Green Capital Requirements

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Introduction

- embed climate-related risks into an otherwise standard model of bank capital regulation
- Outline:
  - Exogenous policy interventions:
    1. neutral capital requirement (Baseline)
    2. brown penalty
    3. green support
  - Model generalization: many firm types
  - Optimal capital requirement setting:
    1. in the absence of climate-related risks
    2. how different categories of climate-related risks affect the optimal capital requirement under *a prudential mandate*
    3. when a regulator with a broader *impact mandate* accounts for carbon externalities

Benchmark model

- 3 types of agents: Firms, Banks, and a regulator
- 2 periods: firms invest at t=0 and realize cash flows at t=1

Firms:

- infiniteimal with mass one
- born with a type $\in \{C, D\}$ with population (π_c, π_d)
- cashless, fixed cost $I > 0$ at t=0 to be borrowed from banks
- cash flows X_q at t=1, $q \in \{C, D\}$ follow log normal distribution $\bar{X}_q, \delta_q$
- positive $NPV_q = \bar{X}_q - I > 0$ with $NPV_C < NPV_D$, while emissions $\phi_D > \phi_C = 0$

Banks

- ex-ante identical, of mass one
- endowned with equity $E < I$ and raise deposits D from competitive depositors
- balance sheet: $A = E + D$ where E is assumed fixed due to prohabitively high cost of issuing new equity
- Banks maximize equity value by choosing equity ratio $e = \frac{E}{A}$ and loan portfolio $\mathbf{w} = \{w_c, w_D\}$
  $V = \max_{e,\mathbf{w}} E[1 + r_E(e, \mathbf{w})]$
  given E, essentially maximize $ROE = r_E(e, \mathbf{w})$

Regulator set loan capital requirement $\underline{e}_q$:

Given w_q, bank faces an equity ratio constraint: $e \geq e_{min}(\mathbf{w}) = \sum_q w_q \underline{e}_q$.

Baseline Analysis

Proof of Result 1: Let $y_q \geq 0$ denote the interest rate that a borrower of type q promises to pay on the loan of size I. (This promised yield will be endogenous in equilibrium, see Results 2 and 3). Then, if a bank lends only to borrowers of type q (i.e., $w_q = 1$) and chooses a feasible equity ratio $e \geq \underline{e}_q$, its expected return on equity can be written as:

$$r_E = \frac{\mathbb{E}\left[\max\left\{\min\left\{I\left(1+y_q\right), X_q(s)\right\} - (1-e)\,I, 0\right\}\right] - eI}{eI} \tag{A.1}$$

$$= \frac{\mathbb{E}\left[\max\left\{\min\left\{I y_q, X_q(s) - I\right\}, -eI\right\}\right]}{eI}. \tag{A.2}$$

$$r_E = \frac{\mathbb{E}\left[\min\left\{I y_q, X_q(s) - I\right\}\right] + \mathbb{E}\left[\max\left\{-eI - \min\left\{I y_q, X_q(s) - I\right\}, 0\right\}\right]}{eI}, \tag{A.3}$$

$$r_E = \frac{\mathbb{E}\left[\min\left\{I y_q, X_q(s) - I\right\}\right] + \mathbb{E}\left[\max\left\{I\left(1-e\right) - X_q(s), 0\right\}\right]}{eI}. \tag{A.4}$$

Equation (A.4) shows that the bank's ROE is strictly decreasing in e, so that the bank optimally chooses the minimum equity co-financing $e = \underline{e}_q$. Moreover, mixing two borrower types is strictly dominated because diversification lowers the bank's put value.

Equilibrium with Exogenous Capital Requirements: supply side

Result 1 *The regulatory leverage constraint* $e^* = e_{\min}(\mathbf{w}^*)$ *binds and individual banks find it optimal to specialize in funding either clean or dirty firms.*

Result 1 states that individual banks maximize the amount of deposit funding and choose specialized portfolios.[9] This is optimal because deposit insurance generates a subsidy for deposit funding. Specialization maximizes this subsidy. The value of this deposit insurance put is passed on to bank equityholders via the competitive pricing of deposits.

Analogy to demand theory:

- a firm borrowing from a bank is similar to a consumer with consumption good being $I\underline{e}_q$ units of bank equity (space on the B/S)
- banks rank borrowers according to the maximum ROE associated with a loan to a borrower (determined by the maximum interest rate the borrower is willing to pay, *reservation prices* in the form of the max ROE that a borrower can offer to a bank)

Equilibrium with Exogenous Capital Requirements: demand side

Result 2 *At the maximum interest rate that a borrower of type q is willing to pay, the bank equityholders' expected ROE is given by*

$$r_q^{\max}\left(\underline{e}_q\right)=\frac{NPV_q+PUT_q\left(\underline{e}_q\right)}{I\underline{e}_q}, \tag{5}$$

where $PUT_q\left(\underline{e}_q\right)$ denotes the contribution of the loan to the bank's deposit insurance put,

$$PUT_q\left(\underline{e}_q\right)=\mathbb{E}\left[\max\left\{I(1-\underline{e}_q)-X_q(s),0\right\}\right]. \tag{6}$$

- in case of bank-dependent firm: it is willing to pledge the entire NPV to bank.
- if the firm has outside option, the reservation interest rate y_q^{max} is determined such that a competitive outside investor just breaks even on the investment $I \implies NPV_q = 0$.

(The surplus generated by the loan consists of the NPV of the firm's project and the value of the deposit insurance put associated with the loan under optimal (=maximum) leverage)

Equilibrium with Exogenous Capital Requirements: Equilibrium

Banks behave competitively $\Longrightarrow$ the equilibrium ROE r_E^* is determined by the intersection of the supply (fixed at E) and aggregate demand (from funded loans).

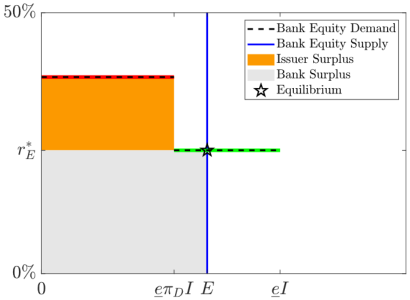


Figure 1. Banking Sector Equilibrium. This figure illustrates the banking sector equilibrium for equal capital requirements of $\underline{e} = 16\%$ for both firm types. The equilibrium ROE is denoted by r_E^*. Dirty firms are depicted in red, clean firms in green.

Equilibrium with Exogenous Capital Requirements: Equilibrium

When *ROE* > 0, it features scarcity rent. The loan rate for the marhginal green borrowers is set such that all surplus accrues to banks.

Result 3 *If* $E < I\sum_q \pi_q \cdot \underline{e}_q$*, bank capital is scarce so that* $r_E^* > 0$*. All borrowers with* $r_q^{max} > r_E^*$ *are fully funded by banks. Marginal borrower types, satisfying* $r_q^{\max} = r_E^*$*, are partially funded. The banking sector's equilibrium ROE satisfies:*

$$r_E\left(\mathbf{w}^*, e_{\min}\left(\mathbf{w}^*\right)\right) = r_E^*. \tag{7}$$

If $E \geq I\sum_q \pi_q \cdot \underline{e}_q$*, all types are fully funded and bank capital is not scarce,* $r_E^* = 0$*.*

- marginal borrower type is important
- depends on both exogeneous firm characteristics and the regulator's choice of capital requirements

Green Tilts to Capital Requirements

- consider a benchmark policy regime with equal capital requirements for dirty and clean loans ($\underline{e}_c = \underline{e}_d = \underline{e} < 1$), then study the effects of green tilts relative to this benchmark
- Benchmark equilibrium with equal capital requirements:
  - dirty loans $>$ clean loans in the demand curve because of their high financial proftiability
  - if very sacrce equity ($E < \pi_D \, \underline{e} \, I$), the marginal borrower is dirty and no clean loans are funded
  - for intermediate levels of bank capital ($\pi_D \, \underline{e} \, I < e < \underline{e} \, I$), the marginal borrower is clean and all dirty loans are funded
  - if equity is abundant, both loans are funded.
- a change in the capital requirement for one type of loan $=$ a change in the relative prices of bank B/S space for clean and dirty loans

  $\Longrightarrow$ characterised by income and subsititution effects:
  - income effect: a higher capital requirement reduces the amount of loans that can be funded
  - substitution effect: a higher capital requirement increases the relative price of the loan

Brown Penalizing Factor

Focus on he case of intermediate equity levels, where the marginal borrower is clean.

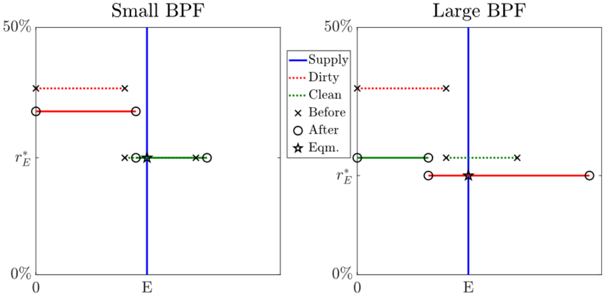


Figure 2. Brown penalizing factor. The figure illustrates the effect of introducing a brown penalizing factor starting from the benchmark of equal capital requirements of $\underline{e} = 16\%$. The left panel illustrates the equilibrium impact of a small brown penalizing factor that leaves the relative ranking of firm types unchanged. The right panel illustrates the equilibrium impact of a large brown penalizing factor that reverses the relative ranking of firm types. Dotted lines and segment endpoints marked $\circ$ denote the benchmark equilibrium. Solid lines and segment endpoints marked $\times$ denote the equilibrium after the introduction of the brown penalizing factor.

Brown Penalizing Factor: proposition 1

Proposition 1 (Brown Penalizing Factor) *Relative to a benchmark with equal capital requirements for clean and dirty loans:*

1. *The effect of a marginal increase in capital requirements for dirty loans (marginal BPF) depends on the capitalization of the banking sector:*
   (a) *If $E < \pi_D \underline{e} I$, a marginal BPF only reduces lending to dirty firms.*
   (b) *If $E \in (\pi_D \underline{e} I, \underline{e} I)$, a marginal BPF only reduces lending to clean firms.*
   (c) *If $E > \underline{e} I$, a marginal BPF does not affect lending.*
2. *If the increase in capital requirements for dirty firms exceeds a cut-off $\Delta_{BPF} > 0$, characterized by $r_D^{\max}(\underline{e} + \Delta_{BPF}) = r_C^{\max}(\underline{e})$, lending to clean firms increases whereas lending to dirty firms decreases.*

Green Supporting Factor

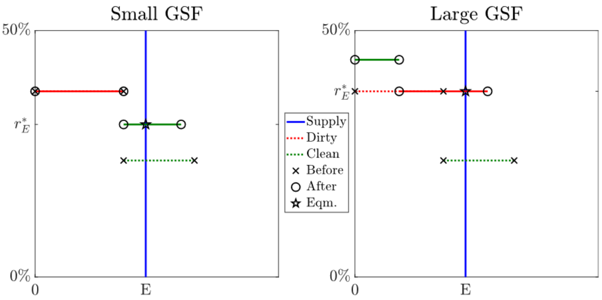


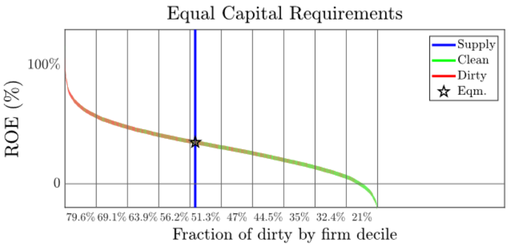
Figure 3. Green supporting factor. The figure illustrates the effect of introducing a green supporting factor starting from the benchmark of equal capital requirements $\underline{e} = 16\%$. The left panel illustrates the equilibrium impact of a small green supporting factor that leaves the relative ranking of firm types unchanged. The right panel illustrates the equilibrium impact of a large green supporting factor that reverses the relative ranking of firm types. Dotted lines and segment endpoints marked $\circ$ denote the benchmark equilibrium. Solid lines and segment endpoints marked $\times$ denote the equilibrium after the introduction of the green supporting factor.

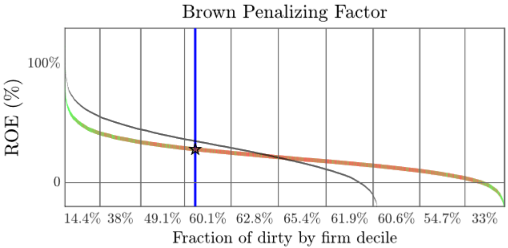
Green Supporting Factor: proposition 2

Proposition 2 (Green Supporting Factor) *Relative to a benchmark with equal capital requirements for clean and dirty loans:*

1. *The effect of a marginal decrease in capital requirements for clean loans (marginal GSF) depends on the capitalization of the banking sector:*
   - (a) *If* $E \in (\pi_D \underline{e} I, \underline{e} I)$*, a marginal GSF increases lending to clean firms.*
   - (b) *A marginal GSF has no effect on bank lending otherwise.*
2. *If the decrease in capital requirements for clean firms exceeds a cut-off* $\Delta_{GSF} > 0$*, characterized by* $r_D^{\max}(\underline{e}) = r_C^{\max}(\underline{e} - \Delta_{GSF})$*, lending to clean firms increases whereas lending to dirty firms decreases, strictly so if not all firms are financed post intervention.*

Generalization: many firm types





Optimal Capital Requirements: no climate risks

The prudential regulator trades off the financial value of bank lending against the deadweight cost of the deposit insurance put:

$$\max_{\underline{\mathbf{e}}} \Omega_P = \max_{\underline{\mathbf{e}}} \sum \omega_q(\underline{\mathbf{e}}) \left[\mathrm{NPV}_q - \lambda \cdot \mathrm{PUT}_q(\underline{e}_q)\right], \tag{8}$$

where the notation $\omega_q(\underline{\mathbf{e}})$ and $\mathrm{PUT}_q(\underline{e}_q)$ highlights the dependence of bank funding decisions and the deposit insurance put on the capital requirements for clean and dirty firms, $\underline{\mathbf{e}} = (\underline{e}_C, \underline{e}_D)$.

Rewrite:

$$\max_{\underline{\mathbf{e}}} \Omega_P = E \max_{\underline{\mathbf{e}}} \sum \tilde{\omega}_q(\underline{\mathbf{e}}) \, \mathrm{PPI}_q(\underline{e}_q), \tag{9}$$

where $\tilde{\omega}_q \in [0,1]$ reflects the fraction of total equity that the banking sector allocates to funding type q, and where $\mathrm{PPI}_q(\underline{e}_q)$ denotes the *prudential profitability index*. In analogy to the banker's maximal ROE given in equation (5), the PPI reflects the surplus created per unit of bank equity as seen from the prudential regulator's perspective,

$$\mathrm{PPI}_q(\underline{e}_q) = \frac{\mathrm{NPV}_q - \lambda \cdot \mathrm{PUT}_q(\underline{e}_q)}{I\underline{e}_q}. \tag{10}$$

Main difference between the regulator's PPI and bank's ROE

- the deposit insurance put enters with opposite sign ⇒ wedge between prudential preferences and those of the banking sector

$$r_q^{\max}\left(\underline{e}_q\right) = \frac{NPV_q + PUT_q\left(\underline{e}_q\right)}{I\underline{e}_q}, \tag{5}$$

- regulator internalizes that the PPIs for each type are affected by the chosen capital regulation

Assuming the cost of public funds is sufficiently high $\lambda > max_q \frac{NPV_q}{PUT_q(0)}$ (PPI bounded above), the capital requirement that maximizes the PPI for type q ($\underline{e}_q^{PPI}$) is given by the first order condition:

$$\mathrm{PPI}_q(\underline{e}_q) = \lambda \left| \frac{\partial \mathrm{PUT}_q}{\partial \underline{e}_q} \right| / I. \tag{11}$$

LHS: marginal benefit of lowering the capital requirement for type q
RHS: marginal (social) cost of lowering the capital requirement
$\Longrightarrow$ regulators prefer borrower with higher PPIs (*Deinifition 1*)

Optimal Capital Requirement without climate risks: Results

Proposition 3 (Principles of Optimal Prudential Regulation) *Optimal prudential regulation is characterized by the following four principles.*

P1: All bank equity is used to fund loans,

$$\sum_q \omega_q(\underline{e})\, \underline{e}_q I = E. \qquad (12)$$

P2: For sufficiently low levels of bank equity, $E \leq \pi_D \underline{e}_D^{PPI} I$, the regulator induces banks to lend exclusively to its preferred type D.

P3: If firm type q is partially funded (there is at most one such type), its capital requirement maximizes PPI_q,

$$e_q^* = \underline{e}_q^{PPI}. \qquad (13)$$

P4: If both firm types are funded, marginal deposit-insurance puts are equalized across types,

$$\frac{\partial PUT_D}{\partial \underline{e}_D} = \frac{\partial PUT_C}{\partial \underline{e}_C}. \qquad (14)$$

P1: Funded loans fully exhaust the equity of the banking sector
P2: The first funded type is the regulatr's preferred type D
P3: optimal capital requirement for the marginal type maximizes the PPI
P4: links capital requiremens of inframarginal borrowers to those of marginal borrowers

The effect of climate-related risks on the optimal capital requirement

Classification of climate-related risks based on cause (row) and effect (column):

		EFFECT ON	
		Firms funded by banking sector	Other agents
CAUSED BY	Firms funded by banking sector	Bank-Bank (Section 4.2.3)	Bank-Other (Section 4.2.2)
	Other agents	Other-Bank (Section 4.2.1)	Other-Other (X)

BB: considers the effects of emissions caused by bankfunded firms on risks in the banking sector
BO: considers the effects of emissions caused by bank-funded firms on risks in the real economy
OB: considers the effects of climate-related risks in the real economy on risks in the banking sector
OO: considers the effects of climate-related risks in the real economy on risks in the real economy

prudential regulator: BB+OB
impact regulator: BB+BO+OB
(No regulator considers OO because no relevant for banking sector)

Exogenous climate-related financial risks

Type OB: risks that affect bank-funded firms but are caused by others. E.g., regulatory transition risks.

Understood via a comparative statics analysis w.r.t. the parameters of the cash-flow distribution ($\bar{X}_d \downarrow$ and/or $\sigma_d \uparrow$)

Lemma A.1 *Suppose a borrower's cash flow distribution is log-normal with mean cash flow $X_q(s)$ and return volatility σ. Then, if this borrower is funded by a bank in an optimal portfolio (see Result 1), the value of the deposit insurance put is given by:*

$$PUT_q\left(\underline{e}_q\right) = N\left(-d_2\right)\left(1-\underline{e}_q\right)I - N\left(-d_1\right)\overline{X}_q, \tag{A.8}$$

$$d_1 = \frac{\ln\left(\overline{X}_q\right) - \ln\left(I\left(1-\underline{e}_q\right)\right)}{\sigma} + \frac{\sigma}{2}, \tag{A.9}$$

$$d_2 = \frac{\ln\left(\overline{X}_q\right) - \ln\left(I\left(1-\underline{e}_q\right)\right)}{\sigma} - \frac{\sigma}{2}, \tag{A.10}$$

where N denotes the standard normal cumulative distribution function.

$\sigma_d \uparrow \implies PUT_D(underbare_D) \uparrow$ & $\bar{X}_d \downarrow \implies NPV_D \downarrow$
both $\Rightarrow$ marginal prudential cost of funding dirty projects $\uparrow \iff \underline{e}_D \uparrow$

Optimal Marginal policy adjustments: OB risks

Proposition 4 (Optimal Marginal Policy Adjustments: OB risks) *A marginal increase in the cash-flow volatility of dirty firms σ_D or a marginal reduction in their expected cash flow $\overline{X}_D$*

1. *increases $\underline{e}_D^*$;*
2. *has no effect on $\underline{e}_C^*$ when clean is marginal (Region 3) and decreases $\underline{e}_C^*$ when both types are fully funded (Region 4).*

2nd part: spillover effects on clean firms originating from climate-related risks that affect only dirty firms

moderate vs large OB risks

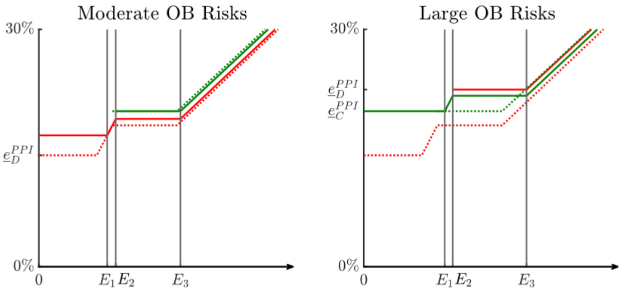


Figure 6. Effects of OB climate risks on optimal prudential capital regulation. The figure plots the effect of other-financial (OB) risks on optimal prudential capital requirements for clean and dirty types. In this example OB risks take the form of a reduction in the expected profitability of dirty firms $\overline{X}_D$, for example, due to transition risk. The left panel illustrates the effect of moderate OB risks, which do not affect the regulator's ranking of firm types. The right panels illustrates the effect of large OB risks that reverse the regulator's ranking of firm types. Solid lines depict optimal capital requirements that take into account OB risks. Dashed lines depict prudential capital requirements that do not take into account OB risks. Note that changes in capital requirements due to OB risks shift the region boundaries relative to Figure B.1.

most cases: a brown penalizing factor;
in some instances: a green supporting factor

Optimal Marginal policy adjustments: moderate OB risks

Corollary 1 (Real Effects of Optimal Marginal Policy Adjustments: OB risks)
The optimal policy response to a marginal increase in the cash-flow volatility of the dirty firms σ_D and/or a marginal reduction in their expected cash flow $\overline{X}_D$

1. *crowds out lending to dirty firms if bank equity is low, $E < E_1$;*
2. *crowds out lending to clean firms if bank equity is intermediate $E \in (E_2, E_3)$.*

Why sacrificing the clean loans?:
A prudential supervisor only cares about climate-risks through their effect on firm cash flows and in turn financial stability in the banking sector.

Optimal Marginal policy adjustments: large OB risks

Proposition 5 (Policy Adjustments in Response to Large OB risks) *The regulator's preferred type switches from dirty to clean if*

1. *the expected cash flow of dirty firms $\overline{X}_D$ decreases sufficiently;*
2. *the return volatility of dirty firms σ_D increases sufficiently and $\frac{NPV_D}{I} < PPI_C(\underline{e}_C^{PPI})$.*

When the regulator's preferred type switches from dirty to clean, funding for clean firms increases and funding for dirty firms decreases.

only when the climate effects are sufficiently large, clean firms deliver the highest PPIs.

Exernalities on other agents: BO risks

Include: direct externalities caused by carbon emissions and financial risks generated by emissions of bank-funded firms (but materialize outside of the banking sector)

Prudential supervisor's objective function does not account for externalities on others $\Longrightarrow$ **no effect on the optimal capital requirement**

Impact regulator internalizes the externalities on others:

$$\max_{\underline{\mathrm{e}}} \Omega_G = \max_{\underline{\mathrm{e}}} \sum \omega_q (\underline{\mathrm{e}}) \left[\mathrm{NPV}_q - \phi_q - \lambda \cdot \mathrm{PUT}_q(\underline{e}_q) \right]. \tag{15}$$

In analogy to the PPI, we can then define a social profitability index (SPI), which captures the impact regulator's "bang for buck" including the social costs generated by carbon externalities ϕ_q,

$$\mathrm{SPI}(\underline{e}_q) = \frac{\mathrm{NPV}_q - \phi_q - \lambda \cdot \mathrm{PUT}_q(\underline{e}_q)}{I\underline{e}_q}. \tag{16}$$

$\Longrightarrow$ prefer the type with the highest SPI

Characterization of the optimal capital requirement under impact supervision: replacing $PPI(\underline{e}_q)$ with $SPI(\underline{e}_q)$.

When including carbon externalities leads to a reversal in the regulator's ranking?

Focus on the case where externalities are large enough to make SPI negative for dirty firms: $\phi_D > NPV_D$

Under this assumption, carbon emissions are so significant that funding dirty firms reduces social surplus even when capital requirements for dirty loans are set to 100% (i.e., $\mathrm{SPI}_D(1) = \frac{\mathrm{NPV}_D - \phi_D}{I} < 0$). Yet, even at a 100% capital requirement banks find it privately profitable to finance dirty loans because $r_D^{\max}(1) = \frac{\mathrm{NPV}_D}{I} > 0$.

$\Longrightarrow$

Observation 2 *If $NPV_D > 0$, financing dirty firms is profitable for banks even under maximum capital requirements of 100%.*

limitations of capital requirements in addressing general carbon externalities

100% capital requirement = the deposit insurance put disappears $\Longrightarrow$ No distortions generated by the deposit insurance put

BUT in the presence of externalities: even when $\underline{e}_D = 1$, dirty firms with negative social value can attract funding given that

$$r_D^{\max}(1) = \frac{\mathrm{NPV}_D}{I} > 0 > \frac{\mathrm{NPV}_D - \phi_D}{I} = \mathrm{SPI}_D(1). \tag{17}$$

Explain:
Recall that banks allocate funds to the type with highest ROE r_q^{max} given capital requirement $\underline{e}_q$.
When $r_c^{max} > r_D^{max} > 0$, banks fund the clean type first and use the remaining equity to fund dirty firms.
When $r_D^{max} > r_c^{max} > 0$, banks still fund the dirty type first.

Capital reuglation under an impact mandate

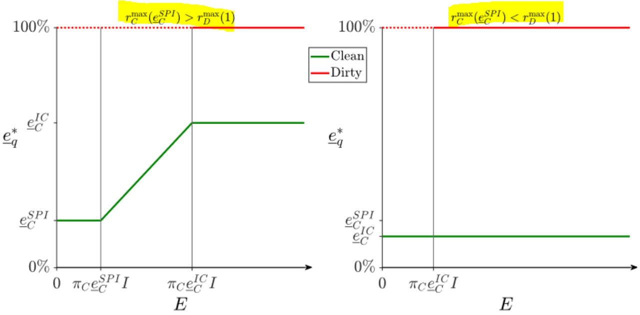


Figure 7. Capital regulation under an impact mandate. This figure plots optimal capital requirements under the green regulator's objective function (15). The left panel illustrates the case, in which banks' IC constraint is not binding. Hence, it is initially possible to set $\underline{e}_C^* = \underline{e}_C^{SPI}$ and to incentivize banks to lend to clean firms by setting capital requirements for dirty firms to 100%. In the right panel, setting $\underline{e}_C^* = \underline{e}_C^{SPI}$ would violate banks' IC constraint and they would therefore lend to dirty firms first. Therefore, the green regulator is forced to lower the capital requirement for clean loans to $\underline{e}_C^* = \underline{e}_C^{IC} < \underline{e}_C^{SPI}$.

Left: set $\underline{e}_C^* = \underline{e}_c^{SPI}$ to maximize SPI and $\underline{e}_D = 1$ to ensure clean loans go first
In $[\pi_c \underline{e}_c^{SPI}, \pi_c \underline{e}_C^{IC}]$, raise capital requirement to exhaust equity until $r_C^{max}(\underline{e}_C^{IC}) = r_D^{max}(1)$(avoid dirty loans and lower clean loan deposit insurance put)

Right: $\underline{e}_c^{SPI}$ cannot reverse the ranking of the types in banks' decision-making $\Longrightarrow$ lower $\underline{e}_c$ to have at least $r_C^{max}(\underline{e}_C^{IC}) = r_D^{max}(1)$. impossible to induce clean lending by only raising the dirty capital requirement; it requires to subsidize clean lending. **Impact regulator sacrifices w.r.t. the prudential objective**.

recall the Prudential regulator's problem

Problem 1 *The prudential regulator solves:*

$$\max_{\underline{\mathbf{e}}} \Omega_P = E \max_{\underline{\mathbf{e}}} \sum \tilde{\omega}_q (\underline{\mathbf{e}}) \, PPI_q(\underline{e}_q), \tag{A.29}$$

s.t. to a short-selling constraint (i.e., the equity allocated to each type is non-negative),

$$\tilde{\omega}_q (\underline{\mathbf{e}}) \geq 0, \tag{A.30}$$

the constraint that the mass of funded firms cannot exceed the supply of each type π_q*,*

$$\tilde{\omega}_q (\underline{\mathbf{e}}) \, E \leq \pi_q \underline{e}_q I, \tag{A.31}$$

and the incentive constraint governing the banking sector's privately optimal allocation of equity,

$$\tilde{\omega}_q (\underline{\mathbf{e}}) = \frac{\min \left\{ \max \left\{ E - \sum_{\check{q}: r_{\check{q}}^{\max} > r_q^{\max}} \pi_{\check{q}} \underline{e}_{\check{q}} I, 0 \right\}, \pi_q \underline{e}_q I \right\}}{E}. \tag{IC}$$

Formalize results

Proposition 6 (The Limits of Green Capital Requirements) *The regulator's ability to use capital requirements to reduce dirty lending is limited.*

1. *If the banking sector is sufficiently well capitalized,* $E > \pi_C \underline{e}_C^{IC} I$, *capital requirements cannot prevent the funding of dirty loans.*

2. *If bank equity capital is limited,* $E \leq \pi_C \underline{e}_C^{IC} I$, *capital requirements can prevent the funding of dirty loans. However, if dirty loans are sufficiently profitable,* $r_C^{\max}\left(\underline{e}_C^{SPI}\right) < r_D^{\max}(1)$, *the regulator has to reduce the capital requirement for clean loans below the prudentially optimal level,* $\underline{e}_C^{IC} < \underline{e}_C^{SPI}$, *thereby sacrificing financial stability.*

Endogenous climate-realted financial risks: BB risks

Include: physical risks caused by the missions of bank-funded firms which impose negative production externalities for other bank-funded firms

Accounted for by the prudential regulator.

Implications: Non-bank financing

Allowing for non-bank financing via the borrower's reservation interest rate:
(at the limit) banks'max ROE $r_q^{max}(\underline{e}_q) = \frac{PUT_q(\underline{e}_q)}{I\underline{e}_q}$.

Implication: If (some) dirty firms have access to alternative sources of financing, the impact regulator is constrained by leakage due to substitution to other funding markets
$\Longrightarrow$ **no longer BO or BB risks but OB as to OO risks**

Observation 3 *The impact regulator aims to reduce carbon emissions and therefore would like to prevent substitution to non-bank funding. The prudential regulator welcomes substitution because it removes risk from the banking sector.*

Implications: Bank Capital scarcity and the cost of raising E

- Qualitative results are unchanged if banks can raise additional equity at a positive marginal cost
- If the marginal cost of raising additional bank equity is zero, then bank capital is never scarce.
  $\Longrightarrow$ setting E to a sufficiently large value, prudential regulation is no longer subject to a trade-off.
  $\Longrightarrow$ Sufficiently high capital requirements (formally $e_q = 1$) eliminate the social cost of bailouts without adverse effects on socially valuable lending.
  $\Longrightarrow$ Abundant bank equity eliminates the impact regulator's ability to use capital requirements as a tool to reduce emissions. (both types will be fully funded)

To sum, capital requirements are an effective tool to reduce carbon externalities only if firms do not have alternative (non-bank) funding sources and if bank capital is sufficiently scarce.

Implications: Carbon taxes and capital requirements

A prudential regulator views carbon taxes as a source of transition risk $\rightarrow$ optimal prudential capital regulation accounts for this risk by raising capital requirements for carbon-intensive loans.

carbon taxes are more effective than capital requirements when it comes to reducing externalities:

- In contrast to capital requirements, sufficiently high carbon taxes can always ensure that investing in firms with negative SPI is unprofitable.
- because carbon taxes are independent of the lender's identity (e.g., banks or public markets), carbon taxes reduce the profitability of lending to dirty firms both for banks and non-banks.
- impediments to efficient environmental regulation such as the inability of governments to commit to future policies
  $\Longrightarrow$ if governments are subject to a commitment problem, capital regulation can play an indirect role in reducing carbon emissions by facilitating government action.

Implications: others

Imperfect observability of firm types:
If, for example, clean firms consisted both of risky clean firms and safe clean firms, a blunt green supporting factor for all clean firms would disproportionately benefit risky clean firms, which would benefit from a larger increase in the value of the deposit insurance put. This could incentivize banks to take on excessive "green risks"

Firms' choice of production technology:
If, in addition, firms within a given sector had access to a costly pollution-reducing technology, as in Oehmke and Opp (2019), they may have an incentive to invest in these technologies if capital requirements reward such investments. The incentives to become clean would depend on how much doing so increases in the maximum ROE firms can offer to banks.

Conclusion

Highlights:

- increases in capital requirements for dirty loans can reduce clean lending
- addressing climate-related financial risks via capital requirements is not equivalent to reducing emissions
- using capital requirements to discourage the funding of carbon-intensive activities is less promising:
  $\Longrightarrow$ as long as activities with high carbon emissions remain profitable, removing loans that fund these activities from the banking sector may either be impossible altogether or sacrifices financial stability
  $\Longrightarrow$ even if capital regulation can successfully remove dirty loans from the banking system, high-emitting activities will likely attract funding elsewhere as long as they offer a positive return to investors
- Interventions that directly reduce the profitability of carbon-intensive investments (e.g., a carbon tax) are more effective tools to reduce carbon emissions. (capital requirements can play an indirect role to help facilitate carbon taxes or stricter environmental regulation)

The end!