag{30}$$

In (30), $k^{\text{BR}}(\lambda)$ is given by (20); as for $k^{\text{GR}}(\lambda)$, it is given by (20) for $\lambda \in [\lambda_{\text{bank}}^{\text{GR}}, \lambda_{\min})$, by (26) for $\lambda \in [\lambda_{\min}, \lambda_{\text{mkt}}^{\text{BR}})$, and by (28) for $\lambda \in [\lambda_{\text{mkt}}^{\text{BR}}, \lambda_{\text{mkt}}^{\text{GR}})$. Existence and uniqueness of $r_E^{\text{req}}$ can be shown as for $r_E$.

We now provide a numerical example to show that the set of exogenous parameter values for which all parametric restrictions are satisfied is non-empty, and compute the laissez-faire equilibrium and the equilibrium with the minimum capital requirement. This is not meant to be a model calibration. Parameters used in the example and its results are illustrated by Figure 3.

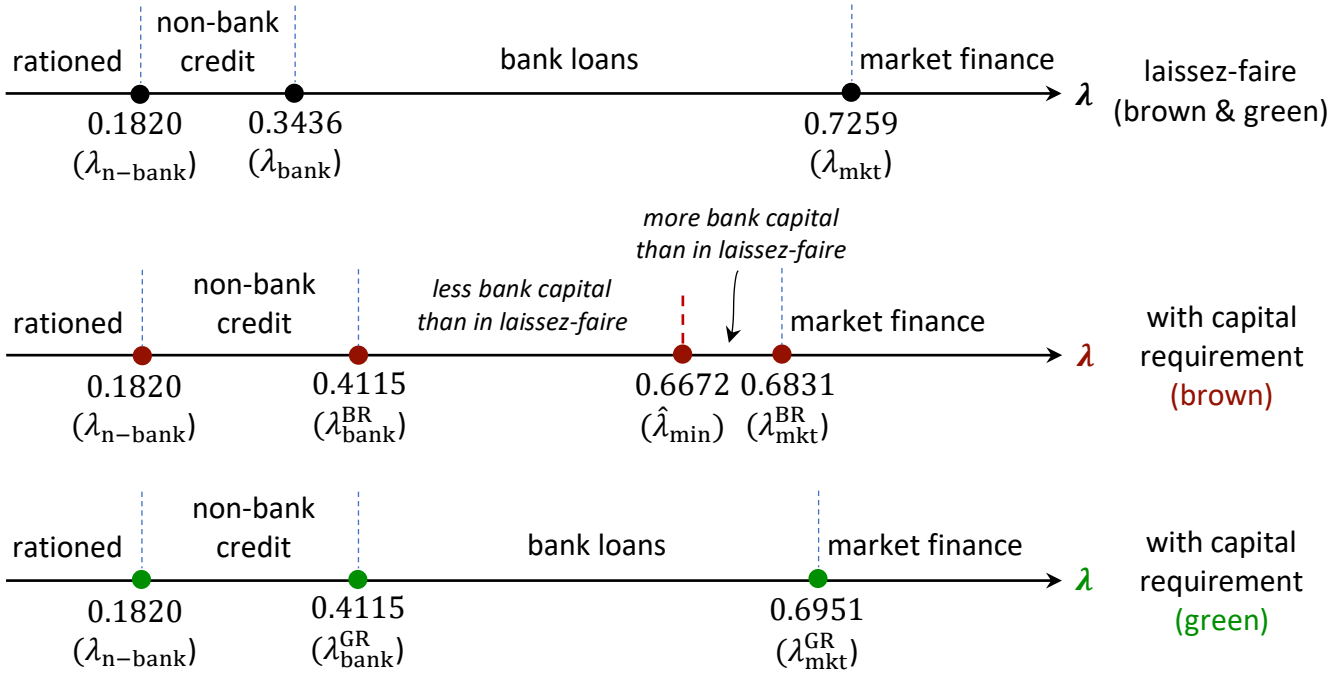



**Figure 3:** *Parameters:* $X = 4$, $\alpha = 0.05$, $\delta = 0.1$, $T = 0.44$, $\theta_T = 0.88$, $K = 0.45$, $k_{\min} = 0.22$, $\lambda \sim U[0,1]$. *Laissez-faire equilibrium (first line):* $r_E = 1.0715$, $\lambda_{\text{n-bank}} = 0.1820$, $\lambda_{\text{bank}} = 0.3436$, $\lambda_{\text{mkt}} = 0.7259$. *Equilibrium with the minimum capital requirement (second and third lines):* $r_E^{\text{req}} = 1.0895$, $\lambda_{\text{n-bank}} = 0.1820$, $\lambda_{\text{bank}}^{\text{BR}} = \lambda_{\text{bank}}^{\text{GR}} = 0.4115$, $\lambda_{\min} = 0.6552$, $\widehat{\lambda}_{\min} = 0.6672$, $\lambda_{\text{mkt}}^{\text{BR}} = 0.6831$, $\lambda_{\text{mkt}}^{\text{GR}} = 0.6951$.

### 4.3 Pollution and Bank Stability

We now examine the impacts of the minimum capital requirement ($k_{\min}$) on pollution and bank stability. As previously shown in Section 4.2 (also illustrated by Figure 3), compared to the laissez-faire equilibrium, brown banks serving sectors $[\lambda_{\text{bank}}^{\text{BR}}, \widehat{\lambda}_{\min})$ keep less capital, while those serving sectors $(\widehat{\lambda}_{\min}, \lambda_{\text{mkt}}^{\text{BR}})$ raise more capital; recall that $\widehat{\lambda}_{\min}$ is determined by (23). Relative to the laissez-faire equilibrium, the economy-wide net change in pollution due to the capital requirement, denoted by $\Delta\text{Po}$, can be written as the sum of four components, $\Delta\text{Po}(i)$, $i \in \{1, 2, 3, 4\}$. The expressions for these components are given in the Appendix (see (A10)). Here, we discuss the economics underlying each component; Figure 3 aids in understanding the explanation. Basically, these components represent the capital-requirement-induced net change in the mass of funded brown projects (each generating pollution $\omega$) in four distinct subsets of sectors.

The first component, $\Delta\text{Po}(1)$, captures the change in pollution by brown firms in sectors $\lambda \in [\lambda_{\text{bank}}, \lambda_{\text{bank}}^{\text{BR}})$. These firms receive bank financing with probability $\gamma(\lambda) = \frac{r_E - (1-\lambda)^2}{1-\lambda\alpha\delta}$ (see (18)) in the laissez-faire but now switch to non-banks. They are funded by non-banks with probability $\gamma_N(\lambda) = \lambda + (1-\lambda)(1-\theta_T)$. The sign of $\Delta\text{Po}(1)$ is ambiguous.

The second component, $\Delta\text{Po}(2)$, represents the change in pollution by brown firms in sectors $\lambda \in (\widehat{\lambda}_{\min}, \lambda_{\text{mkt}}^{\text{BR}})$. Banks serving these firms raise more capital and screen more than in the laissez-faire, thereby reducing the probability of brown investments by $\gamma(\lambda) - \gamma^{\text{BR}}(\lambda)$, where $\gamma^{\text{BR}}(\lambda) = 1 - (1-\lambda)^2 k_{\min}$ (see (25)). Consequently, the capital requirement reduces pollution from these sectors, i.e., $\Delta\text{Po}(2) < 0$.

The third component, $\Delta\text{Po}(3)$, is the change in pollution generated by brown firms in sectors $\lambda \in [\lambda_{\text{bank}}^{\text{BR}}, \lambda_{\min}) \cup (\lambda_{\min}, \widehat{\lambda}_{\min})$. Banks serving brown firms in sectors $[\lambda_{\text{bank}}^{\text{BR}}, \lambda_{\min})$ raise less capital and screen less than in the laissez-faire, thus increasing the probability of brown investments by $\gamma^{\text{BR}}(\lambda) - \gamma(\lambda) = \frac{r_E^{\text{req}} - r_E}{1-\lambda\alpha\delta}$, where $\gamma^{\text{BR}}(\lambda) = \frac{r_E^{\text{req}} - (1-\lambda)^2}{1-\alpha\delta\lambda}$ (see (21)). Similar increases of brown investments, due to the reduction in bank capital, occur in sectors $(\lambda_{\min}, \widehat{\lambda}_{\min})$, except $\gamma^{\text{BR}}(\lambda) = 1 - (1-\lambda)^2 k_{\min}$ (see (25)). Therefore, pollution increases in sectors $\lambda \in [\lambda_{\text{bank}}^{\text{BR}}, \lambda_{\min}) \cup (\lambda_{\min}, \widehat{\lambda}_{\min})$, i.e., $\Delta\text{Po}(3) > 0$.

Finally, brown firms in sectors $\lambda \in [\lambda_{\text{mkt}}^{\text{BR}}, \lambda_{\text{mkt}})$ switch from bank to market financing. This

increases the probability of brown investments by $1 - \gamma(\lambda)$. Consequently, pollution from these sectors increases, i.e., $\Delta\text{Po}(4) > 0$.

Returning to our numerical example, we have $\Delta\text{Po} = \Delta\text{Po}(1) + \Delta\text{Po}(2) + \Delta\text{Po}(3) + \Delta\text{Po}(4) = (-1.5802 \times 10^{-3}) + (-2.6248 \times 10^{-3}) + (4.6706 \times 10^{-3}) + (2.3474 \times 10^{-3}) = 2.8130 \times 10^{-3} > 0$. So, in our example, the minimum capital requirement actually increases total pollution.

Note that $\Delta\text{Po}(1)$ captures the net effect of non-banks on pollution when banks face minimum capital requirements on brown loans. In our example, $\Delta\text{Po}(1) < 0$, so brown firms with $\lambda \in [\lambda_{\text{bank}}, \lambda_{\text{bank}}^{\text{BR}})$ generate less pollution after switching from banks to non-banks. But this needs not to be always the case. When the non-bank's screening precision $\theta_T$ is sufficiently low, brown firms that migrate to non-banks are on average more likely to be funded by non-banks than by banks. In this case, their total pollution may increase ($\Delta\text{Po}(1) > 0$) due to the migration. So, the net effect of non-banks on pollution can be ambiguous. Further, as discussed in Section 4.1, absent non-banks, the brown firms that switch from banks to non-banks in our model would be excluded from the financial system, which would eliminate their pollution. So, even when the switching of firms from banks to non-banks reduces pollution in these sectors (as in our example), the reduction would have been even greater in the absence of non-banks.

Due to the implicit determination of several variables in the expressions for $\Delta\text{Po}(i)$, $i \in \{1, 2, 3, 4\}$, an analytical determination of the sign of $\Delta\text{Po}$ is beyond reach. Intuitively, if the $\lambda$-distribution places a sufficient mass around high-$\lambda$ sectors (in which brown firms switch from banks to the market) and/or a sufficient mass around mid/low-$\lambda$ sectors (in which brown firms remain bank-funded but their banks raise less capital), then there will be more pollution ($\Delta\text{Po} > 0$). Conversely, $\Delta\text{Po}$ will be negative (less pollution) if the distribution has a large mass around mid/high-$\lambda$ sectors, in which case the effect of the capital increase by brown banks serving those sectors dominates.

We now examine bank stability, defined as (the inverse of) the mass of failed bank-funded projects. We view stability as an independent goal of bank regulators and not something synonymous with social welfare. For instance, while pushing away low-$\lambda$ firms to non-banks and high-$\lambda$ firms to market finance reduces project failure *within* banking and increases bank stability in those sectors, the consequent change in economy-wide investments and pollution may lower social surplus.

**Proposition 2** (Pollution and Stability)**.** *The minimum capital requirement's impact on economy-wide pollution is ambiguous. The requirement lowers stability of green banks serving sectors* $\lambda \in [\lambda^{\text{BR}}_{\text{mkt}}, \lambda^{\text{GR}}_{\text{mkt}}) \cup (\lambda^{\text{GR}}_{\text{bank}}, \widehat{\lambda}_{\text{min}}]$ *and brown banks serving sectors* $\lambda \in (\lambda^{\text{BR}}_{\text{bank}}, \widehat{\lambda}_{\text{min}})$*, while increases stability of brown banks serving sectors* $\lambda \in (\widehat{\lambda}_{\text{min}}, \lambda^{\text{BR}}_{\text{mkt}})$*. This stability effect is ambiguous for green banks serving sectors* $\lambda \in (\widehat{\lambda}_{\text{min}}, \lambda^{\text{BR}}_{\text{mkt}})$*.*

# 5 Policy Implications

We can draw some policy implications from our analysis. The most important one perhaps is the one that echoes concerns of Carney (2015) and Woods (2022) regarding the use of prudential bank regulation to achieve climate goals. There has been little theoretical research on the potential effects of such measures, and our analysis reveals the possibility of unintended consequences. One such consequence is *lower bank stability* despite *higher* capital requirements on brown loans. This underscores that increased capital requirements for a specific loan category need not always translate into greater bank safety and soundness. Additionally, depending on the cross-sectional distribution of firm quality/size, this could paradoxically lead to an *increase* in total pollution.

Second, increasing capital requirements on brown bank loans opens up the possibility of regulatory arbitrage. Acharya, Schnabl, and Suarez (2013) empirically examine asset-backed commercial paper conduits that experienced stress during the 2007-09 crisis. They conclude that an important motive for setting up these conduits was regulatory arbitrage, namely to reduce regulatory capital requirements, and this effect was particularly pronounced among lower-capital banks. Recent evidence from Müller, Nguyen, and Nguyen (2025) suggests the emergence of similar securitization practices, allowing banks to sustain their brown loan origination businesses without keeping additional capital. As noted earlier, this could exacerbate the origination of bad brown loans beyond the levels predicted by our analysis.

Third, a clear implication of our analysis is that raising the minimum capital requirement on brown loans will lead to a contraction in bank lending – not just to brown firms but across the board, including green firms. Consequently, more credit will be extended by relatively-less-regulated

non-banks and directly by the capital market.[24]

Finally, any attempt to tie higher capital requirements to brown loans means that bank regulators will need to develop expertise in differentiating between loans that are good for the climate and those that are not. This can be difficult in practice for certain types of loans. Take the example of gasoline-powered cars, hybrids, and electric vehicles. The issue of which type of car is best for the environment overall is still being debated (see, for example, Buschbacher and Myers (2024)). Similar controversies rage on regarding energy sources, e.g., nuclear versus wind and solar power. This means that bank regulators may get embroiled in political disputes over how loans should be categorized for computing capital requirements.

Having said all these, we would like to emphasize that this paper is *not* arguing against higher capital requirements on banks. On the contrary, we acknowledge that bank capital requirements are an excellent prudential regulation tool, in line with previous research on this issue (e.g., Thakor (2014)). The big message of this paper – one that transcends model specifics – is this. Because of the plethora of advantages of debt over equity for banks, excessive bank leverage is a serious concern for bank stability, and capital requirements are needed to contain bank leverage. But capital requirements cannot eliminate the entire mountain of distortions in the system, and attempting to use them to target issues outside the boundaries of prudential regulation – including climate change – can generate unanticipated consequences via the waterbed effect. These consequences may not only lessen the effectiveness of capital regulation, but may also necessitate additional regulatory responses with their own waterbed effects.

**Potential Policy Responses:** Regulators may attempt to mute the general equilibrium cost-of-capital externality by infusing capital into banking. This could be achieved through equity purchases as in the Capital Purchase Program during the 2007-09 financial crisis. The capital provision could even be subsidized, which would necessitate a reallocation of government funding, so the consequent general equilibrium effects would need to be carefully examined.

Designing an effective capital provision scheme will require regulators to address various complex-

[24]This can have adverse consequences for the real economy (e.g., Banerjee, Gambacorta, and Sette (2021) and Cerqueiro, Ongena, and Roszbach (2020)).

ities. Due to the nature of bank screening, higher regulatory capital requirements – which induce greater screening precision – do not affect banks' funding of good brown loans and, therefore, pollution associated with these loans.[25] Rather, they reduce the funding of bad brown loans. In this sense, higher capital serves the purpose of reducing pollution from bad brown loans, provided these loans that banks do not make are not funded elsewhere.

Now consider sector $\lambda$, in which a bad brown loan is financed with probability $\gamma(\lambda) - \lambda = 1 - \lambda - (1-\lambda)^2 k(\lambda)$, meaning each additional unit of bank capital reduces this probability by a greater amount when $\lambda$ is lower. In other words, bank capital has a higher marginal value in reducing pollution in lower-$\lambda$ (smaller) sectors. In our model, the regulatory capital requirement, $k_{\min}$, is independent of $\lambda$. Since the privately-optimal capital is decreasing in $\lambda$, the higher-$\lambda$ banks keep relatively low capital levels. Therefore, the regulatory capital requirement binds most for these banks, prompting them to raise the most additional capital. However, this means that the most capital is raised in sectors where its marginal value in reducing pollution is the lowest.

An alternative would be to require banks serving lower-$\lambda$ sectors to raise more capital. But this triggers the general equilibrium cost-of-capital externality. Regulators may thus wish to consider providing subsidized capital to these banks.

This approach will not mute the competition channel, however, which operates as long as brown firms can access market finance. Bank regulators need to develop a deep understanding of the dynamics of brown-green competition in any bank-funded sector, and modify accordingly stress tests involving various capital requirement scenarios. This seems a complicated exercise. More broadly, our analysis underscores the importance of not viewing bank regulation as a tub on its own bottom. When bank regulation is used to influence brown-versus-green investments, it creates a pollution externality by driving brown firms to the capital market. This is tantamount to bank regulators simply pushing the pollution problem to the market and making it worse. Additionally, market finance introduces a banking stability externality. Therefore, any bank regulation initiatives need to take an *integrated* approach to address both externalities, suggesting the need to *coordinate* bank and market regulations.

[25] Recall that screening involves no type-1 errors in our model.

An alternative approach would involve rewarding banks *ex post* for making *good* green loans. The regulator could provide these rewards in various forms. For example, it could be to allow a certain portion of dividends to be treated as a tax-deductible expense.[26] The advantage of these types of rewards is that they provide stronger incentives for banks to make green loans with a high level of screening provision, even if these banks do not raise more capital.

# 6 Conclusion

We have examined the effects of using bank capital requirements to reduce brown lending. Due to general equilibrium effects, this can potentially *increase* pollution as large brown firms switch from banks to the market, and also diminish banking stability. Additionally, it will lead to a contraction in bank lending across the board, as banks cut back on all loans, not just brown loans. An important takeaway for proponents of using the banking system to achieve climate objectives is that firms borrowing from banks have alternative funding sources, so inducing them to exit banking may generate a waterbed effect that produces outcomes that are contrary to those intended. On the other hand, attempting to regulate non-banks and the capital market to counter these effects may open a Pandora's box of additional unexpected consequences. This remains an area for future research.

[26] Schepens (2016) provides evidence that when Belgium permitted banks to treat a portion of dividends on equity as tax-deductible expenses, banks increased their capital ratios. Moreover, there was also a significant reduction in risk-taking for *ex ante* low-capital banks.

## Appendix: Proofs

**Proof of Lemma 1.** In equilibrium, constraints (3) and (7) must be binding, i.e., $r_D = 1+\frac{(1-\lambda)(1-\theta)}{\lambda[1-\alpha\tilde{\gamma}(\lambda)]}$, and $L - r_D(1-k) = \frac{r_E k+\frac{\theta^2}{2}-[\lambda\alpha\tilde{\gamma}(\lambda)(1-\delta)+(1-\lambda)\theta]k}{\lambda[1-\alpha\tilde{\gamma}(\lambda)]}$. Using (5), we rewrite the problem in (6) as

$$\min_{k\in[0,1]} \; L = \frac{\frac{(1-\lambda)^2}{2}k^2 + [r_E - 1 + \lambda\alpha\delta\tilde{\gamma}(\lambda) - (1-\lambda)^2]k + 1 - \lambda\alpha\tilde{\gamma}(\lambda)}{\lambda[1-\alpha\tilde{\gamma}(\lambda)]}. \tag{A1}$$

Denote the solution as $k(\lambda)$. Since $\frac{\partial^2 L}{\partial k^2} > 0$ and $\frac{\partial L}{\partial k}|_{k=1} > 0$, we have $k(\lambda) < 1$. Suppose $\frac{\partial L}{\partial k}|_{k=0} < 0$ (which, as shown in the proof of Proposition 1, requires $\lambda$ to be below a cutoff $\lambda_{\text{mkt}}$), so $k(\lambda) > 0$ ($k(\lambda) = 0$ would correspond to market finance). Thus, the first-order condition, $\frac{\partial L}{\partial k} = 0$, yields

$$k(\lambda) = 1 - \frac{r_E - 1 + \lambda\alpha\delta\tilde{\gamma}(\lambda)}{(1-\lambda)^2}. \tag{A2}$$

Substituting (A2) into (5), we have $\theta = 1 - \lambda - \frac{r_E - 1 + \lambda\alpha\delta\tilde{\gamma}(\lambda)}{1-\lambda}$. Substituting that into $\gamma(\lambda) = \lambda + (1-\lambda)(1-\theta)$ yields (9). ■

**Proof of Proposition 1.** From (A1), we have $\frac{\partial^2 L}{\partial k^2} > 0$. If $\frac{\partial L}{\partial k}|_{k=0} = \frac{r_E - 1 + \lambda\alpha\delta\tilde{\gamma}(\lambda) - (1-\lambda)^2}{\lambda[1-\alpha\tilde{\gamma}(\lambda)]} \geq 0$, i.e., $r_E - 1 + \lambda\alpha\delta\tilde{\gamma}(\lambda) - (1-\lambda)^2 \geq 0$, then the optimal solution for $k$ in (A1) is $k(\lambda) = 0$. This corresponds to market finance: the entire \$1 is debt financed. If a firm chooses market finance, so does its competitor, hence $\tilde{\gamma}(\lambda) = 1$. Then, the condition for market finance becomes $r_E - 1 + \lambda\alpha\delta - (1-\lambda)^2 \geq 0 \;\Rightarrow\; \lambda \geq \lambda_{\text{mkt}}$, where

$$\lambda_{\text{mkt}} = \frac{(2+\alpha\delta) - \sqrt{(2+\alpha\delta)^2 - (8 - 4r_E)}}{2}. \tag{A3}$$

It can shown that $\lambda_{\text{mkt}} < 1$, since $r_E > 1 - \alpha\delta$. Clearly, $\frac{\partial \lambda_{\text{mkt}}}{\partial r_E} < 0$.

For $0 \leq \lambda < \lambda_{\text{mkt}}$, we have $\frac{\partial L}{\partial k}|_{k=0} < 0$. Since $\frac{\partial L}{\partial k}|_{k=1} > 0$, the optimal solution $k(\lambda) \in (0,1)$ in (A2) is given by $\frac{\partial L}{\partial k} = 0$. Due to the symmetry in the benchmark, if a firm seeks bank finance, so does its competitor, hence $\tilde{\gamma}(\lambda) = \gamma(\lambda)$. Substituting this into (9), we have $\gamma(\lambda) = r_E - (1-\lambda)^2 + \lambda\alpha\delta\gamma(\lambda)$, yielding (18). Substituting (18) into (A2) and letting $\tilde{\gamma}(\lambda) = \gamma(\lambda)$ yield (16). Substituting (16) into (5) yields (17). The comparative statics of $\gamma(\lambda)$ with respect to $\lambda$, $\alpha$, $\delta$ and $r_E$ follow immediately from (18). It is also clear from (18) that $\gamma(\lambda) > 0$ and $\gamma(\lambda) < 1$ (given $\lambda < \lambda_{\text{mkt}}$). Write $k(\lambda)$ as $k(\lambda) = 1 - \frac{r_E - 1 + \lambda\alpha\delta\gamma(\lambda)}{(1-\lambda)^2}$ (using (A2)): since $\gamma(\lambda)$ is increasing in $\lambda$, $\alpha$, $\delta$ and $r_E$, it is clear from this

expression that $k(\lambda)$ is decreasing in $\lambda$, $\alpha$, $\delta$ and $r_E$. Given this, it is clear that $\theta(\lambda) = (1-\lambda)k(\lambda)$ (see (5)) is also decreasing in $\lambda$, $\alpha$, $\delta$ and $r_E$.

Next, we determine $\lambda_{\text{n-bank}}$. From (13), we have $\frac{\partial \pi_{\text{n-bank}}(\lambda)}{\partial \lambda} = 1 - \theta_T + [1 - 2\alpha\lambda - \alpha(1-2\lambda)(1-\theta_T)](X-1) > 0$; the inequality is ensured by (1). Since $\pi_{\text{n-bank}}(0) = -(1-\theta_T) - T < 0$, assuming $T$ is not too large so $\pi_{\text{n-bank}}(\lambda_{\text{mkt}}) > 0$,[27] then $\lambda_{\text{n-bank}} \in (0, \lambda_{\text{mkt}})$ is uniquely determined by $\pi_{\text{n-bank}}(\lambda_{\text{n-bank}}) = 0$:

$$\lambda_{\text{n-bank}} = \frac{(X-\theta_T) - \alpha(1-\theta_T)(X-1) - \sqrt{[(X-\theta_T) - \alpha(1-\theta_T)(X-1)]^2 - 4\alpha\theta_T(1-\theta_T+T)(X-1)}}{2\alpha\theta_T(X-1)}. \tag{A4}$$

It is clear that $\frac{\partial \lambda_{\text{n-bank}}}{\partial r_E} = 0$.

We then examine $\lambda_{\text{bank}}$. Substituting the expressions for $k(\lambda)$ in (16) and $\gamma(\lambda)$ in (18) into the expression for $L$ in (A1) (letting $k = k(\lambda)$ and $\tilde{\gamma}(\lambda) = \gamma(\lambda)$) yields $L = 1 + \frac{1-\lambda-\frac{1}{2}\left[\frac{1-\gamma(\lambda)}{1-\lambda}\right]^2}{\lambda[1-\alpha\gamma(\lambda)]}$ and, hence, $\pi_{\text{bank}}(\lambda) = \lambda[1-\alpha\gamma(\lambda)](X-L) = \lambda[1-\alpha\gamma(\lambda)](X-1) - (1-\lambda) + \frac{1}{2}\left[\frac{1-\gamma(\lambda)}{1-\lambda}\right]^2$. It can be shown that $\frac{\partial \pi_{\text{bank}}(\lambda)}{\partial \lambda} > 0$, ensured by (1). It has been verified $\frac{\partial \pi_{\text{bank}}(\lambda)}{\partial \lambda} - \frac{\partial \pi_{\text{n-bank}}(\lambda)}{\partial \lambda} > 0$ for $\alpha = 0$, so by continuity there exists values of $\alpha$ in the neighborhood of zero in which $\frac{\partial \pi_{\text{bank}}(\lambda)}{\partial \lambda} - \frac{\partial \pi_{\text{n-bank}}(\lambda)}{\partial \lambda} > 0$. Condition (1) has been shown to suffice to ensure this. So, assuming $\pi_{\text{bank}}(\lambda_{\text{n-bank}}) < 0$ and $\pi_{\text{bank}}(\lambda_{\text{mkt}}) > \pi_{\text{n-bank}}(\lambda_{\text{mkt}})$,[28] $\lambda_{\text{bank}} \in (\lambda_{\text{n-bank}}, \lambda_{\text{mkt}})$ is uniquely determined by $\pi_{\text{bank}}(\lambda_{\text{bank}}) = \pi_{\text{n-bank}}(\lambda_{\text{bank}})$:

$$\begin{aligned}\lambda_{\text{bank}}(1-\lambda_{\text{bank}})\alpha\left(\theta_T - \frac{(1-\lambda_{\text{bank}})^2 - (r_E - 1 + \lambda_{\text{bank}}\alpha\delta)}{(1-\lambda_{\text{bank}})(1-\lambda_{\text{bank}}\alpha\delta)}\right)(X-1) + (1-\lambda_{\text{bank}})\theta_T \\ = T + \frac{1}{2}\left(\theta_T - \frac{(1-\lambda_{\text{bank}})^2 - (r_E - 1 + \lambda_{\text{bank}}\alpha\delta)}{(1-\lambda_{\text{bank}})(1-\lambda_{\text{bank}}\alpha\delta)}\right)^2.\end{aligned} \tag{A5}$$

[27] The condition is $T < \lambda_{\text{mkt}}\{1 - \alpha[\lambda_{\text{mkt}} + (1-\lambda_{\text{mkt}})(1-\theta_T)]\}(X-1) - (1-\lambda_{\text{mkt}})(1-\theta_T)$, where $\lambda_{\text{mkt}}$ is given by (A3).

[28] The conditions are

$$\lambda_{\text{n-bank}}\left[1 - \alpha\frac{r_E - (1-\lambda_{\text{n-bank}})^2}{1-\lambda_{\text{n-bank}}\alpha\delta}\right](X-1) - (1-\lambda_{\text{n-bank}}) + \frac{1}{2}\left(\theta_T - \frac{(1-\lambda_{\text{n-bank}})^2 - (r_E - 1 + \lambda_{\text{n-bank}}\alpha\delta)}{(1-\lambda_{\text{n-bank}})(1-\lambda_{\text{n-bank}}\alpha\delta)}\right)^2 < 0$$

and

$$\begin{aligned}T > \lambda_{\text{mkt}}(1-\lambda_{\text{mkt}})\alpha\left(\theta_T - \frac{(1-\lambda_{\text{mkt}})^2 - (r_E - 1 + \lambda_{\text{mkt}}\alpha\delta)}{(1-\lambda_{\text{mkt}})(1-\lambda_{\text{mkt}}\alpha\delta)}\right)(X-1) + (1-\lambda_{\text{mkt}})\theta_T \\ - \frac{1}{2}\left(\theta_T - \frac{(1-\lambda_{\text{mkt}})^2 - (r_E - 1 + \lambda_{\text{mkt}}\alpha\delta)}{(1-\lambda_{\text{mkt}})(1-\lambda_{\text{mkt}}\alpha\delta)}\right)^2.\end{aligned}$$

Since $\frac{\partial \pi_{\text{bank}}(\lambda)}{\partial r_E} < 0$[29] while $\frac{\partial \pi_{\text{n-bank}}(\lambda)}{\partial r_E} = 0$, it is clear that $\frac{\partial \lambda_{\text{bank}}}{\partial r_E} > 0$.

Finally, we characterize the upper bound $\bar{K}$ in condition (2) that ensures $r_E > 1$:

$$\bar{K} = 2 \int_{\tilde{\lambda}_{\text{bank}}}^{\tilde{\lambda}_{\text{mkt}}} \tilde{k}(\lambda) f(\lambda) d\lambda, \tag{A6}$$

where $\tilde{\lambda}_{\text{mkt}}$, $\tilde{k}(\lambda)$ and $\tilde{\lambda}_{\text{bank}}$ are computed by letting $r_E = 1$ in the above determinations of $\lambda_{\text{mkt}}$, $k(\lambda)$ and $\lambda_{\text{bank}}$, respectively:

$$\begin{cases} \tilde{\lambda}_{\text{mkt}} = \dfrac{(2+\alpha\delta) - \sqrt{(2+\alpha\delta)^2 - 4}}{2} \\ \tilde{k}(\lambda) = \dfrac{(1-\lambda)^2 - \lambda\alpha\delta}{(1-\lambda)^2(1-\lambda\alpha\delta)} \\ \tilde{\lambda}_{\text{bank}}(1-\tilde{\lambda}_{\text{bank}})\alpha \left( \theta_T - \dfrac{(1-\tilde{\lambda}_{\text{bank}})^2 - \tilde{\lambda}_{\text{bank}}\alpha\delta}{(1-\tilde{\lambda}_{\text{bank}})(1-\tilde{\lambda}_{\text{bank}}\alpha\delta)} \right)(X-1) + (1-\tilde{\lambda}_{\text{bank}})\theta_T \\ \qquad = T + \dfrac{1}{2}\left( \theta_T - \dfrac{(1-\tilde{\lambda}_{\text{bank}})^2 - \tilde{\lambda}_{\text{bank}}\alpha\delta}{(1-\tilde{\lambda}_{\text{bank}})(1-\tilde{\lambda}_{\text{bank}}\alpha\delta)} \right)^2. \end{cases} \tag{A7}$$

Given $K < \bar{K}$ (see (2)), the aggregate demand for bank capital when $r_E = 1$, $\bar{K}$ (see (A6)), would exceed $K$, so we have $r_E > 1$ in equilibrium. When $r_E > 1$, we have $\lambda_{\text{mkt}} < \tilde{\lambda}_{\text{mkt}}$, $k(\lambda) < \tilde{k}(\lambda)$ $\forall \lambda$, and $\lambda_{\text{bank}} > \tilde{\lambda}_{\text{bank}}$, so there exists some unique $r_E > 1$ such that the aggregate demand for bank capital, $2\int_{\lambda_{\text{bank}}}^{\lambda_{\text{mkt}}} k(\lambda) f(\lambda) d\lambda$, falls below $\bar{K}$ and equals $K$ to clear the market for bank capital; the uniqueness of $r_E$ arises from the monotonicity of $\lambda_{\text{mkt}}$, $k(\lambda)$ and $\lambda_{\text{bank}}$ with respect to $r_E$. ■

**Proof of Lemma 2.** Expressions for $k^{\text{BR}}(\lambda)$ and $\gamma^{\text{BR}}(\lambda)$ follow from $k(\lambda)$ in (16) and $\gamma(\lambda)$ in (18), respectively, by replacing $r_E$ there with $r_E^{\text{req}}$. Given $r_E^{\text{req}} > r_E$, we have $k^{\text{BR}}(\lambda) < k(\lambda)$ and $\gamma^{\text{BR}}(\lambda) > \gamma(\lambda)$. The result $k^{\text{BR}}(\lambda) > k_{\min}$ for $\lambda \in [\lambda_{\text{bank}}^{\text{BR}}, \lambda_{\min})$ follows from the definition of $k_{\min}$ in (22) and $\frac{\partial k^{\text{BR}}(\lambda)}{\partial \lambda} < 0$. The cutoff $\lambda_{\text{bank}}^{\text{BR}}$ (*resp.* $\lambda_{\text{bank}}^{\text{GR}}$) is determined by $\pi_{\text{bank}}(\lambda_{\text{bank}}^{\text{BR}}) = \pi_{\text{n-bank}}(\lambda_{\text{bank}}^{\text{BR}})$ (*resp.* $\pi_{\text{bank}}(\lambda_{\text{bank}}^{\text{GR}}) = \pi_{\text{n-bank}}(\lambda_{\text{bank}}^{\text{GR}})$), with $r_E$ being replaced with $r_E^{\text{req}}$ in $\pi_{\text{bank}}(\cdot)$ and $\pi_{\text{n-bank}}(\cdot)$:

$$\begin{aligned} &\lambda_{\text{bank}}^{\text{BR}}(1-\lambda_{\text{bank}}^{\text{BR}})\alpha \left( \theta_T - \frac{(1-\lambda_{\text{bank}}^{\text{BR}})^2 - (r_E^{\text{req}} - 1 + \lambda_{\text{bank}}^{\text{BR}}\alpha\delta)}{(1-\lambda_{\text{bank}}^{\text{BR}})(1-\lambda_{\text{bank}}^{\text{BR}}\alpha\delta)} \right)(X-1) + (1-\lambda_{\text{bank}}^{\text{BR}})\theta_T \\ &\qquad = T + \frac{1}{2}\left( \theta_T - \frac{(1-\lambda_{\text{bank}}^{\text{BR}})^2 - (r_E^{\text{req}} - 1 + \lambda_{\text{bank}}^{\text{BR}}\alpha\delta)}{(1-\lambda_{\text{bank}}^{\text{BR}})(1-\lambda_{\text{bank}}^{\text{BR}}\alpha\delta)} \right)^2. \end{aligned} \tag{A8}$$

[29] Applying the Envelope Theorem to (A1), we see that the value function $L$ increases with $r_E$; $\frac{\partial \pi_{\text{bank}}(\lambda)}{\partial r_E} < 0$ then follows by applying the Envelope Theorem again to (6).

Given $r_E^{\text{req}} > r_E$, the result $\lambda_{\text{bank}}^{\text{BR}} = \lambda_{\text{bank}}^{\text{GR}} > \lambda_{\text{bank}}$, where $\lambda_{\text{bank}}$ is determined by (A5), follow from the fact that $\pi_{\text{bank}}(\cdot)$ is decreasing in $r_E$ while $\pi_{\text{n-bank}}(\cdot)$ does not depend on $r_E$. ■

**Proof of Lemma 3.** We have $k^{\text{BR}}(\lambda) = k_{\min}$ $\forall \lambda \in [\lambda_{\min}, \lambda_{\text{mkt}}^{\text{BR}})$, since the capital requirement binds for brown banks serving sectors $\lambda \in [\lambda_{\min}, \lambda_{\text{mkt}}^{\text{BR}})$ (which follows from the definition of $k_{\min}$ in (22)). Using $\theta = (1-\lambda)k^{\text{BR}}(\lambda)$ ((5)), we have $\gamma^{\text{BR}}(\lambda) = \lambda + (1-\lambda)(1-\theta) = 1 - (1-\lambda)^2 k_{\min}$. Results that $k_{\min} < k(\lambda)$ for $\lambda \in [\lambda_{\min}, \widehat{\lambda}_{\min})$ while $k_{\min} > k(\lambda)$ for $\lambda \in (\widehat{\lambda}_{\min}, \lambda_{\text{mkt}}^{\text{BR}})$ follow from the facts that $k(\widehat{\lambda}_{\min}) = k_{\min}$ ((23)) and $\frac{\partial k(\lambda)}{\partial \lambda} < 0$. The relation between $\gamma^{\text{BR}}(\lambda)$ and $\gamma(\lambda)$ follows by comparing $1-(1-\lambda)^2 k_{\min}$ and $1-(1-\lambda)^2 k(\lambda)$. Lastly, replacing $r_E$ with $r_E^{\text{req}}$ and $\tilde{\gamma}(\lambda)$ with $\gamma^{\text{BR}}(\lambda) = 1-(1-\lambda)^2 k_{\min}$ in (A2) yields (26). Substituting (26) into $\gamma^{\text{GR}}(\lambda) = \lambda + (1-\lambda)(1-\theta) = 1-(1-\lambda)^2 k^{\text{GR}}(\lambda)$ yields (27). ■

**Proof of Lemma 4.** Substituting $r_E$ with $r_E^{\text{req}}$ and letting $\tilde{\gamma}(\lambda) = \gamma^{\text{BR}}(\lambda)$ in (A2) and (9), we have $k^{\text{GR}}(\lambda) = 1 - \frac{r_E^{\text{req}} - 1 + \lambda\alpha\delta\gamma^{\text{BR}}(\lambda)}{(1-\lambda)^2}$ and $\gamma^{\text{GR}}(\lambda) = r_E^{\text{req}} - (1-\lambda)^2 + \lambda\alpha\delta\gamma^{\text{BR}}(\lambda)$, respectively. Since competing brown firms in sectors $\lambda \in [\lambda_{\text{mkt}}^{\text{BR}}, \lambda_{\text{mkt}}^{\text{GR}})$ switch to the market, we let $\gamma^{\text{BR}}(\lambda) = 1$ in these two expressions, yielding (28) and (29), respectively. Lastly, $k^{\text{GR}}(\lambda) = 1 - \frac{r_E^{\text{req}} - 1 + \lambda\alpha\delta}{(1-\lambda)^2} < k(\lambda) = \frac{1}{1-\lambda\alpha\delta}\left(1 - \frac{r_E - 1 + \lambda\alpha\delta}{(1-\lambda)^2}\right)$. Consequently, $\gamma^{\text{GR}}(\lambda) = 1-(1-\lambda)^2 k^{\text{GR}}(\lambda) > 1-(1-\lambda)^2 k(\lambda) = \gamma(\lambda)$. ■

**Proof of Lemma 5.** First, $\lambda_{\text{mkt}}^{\text{GR}}$ is the value of $\lambda$ such that $k^{\text{GR}}(\lambda) = 0$ in (28): when the green bank finds it optimal to raise zero capital, it is equivalent to market finance. Thus,

$$1 - \frac{r_E^{\text{req}} - 1 + \lambda_{\text{mkt}}^{\text{GR}}\alpha\delta}{(1-\lambda_{\text{mkt}}^{\text{GR}})^2} = 0 \quad \Rightarrow \quad \lambda_{\text{mkt}}^{\text{GR}} = \frac{(2+\alpha\delta) - \sqrt{(2+\alpha\delta)^2 - (8 - 4r_E^{\text{req}})}}{2}. \tag{A9}$$

Since $r_E^{\text{req}} > r_E$, we have $\lambda_{\text{mkt}}^{\text{GR}} < \lambda_{\text{mkt}} = \frac{(2+\alpha\delta) - \sqrt{(2+\alpha\delta)^2 - (8-4r_E)}}{2}$ (see (A3)). Next, for a sector-$\lambda$ brown firm, its expected profit from market finance is $\pi_{\text{mkt}}(\lambda) = \lambda(1-\alpha)X - (1-\lambda\alpha)$; see (15). Its expected profit from bank finance is $\pi_{\text{bank}}(\lambda) = \lambda[1-\alpha\gamma^{\text{GR}}(\lambda)]X - \Big[\frac{(1-\lambda)^2}{2}k_{\min}^2 + [r_E^{\text{req}} - 1 + \lambda\alpha\delta\gamma^{\text{GR}}(\lambda) - (1-\lambda)^2]k_{\min} + 1 - \lambda\alpha\gamma^{\text{GR}}(\lambda)\Big]$,[30] where $\gamma^{\text{GR}}(\lambda) = r_E^{\text{req}} - (1-\lambda)^2 + \lambda\alpha\delta$ is in (29). The cutoff $\lambda_{\text{mkt}}^{\text{BR}}$ is determined by $\pi_{\text{mkt}}(\lambda_{\text{mkt}}^{\text{BR}}) = \pi_{\text{bank}}(\lambda_{\text{mkt}}^{\text{BR}})$. Lastly, we show $\lambda_{\text{mkt}}^{\text{BR}} < \lambda_{\text{mkt}}^{\text{GR}}$. Consider a brown firm with $\lambda = \lambda_{\text{mkt}}^{\text{GR}}$. If it were bank funded, the brown bank would face the binding capital

[30] This follows from (6) and (A1), letting $\tilde{\gamma}(\lambda) = \gamma^{\text{GR}}(\lambda)$, $k = k_{\min}$ and $r_E = r_E^{\text{req}}$.

requirement $k_{\min}$. Since a green firm with $\lambda = \lambda^{\text{GR}}_{\text{mkt}}$ is funded by a green bank that raises its privately-optimal capital (instead of $k_{\min}$), the green firm makes a higher profit than the brown firm. So, given $\pi_{\text{bank}}(\lambda^{\text{GR}}_{\text{mkt}}) = \pi_{\text{mkt}}(\lambda^{\text{GR}}_{\text{mkt}})$ for the green firm with $\lambda = \lambda^{\text{GR}}_{\text{mkt}}$, we must have $\pi_{\text{bank}}(\lambda^{\text{GR}}_{\text{mkt}}) < \pi_{\text{mkt}}(\lambda^{\text{GR}}_{\text{mkt}})$ for the brown firm with $\lambda = \lambda^{\text{GR}}_{\text{mkt}}$ (note that $\pi_{\text{mkt}}(\lambda)$ is the same for both brown and green firms with $\lambda = \lambda^{\text{GR}}_{\text{mkt}}$). Thus, the brown firm with $\lambda = \lambda^{\text{GR}}_{\text{mkt}}$ must strictly prefer market finance, and hence $\lambda^{\text{BR}}_{\text{mkt}} < \lambda^{\text{GR}}_{\text{mkt}}$. ■

**Proof of Proposition 2.** The expressions for $\Delta\text{Po}(i)$, $i \in \{1, 2, 3, 4\}$, are as follows:

$$\begin{cases} \Delta\text{Po}(1) = \omega \underbrace{\int_{\lambda_{\text{bank}}}^{\lambda^{\text{BR}}_{\text{bank}}} [\gamma_N(\lambda) - \gamma(\lambda)] f(\lambda) d\lambda}_{\text{switch to non-banks}} \quad \text{(ambiguous sign)} \\ \Delta\text{Po}(2) = \omega \underbrace{\int_{\widehat{\lambda}_{\min}}^{\lambda^{\text{BR}}_{\text{mkt}}} [1 - (1-\lambda)^2 k_{\min} - \gamma(\lambda)] f(\lambda) d\lambda}_{\text{raise more capital}} < 0 \\ \Delta\text{Po}(3) = \omega \underbrace{\int_{\lambda^{\text{BR}}_{\text{bank}}}^{\lambda_{\min}} \frac{r_E^{\text{req}} - r_E}{1 - \lambda\alpha\delta} f(\lambda) d\lambda + \int_{\lambda_{\min}}^{\widehat{\lambda}_{\min}} [1 - (1-\lambda)^2 k_{\min} - \gamma(\lambda)] f(\lambda) d\lambda}_{\text{raise less capital}} > 0 \\ \Delta\text{Po}(4) = \omega \underbrace{\int_{\lambda^{\text{BR}}_{\text{mkt}}}^{\lambda_{\text{mkt}}} [1 - \gamma(\lambda)] f(\lambda) d\lambda}_{\text{switch to market}} > 0. \end{cases} \tag{A10}$$

In (A10), $\gamma_N(\lambda) = \lambda + (1-\lambda)(1-\theta_T)$ and $\gamma(\lambda) = \frac{r_E - (1-\lambda)^2}{1-\lambda\alpha\delta}$ (see (18)). The signs of $\Delta\text{Po}(2)$, $\Delta\text{Po}(3)$ and $\Delta\text{Po}(4)$ are unambiguous, as discussed in the text. The sign of $\Delta\text{Po}(1)$ is undetermined, as $\Delta\text{Po}(1) \propto \int_{\lambda_{\text{bank}}}^{\lambda^{\text{BR}}_{\text{bank}}} \left[\lambda + (1-\lambda)(1-\theta_T) - \frac{r_E - (1-\lambda)^2}{1-\lambda\alpha\delta}\right] f(\lambda) d\lambda$ can be either positive or negative.

Since stability hinges on screening and hence bank capital, results on brown bank stability follow from the explanation of (A10) for brown banks' capital change in the text. For green banks serving sectors $\lambda \in [\lambda^{\text{BR}}_{\text{mkt}}, \lambda^{\text{GR}}_{\text{mkt}})$ or $\lambda \in (\lambda^{\text{GR}}_{\text{bank}}, \widehat{\lambda}_{\min}]$, their capital and hence stability fall because of the elevated competition from the same-sector brown firms switching to the market (the former) or the same-sector brown banks raising less capital (the latter). For green banks serving sectors $\lambda \in (\widehat{\lambda}_{\min}, \lambda^{\text{BR}}_{\text{mkt}})$, while the increased capital cost reduces their capital demand, higher capital raised by the same-sector brown banks induces them to also raise more capital; the net effect is ambiguous. ■

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