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By *Oliver Janke and Gregor Weiß*

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Green Capital Requirements, ESG Rating Uncertainty, And Greenwashing

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ABSTRACT

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Keywords: Bank Capital Regulation, Capital Requirements, Climate Change, Climate Risk, ESG Ratings, Greenwashing.
JEL Classification Numbers: G18, G21, G28.

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1 Introduction

One of the key goals in addressing global warming is the reduction of carbon emissions. To achieve this goal, central banks have begun to assess banking activities not only based on hard economic factors such as expected cash flows, volatility, and security of investments, but also on whether they align with specific green assumptions ("Green Central Banking"). As part of this endeavour, policymakers (see Dombrovskis, 2017), central banks (Bank of England, 2021; Bank for International Settlements, 2021; European Banking Authority, 2022; European Commission, 2021a,b,c), and researchers (see Dafermos and Nikolaidi, 2021; Oehmke and Opp, 2022a) have discussed the potential and risks of using capital requirements to reduce carbon emissions. However, determining whether a firm is truly "green" in the regulator's sense is a challenging task, as it relies on limited information mostly provided by the firm itself. Relying on rating agencies to assess a firm's Environmental, Social, and Governance (ESG) performance is also associated with disadvantages, as recent research by Avramov et al. (2022) and Berg et al. (2022) highlights the shortcomings and uncertainty associated with such ratings. Combined together, in the presence of ESG rating uncertainty and green-/brownwashing by firms, the effectiveness of so-called "green capital requirements" could be significantly impaired.

To model this effect, we propose a framework that incorporates the lack of information about clean or dirty firms. Moreover, we analyze the resulting actions of the bank regulator and the firms into different regimes of regulatory capital. We consider different capital requirements for dirty and clean loans, with the former set higher than the latter to penalize the financing of high-emission projects. In addition, the capital requirements for clean (dirty) loans increase (decrease) according to the regulator's view of the share of clean and dirty firms. As a result, the difference in capital requirements (and the initial advantage of clean loans) is reduced as the economy becomes greener.

The regulator's scope includes not only the goal of financial stability but also the reduction of carbon emissions. We analyze the specific actions of the regulator, such as banks' preference for funding clean firms first, and how dirty firms may react in this situation. In all cases, we also describe the implications for the deposit insurance subsidy as well as carbon emissions.

Our main results are as follows: Green capital requirements, depending on the green-friendly regulator's belief about firm types, can lead to green- or brownwashing actions by both types of firms. While dirty firms do not have an incentive for brownwashing, clean firms may benefit from it if the effect is large enough, allowing them to secure funding before others. Additionally, clean firms may also engage in greenwashing. By doing so, they can decrease capital requirements for dirty loans, creating more equity available for funding clean firms. However, this creates a potential incentive for dirty firms to engage in greenwashing as well. Moreover, within our framework of rating uncertainty and green-/brownwashing "jumps", there can be adverse side effects on financial stability. These shocks in ESG ratings can change the profitability ranking of clean and dirty loans, rendering funding in one firm type no longer worthwhile and leading to potential financial problems. Furthermore, if green-/brownwashing results in lower capital requirements for banks which are in financial troubles, it can contribute to the instability of the banking sector through increased loan defaults. Lower capital requirements also lead to a higher deposit insurance subsidy.

Our model is similar to that of Oehmke and Opp (2022a): It involves two types of firms, clean and dirty. Banks have limited equity and can provide loans to both types of firms. The loans are financed by a portion of the banks' equity as well as deposits that they receive. These loans are not secure and can potentially result in defaults. In such cases, banks first use their equity to cover the losses, and the remaining loss is covered by a deposit insurance subsidy provided by the bank regulator. To reduce the cost for the regulator and society as a whole, he imposes capital requirements ensuring a higher portion of the loans is financed by banks' equity. This approach also leads to more conservative bank lending in the sense of a higher equity ratio. In general, we assume that dirty firms are more profitable than clean firms but also have higher carbon emissions. However, we discuss these assumptions and also consider other scenarios.

The novel feature in our model is the extension of the regulator's imperfect information about the distribution of funding between clean and dirty firms. Based on this information, the regulator assumes a portion for both types of firms, which he takes into account when setting appropriate capital requirements. This belief can be influenced by various parties within or outside the financial market, such as clean and dirty firms, banks, lobbyists, Non-Governmental Organizations (NGOs) like Greenpeace or The Last Generation, and others. As a result, the regulator updates his assumption and adjusts the capital requirements accordingly.

For example, banks funding dirty firms may hope for lower capital requirements if the regulator believes that a significant proportion of firms are already clean (as there is no longer a need for differential treatment of clean and dirty loans). Therefore, it is beneficial for dirty firms or banks funding them to make him believe that the proportion of clean funding is very high, regardless of the actual value. On the one hand, banks benefit from a larger number of funded firms. On the other hand, lower capital requirements also increase their deposit insurance subsidy from the regulator, effectively shifting the financial risk of banks' investments in dirty firms to society. If dirty firms or banks financing them engage in such behavior, we refer to this as *greenwashing*.

Nevertheless, it may also be advantageous for clean firms or banks investing in them to influence the regulator's assumption, but in the opposite direction. Given that clean firms generally experience lower profitability in their production and have limited options to increase their short-term profitability, they may hope to improve their return on equity (ROE) or reduce the ROE of dirty investments through the actions of the regulator. This can be achieved by advocating for lower capital requirements for clean loans or higher capital requirements for dirty loans, which would make investments in clean firms more affordable or expensive for dirty firms, respectively. Therefore, it can be beneficial for clean firms or the corresponding banks to manipulate the regulator's assumption and make him believe that the proportion of dirty banks is very high. Similar to greenwashing, this action can be defined as *brownwashing*.

First, we discuss the scenario where the regulator overestimates or underestimates the true value of the portion of clean and dirty investments. Then, we analyze the impact of brownwashing and greenwashing. As mentioned earlier, in our model, we assume that capital requirements for clean and dirty loans vary depending on the regulator's belief. This results in lower capital requirements for one type of investment and generally higher capital requirements for the other type when the regulator's belief changes. One advantage for the regulator is that deposit insurance subsidies increase for that type of investment with lower capital requirements, while they decrease for the other type. The regulator tends to allocate a higher deposit insurance subsidy to the type that is perceived as more significant.

However, there are risks involved if the regulator's assumption deviates significantly from reality. If there are numerous defaults among the investment type with lower capital requirements, the deposit insurance subsidy will substantially increase. Consequently, both green- and brownwashing can lead to an inaccurate risk evaluation and pose a threat to financial stability. Moreover, greenwashing, brownwashing, or a significant jump in the ESG ratings can also have negative implications from the banks' perspective. When there is a shift in the regulator's belief that results in a substantial change in capital requirements, it can lead to a shift in the ranking of ROE. In other words, clean firms may receive funding priority despite having lower profitability compared to dirty firms. If the regulator also aims to reduce carbon emissions, this change in the investment ranking can help to achieve that goal.

In summary, both green- and brownwashing can result in distortions in terms of accurate risk estimation and financial stability, especially when they impact the regulator's incorrect belief regarding the proportion of clean and dirty investments in the financial market. However, these actions by firms or banks are a consequence of the previous decisions made by central banks and regulators. The policy implemented by these institutions, which involves stronger consideration of environmental effects and the penalization of dirty production while indirectly supporting green-friendly practices, creates incentives for firms to benefit from this policy, even if they do not truly meet the regulator's expectations in reality. Since it does not guarantee the complete exclusion of funding for dirty firms, there are limitations of this policy. Banks are still willing to finance such firms as long as their investments remain profitable, even if the capital requirements are set at the highest level of 100 %.

Regulators can respond to actions like green- and brownwashing in various ways. While a prohibition of such actions may not be practical or effective (since they cannot be really checked), there are other approaches that they can consider. Regulators must make decisions on how much new public information should influence their policies, goals, and future controls. It makes sense for regulators to update their beliefs about the distribution between clean and dirty firms periodically. However, these shifts should not occur too frequently to lower the incentives of manipulations. Moreover, they should be based on different sources of information, events, and other fundamental factors (like independent controls). All these actions not only affect regulators but also have implications for consumers, politicians, and future employees who are interested in supporting a green-friendly economy through their purchasing decisions, taxation policies, and providing human capital.

In addition, regulators can set a portion of capital requirements independent of their belief and firm type. This approach helps balance the information and risk uncertainties. Investing in clean firms can also be more beneficial for banks, as it not only reduces capital requirements but also increases profitability if the return on such investments improves. Regulators can support clean firms by making their investments more affordable. However, completely excluding dirty firms from funding requires the profitability of such firms to be negative. This can be achieved through measures such as carbon emissions taxation or requirements for investments to be used for green-friendly technology transfer.

The proposed model builds on and extends existing literature in this field: The debate on incorporating climate-related risks into bank regulation has been advanced by the conceptual framework developed by Oehmke and Opp (2022a). Our paper significantly extends their work by incorporating two of the most important practical issues in sustainable finance: ESG rating uncertainty and firms' incentives to engage in greenwashing.

Indeed, the effects of climate change on banks are also a topic of discussion within central banks, and several studies examine this issue. Besides others, Shala (2022), Meireles and Sarmento (2012) and Ernst et al. (2022) contribute to this area of research. The analysis of asset pricing and portfolio implications under ESG rating uncertainty gains attention from researchers, including Avramov et al. (2022) and Berg et al. (2022), among others. Effects on the behavior of individuals and firms based on their information about climate aspects are analyzed by various researchers, e. g. Bernard et al. (2022) and Ardia et al. (2020). Gropp et al. (2019), Greenwood and Thesmar (2011), Eisenbach et al. (2021) and Meinerding et al. (2023) consider effects and actions of firms related to their risk attitude, Fang et al. (2023) examine this question under financial fractions and policy uncertainty. Dewatripont and Tirole (2022) discuss the morality of markets and show that intense competition may reduce the standards of very ethical firms if profitable firms do not alter.

Implications of greenhouse gas emissions and other relevant "green" indicators on the policy of bank regulators and central banks are considered by von Kalckreuth (2022), Giovanardi et al. (2022), Schoenmaker (2021) and Hong et al. (2021). Moreover, Hong et al. (2020) explore the adaption of society to manage disaster risks to capital shocks. Relationships between financial constraints and environmental policy are e. g. analyzed by Döttling and Rola-Janicka (2023) and Heider and Inderst (2023). Climate and macroprudential policies in an economy with frictions and transition risk are studied by Carattini et al. (2021). Other possible actions such as unconventional monetary policy, taxation or green quantitative easing done by regulators and policy makers are discussed by Papoutsi et al. (2022), Benmir et al. (2021), Abiry et al. (2022), and Ferrari and Nispi Landi (2022). Moreover, Thakor (2021), Degryse et al. (2022), Mueller and Sfrappini (2022) and Giannetti et al. (2023) analyze the influence of such policies to bank credit allocation, lending and capital structure. The impact as well as the limits of a green supporting and a dirty penalizing factor on climate-related financial risks are e. g. discovered by Dafermos and Nikolaidi (2021) and Thomä and Gibhardt (2019). Camous and Van der Ghote (2022a,b) discuss expectations and misperceptions within this context and face potential consequences. Moreover, Oehmke and Opp (2022b) also propose a theory of socially responsible investment by characterizing conditions under which corresponding investors impact firms which produce social costs.

The remainder of this paper is as follows: In Section 2 we introduce the financial model, the relevant actors, notations and the baseline assumptions about imperfect information. Next, in Section 3, we state our main results. Afterwards, we also state some possible extensions of our model for further research in Section 4 and close the paper with a conclusion in Section 5.

2 Model

Let us consider two points of time ($t = 0, 1$). By assuming no inflation in the market, it simplifies the model and allows for a more straightforward comparison of values and outcomes between the two time periods. However, it is important to note that the possibility of inflation can still be incorporated into the model if needed, but its inclusion may not significantly impact the main results of the paper.

2.1 Market participants

Having three types of market participants with different information sets adds complexity to the model and allows for a more realistic representation of the market dynamics. The differing information sets among the participants can lead to different decision-making processes and outcomes. It is worth noting that the model being based on the analogous one in Oehmke and Opp (2022a) provides a foundation for the analysis and allows for a comparison of results between the two studies.

Firms. The differentiation between clean firms (C) and dirty firms (D) allows for an examination of the influence of green capital requirements in the market. By introducing two types of firms, the model can analyze the effects of interventions that specifically favor or prioritize clean firms. This can include actions such as setting lower capital requirements for loans to clean firms or providing incentives for their investments. The assumption that firms are cashless and infinitesimal ensures that individual firms' actions do not have a significant impact on the overall market dynamics. Instead, the focus is on how the collective behavior of clean and dirty firms, as well as the regulatory interventions, shape the market outcomes. The fraction of each type $q \in \{C, D\}$ is given by $\pi_q = \frac{n_q}{n_C + n_D}$ where we have $\pi_C + \pi_D = 1$.

Note that clean and dirty firms can do green- or brown washing, i. e. making the regulator believe that the fraction of each type is different than it actually is.

In this financial market setting, firms altogether require an initial investment of $I > 0$ at $t = 0$ where we assume that each firm needs an investment of 1, i. e. $n_C + n_D = I$. Cash flows are realized at $t = 1$, i. e. firms of type q need investment of $I_q := \pi_q I$. The cash flows for the firms are assumed to follow a log-normal distribution with parameters μ_q and σ_q, which are specific to each firm type. The expected cash flow is described by X_q and let us define the net present value (NPV) by $\text{NPV}_q := X_q - I_q$.

Assumption 1 *It holds that* $\text{NPV}_q > 0$ *for each* $q \in \{C, D\}$*, but dirty firms are more profitable than green ones, indicated by* $\text{NPV}_D > \text{NPV}_C$*.*

The assumption that clean firms incur investments to improve their environmental status is indeed supported by historical evidence. Transitioning to greener practices often requires substantial investments in renewable energy sources, energy-efficient technologies, waste management systems, and other sustainable practices. These investments can reduce the profitability of clean firms in the short term, as they allocate resources towards environmentally friendly initiatives rather than maximizing immediate financial returns. On the other hand, carbon emissions of each firm of type q are described by ϕ_q where we have $\phi_D > \phi_C \equiv 0$. This crossing over of high profitability with high carbon emissions and low profitability with low carbon emissions is also described in Dewatripont and Tirole (2022).

Banks. Firms can lend money for their production from a continuum of competitive and ex-ante identical banks. Altogether, banks have mass one and are endowed with fixed inside equity $E < I$ which represents the overall amount of equity in the banking sector. This assumption implies that the available equity alone is insufficient to fully finance the assets of all firms. Moreover, it reflects the reality that banks typically rely on a combination of their own equity and external funding sources, such as deposits, to meet the financing needs of firms. By accepting deposits, banks are able to increase their available funds and allocate them towards lending to firms. The deposits provided by depositors represent a form of external funding for banks and play a crucial role in enabling banks to meet the investment requirements of firms. If equity E is therefore not enough to to finance an asset A, banks can ask for additional deposit funding D from competitive depositors, which means

$$A \;=\; E + D.$$

As in Oehmke and Opp (2022a), we assume for simplicity that banks cannot increase their equity since the associated cost equity issuance is very high. Moreover, to provide subsidies for deposit financing we assume that deposit insurance is possible, but not priced.

The bank can split its loans into clean and dirty firms, respectively. Let therefore $w = (w_C, w_D)$ denote the vector of bank loan portfolio weights for clean and dirty firms. Let us define $e := E/A$ as the bank's equity ratio and $r_E(w, e)$ as the bank's expected return on equity (ROE). The banks' objective is to maximize the value of their equity, i. e.

$$V \;=\; \max_{e,w} E \cdot (1 + r_E(w, e)). \tag{1}$$

For fixed E, bank managers aim to maximize the ROE which is also consistent to practical experience. Since we have assumed a zero interest rate, a positive ROE is the prize of the bank for lending its money to firms.

Banks know the exact fraction π_C of clean firms, but they can also do green- or brown washing in order to make the regulator believe in a different value.

Bank regulator. The bank regulator, such as a central bank, plays a crucial role in setting loan capital requirements for banks. These capital requirements serve as a regulatory tool to manage and mitigate risks within the financial sector and promote financial stability. In the given model, the bank regulator sets loan capital requirements for each firm type (clean and dirty) denoted by e_q. These requirements are designed in a way that the bank's equity ratio (e) must satisfy a constraint. The equity ratio represents the proportion of a bank's equity to its total assets. If the benchmark is set to 0, the constraint is always satisfied since $e \geq 0$, meaning that the bank has no restrictions on its lending activities. On the other extreme, if the benchmark is set to 1, the constraint is highly restrictive. In this case, the bank can only use its own equity for loans to firms. By implementing loan capital requirements, the bank regulator aims to strike a balance between promoting lending activity to support economic growth and ensuring the soundness and stability of the financial system.

Compared to the definition of the bank's objective function (see (1)), the (prudential) regulator's goal is to maximize his *prudential profitability index* PPI_q for each firm type $q \in \{C, D\}$ which represents the surplus for the prudential regulator per unit of bank equity considering the capital requirements e_q for type q firms, given by

$$\mathrm{PPI}_q(e_q) \;=\; \frac{\mathrm{NPV}_q - \lambda \cdot \mathrm{PUT}_q(e_q)}{e_q I_q}. \tag{2}$$

His objective function can be then expressed by (cf. (Oehmke and Opp, 2022a, Section 4.1)):

$$\Omega \;:=\; E \cdot \left(\max_{\mathbf{e}} \sum_{q} \tilde{\omega}_q(\mathbf{e}) \cdot \mathrm{PPI}_q(e_q) \right), \tag{3}$$

where $\mathbf{e} = (e_C, e_D)$ and $\tilde{\omega}_q \in [0, 1]$ represents the fraction of bank equity E which is used for funding firms of type q.

On the other hand, if the mandate of the bank regulator is broader and includes environmental issues ("green mandate") it is also in the scope of the "green" regulator to reduce external environmental risks. His objective function is therefore complemented by a carbon factor ϕ_q for firms of type q and the PPI changes to *social profitability index* SPI_q for firms of type $q \in \{C, D\}$ (cf. Oehmke and Opp (2022a)).

Let us now state the assumption about imperfect information on the regulator's side which is one of the main novels of this paper.

Assumption 2 *In the model, the exact type of each firm (clean or dirty) is not directly observable by the bank regulator. This lack of observability introduces information asymmetry into the market. The regulator does not have perfect knowledge about the true fraction π_q, which represents the proportion of clean or dirty firms in the market.*

Indeed, in reality, firms' environmental status is not always readily observable by external parties such as regulators. Firms may have various incentives to withhold or manipulate information about their environmental practices, making it difficult for authorities to accurately assess their true status. This lack of transparency and the potential for firms to misrepresent their environmental status further contribute to the information asymmetry in the market. This lack of information adds to the complexity of decision-making and strategic behavior for regulators in the market.

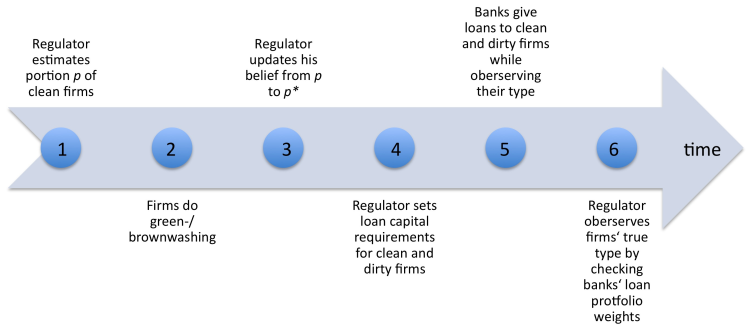


Figure 1: Timeline of the model

2.2 Imperfect information

To make the information structure more clear, let us describe the timeline of the model (see Figure 1): The regulator first assumes the portion of clean firms (p), see time point 1. This value can be influenced by green-/brownwashing by firms (time points 2 and 3). Afterwards, the regulator sets capital requirements for clean and dirty loans which banks have to satisfy. When banks give loans to firms the latter have to reveal the former their true type (time point 5). The regulator can then face the exact firm type at time point 6 when he checks the banks' portfolio weights.

The assumption that the bank regulator does not have full information about the firm's type and the exact portion π_q of clean and dirty firms is indeed novel and introduces an element of uncertainty and imperfect information into the model. This assumption is motivated by practical considerations and real-world dynamics observed in competitive markets.

In reality, firms have incentives to protect their proprietary information and strategic advantages, which may include their environmental status or sustainability practices. Disclosing such information to competitors or regulators could potentially expose them to economic attacks or regulatory actions that may affect their profitability or market position. Therefore, it is reasonable to assume that firms do not willingly reveal their exact firm type or the proportion of clean and dirty firms in the market.

Furthermore, the presence of a regulatory authority can create additional incentives for firms to manipulate information or engage in deceptive practices to influence the regulator's actions in a way that benefits their own interests. In the context of ESG ratings, rating uncertainty is an important factor to consider (cf. e. g. Avramov et al. (2022), Berg et al. (2021) or Berg et al. (2022)). ESG ratings are subject to various methodologies, data sources, and subjective judgments, leading to potential discrepancies and volatility in the ratings assigned to firms. As a result, the regulator's determination of the portion of clean firms based on ESG ratings is likely to be volatile and subject to change if ratings are updated or revised. By incorporating these elements of imperfect information and rating uncertainty, the model captures the realistic dynamics and challenges faced by regulators in assessing and regulating the environmental performance of firms. Indeed, imperfect information can contribute to higher volatility in the economy, particularly during times of financial crises, cf. Hollmayr and Kuehl (2016). Similar examples for dealing with imperfect information on the regulator's side, especially for environment saving regulation, is a longer topic in financial research. One example is the work of Kwerel (1977), who discuss the challenges and strategies for regulatory decision-making under imperfect information.

In the given scenario, the regulator does not possess complete information regarding the true type q of a firm. Instead, the regulator holds an expectation, denoted as p, representing the probability or belief that a firm is of type C (clean). To regulate the capital requirements for each firm type q, the bank regulator establishes loan capital requirements $e_q(p)$ for each firm type q. These capital requirements dictate that the bank's equity ratio e must satisfy the condition

$$e \;\geq\; e_{\min}(w,p) \;:=\; w_C \cdot e_C(p) + w_D \cdot e_D(p). \tag{4}$$

Let us assume that $e_C(p)$ is an increasing function in p where $e_D(p)$ is decreasing in p. This means that the regulator increases the capital requirements for loans to firms of type q in the way that it expects a dominant proportion of such firms to be. Since p represents the expected fraction of clean firms, capital requirements tend to increase the larger p is. On the other hand, a small p represents a dominant fraction of dirty firms. Therefore, e_D should decrease in p. Reasons for the assumptions concerning the monotonicity of the capital requirement functions are given in relevant literature: Bernanke et al. (1999) build a framework which exhibits a financial accelerator, in that endogenous developments in credit markets work to strengthen and spread shocks to the macroeconomy. First discussions to countercyclical capital buffers and endogenization of capital requirements, also based on analysis of Basel I and II regulations, are done by e. g. Dewatripont and Tirole (2012) and Repullo et al. (2010); Repullo (2013). Then, Malherbe (2015) shows that optimal capital requirements are decreasing in expected productivity and increasing in aggregate bank capital. Therefore, as a consequence, optimal capital requirements should be higher in good times, and conversely. Furthermore, Canta (2015) develops a microfoundation macroeconomic model and finds out that required regulatory capital will be always higher in the expansionary phase of the business cycle, such that banks can build up a capital buffer which is used in recessionary phases. Optimal capital requirements in a setting of commercial and shadow banks where only the former face these requirements are discussed by Plantin (2015), Zhang (2020), and Begenau and Landvoigt (2022). The authors show how time-varying capital requirements influence lending interest rate, leverage, credit supply, and risk-taking. Transferring these results to our model, it follows that green capital requirements should also be set countercyclically: If the regulator expects a high proportion of dirty firms (low p) and therefore in higher loans to this firm type, the requirements for these loans should be very high, while those for clean loans should be set tightly. Conversely, if most firms are expected to be clean (high p) and therefore there are more clean loans, capital requirements for dirty loans can be lowered while those for clean credits should be increased. T Nevertheless, we assume that $e_C(p) \leq e_D(p)$ for every p. This implies that regardless of the regulator's expectation of the portion of clean or dirty firms, the capital requirements for dirty loans are always higher than those for clean loans. This disparity in capital requirements reflects the regulator's preference for promoting clean firms and ensuring that banks lending to this firm type have relatively lower capital requirements compared to lending to dirty firms.

In Appendix A.5 we also consider the easier case that $e_C(p) = e_D(p)$ for all $p \in [0, 1]$ which means that the bank regulator sets loan capital requirements $e(p)$ for each firm independent from its type. In other words, banks are required to maintain a minimum equity ratio e that satisfies $e \geq e(p)$, regardless of whether they are lending to clean or dirty firms.

3 Results

Our analysis is based on recent work that provides equilibrium values for exogenously set capital requirements. Specifically, we build on the studies by Oehmke and Opp (2022a) and Harris et al. (2020) and only state the main results without proofs as a starting point for our analysis. According to their results, banks in the model choose to operate with the minimum equity ratio that is acceptable to the regulator. In practice, this implies that banks will rely on deposit funding as much as possible, rather than using their own equity. The presence of deposit insurance in the model is also considered. Deposit insurance acts as a subsidy for deposit funding, providing a level of protection to depositors in case of bank failure. This subsidy encourages banks to rely more on deposit funding since it reduces their exposure to risk. Furthermore, the analysis assumes that banks choose specialized portfolios in terms of the types of firms they fund. In other words, banks allocate their funds either to clean firms or to dirty firms, based on their risk-return considerations and the regulatory environment.

The preference type of a bank is determined by its objective function (1), which is the maximal ROE depending on the maximum interest rate a borrower is willing to pay for the loan from the bank. Assuming that borrowers are dependent on banks for financing and cannot access alternative sources such as the bond market, the maximum ROE that a borrower can offer to a bank is given by the equation:

$$r_q^{\max}(e_q) \;=\; \frac{\mathrm{NPV}_q + \mathrm{PUT}_q(e_q)}{I_q e_q}, \tag{5}$$

where $\mathrm{PUT}_q(e_q)$ denotes the contribution of the loan to the bank's deposit insurance put and is given by

$$\mathrm{PUT}_q(e_q) \;=\; \mathbb{E}\left[\max\{I_q(1-e_q) - X_q(s), 0\}\right].$$

The PUT can be interpreted as follow: If the investment fails and the cash flow of the type q firm is lower than the investment, i. e. $X_q - I_q < 0$, the bank will first finance the loss by its equity. But if the loss exceeds the invested equity $I_q e_q$, the bank's deposit insurance put prevents the bank from loss in its deposit funding.

In the model, the reservation prices of clean and dirty firms determine the demand curve for equity. This demand curve takes the form of a step function. When banks have sufficient equity E, they fully fund their preferred type of firm, referred to as *inframarginal* borrowers. In this case, the equity is allocated to fully finance the preferred firm type according to the banks' profitability considerations. However, if the available equity is not enough to fully fund all the preferred firms, the remaining equity is used to partially finance the second preferred type of firm, the *marginal* borrowers (cf. (Oehmke and Opp, 2022a, Result 1)). The allocation of equity between the two types of firms depends not only on the firms' net present value but also on the capital requirements set by the regulator, which are based on the regulator's belief p about the firms.

3.1 Over- and underestimating of firm types

Let us first examine the effects of over- and underestimating the real portion of firm types p by the regulator. Let us discuss these effects compared to the situation where the regulator is fully or correctly informed, i. e. $p = \pi_C$. By our assumption about the properties of the capital requirement functions it holds:

Proposition 1 *If $p > \pi_C$, banks financing clean firms will face higher capital requirements while these financing dirty firms will face lower ones. The ROE of dirty loans increases, while this of clean loans shrinks, and more dirty firms can secure funding, leading to higher carbon emissions, and the deposit insurance subsidy for dirty loans will be higher.*

On the other hand if $p < \pi_C$, banks financing dirty firms will face higher capital requirements while these financing clean firms will face lower ones. The ROE of dirty loans decreases, while this of clean loans grows, and fewer dirty firms will be able to obtain funding, leading to lower carbon emissions, and the deposit insurance subsidy for dirty loans will be lower.

The proof can be found in Appendix A.1.

Let us give an example for this model to show the preferences of banks and how different expectations about the portion of firm types influence the funding of firms.

Example 3 *The equity of the bank is given by $E = 6$. Let the investment need of both clean and dirty firms is equal at $I_C = I_D = 10$, so the portion of clean firms are 50 %, i. e. $\pi_C = 1/2$. Dirty firms are more profitable, withy $X_D = 70$ and $X_C = 60$, resulting in $\text{NPV}_D = 20$ and $\text{NPV}_C = 10$. Let us fix $p^* = 9/10$ and let be the capital requirement functions given by $e_D(p) = 1 - \frac{1}{2}p$ for dirty loans and $e_C(p) = \frac{1}{2}p$ for clean loans. Therefore, we have that $e_D(p^*) = 11/20 < 6/10 = E/I$, i. e. dirty firms are fully funded with partial equity of $\frac{11}{2}$. The remaining equity $\frac{1}{2}$ is left for clean firms. But for funding they need of equity which is not enough, therefore they are only partially funded by $\frac{10}{9}$ since the condition is $e(p^*) = \frac{9}{20} = \frac{1}{2I}$, which corresponds to 11.1 % of clean firms.*

On the other hand, if the regulator knows the real portion of clean and dirty firms, i. e. π_C, then $e_D(\pi_C) = 3/4$ and $e_C(\pi_C) = 1/4$. Therefore, we have that $e_D(\pi_C) > 6/10 = E/I$, i. e. dirty firms are only partially funded with partial investment of 8 and the whole equity is used for it. Therefore, only 80 % of dirty firms are funded and no clean firm is funded.

Let us now describe the effect of a wrong belief of the regulator when choosing the capital requirements for the special goal.

Proposition 2 *Let $e_D > e_C$ for all p.*

(i) If the regulator chooses $e_C(p)$ and $e_D(p)$ assuming that all firms are fully funded, i. e. $E = (e_C(p)p + e_D(p)(1-p))I$, the following effects occur: If $p < \pi_C$, there will not be

enough equity available to fund all the clean firms. If $p > \pi_C$, all firms will be fully funded and the deposit insurance subsidy will be decreased.

(ii) If the regulator chooses $e_C(p)$ and $e_D(p)$ assuming that clean firms are funded first, i. e. $E = e_C(p)pI$, the following effects occur: If $p < \pi_C$, there will not be enough equity available to fund all the clean firms and only a portion p/π_C of clean firms can be funded. If $p > \pi_C$, all clean firms will be fully funded and the deposit insurance subsidy for clean loans will be decreased.

Indeed, if the regulator overestimates the portion of clean firms (i. e. $p > \pi_C$) it means that he believes there are more clean firms in the market than there actually are. As a result, the regulator would still achieve their goal of funding all clean firms since the capital requirements would be set lower than necessary. This would lead to a lower deposit insurance subsidy. On the other hand, if the regulator overestimates the portion of dirty firms (i. e. $p < \pi_C$) he would not be able to fund all clean firms since the capital requirements would be higher than necessary. This means that some clean firms would not receive the desired funding, as the available equity would not be sufficient to meet the higher capital requirements. Consequently, the regulator would not fully achieve their goal.

3.2 The effect of green- and brownwashing

Indeed, firms have an incentive to influence the belief of the regulator in order to increase their funding from banks. By manipulating the perception of the regulator, firms can potentially benefit from weaker restrictions or requirements, leading to increased access to financing. This manipulation of the regulator's belief is commonly referred to as *greenwashing*. It involves presenting or marketing a firm's activities, products, or practices as more environmentally friendly or sustainable than they actually are.

Since we consider different capital requirement functions e_C and e_D for clean and dirty loans, respectively, we have that $e_D(p)$ is decreasing and $e_C(p)$ is increasing in p. Therefore, a lower $e_D(p)$ leads to a higher deposit insurance subsidy for dirty loans, since we have for $p_0 < p_1$ that

$$\begin{aligned}\mathrm{PUT}_D(e_D(p_0)) &= \mathbb{E}\left[\max\{I_D(1-e_D(p_0)) - X_D(s), 0\}\right] \\ &< \mathbb{E}\left[\max\{I_D(1-e_D(p_1)) - X_D(s), 0\}\right] = \mathrm{PUT}_D(e_D(p_1)).\end{aligned}$$

This means, that greenwashing – no matter by which firm type – increases the subsidy related to dirty loans for the regulator and this is in general not what he has in mind.

In our situation, dirty firms are more profitable than clean ones and therefore it is harder for the latter to get funded. Greenwashing (i. e. increasing p) leads to higher capital requirements for clean loans while those of dirty loans go down. On the one hand this means that clean firms do not have a priori an incentive for greenwashing since this lowers their ROE. On the other hand, they may nevertheless be forced to do it because lower capital requirements for dirty loans help them to get funded by banks. We will discuss these cases in detail: We will consider under which conditions dirty and clean firms first have an incentive for greenwashing. Moreover, we will mark the value of the updated probability p until which the firms will intervene. Since our functions e_q are continuous and monotone in p, we can expect that there exist inverse functions e_q^{-1}. The result is then stated as follow.

Theorem 4

(i) If dirty firms are only partially funded, i. e. $E < e_D(p)I_D$, then dirty firms are willing to pay to increase the value of p to $\tilde{p}$ which is determined by $\tilde{p} = e_D^{-1}(\frac{E}{I_D})$.

(ii) If clean firms are either not funded or only partially funded, i. e. $E < e_C(p)I_C + e_D(p)I_D$, then clean firms are willing to pay to increase the value of p to $\tilde{p}$ which is determined by $\tilde{p} = e_C^{-1}(\frac{E - e_D(\tilde{p})I_D}{I_C})$.

The proof is found in Appendix A.1.

Of course, greenwashing is not free of charge. Therefore, dirty firms have to decide if the costs of greenwashing are worth it to get funded by banks. We will now examine the equilibrium price which a firm of type q is willing to pay for this greenwashing.

Dirty firms are willing to pay some amount K to change p to a new probability $\tilde{p}$ as long as its price does not change the fact that $r_D^{\max,K}(e_D(\tilde{p})) > r_C^{\max}(e_C(\tilde{p}))$ where $r_q^{\max,K}(e_q) := \frac{\mathrm{NPV}_q - K + \mathrm{PUT}_q(e_q)}{I_q e_q}$. Their goal is to reduce $e_D(\tilde{p})$ such that their ROE $r_D^{\max}$ is higher and banks have more means for funding clean and dirty firms. Otherwise, this intervention changes the ranking of the borrower types and induces substitution between these two types. Therefore, it may happen that dirty firms are not willing to increase p such that all dirty firms are funded. It extremely depends on this cost and the profitability of dirty firms. Since e_D is decreasing in p, it means that dirty firms try to increase p. This implies a higher e_C for clean firms since this function is increasing in p. This is illustrated in the left picture of Figure 2.

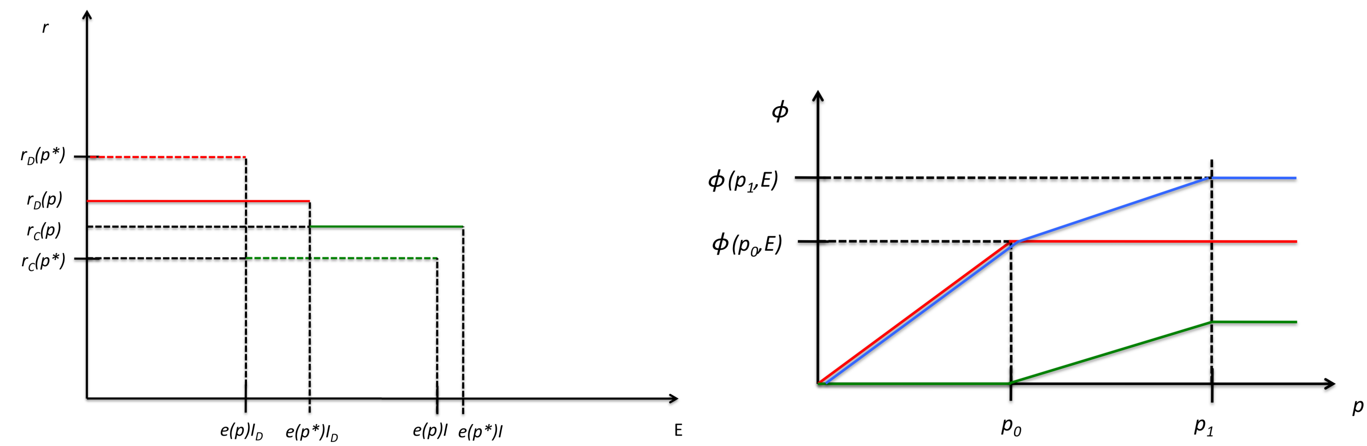
Theorem 5 (Dirty firms' intervention) *Let p be such that $E < e_D(p)I_D$. Let us suppose that dirty firms pay a maximal amount K for a new probability $\tilde{p}$ such that $r_D^{\max,K}(e_D(\tilde{p})) > r_C^{\max}(e_C(\tilde{p}))$.*

(i) If K is chosen such that $\tilde{p} = e_D^{-1}(E/I_D)$, then all dirty firms are fully funded (where the used equity for it is given by $e_D(\tilde{p})I_D$) and no clean firm is funded.

(ii) If K is chosen such that $\tilde{p} > e_D^{-1}(E/I_D)$, then more dirty firms are partially funded (where the whole equity E is used for it) and no clean firms are funded.

Summing up, dirty firms have an incentive for greenwashing only if they are not fully funded. They aim to convince the bank regulator that a higher proportion of firms are clean, which leads to a lower capital requirement for dirty loans and a higher capital requirement for clean loans. Dirty firms engage in greenwashing until all of them are funded. If the cost of greenwashing is sufficiently low, dirty firms will continue manipulating the regulator's belief until all of them secure funding. The subsidy of the loan deposit insurance exhibits changes. It increases for dirty loans as the portion of equity in their investments decreases,

Figure 2: Dirty/Clean firm's intervention - greenwashing: By greenwashing the ROE for dirty (red) firms increases while it decreases for clean firms (dashed lines). Moreover, the equity which is needed for funding dirty firms lowers, while it goes up for clean firms. This is represented by a change of the length of the lines (left panel). Carbon emissions for clean (green), dirty (red) firms and combined (blue) depending on p under greenwashing of dirty firms, while the capital requirement for clean loans stay constant (right panel).



leading to higher risk for payout to bank security holders. On the other hand, it decreases for clean loans as more equity is allocated to funding the same number of clean firms. The increase in the subsidy for dirty loans and the decrease for clean loans pose a disadvantage for the bank regulator. By implicitly providing a bailout guarantee for debtholders of dirty investments, the regulator exposes himself to potential financial risks. An income effect is observed, where the same number of dirty firms is funded with less equity, while more equity is utilized to fund the same number of clean firms.

Furthermore, we describe the effects of greenwashing by dirty firms on carbon emissions when not all dirty firms are funded (otherwise there is no need for dirty firms to do so). For that we suppose that the capital requirements for clean loans stay constant.

Proposition 3 *Let us suppose that the capital requirements $e_D(p)$ for dirty loans decrease for higher p while those of clean loans $e_D(p)$ remain fix. Moreover, dirty firms are the banks' preferred type, but not all dirty firms are fully funded. Then greenwashing leads to higher carbon emissions.*

This effect is represented in the right picture of Figure 2.

Let us now consider actions of clean firms: they are willing to pay some amount K to change p to a new probability $\tilde{p}$ as long as their ROE stays positive, i. e. $r_C^{\max,K}(e_C(\tilde{p})) > 0$. Otherwise, the bank has no incentive to fund them. Unlike dirty firms, where an increase in p reduces their capital requirements and leads to higher funding, the situation for clean firms is more intricate. The reason is that a higher p leads to higher capital requirements for clean loans since $e_C(p)$ is increasing in p. Assuming that p is such that not all clean firms are funded by banks, clean firms have several options to act in order to secure funding:

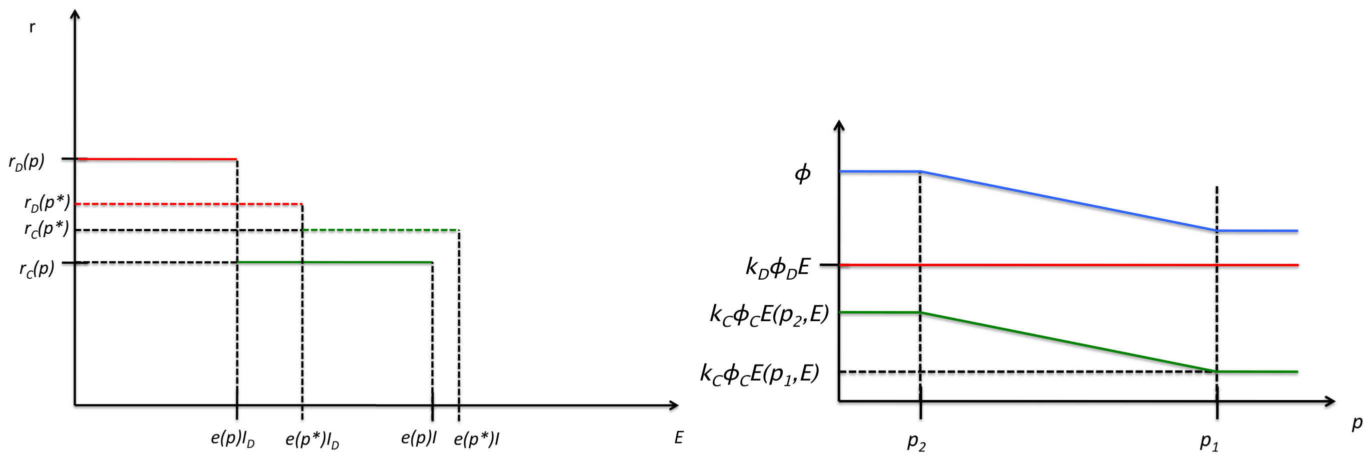
- First, greenwashing, i. e. increasing the value of p leads to lower capital requirements for dirty loans. This means that a smaller portion of equity is required by banks to finance dirty firms. As a result, dirty firms can secure funding with a relatively smaller equity contribution, which may be advantageous for them. On the other hand, for clean loans, a higher p results in increased capital requirements. This implies that a larger portion of equity is needed by banks to finance clean firms.

- Indeed, clean firms have the option of pursuing *brownwashing* as a strategy to address the issue of reduced funding. By lowering the value of p, the capital requirements for clean loans, e_C, decrease, resulting in a smaller portion of equity being used for financing clean firms. This can lead to a higher level of funding for clean firms. At the same time, a lower p increases the capital requirements for dirty loans, e_D, meaning a larger portion of equity is needed for financing dirty firms. The decision to pursue brownwashing as a strategy depends on several factors:

  (a) The specific values of e_C and e_D: Clean firms need to assess whether the decrease in capital requirements for their loans is significant enough to justify the strategy. If the reduction in capital requirements is substantial, it may result in a higher portion of clean firms being funded, as illustrated in the left picture of Figure 3.

  (b) The impact on relative profitability: Lowering p not only affects the capital requirements but also influences the ROE for financing both clean and dirty firm.

Figure 3: Clean firm's intervention - brownwashing: By brownwashing the ROE for financing dirty (red) firms descreases while it increases for clean firms (dashed lines). Additionally, the equity which is needed for funding dirty firms increases, while it decreases for clean firms. This is represented by a change of the length of the clean (left panel). Carbon emissions for clean firms (green) and combined (blue) depending on p under green-/brownwashing of clean firms, while the capital requirement for dirty loans and therefore the carbon emissions for dirty firms (red) are fixed (right panel).



If the decrease in capital requirements for clean loans leads to a higher ROE for funding clean firms compared to dirty firms, it creates a *substitution effect*. This means that banks find it more profitable to fund clean firms, given the lower capital requirements and higher ROE.

Theorem 6 (Clean firms' intervention) *Let the probability p be such that $E < e_D(p)I_D + e_C(p)I_C$.*

(i) If clean firms are willing to pay a maximal amount K such that $e_D(\tilde{p})I_D < E < e_D(\tilde{p})I_D + e_C(\tilde{p})I_C$, then all dirty firms are fully funded using equity $e_D(\tilde{p})I_D$, and clean firms are partially funded using remaining equity $E - e_D(\tilde{p})I_D$.

(ii) If clean firms are willing to pay a maximal amount K such that $E > e_D(\tilde{p})I_D + e_C(\tilde{p})I_C$, then, all firms are fully funded.

(iii) If clean firms are willing to pay a maximal amount K be such that $r_C^{\max,K}(e_C(\tilde{p})) > r_D^{\max}(e_D(\tilde{p}))$. Then:

(a) *If* $e_C(\tilde{p})I_C < E < e_D(\tilde{p})I_D + e_C(\tilde{p})I_C$*, all clean firms are fully funded using equity* $e_C(\tilde{p})I_C$*, and dirty firms are using remaining equity* $E - e_D(\tilde{p})I_D$*.*

(b) *Otherwise if* $E < e_C(\tilde{p})I_C$*, clean firms are partially funded using whole equity* E *and no dirty firm is funded.*

Let us discuss the two different actions of clean firms on the deposit insurance subsidy which is relevant for the bank regulator:

- greenwashing results in a higher subsidy for dirty loans since it leads to a decrease in capital requirements for them (lower $e_D(\tilde{p})$). On the other hand, the subsidy for clean loans will reduce (higher $e_C(\tilde{p})$). This is not the intention of a green-friendly regulator. Therefore, he has no incentive to support this action – especially in this case where only dirty firms are funded and no clean ones.

- brownwashing increases the capital requirements for dirty loans (higher e_D) or reduces funding for dirty firms due to the substitution effect. This leads to a higher deposit insurance subsidy for dirty loans. Moreover, the subsidy of clean loans will increase by the reduction of capital requirements. For a green-friendly bank regulator this effect is very attractive. It is important to note that the increased subsidy for clean loans and reduced diversification of investment types may lead to higher risks. If there is a crisis specific to clean firms, the reduced diversification may result in financial frictions.

Moreover, we describe the effects of green- and brownwashing by clean firms on carbon emissions. For that we suppose that the capital requirements for dirty loans stay constant.

Proposition 4 *Let us suppose that there the capital requirements* $e_C(p)$ *for clean loans increase for higher* p *where these of dirty loans* $e_D(p)$ *are fixed. Moreover, dirty firms are the banks' preferred type. Then greenwashing leads to lower carbon emissions where brownwashing increases carbon emissions.*

This effect is represented in Figure 3.

Let us summarize the effects of green- and brownwashing, i. e. $p_1 > p_0 > p_2$, for a different capital requirement functions $e_C(p)$ and $e_D(p)$ for clean and dirty loans, respectively, depending on the regulator's belief p. We start with greenwashing: it leads to a decrease in capital requirements for dirty loans and an increase in requirements for clean ones. This means that banks find it cheaper to fund dirty firms and more expensive to fund clean firms. So, more dirty firms can be funded due to the lower capital requirements, as they are the preferred type for banks. If all dirty firms are fully funded, there is a possibility of more clean firms being funded as well. However, higher capital requirements for clean loans may result in fewer clean firms being funded. With more dirty firms being funded and potentially fewer clean firms, the carbon emissions in the economy may rise. Furthermore, the deposit insurance subsidy for the regulator increases for dirty investments due to the lower capital requirements. At the same time, the subsidy decreases for clean investments as the capital requirements are higher. This means that the regulator and society bear more risks associated with dirty investments while the risks for clean investments decrease.

Brownwashing has slightly different effects compared to greenwashing. It leads to an increase in capital requirements for dirty loans and a decrease in requirements for clean loans. This makes it more expensive for banks to fund dirty firms and cheaper for them to fund clean firms. If brownwashing is significant enough, a substitution effect may occur where clean firms become the preferred type for banks and are funded first. With fewer dirty firms being funded, the overall carbon emissions in the economy may decrease. The regulator bears fewer risks associated with dirty investments. However, there may be an increased risk for society, as risks from clean investments are taken over by society.

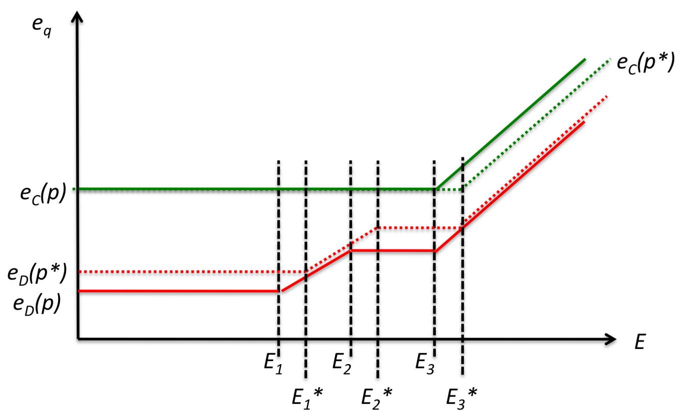
Let us assume that the regulator faces the Principles of Optimal Prudential Regulation (cf. (Oehmke and Opp, 2022a, Proposition 3)). When considering the effects of green- and brownwashing on different sizes of equity E, we assume that there is a small change in the regulator's belief regarding the portion of clean and dirty firms. This small change implies that the ranking between clean and dirty firms does not change, and dirty firms are still funded at first. The other case of a large implication such that the ranking between these two firm types changes is considered in Subsection 3.3. We examine the effects of changes in the capital requirements e_C and e_D for clean and dirty loans, respectively, based on the size of equity E.

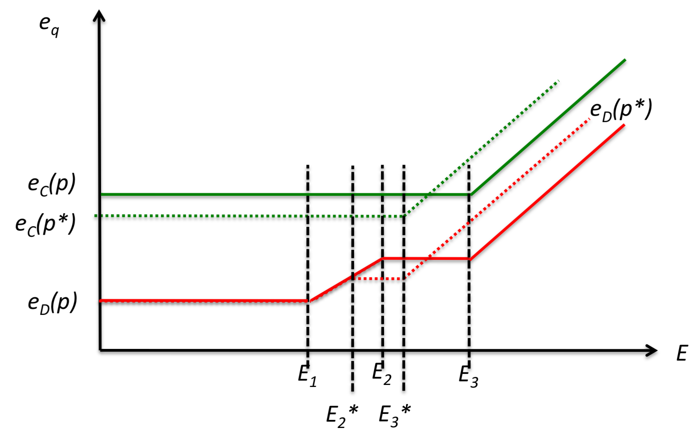
Proposition 5 *Let the regulator follow the Principles of Optimal Prudential Regulation. Under the assumption that dirty firms are the banks' preferred type and a marginal change in regulator's expectation from p to p^* does not change the ranking between these firm types, we can observe the following effects:*

- *If $p^* < p$, the capital requirements e_D increase while e_C remain uneffected if clean firms are only partially funded, but decrease if all firms are fully funded.*
- *If $p^* > p$, the capital requirements e_D decrease while e_C remain uneffected if clean firms are only partially funded, but increase if all firms are fully funded.*

Let us consider the development of capital requirements e_C and e_D depending on the available equity E when we compare the their values for $p = \pi_C$ and for $p^* > \pi_C$. Let us assume that the difference between the real portion and the expected portion by the regulator is small enough such it has no influence to the ranking of clean and dirty firms. To make the effects more clear, we first consider the difference between $e_D(p)$ and $e_D(p^*)$ while e_C first remains unchanged, and show its implication to the development of the capital requirements depending on E: Let $e_D^{\#}(p)$ be the value where banks are indifferent between funding clean or dirty firms at first, i. e. where $r_D^{\max}(e_D^{\#}(p)) = r_C^{\max}(e_C(p))$, and we define $E_2 := e_D^{\#}(p)I_D$. Note that the regions in which only dirty firms are partially funded ($E < E_1$) or fully funded ($E \in (E_1, E_2)$), respectively, as well as where clean firms are partially funded ($E \in (E_2, E_3)$) and where all firms are funded ($E > E_3$) change from E_j to E_j^*, $j = 1, 2, 3$, where $E_j^* > E_j$ for every j. Then with Proposition 5 it follows that e_D for every value of equity E increases while e_C remains unchanged as long as clean firms are not fully funded (i. e. for $E \in (E_2^*, E_3^*)$)

Figure 4: Examples for marginal effects of brownwashing resulting in higher (dirty loans) or less (clean loans) capital requirements such that the ranking between dirty and clean firms do not change – before (solid lines) and after (dotted lines) the response of the regulator. Left picture: Higher capital requirements first for dirty loans (red lines). Right picture: Less capital requirement first for clean loans (green lines).





but will increase if all firms are fully funded ($E > E_3^*$) but on a lower level as before. This is illustrated in the left panel of Figure 4.

Note that also the marginal effects lead to changes in the number of dirty and clean firms which are funded:

- While all dirty firms are already fully funded at E_1 for probability p, this is then realized at $E_1^* > E_1$ for p^*, i. e. for low E some dirty firms cannot hope to get funded;
- on the other hand, while clean firms are getting already partially funded at E_3 for probability p, this is then realized at $E_3^* > E_3$ for p^*, i. e. it is more equity ($E_3^* - E_3$) needed to start lending to clean firms.

From the perspective of the financial regulator, a shift upwards in the capital requirements for dirty loans (e_D) is more beneficial. This is because an increase in the capital requirements for them leads to higher funding costs for banks and reduces the subsidy required from the deposit insurance if investments in dirty firms fail. It also results in a higher portion of equity being used to fund all firms, which enhances financial stability. On the other hand, if the capital requirements for clean loans (e_C) are marginally decreased, it can have the unintended consequence of decreasing the capital requirements for dirty loans as well. This may lead to a higher deposit insurance subsidy for the regulator. In the left picture of Figure 4 this can also seen by less equity which is needed to fund all firms.

3.3 The effect of jumps in ESG ratings

In the case of a large change in the ESG ratings, where the regulator's belief in the portion of clean and dirty firms changes dramatically, it is possible for the ranking between clean and dirty firms to shift. This means that clean firms may become the preferred choice for funding, while dirty loans may face higher capital requirements and therefore reduced funding opportunities for their firms. It is important to note that we are omitting the case of a large increase in the regulator's belief (p) and higher capital requirements for clean loans, as this would make it more difficult for their firms to obtain funding without a change in the preferred ranking of banks.

Theorem 7 *Let dirty firms be the banks' preferred type. Then a significant change in the regulator's expectation from p to $p^* < p$, resulting in a change in the capital requirements e_C (decreasing) and e_D (increasing) such that the ranking between clean and dirty firms changes, i. e. $r_C^{\max}(e_C(p^*)) > r_D^{\max}(e_D(p^*))$, have the following effects:*

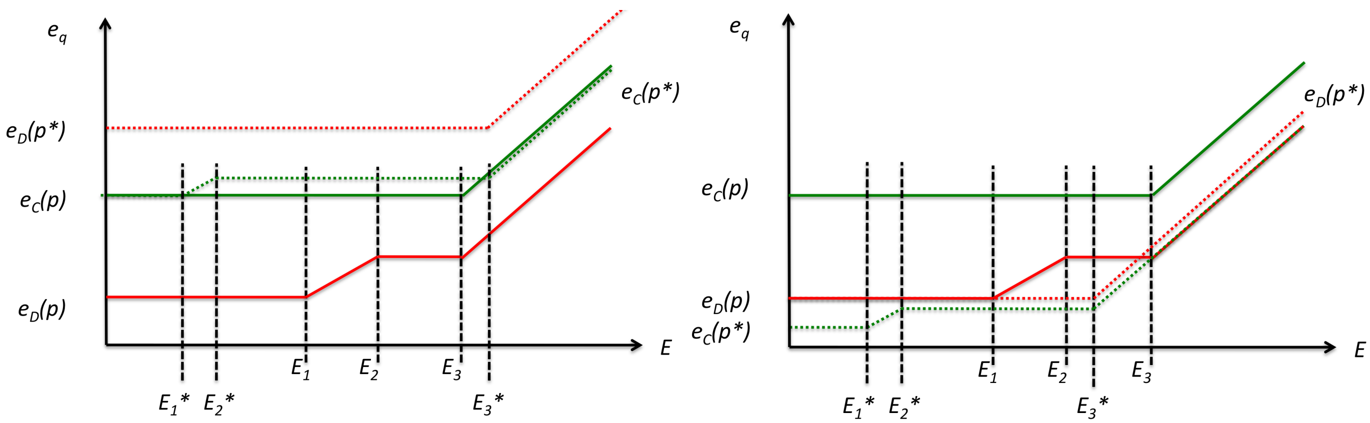
(i) If the equity level E falls within the range where $e_C(p^*)I_C < E < e_D(p^*)I_D + e_C(p^*)I_C$, all clean firms are fully funded utilizing the equity amount specified by $e_C(p^*)I_C$ and dirty firms are partially funded utilizing the remaining equity amount specified $E - e_C(p^*)I_C$.

(ii) If the equity level E is below $e_C(p^*)I_C$, clean firms are partially funded utilizing the entire equity amount E and no dirty firm is funded.

The proof directly follows from Theorem 6 (ii).

Under the Principles of Optimal Prudential Regulation let us now describe the effects of a significant change in the regulator's expectation from p to $p^* < p$ resulting in a change in

Figure 5: Examples for large changes in the regulator's expectation (ESG rating uncertainty) resulting in higher (dirty loans) or less (clean loans) capital requirements such that the ranking between dirty and clean firms will change – before (solid lines) and after (dotted lines) the response of the regulator. Left picture: Higher capital requirements first for dirty loans (red lines). Right picture: Less capital requirement first for clean loans (green lines).



the capital requirements e_C (decreasing) and e_D (increasing) such that the ranking between clean and dirty firms changes:

Proposition 6

(a) e_C remains unchanged if clean firms are only partially funded. Afterwards, e_C increases if all clean firms are funded and no dirty firm is funded, and remains constant if dirty firms are marginally funded. If all firms of all types a fully funded, e_C again increases but with smaller values compared with the previous case.

(b) e_D remains constant until all firms are fully funded. Afterwards, it increase but with larger values compared with the previous case.

The proof as well as the description of the funding regions fo clean and dirty firms depending on available equity are stated in Appendix A.1.

In summary, this subsection highlights how large changes in the regulator's belief, whether induced by jumps in ESG ratings or through actions like green- or brownwashing, can significantly influence the funding of clean and dirty firms by banks under regulatory control.

These changes in belief lead to corresponding changes in the capital requirements for loans of each type of firm. When they are sufficiently large, there is a shift in the ranking of the two types of firms, with clean firms being funded first. From an environmental perspective, this initial shift towards funding more clean firms appears beneficial as it reduces carbon emissions. This shift can be achieved through brownwashing, which increases capital requirements for dirty loans, leading to the same or even higher capital requirements for clean loans until all firms are fully funded. This results in a lower deposit insurance subsidy and a reduced increase in carbon emissions relative to equity increase. On the other hand, if greenwashing involves a downward shift in capital requirements for clean loans, can have adverse effects on financial stability. This is because it leads to an increase in capital requirements for dirty loans, even for higher equity levels. Consequently, the risk is shifted from banks to the regulator, potentially causing financial instability. Additionally, the ability to fully fund all firms with less equity implies that the maximum carbon emissions threshold can be reached with a smaller amount of equity.

3.4 Optimal behavior of the regulator

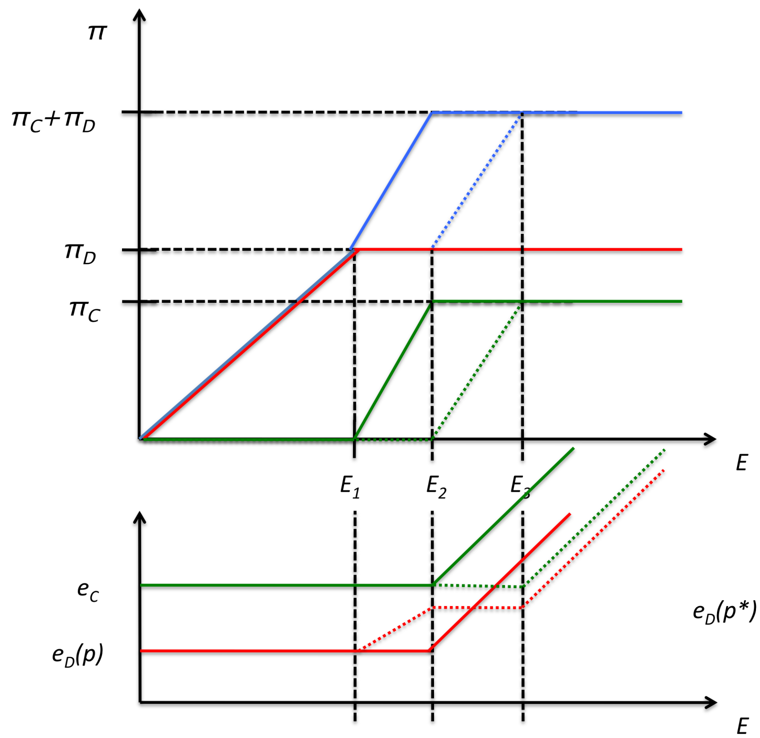
Let us now discuss possible optimal behavior of the regulator to lower the effects caused by green- or brownwashing. Let us point out that information asymmetries between firms and regulators will always exist since the cost for the latter would be prohibitively high to be on the same information level than the former. Moreover, firms may engage in information policies and strategic communication to shape public perception, including that of regulators.

Let us first consider the case where the regulator's goal is the reduction of the deposit insurance put associated with funding type q firms. The effect is illustrated in Figure 6.

Indeed, the regulator can strategically allocate additional equity in the banking sector to reduce the deposit insurance put associated with funding firms of type q which is stated in the following

Remark 8 (Reduction of the deposit insurance put) *By increasing the capital re-*

Figure 6: Example for the effects of actions of the bank regulator to reduce the deposit insurance of dirty loans (red) by increasing the capital requirements of this type (bottom picture) which leads to a later funding of clean firms (green) – top picture. Compare the solid with the dotted lines.



quirements $e_q(p)$ for these loans, the regulator can effectively reduce the risk exposure and potential losses in the event of default. According to principle (i) of the Principles of Optimal Prudential Regulation, the amount of equity E_1 used to fund firms of type q is given by $E_1 = e_q(p)\pi_q I$. By updating the regulator's belief and increasing the capital requirements $e_q(p)$ to $e_q(p^*)$, where $e_q(p)\pi_q I = E_2$, the regulator ensures that the additional equity $E_2 - E_1 > 0$ is used to specifically target the reduction of the deadweight cost associated with the deposit insurance put for loans of type q.

This reallocation of equity allows the regulator to effectively manage and mitigate the risks associated with funding these firms. By strategically using additional equity to reduce the deposit insurance put, the regulator can improve the stability of the financial system and minimize the potential costs associated with insuring the deposits of firms of type q.

Also note that if all firms are fully funded and there is some remaining equity available, regulators can allocate that equity to reduce the deadweight cost for deposit insurance. This can be achieved by increasing the capital requirements for both clean and dirty loans. This follows from principles (i) and (iv) of the Principles of Optimal Prudential Regulation.

Let us consider the case where the regulator will punish dirty firms by setting capital requirements for dirty loans to 100 %, i. e. $e_D(p) \equiv 1$, and for clean firms such that they are funded at first, i. e. $e_C^*(p)$ with $r_C^{\max}(e_C^*(p)) > r_D^{\max}(1)$.

Theorem 9 *Let the regulator follow the Principles of Prudential Regulation. Let $e_D(p) \equiv 1$ and let $e_C^*(p)$ be such that $r_C^{\max}(e_C^*(p)) > r_D^{\max}(1)$. Then clean firms are partially funded if $E < e_C^*(p)I_C$ and fully funded if $E > e_C^*(p)I_C$. If clean firms are fully funded the regulator will increase $e_C^*(p)$ to $e_C^{\#}(p)$ until banks become indifferent between funding clean or dirty firms. Then dirty firms are partially funded if $e_C^{\#}(p)I_C + I_D > E > e_C^{\#}(p)I_C$ and fully funded if $E > e_C^{\#}(p)I_C + I_D$.*

The graphs of the both capital requirements e_C and e_D depending on the available equity are illustrated in the left panel of Figure 7.

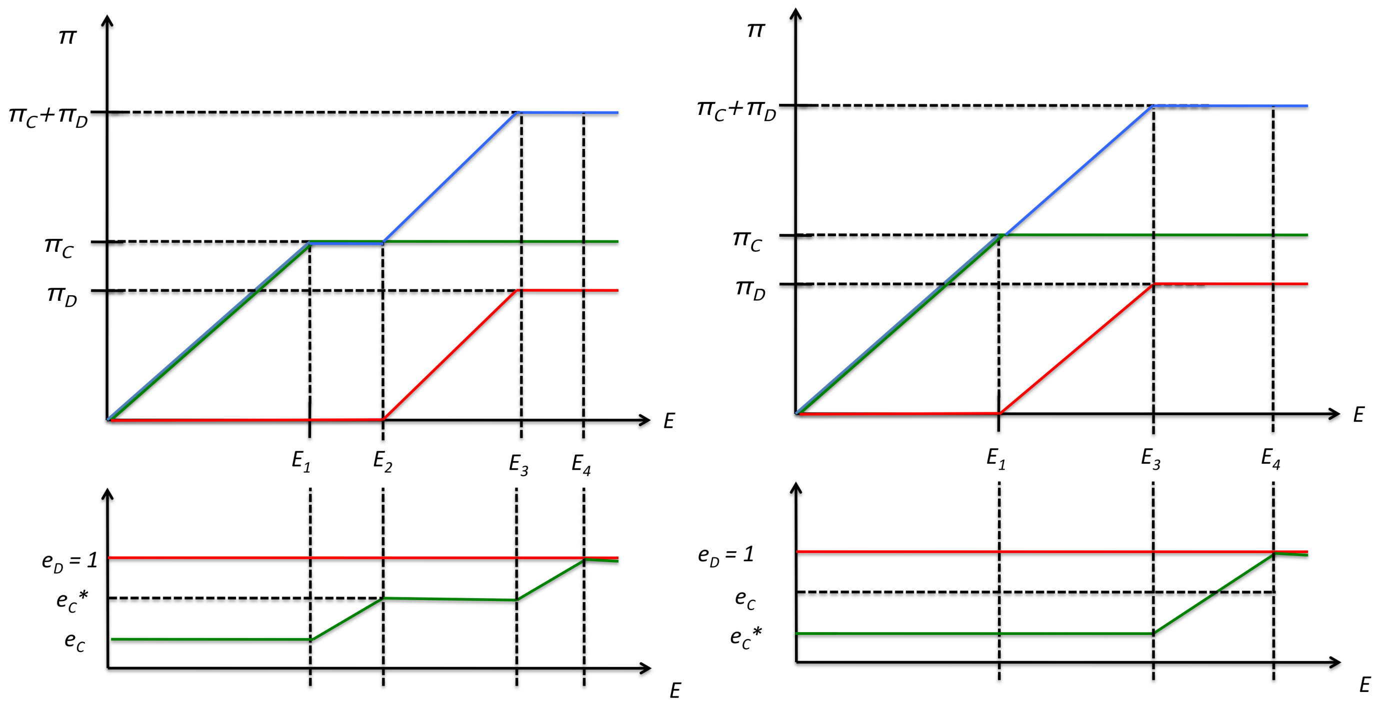
We now focus on the effects of green-/brownwashing to this situation: In the context of green- and brownwashing, the effects on the capital requirements and funding of clean and dirty firms can impact the regulator's optimal behavior. In the case of brownwashing, where the capital requirements for dirty loans are already at 100 %, there would be no direct negative impact on dirty firms. However, it would be beneficial for clean firms since their capital requirements would be reduced. This reduction in capital requirements aligns with the regulator's goal of minimizing the deposit insurance put associated with funding clean firms. While the funding of clean firms becomes cheaper for banks due to lower capital requirements, this new situation would not be beneficial for dirty firms. If all clean firms are fully funded and the regulator increases their capital requirements to a level where banks become indifferent between funding clean and dirty firms ($e_C^{\#}$), the funding of dirty firms would start with the same equity E_3. This implies that they would require higher capital requirements compared to the brownwashing scenario. However, despite the potential disadvantages for dirty firms, the deposit insurance subsidy for clean firms would increase.

Greenwashing can have a negative effect on funding for clean firms as it increases the optimal capital requirements $e_C(p^*)$. If this effect is significant enough, it could lead to a change in the ranking between clean and dirty firms, i.e., $e_C(p^*) > e_C^{\#}$. In this case, the regulator faces a decision. They can either set capital requirements for clean loans that are optimal for them, which would result in dirty firms being funded first, or they can resist this effect and freeze the capital requirements at the indifference value $e_C^{\#}$, where banks are indifferent between funding clean and dirty firms. On the other hand, dirty firms can benefit from the greenwashing effect if their capital requirements are reduced from the current 100 % level, assuming the regulator is willing to adopt the new belief. This implies that in order to ensure clean firms are funded first, the capital requirements for clean loans cannot exceed the new indifference value $e_C^{\#}(p^*)$ for banks. As a result, the reduction in capital requirements for dirty loans leads to a higher deposit insurance subsidy for dirty investments, while the increase in requirements for clean loans reduces their subsidy.

In the scenario, investing in dirty firms may be profitable for banks, even though it has negative social impact from the regulator's perspective. The regulator, however, cannot exclude banks from investing in dirty firms, even with the highest capital requirements of 100 %. To make funding of clean firms more attractive, the regulator can decrease their capital requirements below the optimal level for the regulator. This creates a risk shift from banks to the regulator, as the regulator takes on a larger deposit insurance subsidy for clean loans. By reducing the capital requirements for clean loans, the regulator effectively absorbs more of the risk associated with these investments. This can be seen as a policy decision to incentivize investment in clean firms.

Greenwashing, which leads to lower capital requirements for dirty loans, can reinforce the effect of incentivizing investment in dirty firms. In order to ensure that clean firms are funded first, the regulator may need to reduce the capital requirements for clean loans

Figure 7: Graphs of capital requirements and number of funded clean (green) and dirty (red) firms as well as the sum (blue) for the case where $e_D = 1$ and e_C is set such that clean firms are funded at first. Left picture: Capital requirements e_C^* are such that they are optimal for the regulator until all clean firms are fully funded. Right picture: Capital requirements e_C for clean loans are set such that banks are indifferent between funding clean or dirty firms since optimal capital requirements e_C^* for the regulator are too high such that banks fund clean first at first.



as well. However, this reduction in capital requirements for both clean and dirty loans comes at the cost of a higher risk premium for the regulator and, consequently, for society. The regulator takes on a greater risk exposure by reducing the capital requirements, which can have negative implications for financial stability. Furthermore, the reduction in capital requirements means that the same amount of equity is used to fund both clean and dirty firms, leading to a potentially higher level of carbon emissions. This is because less equity is required to fund the same mass of investments.

If the functions for capital requirements, such as $e_C(p)$ and $e_D(p)$, have lower elasticity (less than one), it means that the relative change in capital requirements is smaller than the change in the regulator's belief, p. In this case, the effects of green- or brownwashing become more expensive to produce the same impact. Having less elastic capital requirement functions can help mitigate some of the negative impacts of greenwashing, as it makes it more difficult for firms to significantly alter the capital requirements and manipulate the funding dynamics. However, even with less elastic functions, it is challenging to completely eliminate the negative impacts of greenwashing on carbon emissions, lending practices, and deposit insurance. One extreme approach to address these concerns is to have fully inelastic capital requirement functions that only change at a specific threshold, represented by $\tilde{p}$ (see Appendix A.6). This means that no matter how much the regulator's belief changes below or above $\tilde{p}$, the capital requirements remain flat. This can potentially mitigate the risk of manipulation but may limit the flexibility needed to respond to changing market conditions and risks. Finding the right balance between flexibility and stability in the capital requirement functions is a challenging task for regulators. It requires considering various factors, including the magnitude of belief changes, the elasticity of capital requirements, and the desired outcomes in terms of financial stability and environmental impact.

Another approach to mitigate the effects of green- and brownwashing is to have flat-rate capital requirements for dirty loans, while allowing the capital requirements for clean loans to vary based on the regulator's belief. By keeping the capital requirements for dirty investment constant, it removes their incentive to engage in greenwashing. For clean loans, if the capital requirements can only be increased and not lowered, it discourages brownwashing. Clean firms would have less incentive to manipulate their information to appear riskier and benefit from lower capital requirements. Additionally, implementing a system of rewards for providing accurate information and penalties for providing false can also deter firms from engaging in green- or brownwashing. By creating financial incentives aligned with providing true information, it becomes more expensive for firms to engage in deceptive practices.

4 Extensions

Production innovation. The model does not account for the possibility of dirty firms transitioning to cleaner practices or clean firms adopting dirtier practices. However, in reality, firms have the potential to invest in productivity and environmental innovations to become cleaner. Dirty firms can allocate resources towards improving their environmental performance, while clean firms may choose to prioritize cost savings over environmental concerns and adopt dirtier practices. In the model, the assumption is made that it is relatively easier and cheaper for firms to engage in green- or brownwashing campaigns to influence public perception rather than undertaking significant changes in their production techniques. This simplification allows for the analysis of the effects of these campaigns on funding decisions and carbon emissions within the given framework.

Different firm types. Indeed, in reality, distinguishing between clean and dirty firms can be more nuanced and complex. In the model, for simplicity and tractability, the distinction is simplified to two firm types: clean and dirty. The regulator establishes a clear definition of what qualifies as a clean firm based on specific criteria, technologies, products, or carbon footprint. The concept of dirty firms is then defined by negation, encompassing all firms that do not meet the criteria set for clean firms. To account for the complexity of transitioning firms and their intermediate steps towards becoming clean, the regulator can play a role by implementing differentiated capital requirements based on the firms' progress and level of environmental impact. By setting varying funding conditions or requirements, the regulator can incentivize and support firms in their journey towards cleaner practices.

Including other externalities. Including additional factors such as taxation, consumer beliefs and preferences, and political actions in the model can capture the interplay between consumer demand, government policies, and the beliefs and expectations of various stakeholders. Future research could focus on empirically estimating and incorporating these factors into the model, allowing for a more nuanced analysis of how these parameters of various actors interact and shape the outcomes in the context of funding clean and dirty firms.

Imperfect information by banks. In reality, banks may not have perfect knowledge about the true nature of a firm's environmental practices and may rely on imperfect observations or signals to make their funding decisions. Future research could explore models that incorporate these aspects, considering the strategic interactions between firms and banks, the information gathering and processing capabilities of banks, and the role of the regulator in monitoring and verifying the information provided by firms. This would provide a more comprehensive analysis of the complexities and dynamics involved in the funding decisions for clean and dirty firms.

Uncertainty about regulator's behavior by firms. Uncertainty about future political and regulatory decisions related to climate change can create challenges for firms in their investment planning and decision-making processes. Incorporating uncertainty about the regulator's behavior and the effectiveness of green-/brownwashing in influencing the regulator's decisions can be an interesting avenue for future research. Firms may face uncertainty about the success of their efforts to influence the regulator's belief and the resulting capital requirements. This uncertainty can impact firms' investment strategies, risk assessments, and overall decision-making.

5 Conclusion

In this paper, we propose a model that incorporates imperfect information on the regulator's side regarding the proportion of clean and dirty firms into a framework of green capital requirements. We introduce the concepts of green- and brownwashing, which allow the two types of firms to influence the regulator's belief and manipulate the capital requirements to their advantage. We examine the impact of over- and underestimating the true proportion of clean and dirty firms on capital requirements, return on equity, carbon emissions, and the number of funded firms. We find that these estimation errors can have significant consequences for the allocation of funding and environmental outcomes. Moreover, we focus on the strategic actions of dirty and clean firms to influence the regulator's belief and the resulting market parameters and explore the implications of green- and brownwashing. Furthermore, we introduce shocks to ESG ratings, causing a dramatic shift in the regulator's belief such that funding clean firms becomes more profitable than funding dirty ones. We emphasize that such shifts can have wide-ranging impacts on the financial market and necessitate careful consideration of the resulting risks and benefits.

The model highlights the limitations and potential adverse effects of implementing green capital requirements. It reveals that such requirements can inadvertently incentivize dirty firms to manipulate their green-friendliness to benefit from lower capital requirements. Similarly, clean firms may also engage in greenwashing to increase their chances of obtaining funding with less equity. This manipulation and greenwashing can lead to an increase in carbon emissions. Furthermore, under green capital requirements, jumps in the ESG rating can significantly affect funding decisions of banks and deposit insurance subsidies. This can introduce financial frictions and higher deadweight costs for clean firms. The model suggests that regulators can take measures to limit the influence of firms' actions and discourage deceptive practices. One approach is to use less elastic capital requirement functions, which would make green- and brownwashing more expensive and less effective. However, it is important to note that completely excluding profitable dirty firms from funding may not be feasible. Based on these findings, we argue that, given the practical limitations of rating firms' ESG performance, green capital requirements are counterproductive in achieving both financial stability and a sustainable economy.

References

Abiry, R., M. Ferdinandusse, A. Ludwig, and C. Nerlich (2022): "Green QE carbon pricing: looking at potential tools to fight climate change," *European Central Bank Working Paper Series.*

Ardia, D., K. Bluteau, K. Bouldt, and K. Inghelbrecht (2020): "Climate change concerns and the performance of green versus brown stocks," *Management Science, forthcoming.*

Avramov, D., S. Cheng, A. Lioui, and A. Tarelli (2022): "Sustainable Investing with ESG Rating Uncertainty," *Journal of Financial Economics*, 145, 642–664.

Bank for International Settlements (2021): "Basel Committee advances work on addressing climate-related financial risks, specifying cryptoassets prudential treatment and reviewing G-SIB assessment methodology," *Press Release.*

Bank of England (2021): "Climate-related financial risk management and the role of capital requirements," *Climate Change Adaption Report.*

Begenau, J. and T. Landvoigt (2022): "Financial Regulation in a Quantitative Model of the Modern Banking System," *The Review of Economic Studies*, 89, 1748–1784.

Benmir, G., I. Jaccard, and G. Vermandel (2021): "A time-varying carbon tax to protect the environment while safeguarding the economy," *European Central Bank Research Bulletin*, 86.

Berg, F., K. Fabisk, and Z. Sautner (2021): "Is History Repeating Itself? The (Un)predictable Past of ESG Ratings," *ECGI Working Paper Series.*

Berg, F., J. F. Kölbel, and R. Rigobon (2022): "Aggregate Confusion: Divergence of ESG Ratings," *Review of Finance*, 26, 1315–1344.

Bernanke, B. S., M. Gertler, and S. Gilchrist (1999): *The Financial Accelerator in a Quantitative Business Cycle Framework*, New York and Oxford: Elsevier Science, North Holland, vol. 1C, chap. 21, 1341–1393.

Bernard, R., P. Tzamourani, and M. Weber (2022): "Climate Change and Individual Behavior," *Deutsche Bundesbank Discussion Paper.*

Camous, A. and A. Van der Ghote (2022a): "Financial cycles under diagnostic beliefs," *European Central Bank Working Paper Series.*

——— (2022b): "Financial stability and macroprudential regulation under diagnostic expectations," *European Central Bank Research Bulletin*, 101.

Canta, M. (2015): "Macroeconomic Effects of Banking Regulation in Emerging Markets: The Role of Countercyclical Bank Capital Requirements," *Superintendencia de Banca.*

Carattini, S., G. Heutel, and G. Melkadze (2021): "Climate Policy, Financial Frictions, and Transition Risk," *NBER Working Paper*, 28525.

Dafermos, Y. and M. Nikolaidi (2021): "How can green differentiated capital requirements affect climate risks? A dynamic macrofinancial analysis," *Journal of Financial Stability*, 54, 100871.

Degryse, H., T. Roukny, and J. Tielens (2022): "Asset Overhang and Technological Change," *CEPR Press Discussion Paper.*

Dewatripont, M. and J. Tirole (2012): "Macroeconomic shocks and banking regulation," *Journal of Money*, 44, 237–254.

——— (2022): "The Morality of Markets," *Working Papers ECARES.*

Dombrovskis, V. (2017): "Greening finance for sustainable business," Speech at One Finance Summit, Paris, 12 December 2017.

Döttling, R. and M. Rola-Janicka (2023): "Too levered for Pigou: carbon pricing, financial constraints, and leverage regulation," *European Central Bank Working Paper Series.*

Eisenbach, T. M., D. O. Lucca, and R. M. Townsend (2021): "Resource Allocation in Bank Supervision: Trade-offs and Outcomes," *Federal Reserve Bank of New York Staff Reports.*

Ernst, A., N. Hinterlang, A. Mahle, and N. Stähler (2022): "Carbon Pricing, Border Adjustment and Climate Clubs: An Assessment with EMuSE," *Deutsche Bundesbank Discussion Paper.*

European Banking Authority (2022): "The Role of Environmental Risk in the Prudential Framework," *Discussion Paper.*

European Commission (2021a): "Banking Package 2021: new EU rules to strengthen banks' resilience and better prepare for the future," *Press Release.*

——— (2021b): "Proposed Amendments to the Capital Requirements Directive," *Communication.*

——— (2021c): "Strategy for Financing the Transition to a Sustainable Economy," *Communication.*

Fang, M., P.-H. Hsu, and C.-Y. Tsou (2023): "Pollution Abatement Investment under Financial Frictions and Policy Uncertainty," *Working Paper.*

Ferrari, A. and V. Nispi Landi (2022): "Whatever it takes to save the planet? Central banks and unconventional green policy," *European Central Bank Working Paper Series.*

Giannetti, M., M. Jasova, M. Loumioti, and C. Mendicino (2023): ""Glossy Green" Banks: The Disconnect Between Environmental Disclosures and Lending Activities," *Working Paper.*

Giovanardi, F., M. Kaldorf, L. Radke, and F. Wicknig (2022): "The preferential treatment of green bonds," *Deutsche Bundesbank Discussion Paper.*

Greenwood, R. and D. Thesmar (2011): "Stock Price Fragility," *Journal of Financial Economics*, 102, 471–490.

Gropp, R., F. Noth, and U. Schüwer (2019): "What Drives Banks' Geographic Expansion? The Role of Locally Non-diversifiable Risk," *SAFE Working Paper*, 246.

Harris, M., C. Opp, and M. M. Opp (2020): “The Aggregate Demand for Bank Capital,” *NBER Working Paper*, w27858.

Heider, F. and R. Inderst (2023): “Environmental Policy with Financial Frictions,” *Working Paper*.

Hollmayr, J. and M. Kuehl (2016): “Imperfect Information about Financial Frictions and Consequences for Business Cycle,” *Review of Economic Dynamics*, 22, 179–207.

Hong, H., N. Wang, and J. Yang (2020): “Mitigating Disaster Risks in the Age of Climate Change,” *NBER Working Paper*, 27006.

——— (2021): “Welfare Consequences of Sustainable Finance,” *Working Paper*.

Kwerel, E. (1977): “To Tell the Truth: Imperfect Information and Optimal Pollution Control,” *The Review of Economic Studies*, 44, 595–601.

Malherbe, F. (2015): “Optimal capital requirements over the business and financial cycles,” *European Central Bank Working Paper Series*.

Meinerding, C., Y. S. Schüler, and P. Zhang (2023): “Shocks to tansition risk,” *Deutsche Bundesbank Discussion Paper*.

Meireles, M. and P. Sarmento (2012): “Incomplete Regulation, Asymmetric Information, and Collusion-Proofnessl,” *Economics Research International*.

Mueller, I. and E. Sfrappini (2022): “Climate Change-Related Regulatory Risks and Bank Lending,” *European Central Bank Working Paper Series*.

Oehmke, M. and M. M. Opp (2022a): “Green Capital Requirements,” *Swedish House of Finance Research Paper*, 22-16.

——— (2022b): “A Theory of Socially Responsible Investment,” *Swedish House of Finance Research Paper*, 20-2.

Papoutsi, M., M. Piazzesi, and M. Schneider (2022): “How unconventional is green monetary policy?” *Working Paper*.

Plantin, G. (2015): “Shadow Banking and Bank Capital Regulation,” *The Review of Financial Studies*, 28, 146–175.

Repullo, R. (2013): “Cyclical adjustment of capital requirements: A simple framework,” *Journal of Financial Intermediation*, 22, 608–626.

Repullo, R., J. Saurina, and C. Trucharte (2010): “Mitigating the Pro-cyclicality of Basel II,” *Economic Policy*, 25, 659–702.

Schoenmaker, D. (2021): “Greening monetary policy,” *Climate Policy*, 21, 581–592.

Shala, Iliriana Schumacher, B. (2022): “The Impact of Natural Disasters on Banks’ Impairment Flow – Evidence from Germany,” *Deutsche Bundesbank Discussion Paper*.

Thakor, A. V. (2021): "Politics, Credit Allocation and Bank Capital Requirements," *Journal of Financial Intermediation*, 45, 100820.

Thomä, J. and K. Gibhardt (2019): "Quantifying the potential impact of a green supporting factor or brown penalty on European banks and lending," *Journal of Financial Regulation and Compliance*, 27, 380–394.

von Kalckreuth, U. (2022): "Pulling ourselves up by our bootstraps: the greenhouse gas value of products," *Deutsche Bundesbank Discussion Paper*.

Zhang, J. (2020): "Shadow banking and optimal capital requirements," *Review of Economic Dynamics*, 38, 296–325.

A Appendix

A.1 Proofs

Proof of Proposition 1. We consider the case where $p > \pi_C$ (the other case, $p < \pi_C$, is analogous). Given the assumption that e_C is increasing in p we have $e_C(p) > e_C(\pi_C)$. On the other hand, since e_D is decreasing in p it holds that $e_D(p) < e_D(\pi_C)$. Therefore, it holds for the PUT for dirty firms:

$$\begin{aligned} \text{PUT}_D(e(\pi_C)) &= \mathbb{E}\left[\max\{I_D(1-e(\pi_C)) - X_D(s), 0\}\right] \\ &< \mathbb{E}\left[\max\{I_q(1-e(p)) - X_q(s), 0\}\right] = \text{PUT}_q(e(p)). \end{aligned}$$

This inequality implies that the deposit insurance subsidy for dirty loans is higher. Similarly, for the ROE of dirty loans, we have:

$$r_D^{\max}(e_D(\pi_C)) = \frac{\text{NPV}_D + \text{PUT}_D(e_D(\pi_C))}{I_D e(\pi_C)} < \frac{\text{NPV}_D + \text{PUT}_D(e_D(p))}{I_D e_D(p)} = r_D^{\max}(e_D(p)).$$

Analogous arguments can be made for the case of clean loans, resulting in the conclusion that $r_C^{\max}(e_C(p)) > r_C^{\max}(e_C(\pi_C))$.

Now, let us now examine the effect to carbon emissions: Since dirty loans face lower capital requirements, more dirty firms are funded for a fixed equity E, assuming that not all dirty firms are already fully funded. This can be expressed as:

$$\begin{aligned} p > \pi_C &\Rightarrow e_D(p) < e_D(\pi_C) \\ &\Rightarrow k_D(p,E) \geq k_D(\pi_C,E), \quad k_C(p,E) \geq k_C(\pi_C,E) \\ &\Rightarrow \phi(p,E) = k_D(p,E)\phi_D + k_C(p,E)\phi_C \\ &\qquad > k_D(\pi_C,E)\phi_D + k_C(\pi_C,E)\phi_C = \phi(\pi_C,E), \end{aligned}$$

where the number $k_C(p,E)$ may increase for higher p if $p > \tilde{p}$ where $\tilde{p}$ is such that all dirty firms are fully funded (since the remaining equity can be used to fund clean firms). This implies that there are more carbon emissions for the same equity E.

The same analysis can be applied to the case $p < \pi_C$, which we leave to the reader. □

Proof of Proposition 2. The regulator's intention is to fully fund all firms with respect to their belief p. Therefore, the regulator chooses e_C and e_D such that the equity E is equal to $E = (e_C + e_D(1-p))I$. Using this equation, we can express E as $E = (p(e_C - e_D) + e_D)I$. Now, let's consider the case when $p < \pi_C$. If we replace p with π_C in the equation above while keeping e_C and e_D constant, we have $E < (p(e_C - e_D) + e_D)I$ since $e_C < e_D$. Analogously, for the case when $p > \pi_C$ we show that $E > (p(e_C - e_D) + e_D)I$. With it, the statements in (i) follow. (ii) is analogous. □

Proof of Theorem 4.

(i) According to (Oehmke and Opp, 2022a, Result 1), it is optimal for banks to specialize in funding either clean or dirty firms. Since dirty loans have a higher ROE than clean loans, banks will prioritize funding dirty firms until they are fully funded. Using (4), dirty firms are fully funded as long as $E/I_D \geq e_D(p)$. If this condition is not satisfied, meaning $E < e_D(p)I_D$, dirty firms will only be partially funded. Since e_D is decreasing in p, an increase in p to $\tilde{p}$ is beneficial for dirty firms until it holds that $E = e_D(\tilde{p})I_D$. Solving this equation to $\tilde{p}$ gives the desired result.

(ii) After fully funding the dirty firms, banks will allocate the remaining equity to fund clean firms. Using equation (4), both dirty and clean firms will be fully funded if $E/I = \pi_D e_D(p) + \pi_C e_C(p)$. If this condition is not satisfied, clean firms are only partially funded and they have an incentive to change p to $\tilde{p}$ until $E = e_D(\tilde{p})I_D + e_C(\tilde{p})I_C$. Solving this equation for $\tilde{p}$ gives the desired result. □

Proof of Theorem 5. First, it is important to note that dirty firms only have an incentive for greenwashing when they are not fully funded, i. e. $E < e_D(p)I_D$. Let us assume that $\frac{E}{I_D} = le_D(p)$, where l is constant in the range of $(0, 1)$. Moreover, dirty firms are limited with their investments since it must be guaranteed that they are funded at first by banks, therefore the ROE of dirty loans after the intervention must be above this of clean loans. Then by Theorem 4, it follows:

(i) If K is chosen such that $\tilde{p} = e_D^{-1}(E/I_D)$ we have $\frac{E}{I_D} = e_D(\tilde{p})$. It means that the condition (4) is satisfied for a full funding of dirty firms and there is no funding of clean firms.

(ii) If K is chosen such that $\tilde{p} > e_D^{-1}(E/I_D)$ we have $\frac{E}{I_D} = \tilde{l}e_D(\tilde{p})$ where $1 > \tilde{l} > l$ by the monotonicity of e_D. □

Proof of Proposition 3. As we described before, greenwashing leads to lower capital requirements for dirty loans and therefore requires less equity which to fund the same number of dirty firms. This means for a fixed equity E and if not all dirty firms are already fully funded, that more dirty firms are funded. Altogether, there are more carbon emissions for the same equity, since we have (where p_1 stands for the effects of greenwashing):

$$\begin{aligned} p_1 > p_0 \;&\Rightarrow\; e_D(p_1) < e_C(p_0) \\ &\Rightarrow\; k_D(p_1, E) > k_D(p_0, E), \quad k_C(p_1, E) > k_C(p_0, E) \\ &\Rightarrow\; \phi(p_1, E) = k_D(p_1, E)\phi_D + k_C(p_1, E)\phi_C \\ &\qquad > k_D(p_1, E)\phi_D + k_C(p_0, E)\phi_C = \phi(p_0, E), \end{aligned}$$

where the number $k_C(p, E)$ may increase for higher p if $p > \tilde{p}$ where $\tilde{p}$ is such that all dirty firms are fully funded (since the remaining equity can be used to fund clean firms). □

Proof of Theorem 6. Define $k \in [0, 1)$ as the value that satisfies $\frac{E - e_D(p)I_D}{kI_C} = e_C(p)$, which represents the portion of the investment need I_C of clean firms which is financed by banks. The value is strictly smaller than 1, since otherwise all clean firms were already funded at p. If k is zero, than no clean firm is funded. Similarly, let $\tilde{k} \in [0, 1]$ be the value that satisfies $\frac{E - e_D(\tilde{p})I_D}{\tilde{k}I_C} = e_C(\tilde{p})$, where $\tilde{k}$ the portion of the investment need I_C of clean firms which is financed by banks after greenwashing. Clean firms are willing to go to $\tilde{p}$ if $\tilde{k} > k$, i. e. a higher portion of these firms are funded after this action.

(i) If $\tilde{k} < 1$ then clean firms are partially financed by banks with equity $E - e_D(\tilde{p})I_D$.

(ii) If $\tilde{k} = 1$ then all clean firms are financed by banks.

(iii) If clean firms change p by cost K such that for the new probability we have:

$$r_C^{\max,K}(e_C(\tilde{p})) \ > \ r_D^{\max}(e_D(\tilde{p})),$$

then it becomes more profitable for banks to fund clean firms rather than dirty ones. This implies their equity E is primarily used for green investments (see Theorem 4):

(a) If $E \geq e_C(\tilde{p})I_C$, then all clean firms are fully funded, and the remaining equity is utilized for dirty firms. In this case, clean firms become inframarginal borrowers, while dirty ones are then marginal borrowers.

(b) If $E \geq e_C(\tilde{p})I_C$, clean firms are only partially funded. Again, let $\tilde{k}$ be the portion of clean firms that are funded after the change of p. Due to the monotonicity of e_C, it follows that $\tilde{k} > k$. □

Proof of Proposition 4. Greenwashing leads to higher capital requirements for clean loans, while brownwashing leads to lower capital requirements. Consequently, the amount of equity needed to fund the same number of clean firms decreases with greenwashing and increases with brownwashing. Consider a fixed equity E, and assume that all dirty firms are already funded. In this case, the allocation of equity determines the funding outcome for clean firms. Altogether, there are more carbon emissions for the same equity, since we have (let p_1 represent the probability associated with greenwashing, p_0 represent the original probability, and p_2 represent the probability associated with brownwashing):

$$\begin{aligned} p_1 \ > \ p_0 \ > p_2 \ &\Rightarrow \ e_C(p_1) \ > \ e_C(p_0) \ > \ e_C(p_2) \\ &\Rightarrow \ k_C(p_1, E) \ < \ k_C(p_0, E) \ < \ k_C(p_2, E) \\ &\Rightarrow \ \phi(p_1, E) \ = \ k_D(E)\phi_D + k_C(p_1, E)\phi_C \\ &\qquad \leq \ k_D(E)\phi_D + k_C(p_0, E)\phi_C \ \leq \ k_D(E)\phi_D + k_C(p_2, E)\phi_C \ = \ \phi(p_2, E), \end{aligned}$$

where the number $k_D(E)$ of dirty firms which is funded for fixed E remains constant independent of p. □

Proof of Proposition 5. Given the assumption that the change in the regulator's expectation from p to p^* is only marginal, dirty firms remain the banks' preferred type, i. e. $r_D^{\max}(e_D(p^*)) > r_C^{\max}(e_C(p^*))$.

- If $p^* < p$, it leads to higher $e_D(p^*) > e_D(p)$ (since e_D is decreasing in p) and to lower $e_C(p^*) < e_C(p)$ (since e_C is increasing in p). We consider the developments of $e_C(p^*)$ and $e_D(p^*)$ if equity is raised: Dirty firms are funded at first (Principle 2 of Optimal Prudential Regulation (cf. Oehmke and Opp (2022a))) and $e_D(p^*)$ remains constant as long as dirty firms are partially funded, i. e. as long a $E \in (0, E_1^*)$ where $E_1^* = e_D(p^*)I_D$ (Principles 1 and 3). If dirty firms are fully funded and no clean firm is funded, $e_D(p^*)$ increases as long as dirty firms remain the banks' preferred type,

i. e. if $E \in (E_1^*, E_2^*)$ where $E_2^* = e_D^{\#}(p^*)I_D$ where $e_D^{\#}(p^*)$ is such that $r_D^{\max}(e_D^{\#}(p^*)) = r_C^{\max}(e_C(p^*))$ (Principle 1). If clean firms are only partially funded, i. e. if $E \in (E_2^*, E_3^*)$ where $E_3^* = e_D^{\#}(p^*)I_D + e_C(p)I_C$, $e_D^{\#}(p^*)$ and $e_D(p^*)$ remain constant (Principles 1 and 3). If $E > E_3^*$, all firm types are fully funded, and $e_D^{\#}(p^*)$ and $e_C(p^*)$ increase to $e_C^*(p^*)$ and $e_D^*(p^*)$ (Principle 4). This results in $E = e_C^*(p^*)I_C + e_D^*(p^*)I_D$ (Principle 1).

- If $p^* > p$, it leads to lower $e_D(p^*) > e_D(p)$ (since e_D is decreasing in p) and to higher $e_C(p^*) < e_C(p)$ (since e_C is increasing in p). The further arguments follow a similar logic to the first case.

We can describe the intervals of equity where different types of firms are funded by E_j and E_j^* based on the regulator's expectation p and p^*, respectively. Then the regions in which only dirty firms are partially funded ($E < E_1$) or fully funded ($E \in (E_1, E_2)$), respectively, as well as where clean firms are partially funded ($E \in (E_2, E_3)$) and where all firms are funded ($E > E_3$) change in the following way:

- in the region $(0, E_1^*)$ only clean firms are partially funded;
- in the region (E_1^*, E_2^*) all clean firms are fully funded, but no dirty firm is funded;
- in the region (E_2^*, E_3^*) all clean firms are fully funded and dirty firms are partially funded;
- in the region $(E_3^*, +\infty)$ all firms, both clean and dirty, are fully funded.

Based on Proposition 6, we can observe the following behavior of the capital requirements for clean loans (e_C) and dirty loans (e_D) as the equity E changes:

1. For $E \in (0, E_1^*)$: Only clean firms are partially funded. In this region, e_C remains unchanged, while e_D increases.
2. For $E \in (E_1^*, E_2^*)$: All clean firms are fully funded, but no dirty firm is funded. In this region, e_C remains unchanged, and e_D continues to increase.
3. For $E \in (E_2^*, E_3^*)$: All clean firms are fully funded, and dirty firms are partially funded. In this region, both e_C and e_D remain constant.
4. For $E > E_3^*$: ll firms, both clean and dirty, are fully funded. In this region, both e_C and e_D increase, but e_D may increase on a lower level compared to the earlier stages.

This is illustrated in the left panel of Figure 5.

The shifts in the regulator's expectation from p to p^*, resulting in changes in the capital requirements for clean and dirty loans, can also affect the number of clean and dirty firms that are funded. These effects can be observed as follows:

- Shift to higher $p^* > p$: As the capital requirement for dirty loans increases, more equity is needed to fund all dirty firms. This is reflected in the interval (E_2^*, E_3^*), which becomes longer than before, indicating a larger equity range required to fully fund dirty firms. In other words, the difference between E_3^* and E_2^* is greater than the difference between E_1, showing that more equity is needed to fund all dirty firms under the new expectation p^*.

- Shift to lower $p^* < p$: Conversely, as the capital requirement for clean loans decreases, less equity is needed to fund clean firms. Under the initial expectation p, the banking sector has to invest $E_3 - E_2$ to fund all clean firms. However, under the new expectation p^*, the funding of all clean firms can be achieved with less equity, indicated by E_1^* being smaller than $E_3 - E_2$. □

Proof of Proposition 6. Given the assumptions about the capital requirement functions e_C and e_D for clean and dirty loans, respectively, we consider a large change in the regulator's expectation from p to $p^* < p$. This change leads to higher $e_D(p^*) > e_D(p)$ (due to the decreasing nature of e_D w. r. t. p) and to lower $e_C(p^*) < e_C(p)$ (due to the increasing nature of e_C w. r. t. p). Consequently, clean firms become the preferred type for banks, as $r_C^{\max}(e_C(p^*)) > r_D^{\max}(e_D(p^*))$. Now, let us examine the developments of $e_C(p^*)$ and $e_D(p^*)$ as equity increases: According the Principles of Optimal Prudential Regulation (cf. (Oehmke and Opp, 2022a, Proposition 3)) clean firms are funded first (Principle 2). When clean firms are only partially funded, i. e. as long a $E \in (0, E_1^*)$ with $E_1^* = e_C(p^*)I_C$ (Principles 1 and 3), $e_C(p^*)$ remains constant. If clean firms are fully funded and no dirty firm is funded, $e_C(p^*)$ increases as long as clean firms remain the banks' preferred type. This occurs when $E \in (E_1^*, E_2^*)$ with $E_2^* = e_C^*(p^*)I_C$ where $e_C^*(p^*)$ is determined such that $r_C^{\max}(e_C^*(p^*)) = r_D^{\max}(e_D(p^*))$ (Principle 1). If dirty firms are only partially funded, i. e. if $E \in (E_2^*, E_3^*)$ with $E_3^* = e_C^*(p^*)I_C + e_D(p^*)I_D$, both $e_C^*(p^*)$ and $e_D(p^*)$ remain constant (Principles 1 and 3). When $E > E_3^*$, all firm types are fully funded. In this case, $e_C^*(p^*)$ and $e_D(p^*)$ increase to $e_C^{\#}(p^*)$ and $e_D^{\#}(p^*)$, respectively, according to Principle 4. The equity is allocated as $E = e_C^{\#}(p^*)I_C + e_D^{\#}(p^*)I_D$ (Principle 1). □

Proof of Theorem 9. We divide the size of equity E into four regions:

- In the region $(0, E_1)$ where $E_1 = e_C^*(p)I_C$ only clean firms are partially funded with the optimal capital requirement $e_C^*(p)$ for clean loans.

- In the region (E_1, E_2) all clean firms are fully funded, but no dirty firm is funded. The regulator increases the capital requirements for clean loans to avoid funding in dirty firms and such that the additional equity is used to decrease the deposit insurance subsidy (the PUT_C) for clean loans. $e_C^*(p)$ increases until it reaches $e_C^{\#}(p)$, where banks are indifferent between funding in clean or dirty firms, i. e. $r_C^{\max}(e_C^{\#}(p)) = r_D^{\max}(1)$. The regulator sets the capital requirements for clean loans such that $e_C(p)$ does not exceed $e_C^{\#}(p)$, as banks would prefer lending to dirty firms. The value E_2 is then calculated by $E_2 = e_C^{\#}(p)I_C$.

- If more equity is available, i. e. $E > E_2$, also dirty bank receive funding. In the region (E_2, E_3) all clean firms are fully funded and dirty firms are partially funded until all firms receive funding, i. e. $E_3 = e_C^{\#}(p)I_C + I_D$.

- In the region (E_3, E_4) all firms are fully funded. Any additional equity, i. e. $E - E_3$, is used to decrease deposit insurance subsidy for clean loans by increasing $e_C(p)$. However, it is not possible to analogously increase the capital requirement for dirty loans since e_D is already at its maximum. Therefore, the regulator sets $e_C(p)$ such that $E =$

$e_C(p)I_C + I_D$ for $E \in (E_3, E_4)$ where $E_4 = I_C + I_D$ represents the total funding needed for both clean and dirty firms. $\square$

A.2 Incomplete information about the true firm type

Let us now assume that the regulator does not know the true type (clean or dirty) of a firm but he sets capital requirements $e_C < e_D$. Of course, a clean firm does not have an incentive to cheat the regulator by presenting him their wrong type. On the other hand, for a dirty firm it is beneficial to make the regulator believe that their type is clean to profit from lower capital requirements. We suppose that a regulator estimates the type of each firm by $p \in [0,1]$ where we set $p = 0$ as truly clean and $p = 1$ as truly dirty and suppose a linear estimation for the capital requirement:

$$e(p) \ = pe_D + (1-p)e_C.$$

A firm now has the possibility to change the regulator's estimation from p to $\tilde{p}$ to reduce their capital requirements. Therefore, as long a $p \neq 0$, a firm of each type has an incentive to change the regulator's belief.

Proposition 7 *A firm of type q is willing to pay an amount K to change the regulator's estimation from p to $\tilde{p} = \tilde{p}(K)$ if and only if it holds*

$$r_q^{\max}(e(p)) \ \leq \ r_q^{\max,K}(e(\tilde{p})).$$

The incentive of a firm to change the regulator's estimation about its type (and therefore its capital requirements) consists of increasing their maximal ROE. Since changing the belief of the regulator is not free of charge, a firm is willing to pay the amount K as long as its maximal ROE is larger after the change as before. Therefore, the optimization problem of the firm is a trade-off between increasing their ROE and reducing the costs of seeming more clean.

A.3 Extra-ordinary cases

Let us consider the case where $e_D(p)$ is increasing in p (higher capital requirements for dirty loans as the regulator assumes a higher presence of clean firms) and $e_C(p)$ is decreasing in p (lower capital requirements for clean loans). We analyze the effects and the changes compared to the model in Subsection 2.2.

1. Higher capital requirements for dirty loans: As the regulator assumes a higher presence of clean firms (higher p), the capital requirements for dirty loans increase. This implies that banks need to allocate more equity to fund dirty firms, reflecting the perceived higher risk associated with them. The higher capital requirements for dirty loans incentivize banks to favor clean loans over dirty loans.

2. Lower capital requirements for clean loans: Conversely, as the regulator assumes a higher presence of clean firms (higher p), the capital requirements for clean loans decrease. This means that banks need to allocate less equity to fund clean firms, reflecting the perceived lower risk associated with them. The lower capital requirements for clean loans incentivize banks to prefer lending to clean firms.

Under the remaining assumption that dirty firms are more profitable (and therefore have a higher ROE compared to clean firms), the implications are as follows:

- Incentive for green- and brownwashing: Clean firms have an incentive to engage in greenwashing, which means presenting themselves as more environmentally friendly than they actually are. By doing so, they can lower their capital requirements and reduce the number of funding firms needed to finance their operations. On the other hand, dirty firms have an incentive for brownwashing, which involves downplaying their negative environmental impact. This allows them to benefit from lower capital requirements as well. Both green- and brownwashing strategies aim to minimize the costs associated with capital requirements and increase profitability.

- Regulatory bias against clean firms: The capital requirement functions, which result in higher capital requirements for clean loans and lower requirements for dirty loans, seem to penalize clean firms. This bias reflects the regulator's assumption of higher risks associated with clean firms, potentially due to concerns about financial stability. As a result, funding clean firms becomes more expensive for banks, requiring them to allocate more equity. This makes it harder for banks to increase the portion of clean firms in their portfolio, especially when the initial portion of clean firms is very low.

Similar arguments can be applied the other forms of capital requirement functions, such as step functions.

In contrast to our general model, let us now assume that clean firms are more profitable than dirty ones, which is represented by their net present value $\text{NPV}_C > \text{NPV}_D$. Then several implications can be derived:

- When the capital requirements for both firm types are identical, banks can expect a higher ROE by funding clean firms compared to dirty firms. This is due to the higher profitability of clean firms, as indicated by their higher NPV. Therefore, banks have an incentive to initially fund clean firms. Despite being more profitable, clean firms may still have an incentive for greenwashing if they are only marginally funded and desire to increase the number of funded firms. By manipulating their reported environmental impact or categorization, clean firms may attempt to lower their capital requirements and improve their chances of obtaining funding. This is because a reduction in capital requirements could lead to a higher proportion of funded clean firms. Dirty firms may also be interested in greenwashing, as lower capital requirements could potentially increase the proportion of funded dirty firms. However, it is important to note that the initial advantage lies with clean firms, as they are funded first due to their higher profitability.

- Under the assumption that the capital requirements differ for dirty and clean firms, with $e_C(p)$ is increasing in p, while e_D is decreasing, we can derive the following deductions:

  - Dirty firms will have an incentive for greenwashing only if it leads to an increase in the proportion of funded firms of their type. This can be achieved in two ways: If greenwashing efforts can result in lower capital requirements for dirty loans, it would reduce the amount of equity needed for funding. This could increase the proportion of funded dirty firms, as it becomes easier for banks to meet the capital requirements for such loans. In some cases, a large increase in the value of p (representing the assumption of higher presence of clean firms) could lead to a change in the ranking of ROE between clean and dirty firms. If capital requirements for clean loans become too stringent while they become more lenient for dirty loans, dirty firms may become more attractive to banks in terms of profitability. In such a scenario, dirty firms would be funded first, utilizing the available bank equity, and only the remaining equity could be used for funding clean firms.

  - Clean firms, being funded first due to their higher profitability, do not have an incentive for greenwashing. Greenwashing efforts would increase their capital requirements, potentially making it more difficult for them to meet the requirements and obtain funding. Since clean firms are already prioritized for funding, their focus would be on maintaining their status and not engaging in actions that could jeopardize their funding opportunities. In our model, clean firms can do brownwashing to increase the number of funded firms, since this would lower their capital requirements and leads to more firms which are funded.

- A higher profitability for clean firms can be beneficial for the bank regulator because it lowers the risk associated with investments in these firms. If clean firms are more profitable, they are less likely to default on their loans, reducing the potential losses for banks and the need for deposit insurance subsidies. This can align with the regulator's goal of reducing the subsidy and promoting financial stability. Higher profitability for clean firms can be associated with lower capital requirements. As clean firms are considered less risky due to their higher profitability, the regulator may determine that they require less capital to maintain financial stability. Lower capital requirements for clean loans make it easier for banks to fund clean firms, further encouraging investments in environmentally friendly activities. It is important to note that the higher profitability of clean firms itself can drive increased investment and funding in this sector, without any direct actions from the regulator. Banks, driven by profit motives, may naturally prefer to invest in clean firms due to their higher returns and lower default risk. As it becomes more challenging for dirty firms to secure funding due to higher capital requirements and lower profitability compared to clean firms, they may be compelled to shift their production towards more environmentally friendly alternatives. The difficulty in obtaining funding for dirty activities can act as an incentive for these firms to transition to green-friendly practices in order to attract investment and meet the evolving market demand.

A.4 Funding to clean and dirty firms depending on the size of equity

First, we describe the funding for different firm types depending on available equity E. For that, let us suppose that dirty firms are more profitable than clean ones and can guaranty a higher ROE to the bank. Then we have the following situations:

- $E > e_D(p)I_D + e_C(p)I_C =: E_3$: In this case, there is sufficient equity available to fund all investments from both dirty and clean firms. This situation can occur when banks' equity is large enough to finance all investments without being constrained by the regulator's requirements. On the other hand, this case can be realized if the regulator's requirements $e_C(p)$ and $e_D(p)$ are too weak to restrict banks' investment decisions.

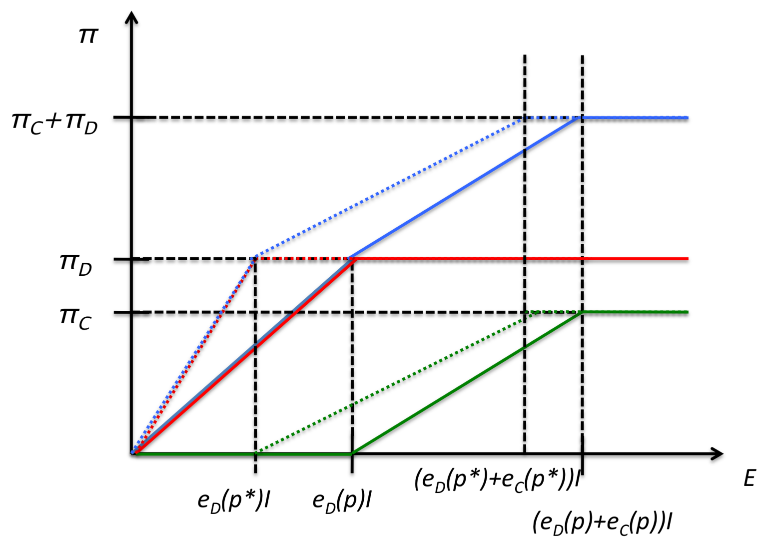
- $E_1 := e_D(p)I_D < E < e_D(p)I_D + e_C(p)I_C$: Dirty firms are fully funded with the equity amount of $e_D(p)I_D$, and the remaining equity $(E - e_D(p)I_D)$ is used to partially fund clean firms. This scenario arises when dirty firms are more profitable and offer a higher ROE for banks. Banks prioritize funding dirty firms until all available equity for them is utilized, and then allocate the remaining equity to partially fund clean firms, subject to regulatory constraints.

- $E < e_D(p)I_D$: In this case, clean firms are not funded, and only dirty firms receive partial funding using the entire available equity E. The equity is insufficient to fund all dirty firms due to its limited amount or because the regulatory requirements are too stringent. Since dirty firms offer higher profitability and ROE, banks prioritize funding them with the available equity, leading to the exclusion of clean firms from funding.

In the situation where dirty firms are initially the preferred type and the regulator's belief p influences the portion π_q of funded firms of type q, let's explore the funding dynamics for clean and dirty firms based on the available equity E. Considering a fixed value of $I = I_C = I_D$ for both clean and dirty firms, we can analyze how the portion of funded firms changes with different capital requirement functions $e_q(p)$. As the available equity E varies, we can observe the allocation of funding between clean and dirty firms. We start in Figure 8 with actions of dirty firms, i. e. they try to increase their fundings. Let p be the starting belief of the regulator (solid line) and p^* be his updated belief (dotted line) after an action of dirty firms. We see by comparing the dotted red line with the solid one, that they are fully funded under less equity E which has to be spent for it $(e_D(p^*)I < e_D(p)I)$. On the other hand, clean firms are funded earlier but more equity is used for it (compare the dotted green line with the solid one). Overall, the funding dynamics indicate that all firms, both clean and dirty, can be fully funded with less equity when the regulator's belief is updated from p to p^* (as shown in the dotted blue line compared to the solid one).

Next, let us consider actions of clean firms in Figure 9. Based on the updated belief of the regulator, denoted as $\tilde{p}$ (dotted line) after an action of dirty firms, we can analyze the funding dynamics for clean and dirty firms. As mentioned before, they can have a marginal (only cost) or a large (substitution) effect:

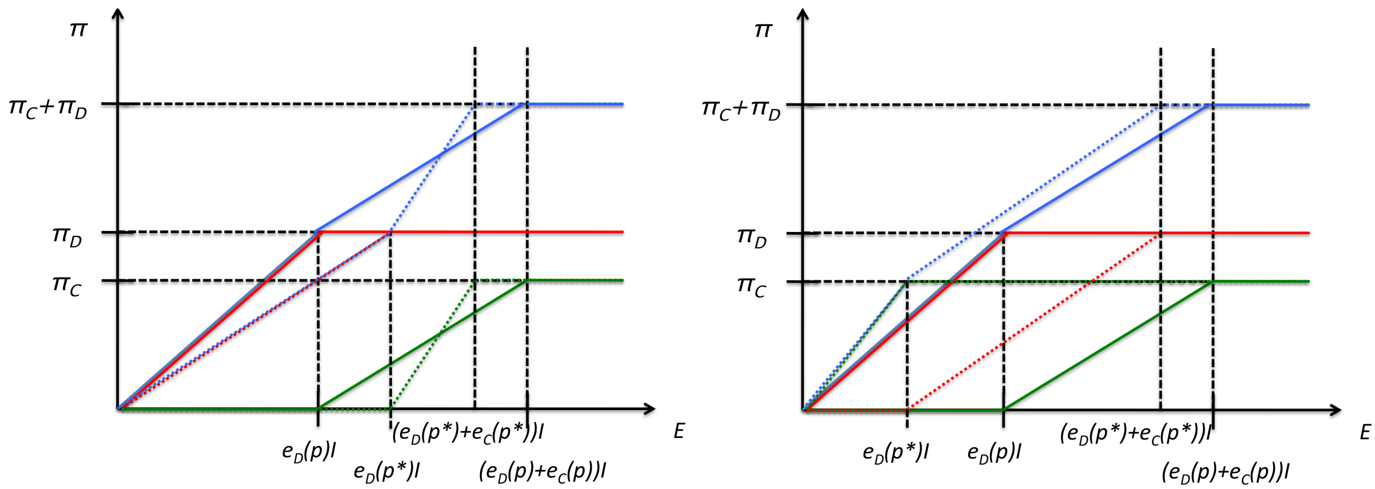
Figure 8: Example for the effects of actions of dirty firms on the funding for dirty (red) and clean (green) firms as well as for both firm types (blue). The solid lines represent the base case where the dotted lines represent the case after the dirty firm's action.



- If the action of clean firms only have a marginal impact, the ranking of both firm types do not change. Nevertheless, clean firms improve the funding in the following way: Comparing the dotted green line with the solid line, we can observe that clean firms are fully funded under less equity E with the updated belief $\tilde{p}$ compared to the starting belief p. Specifically, the amount of equity required to fully fund clean firms decreases (i.e., $E - e_D(\tilde{p}) < E - e_D(p)$). This implies that clean firms are able to achieve full funding with a smaller amount of equity, which is advantageous for this type of firm. Dirty firms are still funded first, similar to the initial belief represented by the solid red line. However, more equity is used to fund dirty firms, as indicated by the red dotted line compared to the solid red line. Overall, the funding dynamics show that all firms, both clean and dirty, can be fully funded with less equity when the regulator's belief is updated to $\tilde{p}$. This is particularly beneficial for clean firms, as they require less equity for full funding compared to the starting belief p.

- If the action of clean firms is sufficiently large to change the ranking of the ROE between clean and dirty loans, we observe a different funding pattern. Let us analyze the funding dynamics based on the updated belief of the regulator, denoted as p^* (dotted lines). With the updated belief p^*, clean firms are funded first, as indicated by the dotted green line. This means that clean firms receive funding before dirty firms, given that the action of clean firms has altered the perception of their profitability. This change in the ranking of ROE leads to a preference for clean firms in terms of funding allocation. Due to the updated belief p^* and the change in the ranking of ROE, dirty firms are not funded initially if the available equity E is less than the capital requirement for clean loans, i.e., $E < e_C(p^*)I$. Once the equity surpasses this threshold, dirty firms are marginally funded, represented by the portion of equity allocated to dirty firms in the dotted red line. This marginal funding continues until the available equity E

Figure 9: Example for the effects of actions of clean firms on the funding for dirty (red) and clean (green) firms as well as for both firm types (blue). The solid lines represent the base case where the dotted lines represent the case after the clean firm's action. Left picture: Marginal intervention (ranking between both types unchanged). Right picture: Large intervention (ranking between both types changed)



reaches or exceeds the combined capital requirement for both clean and dirty loans, i.e., $E \geq (e_C(p^*) + e_D(p^*))I$. After this point, both clean and dirty firms are fully funded, as shown by the dotted blue line.

- Let us discuss the effects on the emissions of dirty and clean firms based on the two scenarios mentioned. When the ranking of the two firm types does not change and when all firms are fully funded with less equity, the cumulative emissions would be the same for both clean and dirty firms. However, it is important to note that the emissions for dirty firms increase at a slower rate compared to the emissions of clean firms, as indicated by the function $\phi^*(E) < \phi(E)$ for a fixed equity E. This suggests that, for the same level of equity investment, dirty firms would have lower emissions compared to clean firms. When the intervention is significant enough to change the ranking of both firm types, the emissions for small equity E would be smaller due to the reduction in emissions from clean firms compared to dirty firms, resulting from the change in ROE ranking. However, it is important to note that since all firms are fully funded under less equity, the cumulative emissions would be higher overall. This is because the increase in emissions from fully funded dirty firms would outweigh the reduced emissions from fully funded clean firms.

A.5 Common capital requirement function

Under the assumption of a common capital requirement function $e(p)$ for clean and dirty loans, where $e(p) = e_D(p) = e_C(p)$ for every $p \in [0, 1]$, and e is a continuous and decreasing function in p with $e(0) = 1$ and $e(1) = 0$, we can make the following observations:

First, let us describe how the capital requirements work depending on given equity E and investment need I: Let us assume that I is invested by E and D and there is no other deposit. The bank equity ratio can then be described by $e = E/I$ where the regulator requires that $E/I \geq e(p)$. Then we have the following situations:

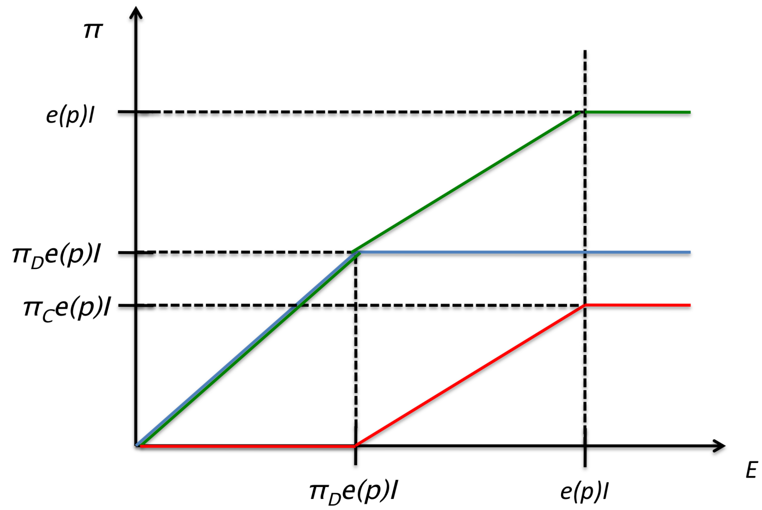
- In the case where $p = 1$, meaning the regulator does not expect any dirty firms, there are no restrictions on the bank in funding firms of any type. This assumption reflects a green-friendly regulator who does not impose capital requirements or restrictions on funding clean firms. With no expectations of dirty firms, the regulator allows the bank to allocate funds freely to clean firms without any constraints. This situation implies that clean firms can be fully funded, and there are no limitations on their access to capital.

- In the case where $E > e(p)I$, all firms of any type can be funded. This situation occurs when the bank's equity is sufficient to finance all investments of both clean and dirty firms, regardless of their profitability. It could be due to the bank having a substantial amount of equity available or the regulator's requirement $e(p)$ being relatively weak and not placing significant restrictions on the bank's investment decisions. However, it is important to note that if $E < I$, there exists a value $0 < e^*(p) < 1$ such that $E < e(p)I$ for all $e(p) \geq e^*(p)$. This means that there is a limit to the amount of funding the bank can provide, and not all firms can be financed. The bank will have to prioritize its funding based on the available equity and the capital requirements set by the regulator.

- If the available equity lies between $e(p)I_D$ and $e(p)I$, dirty firms will be fully funded using the equity amount of $e(p)I_D$. Clean firms will then be partially funded using the remaining equity, which is $E - e(p)I_D$. In this scenario, where dirty firms are more profitable than clean firms, banks prioritize funding dirty firms first. As long as there is sufficient equity available and the regulator's requirements do not restrict funding, banks will allocate their equity to fund dirty firms. Once all dirty firms have been funded, the remaining equity can be used to finance clean firms, subject to any additional regulatory constraints.

- If the available equity is less than $e(p)I_D$, it means that the bank's equity is insufficient to fund both clean and dirty firms according to the capital requirement function $e(p)$. In this situation, clean firms will not be funded at all, and the available equity will be used to partially fund some of the dirty firms. This occurs when the bank's equity is too small or when the capital requirements set by the regulator are too stringent, making it impossible to allocate enough equity and deposit funding to fund all dirty firms. Since dirty firms are more profitable, the bank prioritizes funding them over the clean firms. As a result, clean firms do not receive any funding in this case.

Figure 10: Typical images of π for clean and dirty firms depending on E



- In the special case where $p = 0$, the regulator's belief is that there are no clean firms present, and the capital requirement function becomes $e(0) = 1$. This means that the bank equity ratio must be equal to one, and the entire investment must be financed by the bank's equity alone. Funding with deposits is not possible in this case. However, if the bank's equity E is less than the required investment I, it implies that not all firms can be funded. The two cases described earlier will apply: dirty firms will be partially funded, and clean firms will not receive any funding.

In Figure 10 we show how a typical funding for clean and dirty firms works depending on the size of E. Again we suppose that dirty firms are more profitable than clean ones and banks are willing to support them at first. Once the equity reaches a point where it is sufficient to fully fund all dirty firms ($E = e(p)I_D$), the funding for dirty firms becomes constant. At this point, all dirty firms have received their required funding. As the bank's equity further increases beyond $E = e(p)I_D$, the funding for clean firms begins. Initially, clean firms receive partial funding, and the portion of equity allocated to them increases as the bank's equity increases. This continues until the equity reaches a point where clean firms are fully funded ($E = e(p)I$). After this point, where both dirty and clean firms are fully funded, the portion of equity used for funding remains unchanged since all firms have received their required funding.

Under the assumption that the bank has a preference to finance a specific firm type q, we can consider the condition $E \geq e(p)\pi_q I$ for full funding of all firms of type q. If the bank's equity E meets or exceeds this condition, all firms of type q can be fully funded. In this case, the bank allocates the necessary equity $e(p)\pi_q I$ specifically for funding firms of type q. If there is still some equity remaining after fully funding firms of type q, i. e., $E - e(p)\pi_q I > 0$, the bank can use the remaining equity to finance firms from other types. This implies that the bank can allocate the surplus equity to fund additional firms that are not of type q. Moreover, if some equity is left, i. e. $E - e(p)\pi_q I$, then the remaining equity can be used to finance firms form other types.

In the context of a common capital requirement function $e(p)$ for both clean and dirty loans, we can analyze the conditions under which these firms have an incentive for greenwashing. Moreover, we will mark the value of the updated probability p until which the firms will intervene. Assuming that the function $e(p)$ is continuous and decreasing in p, we can define its inverse function as $e^{-1}(p)$. The result can be stated as follows:

Theorem 10

(i) If dirty firms are only partially funded, meaning that the available equity E is less than the required equity $e(p)I_D$ for dirty loans, then dirty firms have an incentive to pay in order to increase the value of p to $\tilde{p}$. Specifically, the desired value $\tilde{p}$ is given by $\tilde{p} = e^{-1}(E/(\pi_D I))$.

(ii) If clean firms are not funded at all or only partially funded, meaning that the available equity E is less than the required equity $e(p)I$ for clean loans, then clean firms have an incentive to pay in order to increase the value of p to $\tilde{p}$. The desired value $\tilde{p}$ is given by $\tilde{p} = e^{-1}(E/I)$.

The proof is analogous to this of Theorem 4. The reader can refer to the proof of the analogous theorem for a similar argument. We now consider the circumstances under which dirty firms would be willing to engage in greenwashing.

Theorem 11 (Dirty firms' intervention, common capital requirement function) *Let p be such that $E < e(p)I_D$. Suppose that dirty firms are willing pay a maximal amount K to increase the probability to $\tilde{p}$, where $r_D^{\max,K}(e(\tilde{p})) > r_C^{\max}(e(\tilde{p}))$.*

(i) If K is chosen such that $\tilde{p} = e^{-1}(E/I_D)$, then all dirty firms are fully funded, utilizing the entire equity E for funding dirty firms, and no clean firm is funded.

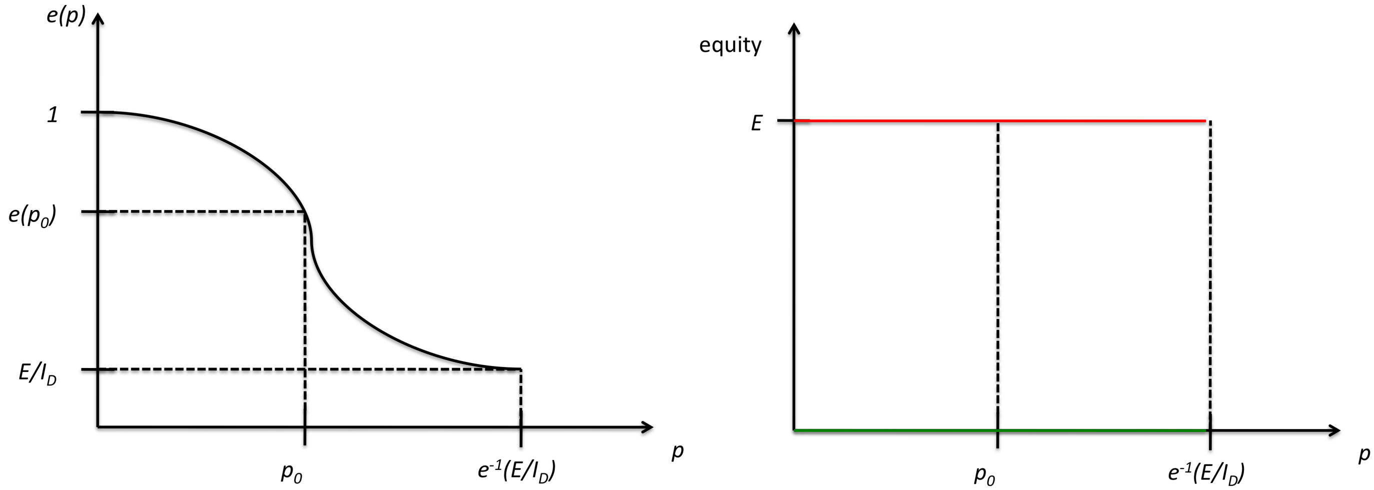
(ii) If K is chosen such that $\tilde{p} > e^{-1}(E/I_D)$, then more dirty firms are partially funded (with the entire equity used for funding dirty firms), and no clean firm is funded.

The proof is analogous to this of Theorem 5 and therefore we leave it to the reader.

In Figure 11 we illustrate the intervention of dirty firms: In the left picture, as p increases, the capital requirements of the regulator decrease. This means that the regulator becomes more lenient in terms of the amount of equity that banks need to hold relative to their investments. This can be represented by a decreasing function that maps p to the corresponding capital requirement $e(p)$. In the right picture, the deployment of equity E for clean and dirty firms is illustrated. For p values below $e^{-1}(E/I_D)$, dirty firms are partially funded, meaning that they receive a portion of the equity E for their investments. Clean firms, on the other hand, may not be funded at all or receive only partial funding. It is important to note that dirty firms are not incentivized to increase p beyond a certain threshold, denoted as $\tilde{p}$. This is because, even if the cost of increasing p does not change the ranking of their profitability, they have no further motivation to do so.

In the special case where dirty firms are only partially funded with $Z_D < I_D$, we can analyze the relationship between equity, deposit funding, and the capital requirement function. Let us denote the amount of deposit funding for dirty firms as D_D. Since banks will use their entire equity E for funding, we have $E \le Z_D$. The equality $E = Z_D$ can only hold

Figure 11: Left: Image of e with the starting value p_0 after the greenwashing of dirty firms $e^{-1}(e/E_D)$. Right: Deployment of E by dirty (red) and clean firms depending on p.



if the capital requirement function $e(\tilde{p})$ equals 1, which corresponds to the case when the probability p is 0. In this case, we can express Z_D as the sum of equity and deposit funding: $Z_D = E + D_D$. By using the condition $E/Z_D = e(\tilde{p})$, we can derive the expression for D_D as follows: $D_D = E(1 - e(\tilde{p}))/e(\tilde{p})$.

Indeed, clean firms have an incentive to pay an amount K to change the probability p to a new value $\tilde{p}$ if it results in a positive ROE, ensuring their eligibility for funding by banks. The objective of clean firms is to decrease the value of $e(\tilde{p})$ in order to increase their ROE, allowing banks to allocate more equity for funding both clean and dirty firms. By reducing the capital requirements through the payment of K, clean firms indirectly support dirty firms as well. This is because the lower capital requirements benefit all loans, regardless of their type. Clean firms aim to improve their own ROE by reducing the capital requirement, but in doing so, they also facilitate the funding of dirty firms. This highlights the interconnectedness of the two firm types and the impact of capital requirements on their funding dynamics.

Theorem 12 (Clean firms' intervention, common capital requirement function) *Let p be such that $E < e(p)I$. Suppose that clean firms pay a maximal amount K to increase the probability to $\tilde{p}$ where $r_C^{\max,K}(e(\tilde{p})) > 0$.*

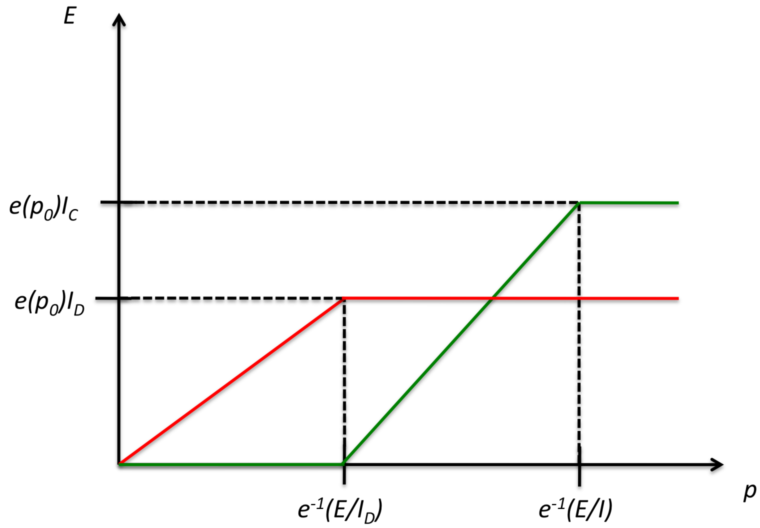
(i) If K is chosen such that $\tilde{p} = e^{-1}(E/I)$, then all dirty and clean firms are fully funded, utilizing the entire equity E for funding all firms (since $e(\tilde{p})I = E$).

(ii) If K is chosen such that $e^{-1}(E/I_D) > \tilde{p} > e^{-1}(E/I)$, then all dirty firms are fully funded (with amount $e(\tilde{p})I_D$ of equity E) and some clean firms are partially funded (with amount $E - e(\tilde{p})I_D$ of equity E).

(ii) Let K such that $e^{-1}(E/I_D) < \tilde{p}$. Then, all dirty firms are partially funded (with full equity E) and no clean firms are funded.

The proof is analogous to this of Theorem 6 and therefore we leave it to the reader.

Figure 12: Image of π before and after clean firm's intervention depending on p

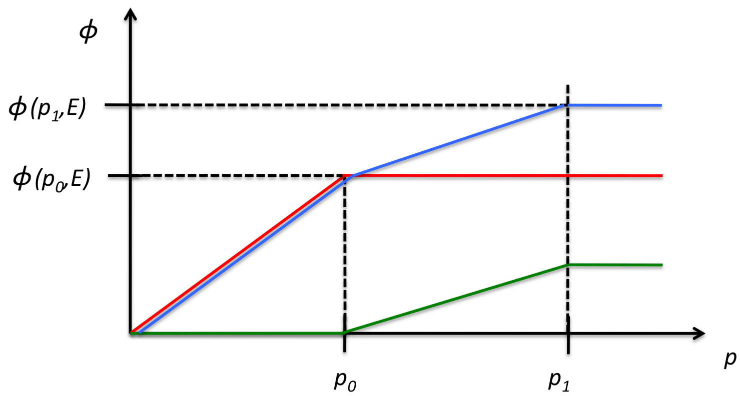


In Figure 12 let us illustrate the deployment of equity E for clean and dirty firms, based on the value of p. If $E < e(p)I_D$, only dirty firms are (partially) funded, and the entire equity E is used for funding them. No equity is allocated to fund clean firms. If $e^{-1}(E/I_D) > p > e^{-1}(E/I)$, dirty firms are fully funded, utilizing an amount of equity $e(p)I_D$. The remaining equity, $E - e(p)I_D$, is allocated to fund (some) clean firms partially. If $p > e^{-1}(E/I_D)$, dirty firms are partially funded, utilizing the full equity E available. No equity is allocated to fund clean firms.

In the special case where clean firms are only partially funded, denoted by $Z_C < I_C$, we can analyze the equity allocation as follows: Dirty firms are fully funded with an amount of $e(\tilde{p})I_D$ of equity E. The remaining equity, $E - e(\tilde{p})I_D$, is available for funding clean firms. Since clean firms are only partially funded, we have $Z_C = E - e(\tilde{p})I_D + D_C$, where D_C represents the deposit funding for clean firms. By the condition $(E - e(\tilde{p})I_D)/Z_C = e(\tilde{p})$, we can determine the value of D_C. Rearranging the equation, we find: $D_C = (E - e(\tilde{p})I_D)\frac{1-e(\tilde{p})}{e(\tilde{p})}$. This expression provides the deposit funding allocated to clean firms, taking into account the available equity and the capital requirement function $e(\tilde{p})$. It is important to note that the equality $E - e(\tilde{p})I_D = Z_C$ is achieved only when $e(\tilde{p}) = 1$, corresponding to $p = 0$. In this case, clean firms receive their full funding requirement, and the deposit funding D_C is determined solely by the remaining equity. This analysis demonstrates how the equity and deposit funding are distributed between dirty and clean firms when clean firms are only partially funded.

In both cases, the intervention of either dirty or clean firms to increase the value of p results in a positive *income effect*. This means that the lending to marginal borrower types increases, leading to a higher allocation of funds to those firms. Dirty firms initially benefit from the income effect, as they are more likely to receive funding due to their higher profitability compared to clean firms. The income effect allows dirty firms to secure funding and expand their operations, assuming they are not inframarginal. It is important to note that in the model with the same capital requirements for both clean and dirty loans, the ranking of firm types does not change. The *substitution effect*, which refers to the change in

Figure 13: Carbon emissions for clean (green), dirty (red) and combined (blue) depending on p



the allocation of funds between different firm types, does not alter the relative profitability or the hierarchy of firms. Overall, the income effect resulting from greenwashing interventions benefits both dirty and clean firms, as it increases the availability of funding for marginal borrower types. However, the substitution effect alone does not alter the relative ranking or profitability of the different types of firms. But first, let us describe the effects of the income effect caused by greenwashing not only on lending and capital requirements, but also on carbon emissions:

Proposition 8 *Let us suppose that the capital requirements for clean and dirty loans are the same and dirty firms are the banks' preferred type. Then greenwashing leads to higher carbon emissions.*

As we described before, greenwashing leads to lower capital requirements, which in turn reduces the amount of equity needed to fund the same number of firms. This implies that with a fixed amount of equity E, more firms can be funded, either dirty or clean, depending on the specific circumstances. Let us denote by k_C and k_D the number of clean and dirty firms, respectively, that are funded by banks. The values of k_C and k_D will depend on the regulator's belief p and the available equity E.

Altogether, there are more carbon emissions for the same equity, since we have:

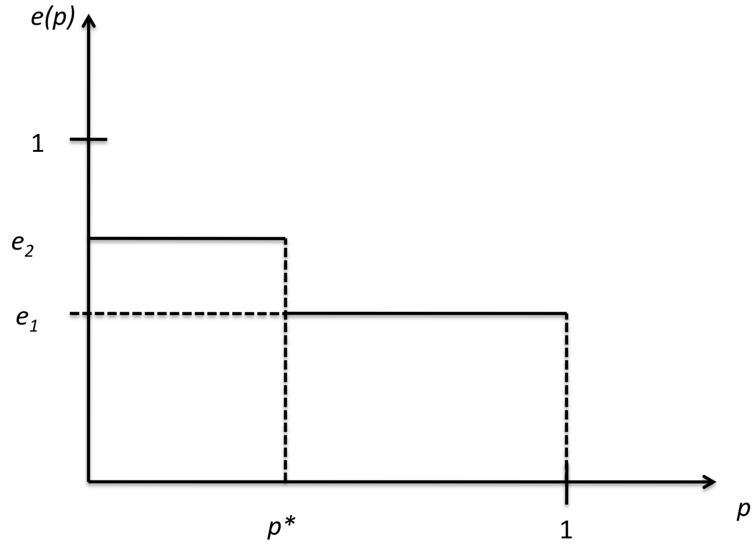
$$
\begin{aligned}
p_1 > p_0 \;\Rightarrow\;& e(p_1) < e(p_0) \\
\Rightarrow\;& k_D(p_1,E) + k_C(p_1,E) > k_D(p_0,E) + k_C(p_0,E) \\
\Rightarrow\;& \phi(p_1,E) = k_D(p_1,E)\phi_D + k_C(p_1,E)\phi_C \\
& > k_D(p_0,E)\phi_D + k_C(p_0,E)\phi_C = \phi(p_0,E).
\end{aligned}
$$

This effect is represented in Figure 13.

Let us summarize the effects of greenwashing, i. e. $p_1 > p_0$, for a common capital requirement function $e(p)$ depending on the regulator's belief p: Greenwashing leads to lower capital requirements for both clean and dirty loans, making funding cheaper for banks. This allows them to fund more firms with the same amount of equity. The income effect comes into play, where the increased funding leads to more dirty firms being funded until they are fully funded. Dirty firms are preferred by banks, so they are prioritized in the funding process. If all dirty firms are already fully funded, the remaining equity can be used to fund more clean firms. This further increases the number of funded firms. The overall effect of greenwashing is an increase in the combined carbon emissions. This is because more firms, both dirty and clean, are funded, leading to higher economic activity and potentially more carbon-emitting activities. Lower capital requirements also mean a higher deposit insurance subsidy for the regulator. This implies that the regulator and society as a whole take on increased risk from potential defaults of investments, which can have financial implications.

A less elastic capital requirement function, where the elasticity is less than one, can mitigate the effects of greenwashing to some extent. With a less elastic function, the relative change in capital requirements is smaller compared to the change in the regulator's belief. This implies that greenwashing becomes more expensive to achieve the same effects in terms of capital requirements. It raises the cost for firms to manipulate their reported carbon emissions and financial positions, making it less attractive or feasible. However, it is important to note that even with a less elastic capital requirement function, the negative impacts of greenwashing on carbon emissions, lending, and deposit insurance cannot be fully eliminated. The effects may be somewhat reduced, but they may still exist to some degree.

Figure 14: Example for a step function $e(p)$ for common capital requirements on clean and dirty loans.



A.6 Capital requirements as step functions

If we consider the special case where the capital requirements for both loan types are constant for different values of p but change at a specific probability $\tilde{p}$, we can mathematically represent this using step functions.

In the case where the capital requirements for both loan types are the same and represented by a step function, let us consider a step function e that takes values in $\{e_1, e_2\}$, where $0 \leq e_1 < e_2 \leq 1$. We define a threshold probability $\tilde{p}$ such that: $e(p) = e_2$ for $0 \leq p \leq \tilde{p}$ and $e(p) = e_1$ for $\tilde{p} < p \leq 1$. This step function captures the change in capital requirements at the threshold probability $\tilde{p}$. For belief values below or equal to $\tilde{p}$, the capital requirement is e_2, and for belief values above $\tilde{p}$, the capital requirement is e_1. An example for such a step function is shown in Figure 14.

In this case, we consider that clean firms can invest with a capital amount K_C and dirty firms can invest with a capital amount K_D, such that the capital requirement function e changes from e_1 to e_2 and vice versa. We analyze the conditions under which firms of different types are willing to invest to change the capital requirement function and examine the implications of such a change on the deposit insurance subsidy. To determine when firms are willing to invest, we consider the profitability of their investment compared to the cost of changing the capital requirement function. Let $r^{\max}$ be the maximum achievable return on equity for both clean and dirty firms.

Let us start with the case $e(p) = e_1$:

- Dirty firms: Dirty firms are not willing to invest in changing the capital requirement because it does not increase the number of funded firms. Additionally, investing would lower their ROE. Therefore, there is no incentive for dirty firms to change the capital requirement.

- Clean firms: Clean firms are also not willing to invest to change the capital requirement from e_1 to e_2. The reason is that the order of ROE does not change with the investment, and there is no opportunity to secure higher funding than before. Investing in this scenario only makes sense from a political standpoint if clean firms are currently not funded at all. In that case, a change in the capital requirement could decrease funding for dirty firms. However, if the ROE for clean firms falls below zero after the investment, it becomes unsuitable for banks to fund them.

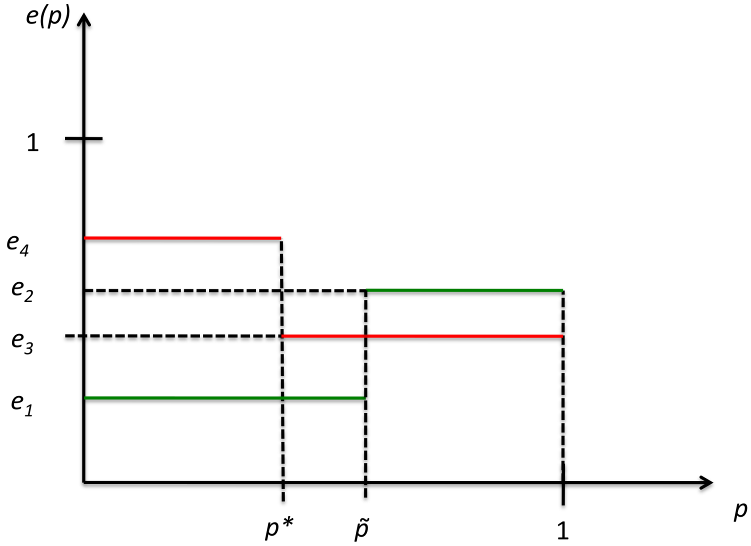
- Regulator's deposit insurance subsidy: A shift from e_1 to e_2 would be beneficial for the bank regulator. It would lower the deposit insurance subsidy required from the regulator since higher capital requirements provide more stability to the financial sector as a whole. This reduction in the deposit insurance subsidy increases the overall stability of the financial system.

Next, let us consider the case $e(p) = e_2$. Here, we consider different situations:

- Let us start with the case that $E < e_2 I_D$:
  - Dirty firms: Dirty firms are only willing to invest K_D to change the capital requirement from e_1 to e_2 if the order of ROE does not change, i. e., if $r_D^{\max,K_D}(e_1) > r_C^{\max}(e_1)$. In this case, more dirty firms can be funded. If $E \geq e_1 I_D$, then all dirty firms are funded. Otherwise, the proportion of funded dirty firms increases from $E/(e_2 I_D)$ to $E/(e_1 I_D)$.
  - Clean firms: Clean firms are only willing to invest K_C to change the capital requirement from e_2 to e_1 if $E \geq e_1 I_D$. In this case, all dirty firms are funded, and clean firms are partially funded with the remaining equity $E - e_1 I_D$. If $E \geq e_1(I_D + I_C)$, then all firms are fully funded.
- Let $e_2 I_D < E < e_2(I_D + I_C)$.
  - Dirty firms: Since all dirty firms are already funded, they have no intention to change the capital requirement from e_2 to e_1.
  - Clean firms: Only a portion of clean firms is funded, specifically $(E - e_2 I_D)/(e_2 I_C)$. By changing the capital requirement from e_2 to e_1, more clean firms would be funded. This is because $(E - e_2 I_D)/(e_2 I_C) < (E - e_1 I_D)/(e_1 I_C)$ and if $E \geq e_1(I_D + I_C)$, then all clean firms are funded.
- If $E \geq e_2(I_D + I_C)$, all firms are already funded, and there is no intention to change the capital requirement from e_2 to e_1 for any loan type.
- Regulator's deposit insurance subsidy: A shift from e_2 to e_1 would increase the regulator's deposit insurance subsidy since it would lower the capital requirements. Therefore, the bank regulator has no incentive to make this change as it does not support the stability of the financial sector as a whole.

Moreover, from the carbon emissions' point of view higher capital requirements, i. e. $e(p) = e_2$ would be more beneficial since this leads to lower the carbon emissions for fixed

Figure 15: Example for a step functions $e_C(p)$ (green) and $e_D(p)$ (red) for different capital requirements on clean and dirty loans, respectively.



equity E. This is because a lower number of firms is funded under higher capital requirements:

$$\begin{aligned} e_1 \ < \ e_2 \ \Rightarrow \ & k_D(e_1, E) + k_C(e_2, E) \ > \ k_D(e_2, e) + k_C(e_2, E) \\ \Rightarrow \ & \phi(e_1, E) \ = \ k_D(e_1, E)\phi_D + k_C(e_1, E)\phi_C \\ & > \ k_D(e_2, E)\phi_D + k_C(e_2, E)\phi_C \ = \ \phi(e_2, E). \end{aligned}$$

Let us now analyze the case where are two different capital requirements for clean and dirty loans, respectively, where both are step functions, i. e. $e_C \in \{e_1, e_2\}$ satisfying $0 \leq e_1 < e_2 \leq 1$ and where $\tilde{p}$ is such that $e_C(p) = e_1$ for $0 \leq p \leq \tilde{p}$ and $e(p) = e_2$ for $\tilde{p} < p \leq 1$ and $e_D \in \{e_3, e_4\}$ satisfying $0 \leq e_3 < e_4 \leq 1$ and where p^* is such that $e_C(p) = e_4$ for $0 \leq p \leq p^*$ and $e(p) = e_3$ for $p^* < p \leq 1$. We assume that the bank regulator, being green-friendly, has a higher capital requirement for dirty loans compared to clean ones when he supposes that dirty firms are in the majority. It is mathematically expressed by $e_2 < e_4$ and $e_1 < e_3$. We do not a priori assume that it also holds $e_2 < e_3$. An example for graphs of e_C and e_D is shown in Figure 15.

Let us first consider the case where clean and dirty firms can invest $K_{C,\tilde{p}}$ and $K_{D,\tilde{p}}$, respectively, such that e_C changes from e_1 to e_2 and vice versa or they have the possibility to invest K_{C,p^*} and K_{D,p^*} to change e_D changes from e_3 to e_4 and vice versa. Let us analyze in which cases, depending on e_j and $r^{\max}$, firms of different types are willing to invest to change e_j. Let us start with the case that $p < \min\{\tilde{p}, p^*\}$, i. e. the regulator assumes a high portion of dirty firms compared to clean ones. In this situation we have $e_C(p) = e_1$ and $e_D = e_4$.

- Let us assume that $E < e_4 I_D$ (otherwise all dirty firms are already funded). Dirty firms are willing to invest $K_{D,\tilde{p}}$ to change e_D from e_4 to e_3 if their ROE remains higher than that of clean firms. This greenwashing action increases the number of funded dirty firms from $E/(e_4 I_D)$ to $\min\{1, E/(e_3 I_D)\}$. If all dirty firms are funded, the remaining equity $E - e_3 I_D$ is used to fund clean firms. If $\tilde{p} \le p^*$, the capital requirements for clean loans remain unchanged at e_1, and a portion of $(E - e_3 I_D)/(e_1 I_C)$ clean firms is funded. If $\tilde{p} > p^*$, the greenwashing of dirty firms also influences the capital requirements for clean loans, increasing them from e_1 to e_2. This decrease in funding efficiency for clean firms reduces the portion of funded clean firms to $(E - e_3 I_D)/(e_2 I_C)$.

- If $p^* < \tilde{p}$, clean firms have an incentive to engage in greenwashing by investing K_{C,p^*}. Although this initially supports dirty firms by reducing their capital requirements, it ultimately benefits clean firms. This action leads to lower capital requirements for dirty loans, allowing more dirty firms to be funded, or if all dirty firms are already funded, it frees up more equity for funding clean firms: $E - e_4 I_D < E - e_3 I_D$. If $p^* \ge \tilde{p}$, clean firms do not have an incentive to engage in greenwashing since it neither decreases their capital requirements (it would increase to e_2) nor increases those of dirty firms (it would decrease to e_3).

- From the perspective of the bank regulator, greenwashing actions are only beneficial if they assume higher risk in funding clean firms. This would increase the capital requirements for clean loans, potentially leading to a lower deposit insurance subsidy. However, it may also result in a higher deposit insurance subsidy for dirty loans, which is undesirable if there is more uncertainty associated with this firm type.

- In terms of carbon emissions, if only e_D shifts from e_4 to e_3 while e_C remains constant, the emissions increase as more dirty firms and potentially more clean firms are funded. If e_C also shifts from e_1 to e_2, the funding of clean firms becomes more expensive, leading to a decrease in the number of funded clean firms and, consequently, lower carbon emissions.

Let us now consider the case that $p > \max\{\tilde{p}, p^*\}$, i. e. the regulator assumes a high portion of clean firms compared to dirty ones. In this situation $e_C(p) = e_2$ and $e_D(p) = e_3$ and there is no incentive for both firm types to do greenwashing. On the other hand it may be beneficial to do brownwashing which we discuss next.

- Dirty firms do not have an incentive to engage in brownwashing because a new $p < p^*$ would increase their capital requirements, resulting in fewer dirty firms being funded. There is also the risk that the ranking of the ROE between clean and dirty loans changes, potentially leading to clean firms being funded first (since they have lower capital requirements).

- Clean firms are only willing to invest $K_{C,\tilde{p}}$ or K_{C,p^*} to change e_C from e_2 to e_1 or e_C from e_3 to e_4 if more clean firms can be funded as a result. This can occur if dirty firms are already fully funded and the portion of clean firms funded by the remaining equity increases (e. g., if $p^* < \tilde{p}$ and clean firms invest $K_{C,\tilde{p}}$). Alternatively, a significant shift in p can occur, decreasing the capital requirements for clean loans to e_1 while increasing those for dirty loans to e_4. If this shift results in clean loans having a higher ROE than dirty loans, clean firms will be funded first, and only the remaining equity $E - e_1 I_C$ (if positive) will be available for funding dirty firms.

- From the perspective of the bank regulator, brownwashing actions would be beneficial if the regulator values the risk associated with dirty loans higher than that of clean ones. By imposing higher capital requirements on dirty loans, the regulator reduces the deposit insurance subsidy for this type.

- In terms of carbon emissions, if only e_C shifts from e_2 to e_1 while e_D remains constant, the emissions increase as more clean firms are funded. If e_D also shifts from e_3 to e_1, the funding of dirty firms becomes more expensive, resulting in a lower number of funded dirty firms and thus lower emissions. In the best-case scenario, if the shift is significant enough that clean firms become the preferred type for banks and are funded first, this would lead to fewer carbon emissions.

Last, let us consider the two cases in between. Let us start with the case that $p^* < p < \tilde{p}$, i. e, $e_C(p) = e_1$ and $e_D = e_3$.

- Dirty firms are not willing to invest $K_{D,\tilde{p}}$ to change e_C from e_1 to e_2 because they already have a higher ROE compared to clean loans. Therefore, such a change would not provide any advantages for them since they are already funded and do not have the opportunity for increased funding.

- Clean firms do not have an incentive to engage in greenwashing by investing $K_{C,\tilde{p}}$ to change e_C from e_1 to e_2 because it would result in higher capital requirements for them without the potential for increased funding. However, clean firms may choose to engage in brownwashing by investing K_{D,p^*} to change e_D from e_3 to e_4. This only makes sense if the ranking of the ROE between the two firm types changes, i. e., $r_C^{\max}(e_1) < r_D^{\max}(e_4)$, and clean firms are funded first.

- From the perspective of a green-friendly bank regulator, it would be beneficial if clean firms engage in brownwashing and change the ranking of the ROE between the two firm types. This would result in a lower subsidy required for deposit insurance compared to the scenario without this change in probability. If the bank regulator assumes higher risks in green investments, this shift would increase the subsidy for deposit insurance of clean firms.

- In terms of carbon emissions, in this case, where the capital requirements for both loan types are low, changes in capital requirements tend to result in lower emissions. If the ranking between clean and dirty firms changes and clean firms are funded first, carbon emissions can be significantly reduced.

Now, we consider the case of $\tilde{p} < p < p^*$ $e_C(p) = e_2$ and $e_D = e_4$.

- Dirty firms are willing to engage in greenwashing by investing K_{D,p^*} to change e_D from e_4 to e_3 if the ranking of the ROE does not change (i. e., dirty firms are funded first) and if not all dirty firms are already funded (i. e., $E < e_4 I_D$). By changing e_D from e_4 to e_3, more dirty firms can be funded by banks: If $E > e_3 I_D$, all dirty firms are funded (and the remaining equity is used for funding clean firms), and if $E < e_3 I_D$, a portion of $E/(e_3 I_D)$ of dirty firms receives funding (with no clean firms being funded).

- Clean firms are only willing to engage in brownwashing by investing $K_{C,\tilde{p}}$ to change e from e_2 to e_1 if clean firms are only marginally funded by banks (i. e., $e_4 I_D < E < e_4 I_D + e_2 I_C$). In this case, there are more clean firms that receive funding since $(E - e_4 I_D)/(e_2 I_C) < (E - e_4 I_D)/(e_1 I_C)$. If the shift is large enough to change the ranking of the ROE between dirty and clean loans, clean firms are funded first. If $E > e_1 I_C$, all clean firms are funded, and if $E < e_1 I_C$, a portion of $E/(e_1 I_C)$ clean firms is funded.

- From the perspective of the bank regulator, the deposit insurance subsidy for dirty loans decreases due to greenwashing, while it decreases for clean loans due to brownwashing.

- In terms of carbon emissions, in this case, where the capital requirements for both loan types are high, changes in them tend to result in higher emissions.

Summing up, the incentives for clean and dirty firms to engage in green- or brownwashing depend on the specific baseline conditions, such as the capital requirements and the funding status of each loan type. In cases where there are step functions in the capital requirements, the analysis becomes more nuanced. When there is a common capital requirement function for both loan types, both clean and dirty firms have an incentive to engage in greenwashing in order to lower their capital requirements and make funding their investments cheaper. However, this poses risks for the regulator, such as an increase in the deposit insurance subsidy, as well as potential higher carbon emissions if the lower capital requirements lead to increased funding of dirty firms.

Indeed, when there are different capital requirement functions for clean and dirty loans, the dynamics become more complex. In the case of greenwashing by dirty firms, where they lower their capital requirements, it would be reasonable for the regulator to keep the capital requirements for clean loans constant. This ensures that the risk balance remains intact and that the incentives for dirty firms to engage in greenwashing do not lead to an excessive increase in funding for clean firms, potentially resulting in higher regulatory risks. Conversely, if clean firms engage in brownwashing by lowering their capital requirements, it would be prudent for the regulator to not only reduce the requirements for clean loans but also simultaneously increase the requirements for dirty loans. This approach aims to balance the risks associated with brownwashing, as lower requirements for clean loans may lead to increased funding and potential instability, while higher requirements for dirty loans help mitigate the risk of funding environmentally harmful activities and reduce carbon emissions. By adjusting the capital requirements in this manner, the regulator can maintain a risk-balanced approach, incentivize environmentally friendly investments, and mitigate the potential negative impacts on both financial stability and the environment.

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