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GREEN-SUPPORTING FACTORS, BROWN-PENALISING FACTORS AND THE PRUDENTIAL FRAMEWORK

A THEORETICAL APPROACH

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ABSTRACT

Proposals to include adjustments such as brown penalising and green supporting factors in the prudential regulation are meant to direct bank lending towards environmentally friendly projects. However, such adjustments can blur the lines between prudential credit risk assessment and environmental objectives. Favouring green projects, although clearly socially responsible in the long term, may channel bank lending towards excessively risky assets in the short term and provide a distorted picture of the true financial health of the bank. We adopt a principal–agent approach to formalise this trade–off and highlight its impact on bank lending. We also show that – in the presence of investor pressures or uncertainty of green asset returns – banks could decide to redirect lending towards green projects without direct regulatory intervention as formulated in the pillar I framework.

KEYWORDS

Prudential policy, climate risks, green finance, Walsh contract

JEL CODES

E50, D86, G28, Q58

1. Introduction

How to account for environmental risks in prudential capital requirements is a topic of intense discussion from both the academic (Thomä and Gibhardt, 2019; Dafermos and Nikolaidi, 2021) and policy (ESRB, 2022; EBA, 2023) perspectives. One approach that has received particular attention is the application of green–supporting factors (GSF) and brown–penalising factors (BPF), which represent a given amount of regulatory capital banks could release from (or should hold in addition to) their extant risk–based capital requirements for green (brown) assets.[1] The aim of these tools is to account for environmental risks on top of what might already be included in the purely risk–based prudential requirements and, in this way, to incentivise the financial sector to increase (reduce) its exposure to green (brown) projects. However, while adjustments like GSF and BPF may be helpful in serving this objective in theory, in practice they also entail undesirable side effects in terms of prudential risk considerations.

The 2023 EBA report (EBA, 2023) covers much of this discussion from the policy perspective. The report argues that notwithstanding the undisputed importance of climate–related risks for banking and finance, such risks are best managed within the current risk–based framework rather than by introducing dedicated treatments such as GSF/BPF. The key motivation for this conclusion is that the risk–based framework can be seen as already encompassing environmental risk factors for example in the form of internal and external rating requirements. In the absence of a clear *risk differential* whereby environmental risks are fundamentally distinct from prudential risk considerations a dedicated treatment by such factors could instead lead to double counting of risks, insufficient incentives for brown industries to embark on green transition, misallocation of bank lending from the prudential risk perspective and a loss of focus from the primary objectives of financial regulation.[2]

Another important point to consider is that environmental and prudential risk factors are often imperfectly correlated. Assume for a moment a world with only green and brown assets which show a clear risk differential to prudential credit risk. In that case, the riskiness of the assets could be decomposed into an intrinsic credit risk component, addressed by traditional regulatory capital measures, and an environmental risk component, addressed by GSF/BPF. From an environmental risk perspective, brown assets are considered riskier than their green

[1] In the body of this paper, we consider supporting/penalising factors in their "additive" form, in line with the most supported view at the moment. A "multiplicative" alternative is presented in appendix A.

[2] As a deviation to the Basel regime, the EU co–legislators have included supporting factors for SME and infrastructure lending to the EU implementation (CRR2 and CRR3). An EBA report (EBA, 2016) on the effectiveness of the SME supporting factor (SME SF) showed no evidence that the SME SF had provided additional stimulus for lending to SMEs compared the large corporates. In particular, it was found that SMEs faced similar probability to be credit constrained as large firms in the period following the introduction of the SME SF. While these results may call into question the appropriateness of the SME SF from a prudential standpoint, the EBA also noted that the SME SF also served other, non-prudential purposes and that its impact should be assessed over a longer period. For other studies using country-level data, see e.g. Dietsch et al. (2016) and Düllmann et al. (2014).

counterparties. Therefore, if brown assets also featured higher intrinsic credit risk, penalising them on environmental grounds would be consistent with standard prudential risk assessment that assigns a higher risk weight on assets with higher credit risk. In this case the environmental and prudential objectives are closely correlated. In reality however, brown firms are often characterised by higher creditworthiness than their green counterparties since the former tend to represent well–established industries with strong balance sheets and long credit histories. Even if this picture is likely to change over time as environmental risks on brown assets start to materialise while more green firms start to develop stronger credit fundamentals, at present the limited or even negative correlation between the measures of environmental risk and prudential risk would speak against penalising brown assets even in the presence of a risk differential. Doing so would contribute to a miscalibration of bank capital requirements from the prudential perspective.

Such imperfect correlation between the risk factors or, alternatively, the lack of a clear risk differential, serves as a starting point for our analysis. We propose a simple theoretical framework that formalises the trade–off between prudential and environmental risks under various circumstances. As found by Oehmke and Opp (2023) in a recent paper, the inclusion of environmental risk factors in prudential regulation can produce negative consequences in terms of financial stability. Relative to their work, we add a political economy dimension that accounts for the principal–agent relationship between government and prudential regulator. To account for this dimension is important to establish the argument that environmental measures are not necessarily the result of a proper prudential assessment but could also be a byproduct of political agendas that may clash with the intrinsic objectives of the regulator. As a consequence of the emerging tradeoff, the effectiveness of both prudential and environmental objectives could be compromised.

In our model, prudential regulator has the mandate to set capital buffers for bank exposures, based exclusively on prudential credit risk concerns as measured by asset–specific risk weights. In contrast to the regulator, the government's preferred capital buffers account for both prudential credit risk *and* environmental risk considerations. The environmental components are captured by the GSF/BPF, which the government introduces by adjusting the regulator's contractual mandate.

In our model, government is not able to directly amend the regulator's mandate. The former can instead offer the latter an incentive contract that is designed to align regulator's preferences with those of the government (Walsh, 1995). The "contracting approach" (Persson and Tabellini, 1993; Fratianni et al., 1997), as initially proposed by C. E. Walsh (1995), was introduced as a solution to the well–known inflation bias that originates from the government's time inconsistency problem. Relative to other proposals of eliminating the inflation bias, the contracting approach has applications in any setting where the incentives of the principal are imperfectly aligned with those of the agent (see e.g. Holmstrom, 1977; Laffont and Tirole, 1993; and Chortareas and Miller, 2010). In our framework the principal-agent conflict arises due to misaligned incentives between the government and the regulator.[3]

Finally, in addition to the government and the regulator, the model also includes a representative bank who decides how much lending to allocate between green and brown projects, based on the relative financial returns of the projects and the capital buffers set by the regulator.

In the second part of the paper, we make two modifications to our model to analyse whether outcomes akin to the top–down regulatory stance could be reached by other means. First, we assume that instead of adjustments to the prudential principal-agent framework the environmental considerations enter via the preferences of the representative bank which values lending to green rather than brown projects. This could be, for example, due to investor pressures, bank managerial choices, or corporate commitments (Mésonnier, 2021). Second, we look at how uncertainty about the returns of green assets affects the representative bank's credit allocation decision in the absence of a top–down regulatory intervention to support green lending.

We find that all these approaches can turn an initial equilibrium where brown lending is dominant (due to superior profitability and/or credit fundamentals) into one where banks increase their lending to green projects. Alternatively, all three alternative mechanisms can also induce the bank to channel more lending to green projects when green lending is already predominant in equilibrium. Indeed, the GSF/BPF, the bank's green preferences, and uncertainty about the returns of the green projects all lead to qualitatively similar results even though the necessary adjustments to the various parameters may differ quantitatively. This also means that one approach may be preferred to another depending on the specific circumstances as captured by the model's parameters.

Importantly, however, the top–down approach of GSF/BPF distorts the outcomes stemming from rational free–market decisions of a profit maximising bank (such as, to lend to brown firms when these are profitable and/or of superior credit quality). Such distortions could ultimately make banks vulnerable by encouraging them to lend to risky projects while holding insufficient capital against credit risk that arises from green companies. When such outcomes instead are the result of the bank's own bottom–up decisions – either based on their disclosed environmental preferences or the bank managements' optimal choices under uncertainty – the actions by the regulator will not be the source of potential distortions.

The rest of this paper proceeds as follows: in section 2 we review the related literature and describe the Walsh contract in the current context. Section 3 presents the baseline preferences of government and regulator which differ in terms of the environmental preferences. Section 4 first introduces the Walsh contract, interpreted as an instrument for the government to offset the

[3] Whereas in our model the government acts as the instigator of the regulator's incentive to account for climate risks, the framework also applies to the case where the regulator wishes to pursue environmental policies independently even if such objectives are not part of the mandate. For instance, one may envision a situation where a regulator autonomously decides that climate risks should be accounted for but needs a higher-level approval to adjust the original mandate. The contract, which can be either implicit or explicit, can be formulated to also cover this case.

misalignment in outcomes that emerges in the baseline model. We then characterise the problem of the profit–maximising, representative bank. Section 5 presents the two main extensions to the model, bank's green preferences and uncertainty about the green returns. Section 6 concludes.

2. Literature Review

There is growing academic literature on how a firm's ESG standing can affect its credit rating and attractiveness to investors, however the conclusions remain somewhat mixed. In their meta–analysis, Revelli and Viviani (2015) suggest that socially–responsible investing is neutral on financial performance. On the other hand, Chava (2014) shows that ESG performance impacts the cost of a firm's external financing. Bauer and Hann (2010) find that poor environmental performance can result in a lower credit rating due to the firm's exposure to legal, reputational and regulatory risks associated with disruptive climate events. More recent studies have outlined how ESG, and specifically environmental performance, can have an adverse impact on assessments of credit risk. Monnin (2018) shows that the realisation of climate risks can negatively affect the income and wealth of both households and corporations. Since these sectors tend to be major providers of collateral, higher climate risk can translate into higher credit risk. Mathiesen (2018) finds evidence that credit–rating agencies may underestimate climate risks.

In the wake of growing awareness of environmental risks and climate change, central banks and financial regulators have started to investigate how to include climate risks into their own internal risk assessments (ECB and ESRB, 2022; EBA, 2022). The ECB also suggested that financial institutions in the euro area should identify and quantify climate risks as part of the process to ensure capital adequacy (ECB, 2020). The Hong Kong Monetary Authority announced that it would engage with international partners to redefine its processes for capital adequacy assessment with this respect (HKMA, 2022). Following these openings various micro and macroprudential measures have been proposed to incorporate climate risks in the prudential framework.

On the microprudential side, there is an active debate about whether pillar I, II or III measures would be the most effective ones to capture climate risk in prudential regulation (Dikau and Volz, 2019; ECB and ESRB, 2022). In fact, the Network for Greening the Financial System (NGFS, 2022) reported that a backward–looking analysis only resulted in limited ex–post risk differentials between green and brown assets, but this might be due to methodological problems. Analyses carried out by the Bank of England (BoE, 2021) suggests that while pillar I measures could be effective in tackling the financial risks caused by climate change, they are less impactful on its causes. Campiglio et al. (2018) highlight potential drawbacks in differentiated treatment that could jeopardise prudential policy objectives, and argues that since capital adequacy assessments are a key source of information for investors about the bank's financial health, such disclosures should remain strictly risk–based. Different kinds of potential drawbacks are also highlighted by Annicchiarico et al. (2021) and Masciandaro and Russo (2022).

On the macroprudential side, ECB and ESRB (2022) point out that systemic–risk buffers rather than countercyclical capital buffers may be better suited to account for environmental risks. However, severe data limitations restrict the generality of the conclusions. Empirical credit risk assessments are based on historical data, which is scarce or non–existent for environmental risk analysis. The same problematics highlighted by the NGFS (2022) thus apply. Even data about past or current exposures to climate risks are extremely scarce in the current stage (Campiglio et al., 2018; BoE, 2021).

A key reference for our paper is a recent report by EBA on the environmental and social risks in the prudential framework (EBA, 2023). An important conclusion of the report is that owing to its risk–based nature, the current prudential framework is ill–suited to tackle transition risks that can only be quantified using scenario analysis. For physical environmental risks a link could theoretically be established in the case where a realised loss could be reliably attributed to ESG factors. [A dedicated prudential treatment of environmental factors, such as those already in use for lending to SMEs and infrastructure projects, is seen undesirable for several reasons: it could hinder prudential tools from reaching their primary objective of financial stability, funds could be directed to still financially unsound borrowers, and the necessary financial resources for brown firms to transition to green ones could be severely reduced.] The report concludes that due to the challenges in identifying risk differentials between environmental and prudential risks, and the risk of double–counting owing to the elements already in place in the current risk–based framework, "targeted amendments[4] to the existing prudential requirements would address these risks more accurately than such adjustment factors".

This paper contributes to the literature by identifying how, in the standard prudential framework, dedicated capital treatment for environmental purposes may affect the allocation of credit to brown and green projects. A key contribution of the analysis is to highlight the trade–offs that arise in such differential risk treatment. Our model sets up a principal–agent framework between the government and the prudential regulator. The government designs a contract for the regulator that aligns the preferences of the latter with those of the former. We follow the work by Walsh (1995) and subsequent research (Chortareas and Miller, 2003) who proposes a contract designed by the government which enters the policymaker's (central bank in his case) loss function. The contract penalises the regulator from deviations from the target variable(s) set by the government: depending on these penalties, the contract will be more or less effective in achieving the principal's objectives. Such an approach is also familiar from the agency problems identified between governments and their agencies as elaborated in detail by Laffont and Tirole (1993).

[4] For instance, in internal ratings, modelling etc.

3. Policymakers' Preferences

In this section we derive the bank capital buffers that the government and the regulator would assign on brown and green loans, only based on their individual preferences. These preferences are not homogenous and they can be summarised by the loss functions of the two players: on the one hand, the government wants the buffers to be set taking environmental risks into account; on the other hand, the regulator would set the buffers only based on the intrinsic credit risk associated with the projects. Such intrinsic credit risk is measured by the prudential risk weights applicable to green and brown loans. The environmental dimension is represented by GSF/BPF, which adjust the risk weights down (green) or up (brown). In the baseline scenario, the equilibrium buffers are solved separately for the government and the regulator. The principal–agent relationship is established at the second stage.

3.1 Government

The baseline scenario sets the equilibrium outcomes in the case where the two authorities operate in isolation. We design the government's loss function as follows:

$$L_{gov} = \frac{(b_G - b_{G,\,gov})^2}{2} + w_{gov}\frac{(b_B - b_{B,\,gov})^2}{2} \tag{1}$$

where $0 < b_G < 1$ and $0 < b_B < 1$ are the asset–specific buffers[5]. The parameters $b_{G,\,gov} = \rho_G - \alpha$ and $b_{B,\,gov} = \rho_B + \alpha$ denote the regulatory capital buffers on green and brown loans that the government would ideally like to have. They are proportional to the asset–specific risk weights, given by $\rho_G > 0$ and $\rho_B > 0$, adjusted by the supporting (penalising) factor[6], given by $0 < \alpha < 1$.

Finally, the parameter $w_{gov} > 0$ is the weight assigned by the government to the effect of the brown capital buffer relative to that of the green capital buffer. The lower this weight, the less concerned the government will be about stabilising the brown buffer b_B around its preferred level $b_{B,\,gov}$ relative to stabilising the green buffer around $b_{G,\,gov}$. In other words, the lower this parameter, the more concerned the government will be about a "correct" calibration, from its perspective, of the green buffer relative to the brown buffer. Deviations of the actual buffers b_G and b_B from the preferred values entail losses. Specifically, buffers which are set too high would excessively constrain bank lending, while buffers that are set too low could jeopardise financial stability. These considerations are captured by the squared terms.

If the government could set the buffers itself, it would do so solving the following problem:

[5] The subscripts *B* and *G* indicate variables and parameters respectively pertaining to brown and green assets, *gov* instead indicates whether they pertain to the government.

[6] We see that BPF and GSF do not need to be symmetrical. This choice has been made to ease our calculations. Yet, we also tested our model for different values of the factors. While results of course change in size, they are not affected qualitatively.

$$\min_{b_B,\, b_G} L_{gov}\,,$$

where L_{gov} is given in (1). This gives the brown and green buffers as:

$$b_B = \rho_B + \alpha = b_{B,\,gov}, \tag{2}$$

$$b_G = \rho_G - \alpha = b_{G,\,gov}. \tag{3}$$

Of course, the government would set the actual buffers equal to the respective preferred levels. The green buffer is reduced by the negative supporting factor whilst the brown buffer is increased by the positive penalising factor.

3.2 Regulator

The regulator's loss function (preferences) resembles the one of government but for the preferred levels of green and brown buffers:

$$L_{reg} = \frac{(b_G - b_{G,\,reg})^2}{2} + w_{reg}\frac{(b_B - b_{B,\,reg})^2}{2}, \tag{4}$$

with $b_{G,\,gov} = \rho_G$ and $b_{B,\,gov} = \rho_B$. For the regulator, these preferred levels do not account for the environmental concerns put forth by the GSF/BPF, only the credit risk considerations measured by the risk weights. The other variables and parameters have the same interpretations as above, but are now considered from the regulator perspective[7]. The regulator's problem is the following:

$$\min_{b_B,\, b_G} L_{reg}\,,$$

where L_{reg} is as in (4). Its solution gives:

$$b_B = \rho_B = b_{B,\,reg}, \tag{5}$$

$$b_G = \rho_G = b_{G,\,reg}. \tag{6}$$

If the regulator were to choose the buffers alone and did so only based on prudential risk concerns, then the buffers would be functions of the respective risk weights only, corresponding to the regulator's preferred levels. We assume that the government knows the regulator's preferences and thus the buffers he would set.

[7] The subscript *reg* indicates those variables and parameters that pertain to the regulator.

4. The Walsh Contract

Government and regulator are intertwined by both institutional and informal relationships, where the latter serves as the agent of the former. As principal, the government exercises a given degree of delegatory powers over the agent, the regulator, which is assigned some given mandates. These mandates are usually defined as the agent is established and stay fixed thereafter. Yet, the government may still want to influence the action of the regulator ex post. For instance, to accommodate different phases of the political cycle or face new kinds of shocks. Given the rigidity of the mandates, the government can try to influence the agent, without amending them, through an informal contract.

The contract represents an incentive scheme which *adds to*, and does not replace, the original incentives of the agent. Specifically, by indirectly penalising (e.g. through unfriendly political declarations, no renewal of office etc.) the regulator if the targets preferred by the government are not achieved. The regulator still chooses the instrument setting, but also subject to the incentives of the contract. The government's objective is to achieve an outcome where the realised buffers equal those that minimise the government's loss, i.e. (2) and (3). Knowing that the regulator would set the brown and green buffers respectively lower than higher than these – see (5) and (6) – the optimal contract penalises the regulator if b_B is set lower than in (2) and if b_G is set higher than in (3). The regulator's loss function when accounting for the contract is:

$$\begin{aligned} L^T_{reg} &= \frac{(b_G - b_{G,\,reg})^2}{2} + w_{reg}\frac{(b_B - b_{B,\,reg})^2}{2} + \delta T, \\ T &= t_G(b_G - b_{G,\,gov}) + t_B(b_{B,\,gov} - b_B). \end{aligned} \tag{7}$$

The contract the regulator is offered is given by T. The degree of independence of the regulator is measured by parameter $\delta \geq 0$. A fully independent regulator ($\delta = 0$) will not care about the contract, but whenever $\delta > 0$ the government will penalise the regulator for target misses as described above. Specifically, $t_G > 0$ and $t_B > 0$ are the penalty rates applied by the government in these cases. The structure of this loss function is coherent with those commonly used in the contracting approach of the literature (see e.g. Walsh, 1995; Persson and Tabellini, 1993; Fratianni et al., 1997): it includes a "social loss" component – the first two terms – accounting for the losses stemming from missed targets, and a "private loss" component which is determined by the contract.

4.1 The Regulator's Problem with the Walsh Contract

The regulator's problem when he accounts for the contract becomes:

$$\min_{b_B,\, b_G} L^T_{reg}\,,$$

where L^T_{reg} is given in (7). Solving the problem yields:

$$b_B = \frac{\delta t_B}{w_{reg}} + \rho_B, \tag{8}$$

$$b_G = \rho_G - \delta t_G. \tag{9}$$

To retrieve the values of t_B and t_G such that (8) and (9) will respectively be equal to (2) and (3), it is enough to take the difference between the two pairs of equations. This gives the penalty terms as:

$$t_B = w_{reg}\frac{\alpha}{\delta}, \tag{10}$$

$$t_G = \frac{\alpha}{\delta}. \tag{11}$$

The penalties are increasing in α and not defined for a fully independent regulator. This induces the regulator, if it takes the contract into account, to align the buffers to the preferences of the government.

4.2 The Regulator's Problem with the Walsh Contract

The final part of the model setup is to define the objectives of the representative bank. The bank can lend to both brown and green projects. Its overall return is:

$$R = r_G sL + r_B(1-s)L, \tag{12}$$

where L represents the total amount of funds lent, and $0 \le s \le 1$ is the share of total lending allotted to green projects; $r_G > 0$ and $r_B > 0$ denote the certain returns of the green and brown loans[8], respectively.

Bank lending must respect the following regulatory constraint: $b_G\rho_G sL + b_B\rho_B(1-s)L \le E/\gamma$, where $E > 0$ is the fixed amount of bank equity. We also introduce parameter $0 < \gamma < 1$, which represents a non–asset specific regulatory requirement the bank is subject to (it can be interpreted as a kind of capital adequacy ratio). We assume that lending one more unit to either sector is always beneficial to the bank. Therefore, this constraint will be saturated in equilibrium. It can thus be rewritten in terms of the maximum amount of loans as:

$$L = \frac{E}{\gamma[b_B\rho_B(1-s) + b_G\rho_G s]}. \tag{13}$$

Replacing (13) into (12), and dividing both sides by E, gives the bank's return on equity:

$$R/E = \frac{r_G s}{\gamma[b_B\rho_B(1-s) + b_G\rho_G s]} + \frac{r_B(1-s)}{\gamma[b_B\rho_B(1-s) + b_G\rho_G s]}. \tag{14}$$

The objective of the bank is to decide how much to allocate to green and brown projects (i.e., to set s), so to obtain the highest possible return on equity subject to the buffers set by the

[8] In the subsequent section, we analyse the case of stochastic green returns.

regulator. After replacing into R/E the values of these buffers – that is: (2) and (3) or, alternatively, (8) to (11) – the first derivative $f'(s)$ of R/E is:

$$\frac{r_G(\rho_B + \alpha)\rho_B - r_B(\rho_G - \alpha)\rho_G}{\gamma[(\rho_B + \alpha)\rho_B(1 - s) + (\rho_G - \alpha)\rho_G s]^2} = \begin{cases} f'(s) < 0 \ if \ \dfrac{r_G}{(\rho_G - \alpha)\rho_G} < \dfrac{r_B}{(\rho_B + \alpha)\rho_B} \\ f'(s) = 0 \ if \ \dfrac{r_G}{(\rho_G - \alpha)\rho_G} = \dfrac{r_B}{(\rho_B + \alpha)\rho_B} \\ f'(s) > 0 \ if \ \dfrac{r_G}{(\rho_G - \alpha)\rho_G} > \dfrac{r_B}{(\rho_B + \alpha)\rho_B} \end{cases}$$

The sign of this derivative depends on how the values of the different parameters compare to each other. The left and right–hand sides of each condition determining the sign of $f'(s)$ can be respectively interpreted as the risk–adjusted returns[9] on green (left) and brown (right) loans. Three cases can emerge, resulting in as many equilibria. Starting from the one where the first derivative is null, i.e.:

$$\frac{r_G}{(\rho_G - \alpha)\rho_G} = \frac{r_B}{(\rho_B + \alpha)\rho_B}, \tag{15}$$

the bank will be indifferent in choosing any share of green projects, as the risk–adjusted returns on the two types of loans are identical.

If the parameter values are such that:

$$\frac{r_G}{(\rho_G - \alpha)\rho_G} > \frac{r_B}{(\rho_B + \alpha)\rho_B} \tag{16}$$

the bank will set $s^* = 1$ ("green equilibrium"), as green risk–adjusted returns are larger than brown risk–adjusted returns (the first derivative of R/E with respect to s is positive in this case, therefore R/E is increasing in s). On the other hand, if:

$$\frac{r_G}{(\rho_G - \alpha)\rho_G} < \frac{r_B}{(\rho_B + \alpha)\rho_B} \tag{17}$$

the bank will set $s^* = 0$ ("brown equilibrium"), as brown risk–adjusted returns are larger than green risk–adjusted returns (the first derivative of R/E with respect to s is negative in this case, therefore R/E is decreasing in s). Note that while a higher regulatory capital requirement (γ) reduces the total amount of lending to the corporate sector, it does not affect the allocation of lending between green and brown projects.

Putting all the elements together, in the absence of the GSF/BPF α, the outcome is not based on any environmental considerations and the prevailing equilibrium will depend on how r_B and ρ_B

[9] The size of r_G and r_B already encompasses the riskiness of the underlying asset. By "adjusted" here we mean a comprehensive measure of returns, used by the bank in its optimisation problem, that also accounts for the capital requirements it will be subject to.

compare to r_G and ρ_G. When α is introduced, it is easy to see that (16) is more likely to hold and (17) is less likely to hold. The prevailing equilibrium will then be determined by how α, and thus environmental concerns, affect the relations among the non–environmental parameters. In fact, as will be shown in the next section, it is possible to find a critical value of α beyond which an initially brown equilibrium – as captured by expression (17) – is turned into a green equilibrium – as captured by expression (16). While this is how the GSF/BPF are meant to work, it is also clear that such an outcome could be highly distortionary from the intrinsic credit risk perspective.

4.3 Numerical Examples

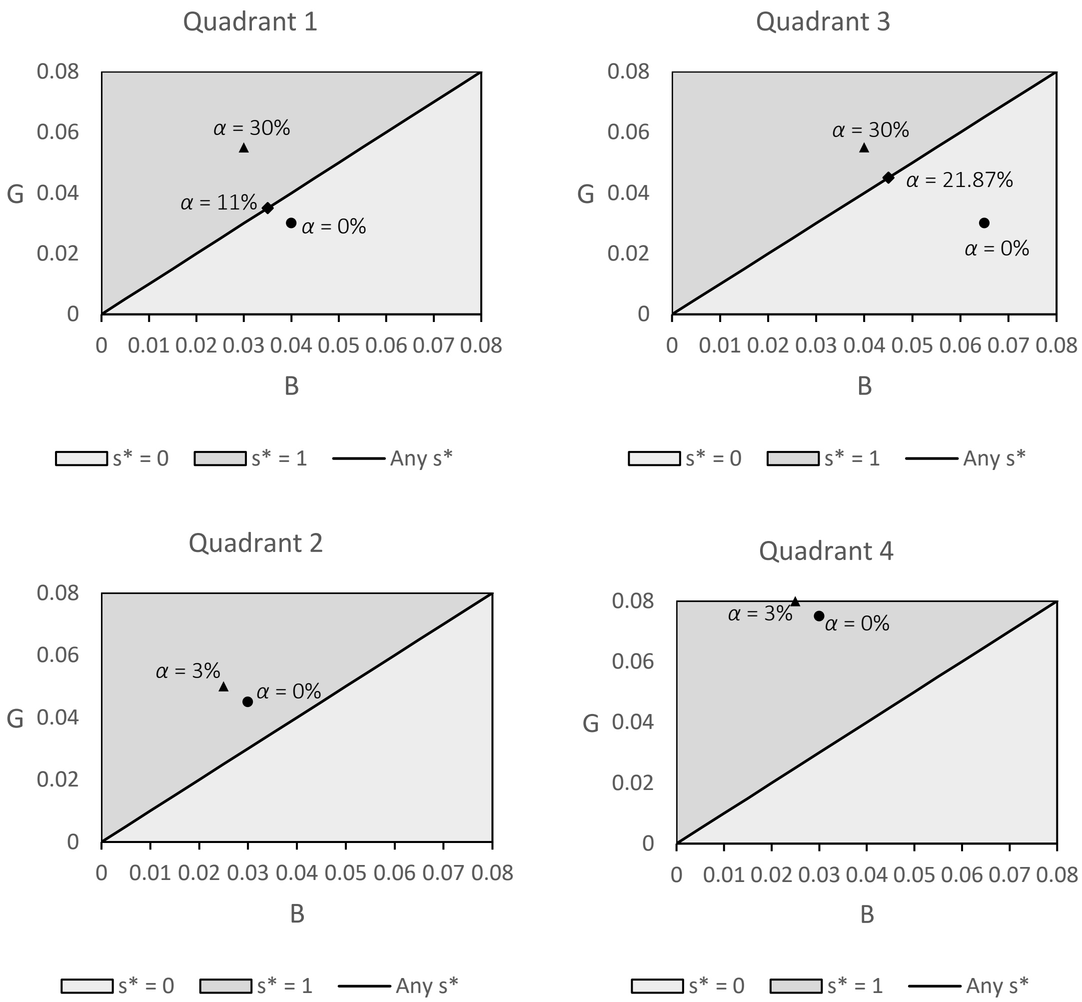
We now turn to study the interactions between the prudential and the environmental parameters by means of numerical simulations and graphical illustration. Figure 1 captures the set of possible equilibria and helps to visualise the effects of α. Let us set:

$$G = \frac{r_G}{(\rho_G - \alpha)\rho_G}$$
$$B = \frac{r_B}{(\rho_B + \alpha)\rho_B},$$

The bank will allocate all loans to green projects (set $s^* = 1$) for $G > B$, and all loans to brown projects (set $s^* = 0$) for $G < B$. For $G = B$, the bank will be indifferent to any value of s.

In each quadrant of Figure 1, the set of potential outcomes consists of the green equilibria (the north–western dark gray area), the brown equilibria (the south–eastern light grey area), and the 45º line separating the two areas. The 45º line captures all equilibria where the bank is indifferent between the specific allocation of projects. We focus on the effects of the GSF/BPF in two scenarios: (i) the returns on green versus brown lending differ but we fix the prudential risk weights assigned to the two types of exposures (quadrants 1 and 2); and (ii) the prudential risk weights on green versus brown exposures differ but we fix the returns on lending to the two types of projects (quadrants 3 and 4).

Figure 1. Euilibria in the Baseline Scenario



Quadrant 1

We choose the following parameter values: in quadrant 1, we set r_B = 1.5% > r_G = 1%, ρ_B = 70% and ρ_G = 65%. For α = 0, the resulting regulatory capital buffers will be b_B = 70% and b_G = 65%. For these parameter values, we get G = 0.03 < B = 0.04: the bank chooses $s*$ = 0 and allocates no funds to green projects even if the prudential capital requirement for brown loans is higher than for green loans. The higher return offered by lending to brown assets more than offsets the higher regulatory capital assigned on brown projects. The resulting brown equilibrium can be identified as the circle in the light gray (south–eastern) region.

To see how changing the value of α can affect the equilibrium level of $s*$, we first solve for α such that $G = B$. This gives α = 11%, which in turn results in $G = B$ = 0.037. In quadrant 1, this equilibrium corresponds to the rhombus on the 45º line. To tilt the allocation of funds in favour of green projects, α should therefore exceed 11%. Considering α = 30%, the green equilibrium has G = 0.055 > B = 0.03, which is represented by the triangle in the dark grey (north–western) region.

We can also verify how the total amount of bank lending is affected in this scenario. Recalling that the total lending to the corporate sector is defined as in (13), let us assume that E = 1 and γ = 10%. In the initial case with α = 0 the bank will set s^* = 0. Plugging these values into (13) together with the rest of the parameters we get the total amount of bank lending L = 28.57. We showed above that to shift the bank's preferences towards green loans, α should be higher than 11%. We set α = 30% which implies that s^* = 1. Repeating the same exercise with equation (13), this time we obtain L = 57.14. Therefore, a higher α has a positive impact on total lending in the economy. Given that for green loans α is subtracted from the required capital buffer, a higher share of loans allocated to green projects means that for a given capital E, the total amount of funds lent to the corporate sector increases.

Quadrant 2

In quadrant 2, we keep ρ_B = 70% and ρ_G = 65% but set r_B = 1% < r_G = 1.5%. Green projects now yield a higher return than brown projects. For α = 0, the regulatory capital buffers remain unchanged from the previous case at b_B = 70% and b_G = 65%, respectively. It is clear that, in this case, the bank chooses s^* = 1 even in the absence of the GSF/BSF, since green projects generate both a higher return *and* require less regulatory capital. For these parameter values, we obtain G = 0.046 > B = 0.028. In quadrant 2, this corresponds to the circle in the dark grey (north–western) region.

This time, introducing a positive α would reinforce the relationship between G and B. For instance, considering α = 3%, we obtain G = 0.048 > B = 0.027, which corresponds to the triangle in the dark grey (north–western) region. To make the bank indifferent between green and brown loans, α should be negative, thus penalising green lending and supporting brown lending. Even if technically feasible, such a scenario would be incoherent, and it is therefore not included in the chart. Following the same procedure as above, with α = 0 the total amount of funds lent is L = 30.76. Introducing α again results in a capital relief and increases total lending to firms to L = 32.35.

Quadrant 3

In quadrant 3, we switch our focus to the risk weights and set ρ_B = 50%, ρ_G = 65% and r_B = r_G = 1%. For α = 0, the brown buffer now becomes b_B = 50% while the green buffer remains at b_G = 65%. This results in G = 0.03 < B = 0.067 and the bank chooses s^* = 0. Given that brown projects yield the same return as green ones but are assumed to be less capital–intensive, no green projects will be financed. This equilibrium corresponds to the circle in the light grey (south–eastern) region of quadrant 3.

The value of α which ensures that G = B is 21.87%, which results in G = B = 0.046. This corresponds to the rhombus on the 45º line. Therefore, when green firms are intrinsically riskier than brown firms – for example due to their nature as start–up enterprises and/or limited credit history – for the brown equilibrium to be tilted to green the supporting/penalising factor should be higher than 21.87% which is meaningfully higher than in the case of Quadrant 1. For α = 30%, we get G = 0.057 > B = 0.041, so that s^* = 1. This is shown by the triangle in the dark grey (north–

eastern) region. As regards the total amount of bank lending, for α = 0 this becomes L = 66.67. How the amount of total lending is affected by α depends on α. For α = 30%, we get L = 57.14 and the total amount of lending is reduced due to the increased allocation to brown assets due to their assumed superior credit quality.

Quadrant 4

In quadrant 4, we choose ρ_B = 70%, ρ_G = 45% and $r_B = r_G$ = 1%. For α = 0, the buffers are set at b_B = 70% and b_G = 45%. In this case, the bank will choose s^* = 1 without any GSF/BPF needed, since both green and brown projects generate identical returns but green projects are subject to less stringent capital requirements. Indeed, these parameter values give G = 0.074 > B = 0.028, as shown by the circle in the dark grey (north–western) region. A positive α would reinforce these results. For α = 3%, we obtain G = 0.079 > B = 0.027, as shown by the triangle in the same region. The total amount lent to firms increases from L = 74.07 to L = 79.36.

Overall, we see that the GSF/BPF are able to either turn a brown equilibrium into green, or reinforce an existing green equilibrium. To obtain the same magnitude of results (i.e. the same values of B and G), we also see that the factors are relatively more effective when the risk weights of brown and green projects are similar, rather than when returns are. In other words, smaller supporting/penalising factors are needed to achieve given values of B and G in the first case relative to the latter.

5. Alternative Scenarios with No Dedicated Prudential Treatment

In this section we consider two alternative scenarios where the GSF/BPF are not applied, in other words a dedicated pillar I intervention is avoided. In the first scenario the bank itself can have an intrinsic preference for green projects in the allocation of its funds. In the second scenario, the return on green loans is made stochastic. A sufficiently high probability of a high return on green projects can motivate the bank to finance such projects even when it otherwise would not do so.

5.1 Bank's Green Preferences

First, let us consider how the outcomes of the main model would change if the bank had an intrinsic preference for green loans relative to brown ones. Such preferences may be dictated, for instance, by investor pressure which interacts with the usual risk and return considerations of a profit maximising bank. The objective of the bank is still to maximise its return on equity by choosing s, but in this case a preferential treatment is given to green projects. The bank's overall return is:

$$R = \tau r_G sL + r_B(1 - s)L, \tag{18}$$

where $\tau \geq 1$ entails a relative preference for green loans, and all the other variables and parameters have the same meaning as before.

Next, consider again the maximum loanable amount as shown in (13). Plugging this into equation (18) and dividing both sides by E, gives the bank's return on equity as:

$$R/E = \frac{\tau r_G s}{\gamma[b_B\rho_B(1 - s) + b_G\rho_G s]} + \frac{r_B(1 - s)}{\gamma[b_B\rho_B(1 - s) + b_G\rho_G s]}. \tag{19}$$

The regulator sets the green and brown buffers as in (5) and (6). After replacing these values into (19), the first derivative $f^{'}(s)$ of R/E is now:

$$\frac{\tau r_G\rho_B^2 - r_B\rho_G^2}{\gamma[\rho_B^2(1 - s) + \rho_G^2 s]^2} = \begin{cases} f^{'}(s) < 0 \; if \; \frac{\tau r_G}{\rho_G^2} < \frac{r_B}{\rho_B^2} \\ f^{'}(s) = 0 \; if \; \frac{\tau r_G}{\rho_G^2} = \frac{r_B}{\rho_B^2} \\ f^{'}(s) > 0 \; if \; \frac{\tau r_G}{\rho_G^2} > \frac{r_B}{\rho_B^2} \end{cases}$$

The condition such that $f^{'}(s)$ is null is:

$$\frac{\tau r_G}{\rho_G^2} = \frac{r_B}{\rho_B^2}. \tag{20}$$

Similarly to the main model, when this condition holds the bank is indifferent between any s. Whether this is the case or not now depends on how the returns, risk weights and government's preferred buffers interact with τ, rather than with α (which is not accounted for in this scenario). The two alternative outcomes are:

$$\frac{\tau r_G}{\rho_G^2} > \frac{r_B}{\rho_B^2}, \tag{21}$$

for which the bank will set $s^* = 1$ (green equilibrium) as R/E is increasing in s under this condition, and:

$$\frac{\tau r_G}{\rho_G^2} < \frac{r_B}{\rho_B^2}, \tag{22}$$

for which the bank would set $s^* = 0$ (brown equilibrium) as R/E is decreasing in s under this condition.

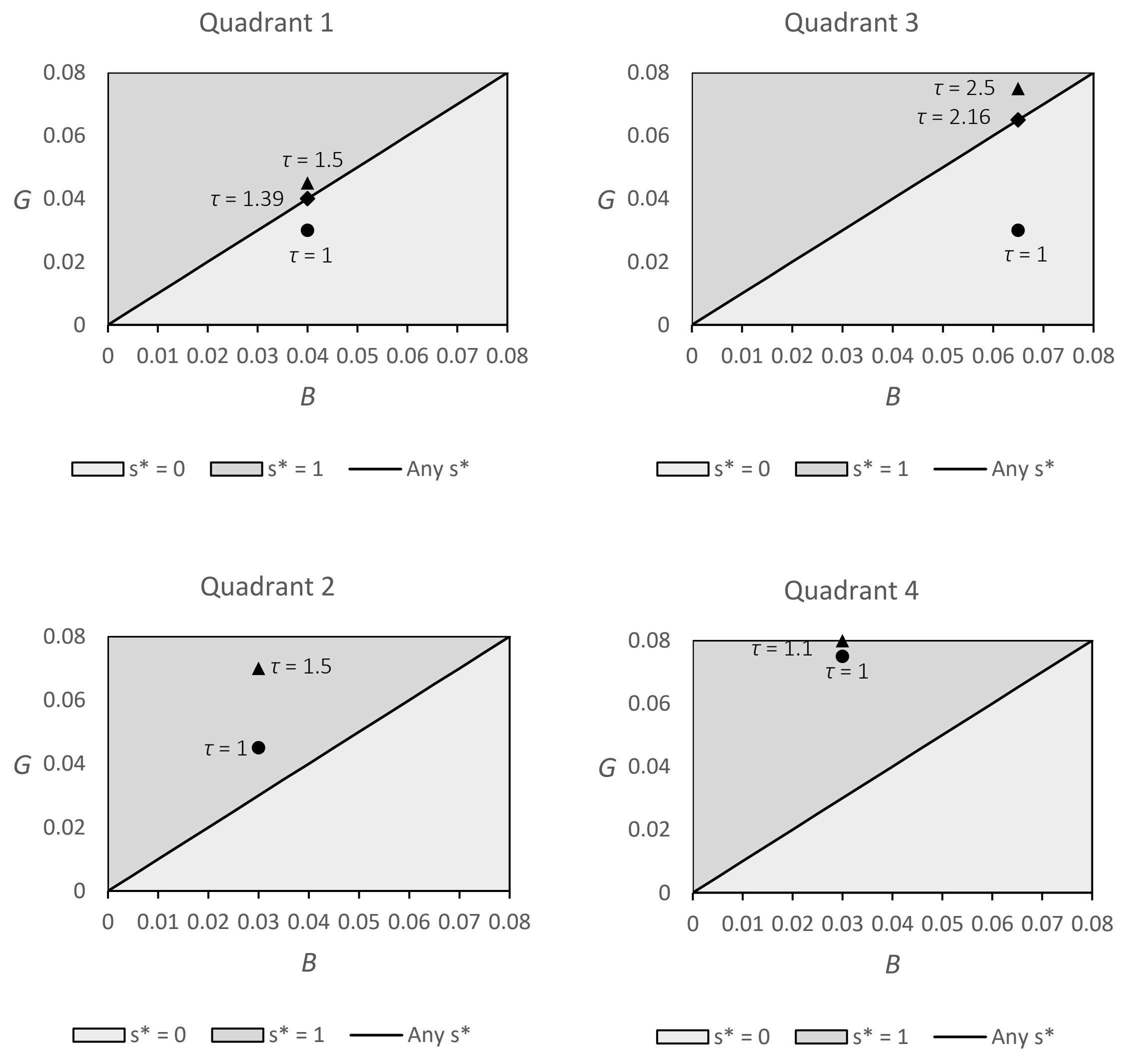
Of course, the presence of τ makes (21) easier to satisfy and (22) harder to satisfy. It therefore turns out that a preference by the representative bank to lend to green projects has a similar effect as the GSF/BPF. A brown equilibrium may be turned to a green equilibrium, or an existing green equilibrium may be reinforced. Figure 2 shows these cases, where B and G are now:

$$G = \frac{\tau r_G}{\rho_G^2}$$

$$B = \frac{r_B}{\rho_B^2}.$$

We analyse how τ interacts with different returns (quadrants 1 and 2) and risk weights (quadrants 2 and 3). Specifically, in quadrants 1 and 2 we set ρ_B = 70% and ρ_G = 65%, and then assume r_B = 1.5% > r_G = 1% in quadrant 1 and r_B = 1% < r_G = 1.5% in quadrant 2. In quadrants 3 and 4, we instead fix, $r_B = r_G$ = 1%, and set ρ_B = 50% and ρ_G = 65% in quadrant 3 and ρ_B = 70% and ρ_G = 45% in quadrant 4.

Figure 2. Euilibria in the Scenario with Bank’s Green Preferences



The outcomes are similar than the ones in Figure 1. In case no preference for green lending is present, the results are similar than in the main model when no GSF/BPF is applied. In other words, the values of B and G in all the quadrants are the same in figure 1 and 2 when $\alpha = 0$ and $\tau = 1$, respectively. On the other hand, given the different way how the GSF/BPF and the bank preferences enter the bank's optimisation problem, the values of α and τ that would tilt a brown equilibrium into green, or reinforce a green equilibrium for any given values of B and G, are quantitatively different. As we have designed them, a preference parameter smaller than the GSF/BPF would be needed to achieve the same B and G.

In contrast, the impact on the overall amount of lending to the firms is different than in the case with GSF/BPF. Unlike that case, the bank's preference for green lending does not directly affect the regulatory buffers and thus the set of capital requirements which define the bank's lending capacity. In the case where the bank's preferences reinforce an existing green equilibrium (quadrants 2 and 4), the overall amount of loans will not change (and is respectively given by 30.76 and 74.07). In the case where the equilibrium switches from brown to green (quadrants 1 and 3) overall lending will increase in quadrant 1 (from 28.57 to 30.76) as green loans are subject to lower capital requirements than brown loans. In quadrant 3, instead, total lending will decrease (from 66.67 to 30.76) since green projects are now assumed to be riskier and will therefore be subject to higher capital requirements.

5.2 Uncertainty around the Returns on Green Projects

We now turn to the second extension of the model where the profitability of the green projects is uncertain to the bank. Whether returns are stochastic or not does not affect the regulator's problem, which stays the same as in section **Error! Reference source not found.**. On the contrary, t he representative bank's optimisation problem is affected. We assume returns on brown loans are certain and given by $r_B > 1$. Returns on green loans are instead stochastic, and defined as:

$$r_G = \begin{cases} r_{G,>1} > 1 \text{ with probability } \beta \\ 0 \text{ with probability } 1 - \beta \end{cases} . \tag{23}$$

We assume that green returns are uncertain whereas brown projects yield a certain return. This is to highlight once again the relative financial safety (at least in the short term) of the brown projects vis–à–vis the green ones.

The bank's overall returns are now given by:

$$R = (r_G - 1)sL + (r_B - 1)(1 - s)L, \tag{24}$$

which, after replacing L with the maximum loanable amount as in (13) and dividing both sides by E, gives the return on equity:

$$R/E = \frac{(r_G - 1)s}{\gamma[b_B\rho_B(1 - s) + b_G\rho_G s]} + \frac{(r_B - 1)(1 - s)}{\gamma[b_B\rho_B(1 - s) + b_G\rho_G s]}. \tag{25}$$

Therefore, the *expected* return on equity of the bank is:

$$Exp[R/E] = \frac{(\beta r_{G,>1} - 1)s}{\gamma[b_B \rho_B (1-s) + b_G \rho_G s]} + \frac{(r_B - 1)(1-s)}{\gamma[b_B \rho_B (1-s) + b_G \rho_G s]}. \tag{26}$$

After replacing the values of the buffers set by the regulator – as in (5) and (6) – into $Exp[R/E]$, its first derivative $f'(s)$ is[10]:

$$\frac{(\beta r_{G,>1} - 1)\rho_B^2 - (r_B - 1)\rho_G^2}{\gamma[\rho_B^2(1-s) + \rho_G^2 s]^2} = \begin{cases} f'(s) < 0 \ if \ \dfrac{\beta r_{G,>1} - 1}{\rho_G^2} < \dfrac{r_B - 1}{\rho_B^2} \\ f'(s) = 0 \ if \ \dfrac{\beta r_{G,>1} - 1}{\rho_G^2} = \dfrac{r_B - 1}{\rho_B^2} \\ f'(s) > 0 \ if \ \dfrac{\beta r_{G,>1} - 1}{\rho_G^2} > \dfrac{r_B - 1}{\rho_B^2} \end{cases}$$

The condition such that this derivative is null is:

$$\frac{\beta r_{G,>1} - 1}{\rho_G^2} = \frac{r_B - 1}{\rho_B^2}. \tag{27}$$

Similarly to the deterministic version of the model, this condition implies that the bank will be indifferent in setting any s.

If, instead, the condition is not verified, either a green or a brown equilibrium will emerge depending on the interaction among returns, buffers and risk weights. The outcome now also depends on the probability that the green return is higher than 1. Specifically, if:

$$\frac{\beta r_{G,>1} - 1}{\rho_G^2} > \frac{r_B - 1}{\rho_B^2}, \tag{28}$$

the bank will set $s^* = 1$ (green equilibrium), since the expected return on equity under this condition is increasing in the share of green loans. On the other hand, for:

$$\frac{\beta r_{G,>1} - 1}{\rho_G^2} < \frac{r_B - 1}{\rho_B^2}, \tag{29}$$

the bank will set $s^* = 0$ (brown equilibrium), since the expected return on equity under this condition is decreasing in the share of green loans.

[10] Assuming a positive risk weight for returns which are certain might seem counterintuitive. This is a simplifying assumption, our aim just being to consider brown returns which are more certain relative to green ones. Similar results would be obtained by assuming a positive degree of uncertainty on both returns, but lower from brown ones.

While the graphical representation of these equilibria would be qualitatively similar to the one in Figure 1, with this setting we can evaluate the bank's expected return on equity depending on the probability that a given green return is realised. First, let us set ρ_B = 70% and ρ_G = 65% and then assume $r_B = r_{G,>1}$ = 150%. For these parameters, the value of β such that the bank is indifferent to any value of s – i.e. the value of β under which condition (27) is verified – is 97.6%. For values of β lower than this threshold the bank would set s^* = 0, and its expected return on equity would be 14.28. Setting β above the threshold, e.g. β = 98%, the bank would instead set s^* = 1 and, for this probability, its expected return on equity would be 14.46.

More importantly, this scenario also introduces the possibility for the bank to lose the amount of funds it had decided to lend to green projects. To see how, consider the case where the parameters values are such that condition (28) is satisfied and the bank allocates all loanable funds to green projects. This decision is based (among others) on a sufficiently large probability β of achieving $r_{G,>1}$. Yet, this decision is still based on the bank's expectations. If these were to be proven wrong, the bank's *realised* return on equity as shown in equation (25) could end up being significantly lower than its expectation as shown in equation (26), or even negative.

For instance, if all parameter values remained as in the previous example but the realised green return was 0, the bank's return on equity would be – 30.76. Such a problem does not emerge with brown returns because in the model they are considered certain. However, the results would not qualitatively change if also the brown returns were uncertain, as long as they are *less* uncertain than the green returns. Since green projects are typically associated with more uncertain outcomes, lending decisions that are based on overly optimistic expectations could generate unforeseen realised losses and substantial bank capital depletion.

6. Conclusion

This paper adopts the principal–agent approach to analyse the interactions between government, prudential regulator and the banks. The regulator only cares about the intrinsic credit risk characteristics of banks. The government shares the concern about credit risks but is also concerned about environmental aspects. The government may impose its preferences on the regulator by designing an incentive contract for the latter. The representative bank maximises returns from lending to green and brown firms, taking the regulatory framework as given. The resulting equilibria are characterised by the interplay between the environmental aspects, the intrinsic credit risk, and asset returns. In comparison to the models that have been proposed until now, our theoretical approach explicitly formalises the principal–agent relationship between government and regulator, thus providing results that capture the potential trade-offs stemming from this institutional link.

The model confirms that including environmental considerations in prudential measures could be an effective tool to redirect financing towards green projects. However, the model also highlights the costs from the resulting distorted credit risk assessments. On the one hand, accounting for climate risks in capital requirements regulation can benefit the financing of the green sector under specific conditions, turn initially brown equilibria into green ones, or reinforce those equilibria that initially were already green. A combination of GSF/BPF and an incentive contract to the regulator can therefore introduce environmental elements into the prudential capital buffers set by an independent regulator who would otherwise only care about credit risk aspects. On the other hand, a blanket framework where pillar I measures are used to boost the attractiveness of green financing could end up favouring assets which are either intrinsically risky from the pure credit risk standpoint or would ordinarily not be financed by banks due to their inferior return characteristics. The consideration about the relative riskiness of green versus brown activities should be part of any public policy assessment. Concentration of financing in a sector whose risk and return characteristics may be inferior to other sectors could lead to a systematic misallocation of credit, thus potentially jeopardising financial stability. In this sense, one source of risk (the exposure of brown assets to environmental shocks) could be translated into another source of risk (the concentration of financing in risky activities). Other policy tools, such as taxes and R&D subsidies, could be less distortionary and thus better suited to deal with such important trade-offs.

We also find that allocating relatively more funds to green projects increases the total amount of lending to the economy, provided that green projects are subject to a relatively lower capital buffers than brown projects. A lower prudential capital requirement (γ) increases the overall amount of loanable funds, but it does not affect the distribution of lending between the green and the brown projects. Independent of the specific equilibrium outcomes the inclusion of the GSF/BPF would however add to the complexity of the framework, making it harder for investors to infer the true underlying risks in the banks' lending portfolios.

The model produces qualitatively similar results if instead of the GSF/BPF the bank had an intrinsic preference to finance green projects, or if there is uncertainty about the returns on green projects. We find that also under these specifications it is possible to twist the equilibrium outcomes in favour of green projects, but without the need to adjust the prudential risk parameters. Yet, while such features are helpful in avoiding a dedicated intervention by the policymaker in the pillar I framework, they still produce trade-offs and multiple equilibria. More research is needed to design prudential tools that help policymakers to strike the right balance between prudential and environmental aspects.

7. Appendix A: The Case of Multiplicative Factors

An alternative to GSF/BPF that *add* to the current risk measures, factors that *scale* these measures could also be envisioned. In other words, rather than being added to/subtracted from the risk weights, the factors would act as multipliers to the risk weights. In this case, to have an impact, the supporting (penalising) factor should be lower (higher) than 1. While this approach would not meaningfully affect the *process* to set *s*, the *results* may differ.

In the baseline case (with no contract), the optimisation problem of the regulator is still as in section **Error! Reference source not found.**, as in neither scenario the regulator autonomously a ccounts for the GSF/BPF. It would thus set the buffers as in (5) and (6). With multiplicative factors, instead, the loss function of the government is given by:

$$L_{gov} = \frac{(b_G - b_{G,\,gov})^2}{2} + w_{gov}\frac{(b_B - b_{B,\,gov})^2}{2}, \tag{30}$$

where $0 < 1 - \alpha < 1$ is the supporting factor and $0 < 1 + \alpha < 1$ is the penalising factor. All the other terms have the same interpretation as in the additive case.

The government would like to set the buffers to solve:

$$\min_{b_B,\, b_G} L_{gov}\,,$$

which yields:

$$b_B = \rho_B(1 + \alpha) = b_{B\,gov}, \tag{31}$$
$$b_G = \rho_G(1 - \alpha) = b_{G,\,gov}. \tag{32}$$

Given that these values do not correspond to those the regulator would autonomously set, the government would still be incentivized to offer a contract.

When the contract is offered, the regulator's loss function becomes:

$$\begin{aligned} L^T_{reg} &= \frac{(b_G - b_{G,\,reg})^2}{2} + w_{reg}\frac{(b_B - b_{B,\,reg})^2}{2} + \delta T, \\ T &= t_G[b_G - b_{G,\,gov}] + t_B[b_{B\,gov} - b_B]. \end{aligned} \tag{33}$$

Therefore, the corresponding optimisation problem is:

$$\min_{b_B,\, b_G} L_{reg}^T ,$$

with L_{reg}^T as in (33). The resulting buffers are as in (8) and (9). However, the penalty terms will no longer be the same. Taking the difference between the pairs (8)–(31) and (9)–(32) gives:

$$t_B = w_{reg} \frac{\alpha \rho_B}{\delta}, \tag{34}$$

$$t_G = \frac{\alpha \rho_G}{\delta}. \tag{35}$$

The bank's return on equity is still as in (14), and its derivative after replacing the values of the buffers set by the regulator – (31) and (32) – is:

$$\frac{r_G \rho_B^2 (1+\alpha) - r_B \rho_G^2 (1-\alpha)}{\gamma[\rho_B^2 (1+\alpha)(1-s) + \rho_G^2 (1-\alpha) s\}^2} = \begin{cases} f'(s) < 0 \; if \; \dfrac{r_G}{\rho_G^2 (1-\alpha)} < \dfrac{r_B}{\rho_B^2 (1+\alpha)} \\ f'(s) = 0 \; if \; \dfrac{r_G}{\rho_G^2 (1-\alpha)} = \dfrac{r_B}{\rho_B^2 (1+\alpha)} \\ f'(s) > 0 \; if \; \dfrac{r_G}{\rho_G^2 (1-\alpha)} > \dfrac{r_B}{\rho_B^2 (1+\alpha)} \end{cases}$$

The condition such that the derivative is null is:

$$\frac{r_G}{\rho_G^2 (1-\alpha)} = \frac{r_B}{\rho_B^2 (1+\alpha)}. \tag{36}$$

If this condition holds, the bank will be indifferent in choosing any value of s. Instead, the bank would set $s^* = 1$ if:

$$\frac{r_G}{\rho_G^2 (1-\alpha)} > \frac{r_B}{\rho_B^2 (1+\alpha)}, \tag{37}$$

and $s^* = 0$ if:

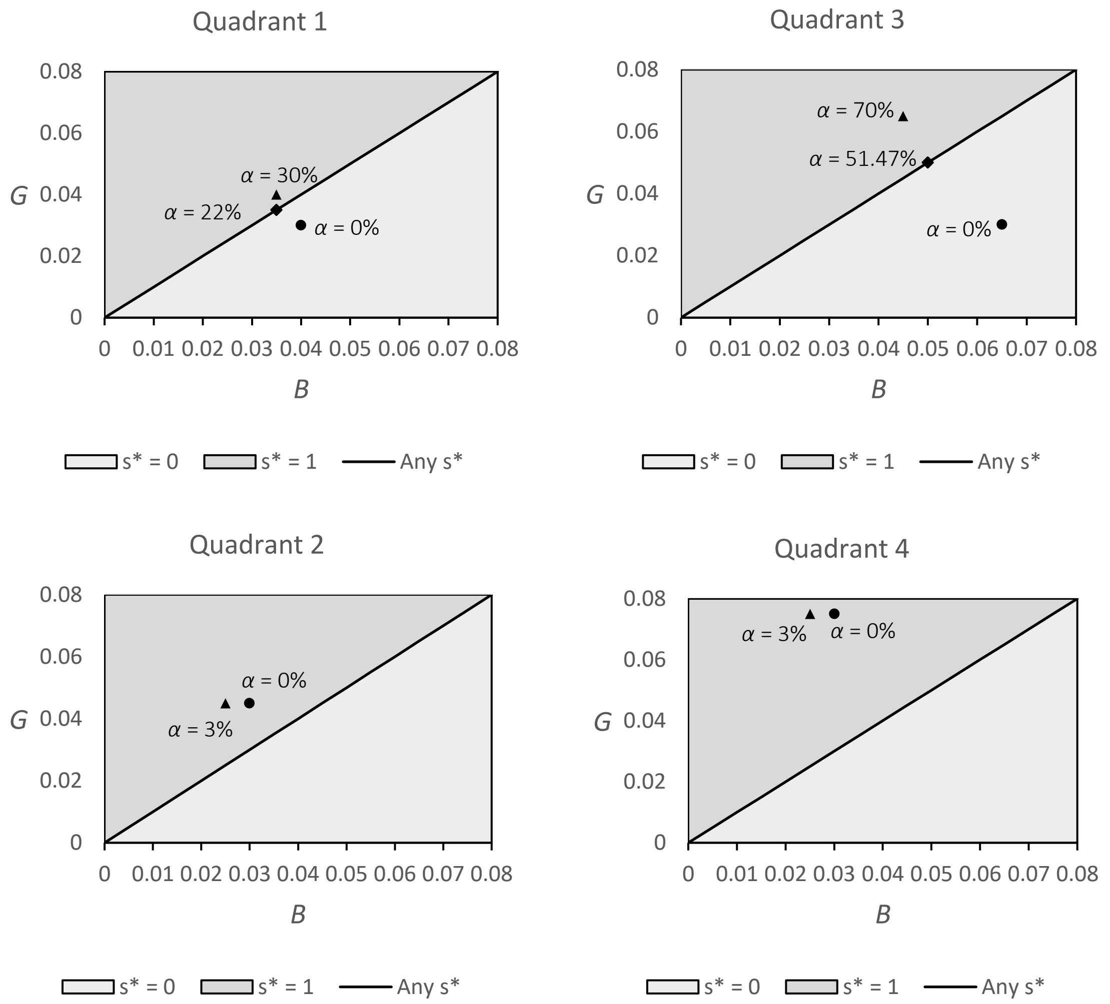
$$\frac{r_G}{\rho_G^2 (1-\alpha)} < \frac{r_B}{\rho_B^2 (1+\alpha)}. \tag{38}$$

As in the previous case, we can illustrate the equilibria graphically (see figure 3), and highlight the effects of α depending on how the other parameters relate to each other. This time, let us set:

$$G = \frac{r_G}{\rho_G^2 (1-\alpha)},$$

$$B = \frac{r_B}{\rho_B^2 (1+\alpha)}.$$

Figure 3. Euilibria in the Scenario with Multiplicative Factors



Quadrant 1

Like in the case of additive factors, in quadrant 1 we set r_B = 1.5% > r_G = 1%, ρ_B = 70% and ρ_G = 65%. When α = 0 the values of G and B will be the same as in the additive case (G = 0.03 < B = 0.04), since the optimisation problems are identical. Therefore, even under multiplicative factors the bank would choose $s*$ = 0. This equilibrium is represented by the circle in the light grey (south–eastern) region of quadrant 1. This time, solving for α such that G and B even out yields α = 22%. This is represented by the rhombus on the 45º line and corresponds to G = B = 0.037. Finally, for α larger than 22%, the bank will choose $s*$ = 1. Taking again α = 30%, yields G = 0.04 > B = 0.035, as shown by the triangle in the northwestern dark–gray region.

Therefore, ceteris paribus, applying multiplicative as opposed to additive factors pushes up the minimum size of the factors that is required for green lending to become profitable for the bank. As regards the total amount of funds loaned out, setting α = 0 ($s*$ = 0) gives L = 28.57, which is almost identical to the additive case. However, setting α = 30% ($s*$ = 1) yields L = 40 which is substantially lower than in the additive case. As in the previous scenario, in the green equilibrium the bank ends up lending out more, as its regulatory capital decreases when lending to green projects increase.

Quadrant 2

In quadrant 2, we set r_B = 1% < r_G = 1.5%, ρ_B = 70% and ρ_G = 65%. As before, G and B will be the same as for additive factors if α = 0, so that G = 0.046 > B = 0.028 and s^* = 1. This corresponds to the circle in the dark–gray northwestern region of quadrant 2. Introducing α reinforces the green equilibrium outcome. Setting α = 3%, we obtain G = 0.047 > B = 0.027, still resulting in s^* = 1. As regards the total amount of loans, this moves from L = 30.76 for α = 0 to L = 31.49 for α = 3%, since α frees capital from (and for) green projects. The difference in lending volumes between the additive vs. multiplicative factors is narrower than in Quadrant 1 but remains in favour of additive factors.

Quadrant 3

In quadrant 3, we focus on the risk weights, and set r_B = r_G = 1%, ρ_B = 50% and ρ_G = 65%. Results are again the same as for additive factors when α = 0, that is G = 0.03 < B = 0.067 and s^* = 0. This corresponds to the circle in the light–grey southeastern region. The value of α such that G = B is α = 51.47%, which gives G = B = 0.05, represented by the rhombus on the 45º line. Setting α = 70%, we obtain the a green equilibrium (s^* = 1) such that G = 0.067 < B = 0.047. This corresponds to the triangle in the dark–gray northeastern region. The total amount of loans in this specific case (and with these specific values) stays the same before and after α is introduced, and is given by L = 66.67. This is because the introduction of α counterbalances the disparity in risk weights that existed in favour of brown assets.

Quadrant 4

In quadrant 4, the parameter values are r_B = r_G = 1%, ρ_B = 70% and ρ_G = 45%. α = 0 implies the same results as for additive factors, i.e. G = 0.074 > B = 0.028 and s^* = 1 (circle in dark–gray northeastern region). Introducing a positive α reinforces this result. For α = 3%, we get G = 0.075 < B = 0.027, corresponding to the triangle in the same region. Loans increase from 74.07 with α = 0 to 75.58 with α = 3%, as the capital requirement is reduced. The improvement is however clearly smaller than in the additive case.

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