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The Preferential Treatment of Green Bonds *

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Abstract

We study the preferential treatment of green bonds in the Central Bank collateral framework as an environmental policy instrument within a DSGE model with environmental and financial frictions. Green and conventional entrepreneurs issue bonds to banks that use them as collateral. The associated collateral premium induce entrepreneurs to increase bond issuance, investment, leverage, and default risk. Collateral policy solves a trade-off between increasing collateral supply, adverse effects on entrepreneur risk-taking, and subsidizing green investment. Due to these adverse side effects, optimal collateral policy is characterized by modest preferential treatment, thereby increasing the green bond share and, to a smaller extent, the green investment share, which in turn reduces pollution. The limited response of green investment is directly related to higher risk-taking of green entrepreneurs. Furthermore, we show that preferential treatment is an imperfect substitute of Pigouvian taxation on pollution: only if the optimal tax can not be implemented, optimal collateral policy features preferential treatment of green bonds.

Keywords: Green Investment, Collateral Framework, Environmental Policy

JEL Classification: E44, E58, E63, Q58

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1 Introduction

The Eurosystem could introduce climate-related disclosure requirements for private sector assets as a new eligibility criterion or as a basis for differentiated treatment of collateral and asset purchases.
Drudi et al. (2021)

The European Central Bank (ECB) announced to take a more active role in environmental policy after concluding its strategy review. One candidate instrument is the preferential treatment of green bonds in its collateral framework, i.e. the conditions under which banks can pledge assets to obtain short-term funding from the Central Bank.[1] The People's Bank of China (PBoC) started accepting green bonds as collateral on preferential terms in 2018, which resulted in a substantial decline of green bond yields relative to their conventional peers (Macaire and Naef, 2021). However, there is limited knowledge about the impact of preferential collateral treatment on green bond issuance, green investment, pollution, and potential adverse side effects on financial stability.

This paper fills this gap by proposing a DSGE model to study the positive and normative implications of this policy. The model features an RBC core extended by environmental externality, a corporate bond market, and a banking sector which uses these bonds as collateral. Tilting collateral policy towards green bonds makes holding such bonds more attractive to banks, which are willing to pay collateral premia on them. This relaxes financing condition for green firms, which respond by increasing their bond issuance and investment: the equilibrium shares of green bonds and capital rise, resulting in less pollution. We provide an analytical characterization of these effects and quantitatively assess them in a calibration to Euro Area data.

Our main results are as follows. First, by reducing the financing costs of green firms, maximal preferential treatment - only accepting green bonds as collateral - can increase the share of green bonds (capital) by almost 8 (4) percent, which reduces pollution. Second, the transmission of preferential treatment to green investment is limited, because green firms find it optimal to use some of the proceeds to finance dividend payouts instead. This in turn increases the leverage ratio of green firms with negative side effects on their default risk.[2] Due to these negative side effects on financial stability, optimal collateral policy features a smaller degree of preferential treatment than the maximum case of only accepting green bonds as collateral. Third, adverse financial stability effects of Pigouvian taxation are very small and welfare gains

[1]Such a policy was also proposed in Brunnermeier and Landau (2020). The ECB will introduce disclosure requirements for private sector assets that may serve as basis for a preferential treatment, which addresses concerns regarding the implementability of such a preferential treatment policy.
[2]Evidence of these firm responses is presented in Grosse-Rueschkamp et al. (2017), Todorov (2020), and Pelizzon et al. (2020).

of Pigouvian taxation exceed the gains from optimal collateral policy by a factor of 25. Fourth, preferential treatment is an imperfect substitute for Pigouvian taxation. The optimal degree of preferential treatment decreases, the closer Pigouvian are to their optimum and ultimately shrink to zero. Fifth, if the Pigouvian tax addressing the environmental friction is set optimally, there is no scope for preferential treatment. However, the Central Bank relaxes the collateral framework in a symmetric way to address collateral scarcity effects of ambitious environmental policy.

As our first contribution, we characterize the transmission of preferential treatment, its adverse side effects, and its interplay with financial stability in general equilibrium. We introduce a role for environmental policy by assuming that there are two types of entrepreneurs, green and conventional. Conventional entrepreneurs generate a negative externality (pollution) during the production of intermediate goods, while green entrepreneurs have access to a clean production technology. Following Heutel (2012) and Golosov et al. (2014), pollution negatively affects final good production, implying sub-optimally low investment into the green technology.

Collateral policy is linked to the real sector by the corporate bond market, where entrepreneurs issue bonds to banks, which can use them to collateralize short-term borrowing. Entrepreneurs have an incentive to issue bonds, because they are assumed to be more impatient than bank-owners, i.e. households. Entrepreneurs default on their bonds if revenues from production fall short of current repayment obligations. Their borrowing is thus determined by a trade-off between relative impatience and bankruptcy costs, which reduce expected future consumption, similar to Gomes et al. (2016).[3]

Banks collect deposits from households, invest into corporate bonds and need to settle liquidity deficits in a costly manner. Specifically, these costs are decreasing in the amount of available collateral, following Piazzesi and Schneider (2021). This introduces a willingness of banks to pay *collateral premia* on corporate bonds.[4] Entrepreneurs respond to increasing collateral premia by increasing their leverage, bond issuance, and investment. However, elevated leverage also implies higher default rates, such that collateral policy (in the absence of preferential treatment) is determined by a financial stability trade-off between incentivizing entrepreneur default risk and increasing collateral supply.

The link between entrepreneurs and collateral policy via banks' demand for bonds allows the Central Bank to affect the relative prices of green and conventional bonds by tilting the collateral framework in favour of green bonds.[5] Ceteris paribus, banks are willing to pay higher

[3]Since our focus is on the collateral framework, we employ a financial friction that restricts *leverage* rather than overall *external financing* as in the canonical financial accelerator model of Bernanke et al. (1999).

[4]Collateral premia on corporate bonds have been documented by Mésonnier et al. (2020), Pelizzon et al. (2020), and Mota (2020). Kaldorf and Wicknig (2021) provide a structural analysis of collateral premia and corporate default risk.

[5]Preferential treatment can take the form of relaxed eligibility requirements, reduced haircuts, or a combination

prices on green bonds relative to conventional bonds, since they can be used more easily to settle liquidity deficits. Preferential treatment increases bond issuance and investment of green entrepreneurs, while conventional entrepreneurs reduce their bond and investment positions. Higher default risk reduces the expected return to green investment, such that the equilibrium green investment share is smaller than the green bond share under such a policy. As a result, the transmission of preferential treatment on the green investment share is substantially dampened.[6] Notably, the effect on the green investment share is *permanent*, i.e. Central Bank collateral policy is *not neutral* even in the long run.[7]

Our second contribution is a quantification of the effects of preferential treatment and the implications for Central Bank policy. We calibrate the model to Euro Area data and conduct a number of policy experiments. First, we study a maximum preferential policy, which makes conventional bonds ineligible and accepts all green bonds without a haircut. This policy induces a green-conventional bond spread (also referred to as *greenium*) of 160bp in equilibrium which translates into a change in the relative share of green bonds from 20% to 21.46% while the share of green capital only increases from 20% to 20.73%.

However, maximal preferential treatment is not optimal from a financial stability perspective, since it increases collateral supply above its optimal level. Therefore, we maximize the welfare objective over both collateral parameters and find that optimal collateral policy treats green bonds preferentially and tightens the treatment of conventional bonds to counter the adverse effects of high aggregate collateral supply. In this case, the greenium amounts to 64bp, the relative share of green bonds goes up to 20.62%, while the share of green capital increases to 20.28%.

While our numerical findings suggest that collateral frameworks can initiate a shift towards green technologies, this shift is small and accompanied by adverse side effects. To put the effects of preferential treatment into perspective, we also consider Pigouvian taxation of pollution, which is the natural policy instrument to address environmental frictions. Such a policy increases the share of green capital to 26.8% and substantially reduces the pollution externality *without* adverse effects on risk-taking. This result should not be misinterpreted as call for Central Bank inaction. The level of the Pigouvian tax that optimally addresses the environmental externality at the same time reduces collateral supply in particular by conventional firms to an

of both. We omit this layer of complexity, since banks increase demand for green bonds in both cases.

[6]This is in line with the literature on eligibility premia. Bekkum et al. (2018) observe a decrease in repayment performance on the mortgage backed securities market following an eligibility easing, which indicates adverse side effects. Harpedanne de Belleville (2019) finds a sizeable increase in investment by issuers of newly eligible bonds following a reduction of collateral requirements in February 2012. Upward adjustments of dividend policy are documented for issuers of QE-eligible bonds by Todorov (2020) and Santis and Zaghini (2021). Risk-taking is documented in Grosse-Rueschkamp et al. (2017).

[7]Asset purchase programmes have an anti-cyclical component by design and, therefore, seem less well suited in an environmental policy context, which by definition addresses long-run problems.

inefficiently low level, i.e. it has a financial stability impact. The Central Bank optimally addresses this by relaxing its collateral policy, thereby ensuring collateral supply stays optimal.[8] However, collateral policy does not involve preferential treatment in this case. In contrast, if public policy is restricted in its ability to set taxes optimally, e.g. due to political economy frictions, the Central Bank can increase welfare by tilting the collateral framework towards green bonds. The extent of preferential treatment monotonically declines, the closer Pigouvian taxation gets to its optimal level: preferential treatment is an imperfect substitute for taxation.[9]

Finally, we corroborate the validity of our policy experiments using two complementary strategies. First, the greenium implied by the optimal collateral framework is closely aligned to the results of Macaire and Naef (2021), who find an average yield reaction of 46 basis points. Second, we obtain data on the European market for green bonds and study their yield reaction around ECB policy announcements regarding its environmental policy in general, and preferential treatment of green bonds in particular. We find a significant yield reduction of 9 basis points in the month following the announcement, relative to a matched control group of conventional bonds. To compare these announcement effect to our model, we interpret the announcement of preferential treatment as a news shock. Since the ECB did not announce a specific date so far, we consider various time horizons and find a model implied yield reduction of 11bp, if preferential treatment applies after three years, , which is consistent with the timeline announced by ECB after the conclusion of the strategy review regarding future environmental policies.

Related Literature. There is a small but fast growing literature that adds environmental aspects to DSGE models suitable for Central Bank policy analysis at business cycle frequencies, such as Heutel (2012). The first paper to explicitly add nominal rigidities into this setting is Annicchiarico and Di Dio (2016), who study the interaction of monetary policy operating through the interest rate channel with environmental policy. Punzi (2019) extends this setup by adding financial intermediation of loans to the credit-constrained corporate sector to study green credit policy. This sets her paper apart from ours, since credit policy tools are typically not part of the Central Bank toolkit.

Some papers explicitly discuss Central Bank environmental action. Papoutsi et al. (2021) show how Central Banks can tilt their asset purchases towards green assets to address environmental frictions. However, they assume that Central Banks are able to buy firm equity and are

[8]This feature is similar to Carattini et al. (2021), who show that macroprudential policy can alleviate adverse effects of carbon taxation in the presence of transition risk. In their model, adverse effects take the form of asset stranding, while in our case adverse effects are linked to collateral scarcity, if conventional firms reduce their bond issuance.

[9]In parallel work, Papoutsi et al. (2021) derive similar results for green QE in the context of *market neutrality*. In our model, setting the green collateral share to the market neutral value dictated by the production technology is optimal only if the Pigouvian tax optimally addresses the financial friction.

silent about the pass-through via the corporate bond market which is generating a limited policy transmission in our model. For a specific assessment of green QE, see Ferrari and Nispi Landi (2020), who find a modestly positive impact on aggregate environmental performance. Böser and Senni (2020) study the effects of making refinancing conditions of banks dependent on the carbon footprint of their assets. While the idea of affecting the capital allocation indirectly via banks is similar to our framework, implementing such a policy requires considerable regulatory and supervisory effort, since bank balance sheets in practice are often opaque. Indeed, such a policy might incentivize banks to hide their carbon exposure in off-balance sheet investment vehicles or engage in other forms of regulatory arbitrage. While we acknowledge that the taxonomy of green bonds is not free of problems as well, these are already being addressed. We then view preferential collateral treatment of green bonds a much more practical policy. Fender et al. (2019) evaluate to which extent green assets can be included in managing the foreign reserve holdings of Central Banks. They find that green bonds are similar in terms of safety and returns to conventional ones but are usually less liquid. Hong et al. (2021) study sustainable investment mandates, which have a similar transmission mechanism on firm investment operating through asset demand by financial intermediaries. In their setup, sustainable investment mandates, in the form of minimum portfolio shares, increase welfare, since they widen the cost of capital wedge between green and conventional firms.

We abstract from an analysis of transition risk, which arises if demand for conventional goods suddenly decreases due to ambitious environmental policy. Carattini et al. (2021) argue that macroprudential policies can address this issue. See also Diluiso et al. (2020) on green credit policy and Catalano et al. (2020) on fiscal policy in the context of transition risk. In all these papers, pollution externalities are assumed to negatively affect total factor productivity. The policy implications drawn from these models may not hold when environmental risk affects financial and macroeconomic stability in different ways. Giglio et al. (2020) and Hong et al. (2020) provide a review of the literature studying the effect of climate risk on other dimensions of financial and macroeconomic stability. Adding these dimensions promises richer policy trade-offs, but is beyond the scope of our paper.

Outline. The paper is structured as follows. We introduce our structural model in section 2 and derive analytical results on the pass-through of collateral policy to entrepreneurs in section 3. Section 4 contains our calibration., while we discuss various policy experiments in section 5. In section 6, we benchmark the policy implications from our model against the effect of ECB announcements on green bond spreads. Section 7 concludes.

2 Model

Time is discrete and indexed by $t = 1, 2, \ldots$ and each period is divided into two sub-periods. The model is cast in real terms and features a representative *household*, two types of intermediate goods producers (*entrepreneurs*), a perfectly competitive *wholesale firm*, aggregating both types of intermediate goods into a composite intermediate good, competitive *final good producers*, financial intermediaries (*banks*), and a public sector consisting of a fiscal authority and the Central Bank. Entrepreneur types are indexed by $\tau \in \{c, g\}$. One type of intermediate goods producers (the *conventional entrepreneur*) causes an externality when producing intermediate goods. The technology of the *green entrepreneur* does not cause the externality. Both types of intermediate goods are aggregated into a composite intermediate good by a perfectly competitive wholesale firm. Competitive final goods producers use the composite intermediate good and labor to produce the final consumption good which they sell to the household. Banks raise deposits from the household to invest into corporate bonds and settle their liquidity deficits by borrowing short-term in the second sub-period. Finally, the fiscal authority can levy a proportional pollution tax on the conventional entrepreneurs' output, while the Central Bank sets the collateral framework. The structure of the model is summarized in Figure 1.

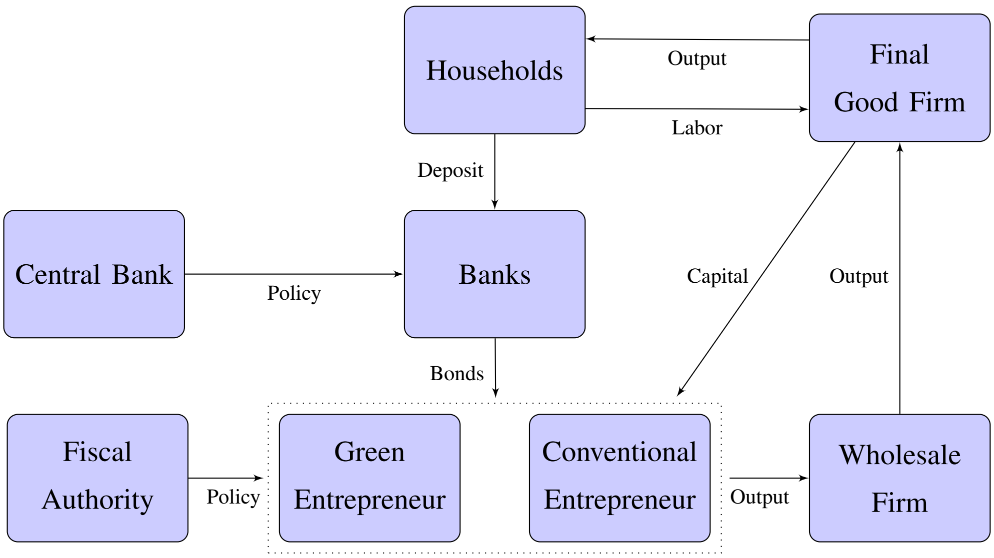


Figure 1: Model Structure

Timing. The sub-periods differ with respect to which markets are active: at the beginning of sub-period 1, all shocks realize and the Central Bank sets its policy with commitment throughout the entire period. Households, firms, and banks make their investment and savings decision. In sub-period 2, only banks are active. They face a liquidity deficit which can only be settled using short-term borrowing against collateral. The timing of events within a period is summarized in Figure 2.

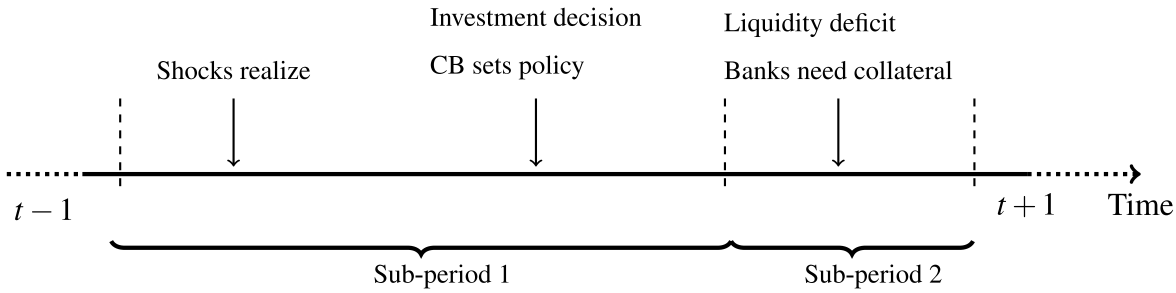


Figure 2: Timing Assumption

2.1 Households

There is a representative household that enjoys utility from consumption c_t, and suffers disutility from supplying labor, l_t at wage rate w_t. To transfer resources across time, the household has access to deposits D_t. Deposits held from time $t-1$ to time t earn the interest rate i_{t-1}^D. The household's discount factor is denoted by β, ω_L is the weight on utility-weighted labor, and γ_C and γ_L are the inverse of intertemporal elasticity of substitution and the inverse of Frisch elasticity of labor supply, respectively. The maximization problem of the representative household is given by

$$\begin{aligned} V(d_t) = \max_{c_t, l_t, d_{t+1}} \frac{c_t^{1-\gamma_C}}{1-\gamma_C} - \omega_L \cdot \frac{l_t^{1+\gamma_L}}{1+\gamma_L} + \beta \mathbb{E}_t \left[V(d_{t+1}) \right] \ , \\ \text{s.t.} \quad c_t + d_{t+1} = w_t l_t + (1 + i_{t-1}^D) d_t + \Pi_t \ , \end{aligned} \tag{1}$$

where w_t denotes the wage rate, and Π_t collects profits from banks and final goods producers. First-order conditions with respect to labor and consumption yield standard inter- and intratemporal optimality conditions

$$c_t^{-\gamma_C} = \beta \mathbb{E}_t \left[(1 + i_t^D) c_{t+1}^{-\gamma_c} \right] \ , \tag{2}$$

$$c_t^{-\gamma_c} w_t = \omega_L l_t^{\gamma_L} \ . \tag{3}$$

2.2 Banks

There is a unit mass of perfectly competitive banks that supply deposits to households and invest into corporate bonds. They participate in asset markets sequentially: in the first sub-period, banks trade with households on the deposit market and with entrepreneurs on the bond market. In the second sub-period, banks face a liquidity deficit which they settle on a collateralized short-term funding market. We solve the bank problem by backward induction.

Banks in Sub-Period 2. Banks enter second sub-period with a fixed corporate bond portfolio, determined in the first sub-period, and face a liquidity deficit ω, which has to be settled immediately. Since no trade with other private agents is possible, deficits have to be settled using short-term funding, either from other banks or from the Central Bank. We assume that settlement is costly, and that these costs can be represented by $\omega \cdot \Omega(\overline{b}^i_{t+1}, \overline{F}_{t+1})$, with the per-unit costs satisfying $\Omega_{b,t} \equiv \frac{\partial \Omega}{\partial \overline{b}^i_{t+1}} < 0$ and $\Omega_{F,t} \equiv \frac{\partial \Omega}{\partial \overline{F}} > 0$. The first assumption on Ω implies that per-unit costs negatively depend on aggregate collateral held by bank i

$$\overline{b}^i_{t+1} = \phi_c q_{c,t} b^i_{c,t+1} + \phi_g q_{g,t} b^i_{g,t+1} \ , \tag{4}$$

which is given by the market value of bonds $q_{\tau,t} b^i_{\tau,t+1}$, weighted with the collateral parameters (ϕ_c, ϕ_g).[10] Banks directly benefit from a relaxation in collateral policy, since this increases available collateral $\overline{b}_{t+1}$ ceteris paribus. While liquidity management costs decrease in collateral supply, they are also assumed to depend positively on the aggregate default risk of the banking sector's assets, defined as a weighted average of entrepreneurs' probability of default

$$\overline{F}_t \equiv \sum_\tau \frac{b_{\tau,t}}{b_{c,t} + b_{g,t}} F_{\tau,t} \ ,$$

where $F_{\tau,t}$ is the probability of default of the type-τ entrepreneur. These probabilities depend on the endogenous leverage decision by entrepreneurs, described below.

The assumption $\Omega_{b,t} < 0$ captures in reduced form the benefits of collateral to settle idiosyncratic liquidity shocks on interbank markets or with the central bank. Since neither the sources of liquidity demand, which might be heterogeneous deposit and credit line withdrawals or market making activity, nor the reason why this market is collateralized are at the heart of our paper, we introduce this feature in reduced form and refer to Corradin et al. (2017), De Fiore et al. (2019), Bianchi and Bigio (2020), and the references therein for more details and different micro-foundations.

The positive dependency of per-unit costs on default risk $\Omega_{F,t} > 0$ reflects the notion that intermediating risky assets and safe deposits is socially costly, which is a recurring theme in the banking literature. Goldstein and Pauzner (2005) propose a model in which bad fundamentals of bank assets increase the probability of a bank run. At the same time, the term $\overline{F}$ does not enter bank first-order conditions, since financial stability only depends on *aggregate* default risk in the banking sector. Consequently, bank funding costs are independent of the riskiness of bank assets and default risk. In practice, this can follow from banks exerting market power

[10] In the calibration and our main policy experiments, we restrict the analysis to time-invariant collateral parameters. While collateral frameworks in practice are occasionally adjusted, this usually happens in response to large shocks to the financial systems. These events are not of first-order importance for an analysis of preferential treatment.

over depositors (Drechsler et al., 2017), deposit insurance (Diamond and Dybvig, 1983), or information insensitivity of bank deposits. For the canonical model, we refer to Diamond (1984). Kacperzyk et al. (2020) lend empirical support by showing that bank funding costs do not depend on idiosyncratic risk of bank assets. Instead funding costs react if the overall solvency of the banking system is in doubt.

Since we abstract from runs and banks perfectly diversify idiosyncratic risk in our model, we view the assumptions on $\Omega(\overline{b}^i_{t+1}, \overline{F}_{t+1})$ as a convenient representation of the key collateral policy trade-off without greatly complicating the exposition: as we show below, lenient collateral policy increases both the aggregate default rate $\overline{F}_{t+1}$ and aggregate collateral $\overline{b}_{t+1}$. The ambiguous impact on $\Omega(\overline{b}^i_{t+1}, \overline{F}_{t+1})$ ensures a meaningful trade-off for the optimal collateral policy problem.

Bank Problem in Sub-Period 1. We follow Cúrdia and Woodford (2011) and assume that banks maximize profits, defined as equity value net of liquidity management costs in (5), subject to the solvency condition (6). Taken the behaviour of other banks, firms and the Central Bank as given, the maximization problem of bank i reads

$$\max_{d^i_{t+1}, b^i_{c,t+1}, b^i_{g,t+1}} \quad \Pi^i_t = d^i_{t+1} - q_{c,t+1} b^i_{c,t+1} - q_{g,t+1} b^i_{g,t+1} - \omega \cdot \Omega(\overline{b}^i_{t+1}, \overline{F}_{t+1}) \tag{5}$$

$$\text{s.t.} \quad (1+i^D_t) d^i_{t+1} = \mathbb{E}_t \left[\mathcal{R}_{c,t+1}\right] b^i_{c,t+1} + \mathbb{E}_t \left[\mathcal{R}_{g,t+1}\right] b^i_{g,t+1} \, . \tag{6}$$

The bond payoff $\mathcal{R}_{\tau,t+1}$ depends on entrepreneur τ's bond issuance and capital choice via the default decision in period $t+1$, which we describe below. Note that the bond payoff $\mathcal{R}_{\tau,t}$ is not affected by the bond holding of an individual bank. Taking first order conditions we get to the bond price equation

$$q_{\tau,t+1} = \frac{\mathbb{E}_t \left[\mathcal{R}_{\tau,t+1}\right]}{(1+\phi_\tau \Omega_{b,t})(1+i^D_t)} \, . \tag{7}$$

which shows that liquidity management costs drive a wedge into the bond price due to the willingness to pay for eligible bonds, since holding eligible corporate bonds reduces the cost of settling liquidity deficits. Moreover, the collateral service premium declines in the amount of collateral $\overline{b}_{t+1}$.

2.3 Firms and Entrepreneurs

Final Good Producers. Competitive final good firms produce a differentiated good y_t using an intermediate good, z, and labor, l. The production technology is given by

$$y_t = (1-\mathcal{P}_t)A_t z_t^{\theta} l_t^{1-\theta} , \tag{8}$$

where A_t is an economy-wide TFP shock that evolves according to

$$\log(A_{t+1}) = (1-\rho_A)\log(A_{ss}) + \rho_A \log(A_t) + \sigma_A \varepsilon_{t+1}^A , \quad \varepsilon_{t+1}^A \sim N(0,1) . \tag{9}$$

Final good production is negatively affected by pollution $\mathcal{P}_t$ that is generated by the conventional entrepreneur (details below). Solving the maximization problem of the firm we get the standard optimal first order conditions that equates the marginal product of the inputs to their market price.

Wholesale Firm. There is a competitive wholesale firm that bundles green and conventional intermediate goods into the homogeneous intermediate good used by final goods firms.[11] Its technology is Cobb-Douglas

$$z_t = z_{g,t}^{\nu} z_{c,t}^{1-\nu} , \tag{10}$$

where ν determines the relative share of the green intermediate sector versus the conventional one.[12] The prices of the intermediate good types τ are denoted by $p_{\tau,t}$. Solving its profit maximization problem yields

$$\nu p_{z,t} z_t = p_{g,t} z_{g,t} , \tag{11}$$

$$(1-\nu) p_{z,t} z_t = p_{c,t} z_{c,t} . \tag{12}$$

Entrepreneurs: Technology. Entrepreneurs produce the intermediate goods z_τ, $\tau = \{c,g\}$. As in most environmental DSGE-models, the production of conventional entrepreneurs increases pollution $\frac{\partial \mathcal{P}_t}{\partial z_{c,t}}$. Entrepreneurs are risk-neutral over (potentially negative) consumption and are relatively more impatient than the household so that they discount the future with a discount factor $\widetilde{\beta} < \beta$. This assumptions ensures that entrepreneurs are borrowers in equilibrium.

[11] We assume that the pollution externality does not affect the wholesale firm, which does not internalize that its demand for conventional intermediate goods has adverse effects on aggregate final goods production. This eliminates the possibility of coordination among firms, which could arise if final goods producers directly used intermediate goods as an input.

[12] In appendix C.2 we conduct a robustness analysis using a CES-function and find only minor differences to the Cobb-Douglas case.

The production technology of the entrepreneur of type τ is linear in capital and subject to an uninsurable idiosyncratic shock $m_{\tau,t}$

$$z_{\tau,t} = m_{\tau,t} k_{\tau,t} \ . \tag{13}$$

Following Bernanke et al. (1999), the idiosyncratic shock satisfies $\mathbb{E}[m] = 1$ and a monotone hazard rate property of the form $\partial(h(m)m)/\partial m > 0$, where $h(m) = \frac{f(m)}{1-F(m)}$ denotes the hazard rate. Here, $f(m)$ and $F(m)$ denote the pdf and cdf, respectively. Capital $k_{\tau,t}$ depreciates at rate δ, which is common to both production technologies. Then, the law of motion for capital of entrepreneurs of type τ is given by

$$k_{\tau,t+1} = i_{\tau,t} + (1-\delta)k_{\tau,t} \ , \tag{14}$$

where $i_{\tau,t}$ denotes entrepreneurial investment.

Entrepreneurs: Financial Side. We assume that both entrepreneur types are subject to the same financial friction.[13] Specifically they finance their activities by issuing equity, modelled as negative consumption, or by issuing discount bonds. They mature stochastically each period with probability $0 < s \leq 1$ and promise to pay one unit of the final good in $t+1$ in case of no default.[14] With probability $1-s$ the bond does not mature and is rolled over at next period's market price $q_{\tau,t+1}$. In case of default, banks holding distressed bonds effectively replace the entrepreneur as shareholder: they seize the output *only in the default period*, restructure the firm, and resume to being creditors after the entrepreneur's debt has been restructured. Importantly, bonds that do not mature are assumed to be unaffected by the restructuring process, i.e. they are simply rolled over. While in practice, restructuring takes several periods, we follow Gomes et al. (2016) and take a shortcut by assuming that capital owners are able to renegotiate the financial structure without delay in the default period. This shortcut facilitates aggregation into a representative green and conventional entrepreneur, respectively. The maximization

[13] There are few empirical results regarding the pricing of *environmental effort* on the corporate bond market, but these point in a similar direction as our findings: Zerbib (2019) finds evidence for only a small negative yield premium on green bonds compared to a comparable conventional bond using a relatively broad sample of US bonds. The premium that can be explained by investor preferences amounts to merely 2bp. Larcker and Watts (2020) find a green bond premium of zero for US municipal bonds.

[14] Making bonds long-term enables us to generate realistic leverage ratios in the calibration, but is not required for the transmission of collateral policy. We consider the case of nominal bonds in appendix C.1.

problem of a type τ entrepreneur is given by

$$V^E(b_{\tau,t},k_{\tau,t}) = \max_{b_{\tau,t+1},k_{\tau,t+1}} \widetilde{c}_{\tau,t} + \widetilde{\beta}\mathbb{E}_t\left[V^E(b_{\tau,t+1},k_{\tau,t+1})\right] \quad \text{s.t.}$$

$$\widetilde{c}_{\tau,t} = (1-G(\overline{m}_{\tau,t}))p_{\tau,t}(1-\chi_\tau)k_{\tau,t} - i_{\tau,t} - (1-F(\overline{m}_{\tau,t}))sb_{\tau,t} + q(\overline{m}_{\tau,t+1})(b_{\tau,t+1}-(1-s)b_{\tau,t}) \ ,$$

$$\overline{m}_{\tau,t} \equiv \frac{sb_{\tau,t}}{p_{\tau,t}(1-\chi_\tau)k_{\tau,t}} \ ,$$

where the default productivity threshold is given by $\overline{m}_{\tau,t}$. This threshold is implicitly defined through the productivity level at which the entrepreneur is indifferent between defaulting and loosing revenues $m_{\tau,t}p_{\tau,t}k_{\tau,t}$, or repaying debt obligations $sb_{\tau,t}$. The term $G(\overline{m}_{\tau,t}) \equiv \int_0^{\overline{m}_{\tau,t}} mdF(m)$ is the average productivity of defaulting entrepreneurs and $F_{\tau,t} = F(\overline{m}_{\tau,t}) \equiv \int_0^{\overline{m}_{\tau,t}} dF(m)$ is the default probability. In case of default, the bank pays restructuring costs φ and is entitled to the entire production output, valued at price $p_{\tau,t+1}$, while the payoff in case of repayment is $b_{\tau,t+1}$.[15] In summary, the *per-unit* bond payoff is

$$\mathcal{R}_{\tau,t} = s\left(G(\overline{m}_{\tau,t})\frac{p_{\tau,t}(1-\chi_\tau)k_{\tau,t}}{sb_{\tau,t}} + 1 - F(\overline{m}_{\tau,t})\right) - F(\overline{m}_{\tau,t})\varphi + (1-s)q_{\tau,t} \ . \tag{15}$$

The first term reflects the payoff from maturing bonds: the first part represents production revenues banks seize in case of default while the second part represents repayment of the principal. The term $F(\overline{m}_{\tau,t})\varphi$ reflects default costs incurred by banks. The share of bonds that are rolled over is valued at the bond market price $q_{\tau,t}$. The parameter χ_τ is a time-invariant tax on production of entrepreneur τ. When it is negative, it can be interpreted as a subsidy and it will be set to zero in the baseline calibration.[16]

Entrepreneurs: Bond Issuance and Investment. As in Gomes et al. (2016), the bond price depends only the default threshold $\overline{m}_{\tau,t}$. Plugging investment (14) and banks' bond pricing condition (7) into the Bellman equation, the first-order conditions for bond issuance and capital holdings read

$$q'(\overline{m}_{\tau,t+1})\frac{\overline{m}_{\tau,t+1}}{b_{\tau,t+1}}\left(b_{\tau,t+1}-(1-s)b_{\tau,t}\right) + q(\overline{m}_{\tau,t+1}) = \widetilde{\beta}\mathbb{E}_t\left[s(1-F(\overline{m}_{\tau,t+1})) + (1-s)q_{\tau,t+1}\right] \tag{16}$$

[15] Attributing restructuring costs to entrepreneurs yields similar mechanics, but is notationally more intensive.

[16] It is not relevant in our setup, whether the entrepreneurs or wholesale firms pay the tax. Attributing it to the entrepreneurs however gives the cleanest comparison to collateral policy, which both operate through the entrepreneurial investment decision in our model.

and

$$1 = -q'(\overline{m}_{\tau,t+1})\frac{\overline{m}_{\tau,t+1}}{k_{\tau,t+1}}\left(b_{\tau,t+1} - (1-s)b_{\tau,t}\right) + \widetilde{\beta}(1-\delta) + \widetilde{\beta}(1-\chi_\tau)\mathbb{E}_t[p_{\tau,t+1}]\big(1 - G(\overline{m}_{\tau,t+1})\big)\ . \tag{17}$$

The analytical steps are relegated to appendix A.1. Equation (16) is a standard optimality condition equating the marginal benefit of issuing more bonds (LHS) with the marginal costs (RHS). Each additional unit of bonds increases funds available in period t by $q(\overline{m}_{\tau,t+1})$ units. At the same time, the bond price schedule is a decreasing function of the default threshold, which we also refer to as the *risk choice*. Since we characterize bond prices by the risk choice $\overline{m}_{\tau,t+1}$, the term $\frac{\overline{m}_{\tau,t+1}}{b_{\tau,t+1}}$ captures the increase of default risk arising from the issuance of an additional unit of bonds. This dilutes the value of existing bond investment $b_{\tau,t+1} - (1-s)\frac{b_{\tau,t}}{\pi_t}$. Due to the concave shape of the debt issuance Laffer curve, the amount of funds available increases in leverage at a diminishing rate up to a certain point. After this point, the dilution effect dominates, and available funds decrease in leverage. Issuing bonds beyond this point is not optimal.

The risk choice has also implications for entrepreneur consumption in $t+1$. Each unit of bonds involves repayment of s, conditional on not defaulting. At the same time, leverage increases the break-even productivity level $\overline{m}_{\tau,t+1}$ in $t+1$, which makes default more likely and, thereby, decreases expected repayment $1 - F(\overline{m}_{\tau,t+1})$. In addition, bond issuance also increases the rollover burden in $t+1$, further reducing expected consumption.

The optimality condition for capital (17) is a simple trade-off between the cost of capital (LHS) and the increase in consumption at t and $t+1$ (RHS). The latter consists of the capital value after depreciation, the marginal value of production net of taxes, and the increase of the bond price stemming from a decrease of the default probability. Increases in the bond price affect consumption in period t, while investment in new capital affects period t+1 consumption through additional resources and production, which are then discounted by $\widetilde{\beta}$.

2.4 Public Policy and Resource Constraint

The Central Bank specifies the collateral framework (ϕ_c, ϕ_g) and the fiscal authority runs a balanced budget

$$\chi_c p_{c,t} z_{c,t} = \chi_g p_{g,t} z_{g,t}\ . \tag{18}$$

The subsidy on green output is completely financed by a tax on conventional goods and there are no further fiscal instruments needed to balance the government budget. Since there are also no central bank profits in this model, this ensures a fair comparison between collateral frameworks and taxes. The resource constraint closes the model

$$y_t = c_t + \sum_\tau (c_{\tau,t} + i_{\tau,t}) + \Omega(\overline{b}_{t+1}, \overline{F}_t) + \sum_\tau \varphi F(\overline{m}_{\tau,t}) b_{\tau,t} \ , \tag{19}$$

where the last two term represents the resource losses due to the liquidity management costs and entrepreneurs' default.

3 Collateral Policy Transmission in a Simplified Setting

In this section, we use simplified version of our model to provide intuition for the numerical policy analysis provided in section 4. We start by expressing equilibrium capital shares in terms of the different policy instruments and then turn to the transmission of collateral policy via entrepreneurs.

3.1 Preferential Treatment, Taxes and the Green Capital Share

How do Central Bank and tax instruments affect the equilibrium share of capital invested in the green and conventional technologies? When abstracting from labor, the production technologies of wholesale and final goods producers can be consolidated into a production function which exhibits decreasing returns to scale due to the pollution externality

$$z_t = \exp\{-\gamma_P k_c\} k_c^{1-\nu} k_g^{\nu} \ . \tag{20}$$

Using the consolidated production function together with the demand for both intermediate goods (11) and (12), the government budget constraint (18) can be rearranged for the budget clearing subsidy on green intermediate goods, given a tax rate χ_c:

$$\chi_g = -\frac{1-\nu}{\nu} \chi_c \ . \tag{21}$$

Combining the investment decision (24) for both entrepreneur types with the intermediate good demand (11), (12), and the production technology (20) we can relate market clearing investment k_τ to the risk-choice $\overline{m}_\tau$:

$$1 = \left(-q_c' \overline{m}_c^2 + \widetilde{\beta}(1 - G(\overline{m}_c))\right)(1-\nu)(1-\chi_c)\exp\{-\gamma_P k_c\} k_g^{\nu} k_c^{-\nu} \ ,$$
$$1 = \left(-q_g' \overline{m}_g^2 + \widetilde{\beta}(1 - G(\overline{m}_g))\right)\nu\left(1 + \frac{1-\nu}{\nu}\chi_c\right)\exp\{-\gamma_P k_c\} k_{g,t+1}^{\nu-1} k_c^{1-\nu} \ .$$

These conditions can be combined into the equilibrium ratio of green and conventional capital.

$$\frac{k_{g,t}}{k_{c,t}} = \frac{\Big(\nu + (1-\nu)\chi_c\Big)}{(1-\nu)(1-\chi_c)} \cdot \frac{-q'_{g,t}\overline{m}^2_{g,t+1} + \widetilde{\beta}(1-G(\overline{m}_{g,t+1}))}{-q'_{c,t}\overline{m}^2_{c,t+1} + \widetilde{\beta}(1-G(\overline{m}_{c,t+1}))} \tag{22}$$

The ratio depends on the tax on intermediate goods and the risk-taking decision of entrepreneurs. Absent fiscal policy and preferential treatment, (22) simplifies to $\frac{\nu}{1-\nu}$, i.e. the green capital share is pinned down by its Cobb-Douglas parameter in the production technology.[17] Equation (22) reveals that fiscal policy can *directly* affect the capital ratio by levying a positive tax on conventional intermediate goods. Setting $\chi_c > 0$ in the first term of (22) increases the green capital ratio above $\frac{\nu}{1-\nu}$ while leaving the financial frictions of entrepreneurs unchanged. However, changing k_c and k_g while keeping $\overline{m}_c$ and $\overline{m}_g$ constant naturally implies changes to b_c and b_g, i.e. there are second round effects on the financial stability trade-off determining collateral policy.

In contrast, the Central Bank can *indirectly* affect the capital allocation by affecting the risk-choice of entrepreneurs through preferential treatment, which induces an increase of k_g, while at the same time k_c decreases. This translates into an increase in the green capital ratio. The very nature of this intervention introduces adverse side effects on risk-taking, which are pivotal for the optimal design of collateral frameworks, as we show next.

3.2 Collateral Policy and Entrepreneurs

In this section, we illustrate the transmission of Central Bank collateral policy can in a simplified setting. We consider a model with one-period bonds and full capital depreciation, i.e. we set $s = \delta = 1$. For simplicity, we also set household labor supply to one and shut off aggregate risk. To obtain closed-form solutions, we also assume that productivity shocks follow a uniform distribution over $[0,2]$ and that liquidity management costs are linear in collateral supply $\overline{b}$, which implies a constant collateral premium $\Omega_b \equiv -\omega,\ \omega > 0$.

While several of those assumptions are clearly stylized, they are imposed for analytical tractability. While endogenous labor supply, long-term bonds and a depreciation rate of less than 100% give a more realistic model fit, normalizing them to one keeps the qualitative properties of the entrepreneur problem intact. As the quantitative analysis will show, the conduct of collateral policy in general and preferential treatment in particular is primarily affected by

[17] Solving the planner problem in an economy without the financial friction yields a (time-invariant) green capital ratio of $\frac{k_g}{k_c} = \frac{\nu}{1-\nu-\gamma_P k_c}$. This ratio exceeds the competitive equilibrium ratio of $\frac{\nu}{1-\nu}$ whenever $\gamma_P > 0$. Furthermore, in this simple economy, this ratio pins down a tax rate χ_c implementing the planner solution. Whenever the economy is subject to financial frictions, the implementation of environmental policy naturally interferes with financial stability. We shed light on these interactions in our quantitative analysis.

time-series means, justifying the abstraction from aggregate risk. Furthermore, aggregate collateral and, thereby, the collateral premium Ω_b do not strongly respond in our main policy experiments.

We start by focusing on entrepreneur's financial frictions and consider a setting with one entrepreneur and no environmental friction. The entrepreneur budget constraint is given by

$$\widetilde{c}_t + k_{t+1} = q(\overline{m}_{t+1})b_{t+1} + (1 - G(\overline{m}_t))k_t - (1 - F(\overline{m}_t))b_t \ .$$

and the default threshold simplifies to $\overline{m}_t = \frac{b_t}{p_t k_t}$. The first-order conditions for bonds and capital are given by

$$q'(\overline{m}_{t+1})\overline{m}_{t+1} + q(\overline{m}_{t+1}) = \widetilde{\beta}(1 - F(\overline{m}_{t+1})) \ , \tag{23}$$

$$1 + q'(\overline{m}_{t+1})\frac{\overline{m}_{\tau,t+1}}{k_{t+1}}b_{t+1} = \widetilde{\beta}\big(1 - G(\overline{m}_{t+1})\big) \tag{24}$$

The risk choice equates additional consumption in the current period with the expected repayment in the next period, discounted by $\widetilde{\beta}$. The capital choice equates the capital price (normalized to one) and the bond price appreciation due to a higher default threshold with the expected (after-tax) payoff from the investment. Since we abstract from aggregate risk in the simplified setting, all time indices are omitted throughout this section. The bank solvency constraint collapses to

$$d = q(\overline{m})(1 - \phi\omega)b \ .$$

Further, from the household's Euler equation we notice that the equilibrium deposit rate equals the the deposit rate equals the household discount rate $i^D = 1/\beta - 1$ such that the bond pricing condition is given by

$$q(\overline{m}) = \beta\frac{G(\overline{m})/\overline{m} + 1 - F(\overline{m}) - \varphi F(\overline{m})}{1 - \phi\omega} \ .$$

The model is closed by the household budget constraint and the demand for intermediate goods. The full system of equations is presented in appendix B. As a first step, we show that by plugging the bond pricing condition into the first-order condition for bonds, (23) can be rewritten as

$$\left(\frac{\beta}{1 - \phi\omega} - \widetilde{\beta}\right)(1 - F(\overline{m})) = \beta\varphi\frac{F'(\overline{m})\overline{m} + F(\overline{m})}{1 - \phi\omega} \ . \tag{25}$$

which determines the risk choice in equilibrium. In the absence of collateral premia, i.e. in the case of $\omega = 0$ or $\phi = 0$, entrepreneurs' risk choice (the default threshold $\overline{m}$) is determined by equating relative impatience $\frac{\beta-\widetilde{\beta}}{\beta}$ and marginal default costs. Collateral premia drive a wedge into this trade-off. Using the uniform distributional assumption, $\overline{m}$ can be determined in closed form:

$$\overline{m} = 2\frac{\beta-\widetilde{\beta}(1-\phi\omega)}{\beta(1+2\phi)-\widetilde{\beta}(1-\phi\omega)} \tag{26}$$

Its derivative with respect to ϕ is positive such that the risk choice $\overline{m}$ is increasing in the collateral premium $\phi\omega$ as in Kaldorf and Wicknig (2021).[18] In appendix B, we show the following proposition, summarizing the comparative static results of the simplified model.

Proposition 1. Increasing the collateral parameter ϕ has a positive effect on bond issuance b and capital k in equilibrium.

The equilibrium effect on entrepreneurs are related to the collateral policy trade-off in the following way: a higher leverage $\overline{m}$ is associated with higher default rates and restructuring costs. At the same time an increase in collateral policy parameters will induce an increase in the market value of bonds outstanding, which implies a decrease in liquidity management costs. If collateral policy tightens the treatment of conventional bonds while relaxing the treatment of green bonds, this negatively affects the investment into conventional technologies and, thereby, pollution. Whether this policy is beneficial or not ultimately depends on whether the negative effects due higher default rates are balanced by the positive effects from reduced pollution and reduced liquidity management costs. In the next sections, we remove the simplifying assumptions and perform a quantitative analysis to shed light on this trade-off.

4 Calibration

In this section, we provide a calibration of the model to European data. Each period corresponds to one quarter. We assume log-utility over consumption, fix the inverse of Frisch elasticity at 1, and set the household discount factor β to 0.99. We set the Cobb-Douglas coefficient, θ, to $1/3$ to get a labor share of $2/3$, and we set the weight ω_L in the household utility function to be

[18] This result does not depend on the uniform distributional assumption, but is obtained for any distribution satisfying the monotone hazard property that we also impose in the full model. Dividing by $1-F(\overline{m})$, this can be expressed in terms of the hazard rate $h(\overline{m})$

$$\frac{\beta-(1+\phi\Omega_b)\widetilde{\beta}}{\beta} = I(\overline{m})\varphi \quad \text{with} \quad I(\overline{m}) \equiv \frac{F(\overline{m})}{1-F(\overline{m})} + h(\overline{m})\overline{m}\,.$$

Due to the monotonicity assumption on $h(\overline{m})$ and the monotonicity property of the default/repayment odds ratio, on the right-hand side, $I(\overline{m})$ increases in $\overline{m}$.

consistent with a steady state labor supply of $1/3$. The TFP shock parameters are conventional values in the RBC literature.

Parameters regarding pollution and the green technology share are important drivers of environmental DSGE models. To ensure that our results are not solely driven by parameter choices, we provide robustness checks for environmental parameters in appendix C.2. For the relative share of the green sector, we use the most recent data on the share of renewable energies in the Euro Area. Although this is only a subset of intermediate goods, it has the advantage that, since renewable energy is a prominent feature of the public discussion, the data quality is excellent. From this data-set we find that the relative share of the green sector is 20%, which directly informs the Cobb-Douglas parameter of the wholesale goods producers ν.[19]

In spirit of Heutel (2012) and Golosov et al. (2014), we assume that pollution costs can be expressed as

$$\mathcal{P}_t = 1 - \exp\{-\gamma_P z_{c,t}\} \ , \tag{27}$$

which, through final good production (8), generates a percentage loss in the production of the final good producer. The function captures the mapping from pollution to real economic damage and the parameter γ_P governs the pass-through from pollution to production losses. We inform the parameter γ_P, governing the externality of conventional production, using estimates of direct costs from pollution and indirect costs from adverse environmental conditions. From the model, we can directly relate this quantity $1-\exp\{-\gamma_P z_c\}$ to observable (long-run) quantities $1 - y/z^{\theta} l^{1-\theta}$. We use the estimate of Muller (2020), who quantifies Damage/GDP at 10% in 2016 for the US. The value of 10% has also been reported in the fourth National Climate Assessment in the US (Reidmiller et al., 2018). Since economic activity in this dimension can be assumed to be similar in the US and the Euro area, we adopt the same value. Rearranging yields the steady relationship

$$\gamma_P = -\frac{\log(y/(z^{\theta} l^{1-\theta}))}{z_c} \ . \tag{28}$$

The next group of parameters is associated with entrepreneurs. Average maturity of corporate bonds corresponds to the mean time to maturity in the *Markit iBoxx* corporate bond index between 2010 and 2019, which is five years, i.e. $s = 0.05$. Following Gomes et al. (2016), the resource losses of default φ are set such that they are consistent with a recovery rate of 70%, defined as realized payoff in default over the promised payoff. The idiosyncratic productivity shock is log-normally distributed with variance ς_M and mean $-\frac{\varsigma_M}{2}$ to ensure that it satisfies

[19] Renewable energy statistics for the EU are accessible here. See also the guide by the Statistical Office of the European Union, 2020.

$E[m] = 1$. This leaves with two free parameters on the entrepreneur side, the discount factor $\widetilde{\beta}$ and idiosyncratic productivity variance ς_M. They are set to match time-series means of spreads and leverage. The model-implied bond spread is defined as

$$x_{\tau,t} \equiv (1 + s/q_{\tau,t} - s)^4 - (1 + i_t^D)^4 \ . \tag{29}$$

For the data moment, we use the *IHS Markit* data from 2010 until 2019 and compute the median bond spread over the entire corporate bond market, i.e. the Investment Grade and High Yield segments, which yields a value of around 100bp.

The final group of parameters is related to banks and collateral policy. We impose symmetric collateral treatment $\phi_{sym} \equiv \phi_c = \phi_g$ and target the empirically observed ratio of eligible corporate bonds to GDP. Averaging over the period 2011-2019, we obtain a value of around 15%.[20] Liquidity management costs are specified as

$$\Omega\left(\overline{b}_t^i, \overline{F}_t\right) = \omega \cdot \max\left\{\eta_0 \overline{F}_t^2 - \frac{l_0}{2}\left(\frac{\overline{b}_t^i}{\omega}\right)^{0.5}, 0\right\} \ . \tag{30}$$

The liquidity deficit ω is set to be consistent with the ratio of interbank market turnover to GDP, as reported in the European Money Market Study 2018. The parameter η_0 determines the weight of corporate default risk in the cost function, while l_0 is the slope of the cost reduction per unit of collateral. Plugging in $\overline{b}_{t+1}^i = 0$ can be interpreted as the cost level of an entirely un-collateralized banking system. We ensure in the calibration that this term is always positive. The marginal cost reduction is obtained from differentiating (30) with respect to total available collateral

$$\Omega_{b,t} = -l_0 \left(\overline{b}_{t+1}\right)^{0.5} (\omega)^{0.5} \ . \tag{31}$$

[20]The amount of eligible corporate bonds is taken from the ECB website.

Table 1: Baseline Calibration

Parameter	Value	Source/Target
Households		
CRRA-coefficient γ_C	1	log-utility
Household discount factor β	0.99	Annual riskless rate 4%
Labor disutility convexity γ_L	1	Frisch elasticity= 1
Labor disutility weight ω_L	6.68	Labor supply= $1/3$
Firms		
Cobb-Douglas coefficient θ	1/3	Labor share = 2/3
Green goods share ν	0.20	Renewable Energy Share in Europe 2018
Externality Parameter γ_P	1.5e-2	Pollution damage/GDP = 0.1
Banks		
Bond maturity parameter s	0.05	*IHS Markit*
Restructuring cost φ	0.2	Recovery rate = 70%
Liquidity deficit ω	2.25	Interbank Turnover/GDP = 3
Liquidity management parameter l_1	74.5	Ex-post optimality of $\phi_{sym} = 0.23$
Liquidity management parameter l_0	0.004	Collateral service premium = -7bp
Entrepreneurs		
Depreciation rate δ	0.067/4	Capital/GDP = 2.1
Entrepreneurs' discount factor $\widetilde{\beta}$	0.9845	Debt/GDP = 0.8
Stdev of idiosyncratic risk ς_M	0.19	Bond spread = 100bp
Central Bank		
Collateral parameter ϕ_{sym}	0.23	Collateral/GDP= 0.15
Shocks		
Persistence TFP shock ρ_A	0.95	Standard
Variance TFP shock σ_A	0.005	Standard

The slope of the liquidity management cost function is calibrated to $l_0 = 0.004$, matching the collateral service premium in the data. Using the ECB list of collateral eligible for main refinancing operations, Pelizzon et al. (2020) identify a collateral premium of -7bp. Mésonnier et al. (2020) also identify an eligibility premium of -7b using a surprise relaxation of eligibility criteria prior to the ECB's additional credit claims program. The model implied collateral service premium is given by the yield differential of the traded bond and a synthetic bond that is not eligible in period t, corresponding to the identification strategy of Pelizzon et al. (2020).

Formally, we have

$$x_{\tau,t} \equiv (1+s/q_{\tau,t}-s)^4 - (1+s/(q_{\tau,t}(1+\phi_\tau \Omega_{b,t}))-s)^4 \; . \tag{32}$$

The parameter η_0 is not identified in our model, since it does not affect the competitive equilibrium: specifically, it has no impact on bond prices. Instead, it gives us an additional degree of freedom regarding the collateral framework, since we set it ex-post and such that $\phi_{sym} = 0.23$, which is the value generating the amount of eligible bonds observed in the data, is optimal according to an utilitarian welfare criterion. Put differently, we assume that the current ECB collateral policy is optimal under the restriction of symmetric collateral policy and parametrize our liquidity management cost function accordingly. Finally, we define the *greenium* as the spread of conventional over green bonds with corresponding maturity

$$\hat{x}_t = x_{g,t} - x_{c,t} \; . \tag{33}$$

Note that the greenium is zero in our baseline calibration due to the assumption of symmetric treatment. The parameterization is summarized in Table 1.

5 Policy Analysis

In this section, we conduct several policy experiments regarding the collateral framework and its interactions with direct taxation of pollution. Throughout the analysis, we employ a utilitarian welfare criterion based on household's unconditional expected utility (1). Following Schmitt-Grohé and Uribe (2007), we evaluate unconditional welfare by approximating it, together with the policy functions, up to second order.[21] We then compute welfare gains of adopting an alternative policy with respect to the baseline policy in terms of consumption equivalents (CE), defined as the additional fraction of consumption that the household living in the baseline economy would need to receive each period to be as better off as the household living in the alternative economy. Given the log-utility assumption on consumption, the consumption equivalent welfare gain has the following expression:

$$c^{CE,policy} \equiv 100 \left(\exp\{(1-\beta)(V^{policy} - V^{base})\} - 1 \right) \; , \tag{34}$$

where V^{base} and V^{policy} are obtained from evaluating (1) under the baseline and alternative policies, respectively. The CE is defined as the fraction of the baseline consumption path that the household would need to receive to be indifferent between baseline and alternative policy.

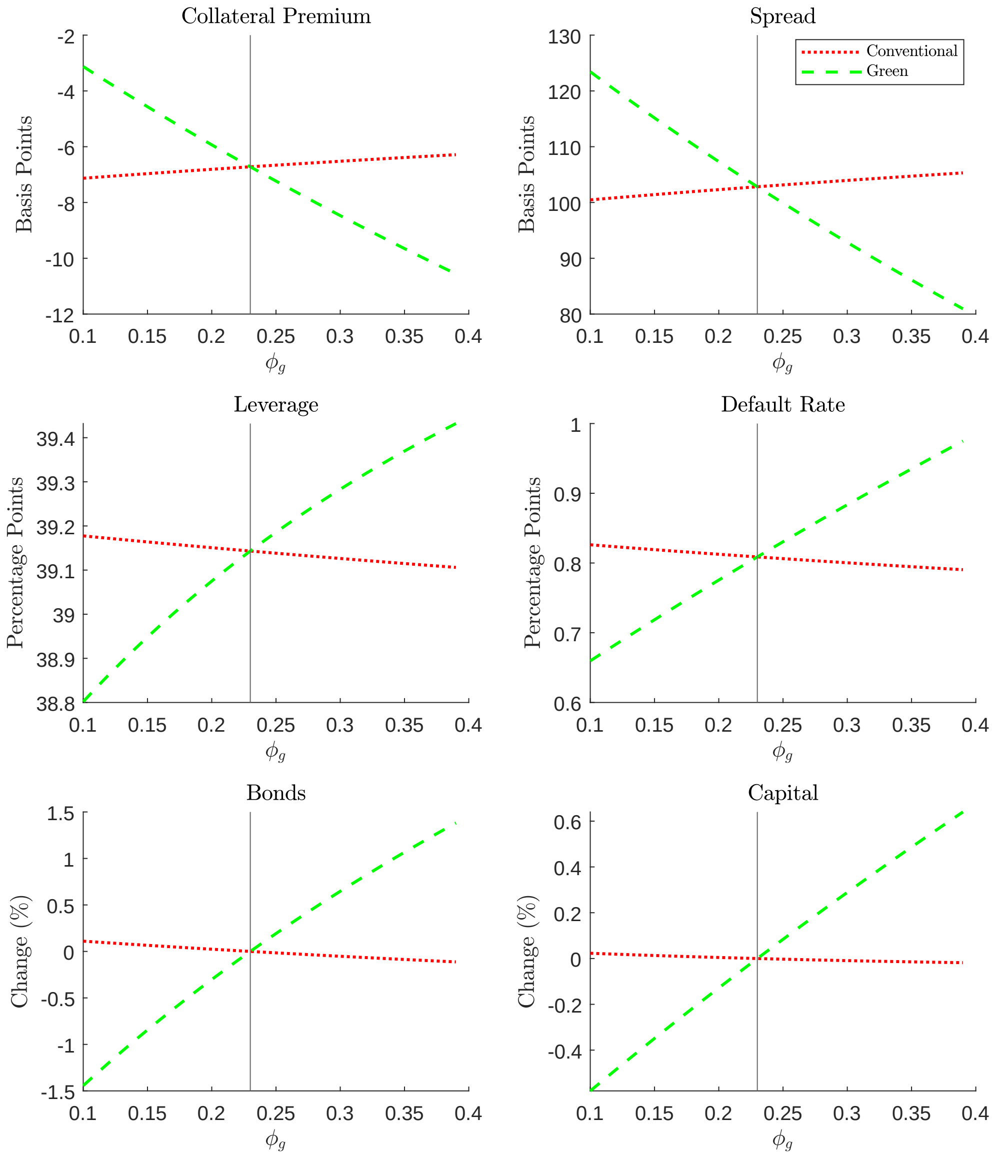
[21] We also explore welfare gains conditionally on being at the deterministic steady state of the baseline calibration and thus explicitly considering the transition period to the new steady state. Results are virtually unchanged.

5.1 Optimal Collateral Policy with Preferential Treatment

Since entrepreneurs are at the heart of the transmission mechanism, we begin by showing the model-implied means of financial market variables for different values of the green collateral parameter in Figure 3. The green and red line denote, respectively, the green and conventional entrepreneur. The top left panel shows that green collateral premia strongly increase in ϕ_g, while at the same time the green bond spread declines, relative to the baseline calibration. Leverage increases by around one percentage point, which translates into a 50% increase in default rates. Notably the increase in collateral premia dominates the effect on corporate bond spreads, which are substantially lower despite elevated default risk.

This lowers the financing costs of green entrepreneurs, such that we observe an increase in their capital holdings, which, for every ϕ_g, falls well short of the increase in bond issuance. For all variables, the reaction of conventional entrepreneurs mirrors the response of their green counterparts, although to a smaller extent. This is an equilibrium effect operating through the perfect substitutability of green and conventional bonds as collateral: the conventional collateral premium $\phi_c\Omega_b$ depends on Central Bank policy and collateral supply. If green entrepreneurs increase bond issuance due to preferential treatment, this makes collateral less scarce, such that Ω_b declines.

Figure 3: Preferential Treatment: Entrepreneurs



Notes: Collateral Premium and Spreads expressed in basis points, leverage and default in percentage points. Bonds outstanding and capital are relative to the baseline of $\phi_{sym} = 0.23$, indicated by the vertical line.

As our first finding, we report the potency of collateral policy and compute welfare under *maximal preferential treatment* in the second column of Table 2. Therefore, we set $\phi_g = 1$ and $\phi_c = 0$ to provide an upper bound for the Central Bank's ability to induce investment into green technologies. The collateral premium on conventional bonds is zero in this case. This policy increases welfare and induces a sizeable increase in the green bond share to 21.46%, while green investment increases to 20.73%, translating into an 8 (4) percent increase relative to the baseline calibration, respectively.

Consistent with our theoretical model, around 50% of the initial effect on the corporate bond market does not carry over to the investment decision, due to the financial friction on entrepreneurs. The converse holds for conventional entrepreneurs, who reduce their bond issuance and capital holdings. This in turn reduces pollution. At the same time, setting $\phi_c = 0$ implies a strong contraction of collateral, leading to a substantial increase in liquidity management costs and a slight decrease in the aggregate default rate. Since optimal collateral policy trades off pollution with default and liquidity management costs, this combination of aggregate default rates and collateral supply is sub-optimal and even decreases welfare relative to the baseline collateral framework. Therefore, we maximize welfare over a fine grid of collateral policy parameters (ϕ_c, ϕ_g), to which we refer as the *optimal collateral policy*, and report selected results in third column of Table 2.

Table 2: Time Series Means for Different Policies

Moment	**Baseline**	**Max Pref**	**Opt Coll**	**Only Tax**	**Glob Opt**
Tax Parameter χ_c	0	0	0	0.085	0.085
Coll. Parameter ϕ_g	0.23	1	0.53	0.23	0.24
Coll. Parameter ϕ_c	0.23	0	0.14	0.23	0.24
Welfare Change (CE)	0%	-0.0292%	+0.0211%	+0.5007%	+0.5008%
Conv. Leverage	39.1%	38.4%	39.1%	39.1%	39.2%
Green Leverage	39.1%	40.2%	39.4%	39.1%	39.2%
Conv. Bond Spread	103bp	142bp	117bp	103bp	102bp
Green Bond Spread	103bp	-19bp	53bp	103bp	102bp
Conv. Coll. Premium	-7bp	0bp	-4bp	-7bp	-7bp
Green Coll. Premium	-7bp	-28bp	-15bp	-7bp	-7bp
GDP	0.8385				
Change from Baseline	-	+0.12%	+0.04%	+0.48%	+0.49%
Default Cost/GDP	1.68%				
Change from Baseline	-	-0.25%	-0.63%	-0.08%	+0.70%
LM Cost/GDP	0.1%				
Change from Baseline	-	+49.4%	+16.3%	-6.5%	-18.5%
Pollution Cost/GDP	10.5%				
Change from Baseline	-	-1.0%	-0.4%	-8.2%	-8.1%
Green Bond Share	20%	21.46%	20.62%	26.80%	26.80%
Green Capital Share	20%	20.73%	20.28%	26.80%	26.80%

Subtracting the green bond spread of 53bp from the conventional bond spread of 117bp gives a greenium of 64bp, which is close to the yield reaction of Chinese green bonds (46bp), following the introduction of preferential treatment by the PBoC in 2018 (Macaire and Naef, 2021).

It is however considerably smaller than under maximal preferential treatment. The increase in green bond issuance (0.62 percentage points) and investment (0.21 percentage points) is consequently smaller as well. The improvement in financial stability by this policy comes at the cost of reducing pollution less effectively.

Quantitatively, we evaluate the welfare gain of optimal collateral policy to be 0.021% relative to the baseline calibration. For maximum preferential treatment the welfare gain is only 0.016%. These numbers are significant when compared to the welfare losses typically obtained by similar exercises in the literature (see Lucas, 1987 and Otrok, 2001). In appendix C.2, we also show that nominal rigidities are not crucial drivers of our results by repeating our policy experiments in an extension with a standard New Keynesian block.

5.2 Interaction with Direct Taxation

While our analysis reveals that the Central Bank can affect the relative size of green and conventional entrepreneurs and, thereby, reduce the pollution externality, this effect is relatively small and induces non-negligible side-effects. In this section, we explore how Pigouvian taxation can reduce pollution externalities. This serves a dual purpose: first, we can put the effectiveness of preferential collateral treatment into perspective, relative to Pigouvian taxation. Second, this also allows us to examine a mix of direct taxation and collateral policies. By assuming a balanced budget in (18), we compare different policy instruments regarding their effectiveness to address environmental policy trade-offs without imposing assumptions on the financing of subsidies or the distribution of tax revenues.

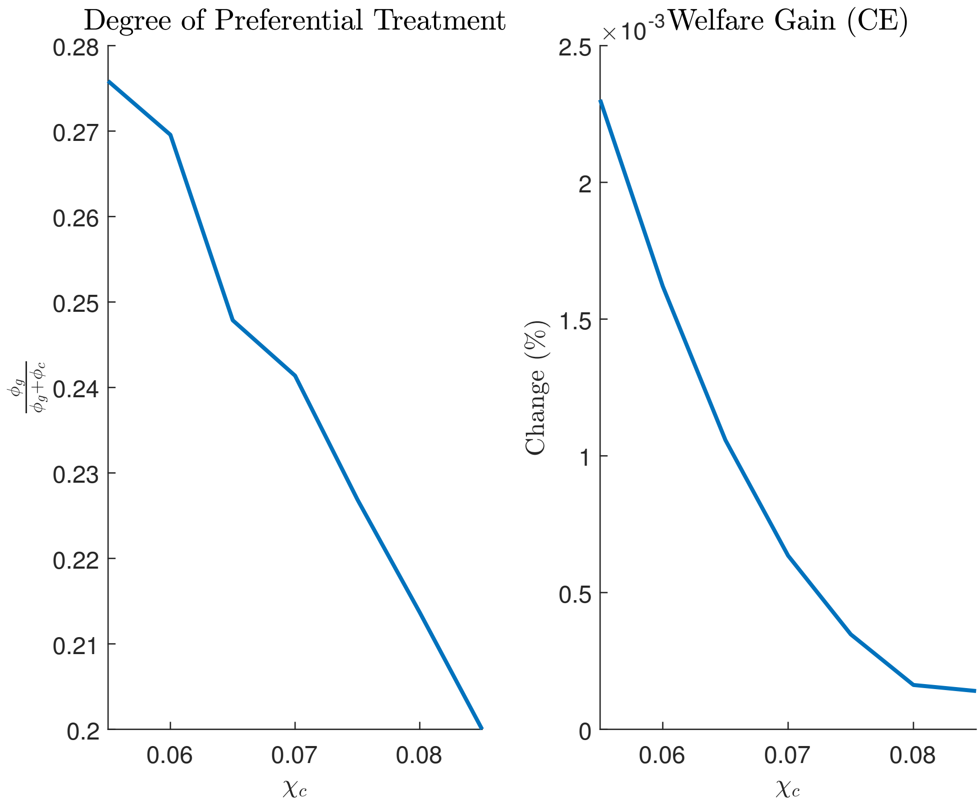
The fourth column of Table 2 corresponds to optimal Pigouvian taxation, holding the collateral framework at its baseline value. The optimal tax on conventional production is at 8.5%, which implies a subsidy of 34% on green intermediate goods, since taxes are rebated to conventional firms proportional to their relative sizes, as determined by the parameter ν in the wholesale good production function. This strongly tilts production towards green inputs and reduces the pollution externality. At the same time this implies a deviation from the optimal input share by the wholesale goods producer, such that the economy contracts. However, the positive effects of reducing the externality exceed resource losses associated with deviating from the baseline input share, such that the optimal tax is positive. The welfare improvement of Pigouvian taxation exceeds the improvement from optimal collateral policy by a factor of 25, measured in consumption equivalents. At the same time, there are no adverse effects on firm risk-taking, since the first-order condition for leverage, (16), is not affected by a tax on production. This suggests that fiscal instruments dominate preferential treatment in addressing environmental frictions.

However, this should not be misinterpreted as a call for Central Bank inaction, since Pigouvian taxation has also a financial stability impact as reported in the fourth column of the third panel in Table 2. The optimal tax affects the collateral policy problem since it simultaneously decreases aggregate default cost/GDP and liquidity management cost/GDP. Relative to the global optimum, reported in the last column of Table 2 collateral is too scarce at the old collateral framework, and the Central Bank optimally is more lenient. Notably, this relaxation is symmetric, i.e. $\phi_c = \phi_g$ and there is no preferential treatment. This incentivizes all firms to increase their bond issuance and, as a side effect, default cost slightly increase while liquidity management costs decline substantially.[22] The welfare gains of adjusting collateral frameworks to mitigate collateral scarcity are positive, but of small size compared to the welfare gains of optimal taxation.

The symmetry result hinges on the assumption that optimal Pigouvian taxes are available. However, the availability of these instruments has been heavily contested by commentators and has indeed motivated Central Banks to explore their possibilities in addressing environmental concerns. In the left panel of Figure 4, we compute the optimal degree of preferential treatment, represented by the share of green collateral $\phi_g/(\phi_c + \phi_g)$, for different levels of the Pigouvian tax. The graph starts at a ratio of four on the left, corresponding to the third column of Table 2, i.e. optimal collateral policy in the absence of taxation. At the globally optimal tax of $\chi_c = 0.085$, this ratio equals $\nu = 0.2$, corresponding to the share of green entrepreneurs. The right panel shows the welfare gain of optimal collateral policy, relative to the baseline collateral framework for different tax rates. This gain is substantial for low taxes, but diminishes as the Pigouvian tax approaches its optimum. While we are not explicit about the origin of this friction, our results indicate that Central Banks can improve on suboptimal taxation, and that the degree of preferential treatment decreases, the closer public policy gets to implementing the optimal Pigouvian tax.

[22] This is similar to Carattini et al. (2021), who show that macroprudential policy can alleviate adverse effects of carbon taxation in the presence of transition risk. In their model, adverse effects take the form of asset stranding, while in our case adverse effects are linked to collateral scarcity, if conventional entrepreneurs shrink their balance sheet size. Notably, optimal macroprudential policy is also symmetric in their model.

Figure 4: Optimal Collateral Policy Under Suboptimal Taxation



Notes: The left panel shows the ratio of green over conventional collateral parameters for different Pigouvian taxes. The right panel shows the relative welfare gain over the situation where collateral policy remains at its baseline value.

6 Yield Reaction to Central Bank Policy Announcements

So far, we analyzed the impact of preferential treatment on the corporate bond market, entrepreneurs, and investment dynamics. While the results of our policy experiments on the greenium are comparable in magnitude to the preferential treatment effect on Chinese green bonds, this observation has to be interpreted with caution due to substantial heterogeneity between China and the Euro area in general, and the monetary policy approaches of the PBoC and ECB in particular. In contrast to the PBoC's policy, ECB communication can only be interpreted as prospect of future preferential treatment, and no details on the start date and extent of preferential treatment have been announced. Consequently, there is no direct counterpart in European bond data, which we can exploit to assess the validity of our policy experiments. Therefore, we examine how the announcements of future preferential treatment affect the model-implied greenium at the time of the announcement. To map this into our model, we draw from the news shock literature and assume that preferential treatment will be implemented with certainty, but at an unknown point in the future. We find that the model implied reaction of the greenium is of similar size as the bond market reaction to speeches of ECB board members.

Construction of Dataset. The first step of our analysis is to identify a list of relevant pieces of ECB communication with significant space or time devoted to environmental policy.[23] We do not include speeches that discuss solely *climate risk* and *transition risk*, since these refer to improving disclosure standards, the extent to which climate risk should be taken into account in credit risk assessment, and asset stranding. All these issues are important for the conduct of Central Bank policy in general, but do not specifically address bond markets. We identify two speeches by ECB board members and three speeches by ECB president Christine Lagarde. We also identify several speeches that are unrelated to Central Bank environmental policy as placebo test. The exact procedure is outlined in appendix D.

We match green and conventional bonds *one trading-day before* each announcement date using a nearest neighbours procedure. The matching is based on a score encompassing credit risk (the spread over EURIBOR-swap), liquidity risk (bid-ask spread), size (amount outstanding), and the cash-flow profile (maturity, coupon). In case even the closest conventional match obtains only for a high score (implying a), we drop the green bond at the respective date. The classification of securities into ”green” and ”conventional” is based on bonds listed in the ”ESG” segments of *Euronext*, the *Frankfurt Stock Exchange* and the *Vienna Stock Exchange*, all of which offer publicly available lists. We limit the analysis to bonds classified as ”green” or ”sustainable”, which leaves us with daily market data and security characteristics of 400 green bonds. For each treatment date we have around 85 bond pairs, leaving us with a total of almost 500 observations. Table D.3 contains summary statistics regarding the matching.

Data: Yield Reaction. At each date, we calculate the reaction of green bond yields relative to a matched control group of conventional bonds, i.e. we test whether the greenium is affected by ECB announcements. In particular, we compute the average yield difference between green bonds and their respective conventional counterparts from $t-20$ until $t-1$ as pre-treatment window and from t to $t+20$ as post-treatment window, where the policy announcement occurred at time t. Pre- and post-treatment windows correspond to one trading month.

[23]The ECB regularly publishes a dataset that contains most speeches delivered by board members and presidents.

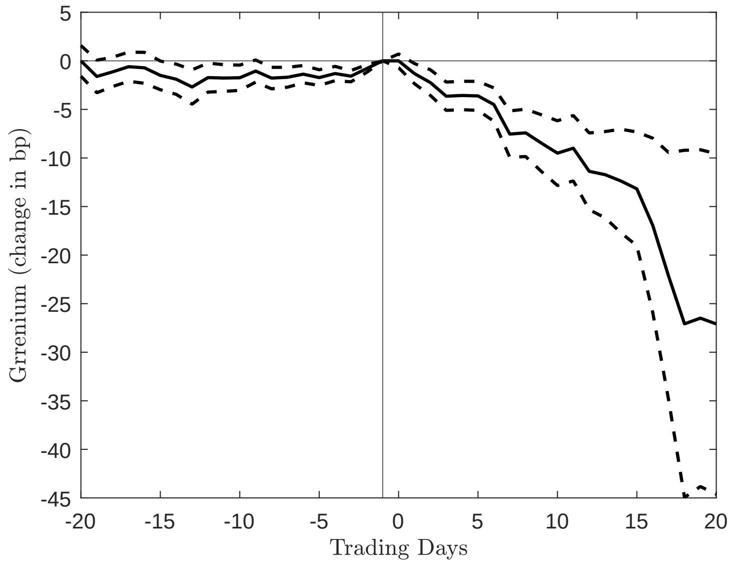


Figure 5: Average Yield Reaction around Treatment Window

Notes: Results are averaged over all policy announcements. Dashed lines represent 95% confidence intervals. All values in basis points.

We average the yield difference across all communication dates and plot the entire treatment window in Figure 5, controlling for pre-trends. Averaging over all announcements and the entire post-treatment window, the announcement effect is significant in statistical terms: after each ECB announcement, green bond yields drop by 9.3bp on average over a twenty trading day window. The change of the greenium is significant two days after the announcement and widens to 25bp twenty trading days after the announcement date. This is economically meaningful and lies in a plausible range, compared to the empirical literature on collateral premia of corporate bonds. The result indicates that bond market investors are willing to pay premia on green bonds, if there is the prospect of preferential treatment.

Model-Implied Yield Reaction. To map these announcements into our model, we draw on the literature on news shocks (Beaudry and Portier, 2004; Barsky and Sims, 2011). Specifically, we enrich the baseline calibration to a news shock to the green collateral parameter ϕ_g for various time horizons. The shock size is set such that ϕ_g attains its value under optimal collateral policy ($\phi_g = 0.53$) in three, five, or seven years. These horizons appear plausible, given that the ECB strategy review itself already took two years and that the actual implementation of preferential treatment takes time to prepare. In the model, anticipation of preferential treatment is linked to the green collateral parameter ϕ_g. Rather then setting the collateral framework to a constant, we impose a persistent log-AR process on the green collateral parameter

$$\log(\phi_{g,t}) = \log(\phi_{sym}) + \sigma_\phi \varepsilon^{\phi}_{t-h} \quad \varepsilon^{\phi}_{t-h} \sim N(0,1) \;, \tag{35}$$

where ϕ_{sym} is the green collateral parameter corresponding to the baseline calibration and h denotes the announcement horizon. The shock standard deviation is set such that it implies preferential treatment in period $t+h$

$$\sigma_\phi = \log(\phi^*_g | \phi_c = \phi_{sym}) - \log(\phi_{sym}) \;. \tag{36}$$

Since the ECB so far did not announce a date after which preferential treatment may be applied, we compute values for different announcement horizons in Table 3: three, five, and seven years.

Table 3: Greenium Reaction: Data vs Model

Data	**Model: Horizon**			
	1 year	3 years	5 years	7 years
-9.3bp	-18.0bp	-10.8bp	-6.5bp	-3.9bp

The announcement effect in the model, as measured by the greenium, lies between -3.9bp and -18bp, depending on the time horizon. A more near-term announcement induces a stronger effect since collateral benefits are priced via the bond continuation value. The shorter the horizon, the less the preferential treatment is discounted. In the three-year-specification, the greenium is -10.8bp on impact, which closely resembles the average effect over all announcement dates and post-treatment days we find in the data (-9.3bp). Arguably, the three-year-horizon seems realistic in case the ECB plans to adapt its collateral framework since it is both sufficiently long-term to work out details but also not too much in the future to miss the current public sentiment to gain support for such a step. We interpret the close fit of our model implication and the data estimate as an additional external validity check of our numerical policy experiments.

7 Conclusion

In this paper, we examine the effectiveness of preferential collateral treatment of green bonds in general equilibrium. Preferential treatment stimulates investment into green bonds. However, the increased investment into green bonds only partially transmits to investment into green technologies due to an increase in green entrepreneurs' leverage and higher default risk. While this policy can be quite powerful in our numerical experiments, the optimal collateral framework features only a small degree of preferential treatment to alleviate negative financial stability effects.

Further, we consider an alternative policy addressing environmental concerns through direct Pigouvian taxation. This policy is most effective in reducing environmental damage, but also implies a decrease in available collateral that is necessary for banks' short-term borrowing. The Central Bank adjusts the collateral framework to alleviate collateral scarcity *without* preferential treatment. If taxes can not be implemented at their optimal level, preferential treatment is an imperfect substitute and increases welfare.

Our results can be read as a call for (1) central bank action if tax policy is not able to adequately address pollution and climate change, (2) a careful assessment of the side effects of central bank preferential treatment on financial stability, and (3) coordination between direct tax policy and central bank collateral policy, to mitigate adverse effects that ambitious environmental policy can inflict on financial stability.

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A Model Appendix

A.1 Entrepreneur Problem

We start with observing that the default threshold of a type τ-entrepreneur in period $t+1$ is given by $\overline{m}_{\tau,t+1} \equiv \frac{sb_{\tau,t+1}}{(1-\chi_\tau)p_{\tau,t+1}k_{\tau,t+1}}$. The threshold satisfies the following properties:

$$\frac{\partial \overline{m}_{\tau,t+1}}{\partial b_{\tau,t+1}} = \frac{s}{(1-\chi_\tau)p_{\tau,t+1}k_{\tau,t+1}} = \frac{b_{\tau,t+1}}{(1-\chi_\tau)p_{\tau,t+1}k_{\tau,t+1}}\frac{s}{b_{\tau,t+1}} = \frac{\overline{m}_{\tau,t+1}}{b_{\tau,t+1}} \tag{A.1}$$

$$\frac{\partial \overline{m}_{\tau,t+1}}{\partial k_{\tau,t+1}} = -\frac{sb_{\tau,t+1}}{(1-\chi_\tau)p_{\tau,t+1}k^2_{\tau,t+1}} = -\frac{b_{\tau,t+1}}{(1-\chi_\tau)p_{\tau,t+1}k_{\tau,t+1}}\frac{s}{k_{\tau,t+1}} = -\frac{\overline{m}_{\tau,t+1}}{k_{\tau,t+1}}\ . \tag{A.2}$$

We assume that $\log(m)$ is normally distributed with mean μ_M and standard deviation σ_M. In the calibration, we ensure that $\mathbb{E}[m] = 1$ by setting $\mu_M = -\frac{\sigma_M^2}{2}$. The CDF of m is given by $F(m) = \Phi\left(\frac{\log m - \mu_M}{\sigma_M}\right)$, where $\Phi(\cdot)$ is the cdf of the standard normal distribution. The conditional mean of m at the threshold value $\overline{m}_{\tau,t+1}$ can be expressed as

$$G(\overline{m}_{\tau,t+1}) = \int_0^{\overline{m}_{\tau,t+1}} mf(m)dm = e^{\mu_M+\frac{\sigma_M^2}{2}}\Phi\left(\frac{\log\overline{m}_{\tau,t+1} - \mu_M - \sigma_M^2}{\sigma_M}\right),$$

$$1 - G(\overline{m}_{\tau,t+1}) = \int_{\overline{m}_{\tau,t+1}}^{\infty} mf(m)dm = e^{\mu_M+\frac{\sigma_M^2}{2}}\Phi\left(\frac{-\log\overline{m}_{\tau,t+1} + \mu_M + \sigma_M^2}{\sigma_M}\right).$$

Note that

$$G'(\overline{m}_{\tau,t+1}) = \overline{m}_{\tau,t+1}F'(\overline{m}_{\tau,t+1})\ . \tag{A.3}$$

For notational convenience, we write the bond price schedule as function of the default threshold $\overline{m}_{\tau,t}$ throughout this section. The bond payoff is given by

$$\mathcal{R}_{\tau,t} = s\left(G(\overline{m}_{\tau,t}) \frac{(1-\chi_\tau)p_{\tau,t}k_{\tau,t}}{sb_{\tau,t}} + 1 - F(\overline{m}_{\tau,t}) \right) - F(\overline{m}_{\tau,t})\varphi + (1-s)q_{\tau,t} \ ,$$

such that we can write the bond price only in terms of the default threshold $\overline{m}_{\tau,t+1}$

$$q(\overline{m}_{\tau,t+1}) = \frac{s\left(\frac{G(\overline{m}_{\tau,t+1})}{\overline{m}_{\tau,t+1}} + 1 - F(\overline{m}_{\tau,t+1}) \right) - F(\overline{m}_{\tau,t+1})\varphi + (1-s)q_{\tau,t+1}}{(1+\phi_\tau \Omega_{b,t})(1+i_t^D)} \ . \tag{A.4}$$

The derivative with respect to the default threshold is given by

$$q'(\overline{m}_{\tau,t+1}) = \frac{-\frac{sG(\overline{m}_{\tau,t+1})}{\overline{m}^2_{\tau,t+1}} - \varphi F'(\overline{m}_{\tau,t+1})}{(1+\phi_\tau \Omega_{b,t})(1+i_t^D)} \ . \tag{A.5}$$

The type-τ entrepreneur maximization problem reads

$$V^E(b_{\tau,t}, k_{\tau,t}) = \max_{b_{\tau,t+1}, k_{\tau,t+1}} \widetilde{c}_{\tau,t} + \widetilde{\beta}\mathbb{E}_t \left[V^E(b_{\tau,t+1}, k_{\tau,t+1}) \right] \ ,$$

where entrepreneur's consumption is given by

$$\begin{aligned} \widetilde{c}_{\tau,t} &= (1-G(\overline{m}_{\tau,t}))(1-\chi_\tau)p_{\tau,t}k_{\tau,t} - (1-F(\overline{m}_{\tau,t}))\, sb_{\tau,t} - k_{\tau,t+1} + (1-\delta)k_{\tau,t} \\ &\quad + q(\overline{m}_{\tau,t})\left(b_{\tau,t+1} - (1-s)b_{\tau,t}\right) \ . \end{aligned}$$

Under the assumption of no delays in restructuring and i.i.d. productivity shocks, the problem boils down to a two-period consideration

$$\begin{aligned} \max_{k_{\tau,t+1}, b_{\tau,t+1}} & - k_{\tau,t+1} + q(\overline{m}_{\tau,t})\left(b_{\tau,t+1} - (1-s)b_{\tau,t} \right) \\ & + \widetilde{\beta}\Big[(1-G(\overline{m}_{\tau,t+1}))(1-\chi_\tau)p_{\tau,t+1}k_{\tau,t+1} + (1-\delta)k_{\tau,t+1} \\ & \quad - s(1-F(\overline{m}_{\tau,t+1}))b_{\tau,t+1} + q_{\tau,t+1}\left(b_{\tau,t+1} - (1-s)b_{\tau,t} \right) \Big] \ , \end{aligned}$$

taken as given continuation value of bonds $q_{\tau,t+1}$.

FOC w.r.t $b_{\tau,t+1}$ The first-order condition for bonds is then given by

$$
\begin{aligned}
0 = &\left[q'(\overline{m}_{\tau,t+1})\frac{\partial \overline{m}_{t+1}}{\partial b_{\tau,t+1}}\left(b_{\tau,t+1}-(1-s)b_{\tau,t}\right)+q(\overline{m}_{\tau,t+1})\right] \\
&+\widetilde{\beta}\left[-(1-\chi_\tau)p_{\tau,t+1}k_{\tau,t+1}G'(\overline{m}_{\tau,t+1})\frac{\partial \overline{m}_{\tau,t+1}}{\partial b_{\tau,t+1}}\right. \\
&\left.\quad -s\left(-F'(\overline{m}_{\tau,t+1})\frac{\partial \overline{m}_{\tau,t+1}}{\partial b_{\tau,t+1}}b_{\tau,t+1}+1-F(\overline{m}_{\tau,t+1})\right)-q_{\tau,t+1}(1-s)\right],
\end{aligned}
$$

which can be expressed as

$$
\begin{aligned}
0 = &\left[q'(\overline{m}_{\tau,t+1})\frac{\overline{m}_{\tau,t+1}}{b_{\tau,t+1}}\left(b_{\tau,t+1}-(1-s)b_{\tau,t}\right)+q(\overline{m}_{\tau,t+1})\right] \\
&+\widetilde{\beta}\left[-aG'(\overline{m}_{\tau,t+1})\frac{\overline{m}_{\tau,t+1}(1-\chi_\tau)p_{\tau,t+1}k_{\tau,t+1}}{sb_{\tau,t+1}}\right. \\
&\left.\quad -s\left(-F'(\overline{m}_{\tau,t+1})\overline{m}_{\tau,t+1}+1-F(\overline{m}_{\tau,t+1})\right)-q_{\tau,t+1}(1-s)\right],
\end{aligned}
$$

and then yields (16). Plugging in $q'(\overline{m}_{\tau,t+1})$ and $q(\overline{m}_{\tau,t+1})$, we have

$$
\begin{aligned}
0 = &\frac{1}{(1+\phi_\tau\Omega_{b,t})(1+i_t^D)}\left[s\left(G'(\overline{m}_{\tau,t+1})-\frac{G(\overline{m}_{\tau,t+1})}{\overline{m}_{\tau,t+1}}-F'(\overline{m}_{\tau,t+1})\overline{m}_{\tau,t+1}\right)\right. \\
&\left. -\varphi F'(\overline{m}_{\tau,t+1})\overline{m}_{\tau,t+1}\right]\frac{b_{\tau,t+1}-(1-s)b_{\tau,t}}{b_{\tau,t+1}} \\
&+\frac{1}{(1+\phi_\tau\Omega_{b,t})(1+i_t^D)}\left[s\left(\frac{G(\overline{m}_{\tau,t+1})}{\overline{m}_{\tau,t+1}}+1-F(\overline{m}_{\tau,t+1})\right)-\varphi F(\overline{m}_{\tau,t+1})+(1-s)q_{t+1}\right] \\
&+\widetilde{\beta}\left[-s\left(G'(\overline{m}_{\tau,t+1})-F'(\overline{m}_{\tau,t+1})\overline{m}_{\tau,t+1}+1-F(\overline{m}_{\tau,t+1})\right)-q_{\tau,t+1}(1-s)\right].
\end{aligned}
$$

Now, using $G'(\overline{m}_{\tau,t+1})=\overline{m}_{\tau,t+1}F'(\overline{m}_{\tau,t+1})$, we can rearrange to obtain

$$
\begin{aligned}
&\frac{s}{(1+\phi_\tau\Omega_{b,t})(1+i_t^D)}\frac{(1-s)b_{\tau,t}}{b_{\tau,t+1}}\frac{G(\overline{m}_{\tau,t+1})}{\overline{m}_{t+1}} \\
&+\left(\frac{1}{(1+\phi_\tau\Omega_{b,t})(1+i_t^D)}-\widetilde{\beta}\right)s\left(1-F(\overline{m}_{\tau,t+1})\right) \\
&+\left(\frac{1}{(1+\phi_\tau\Omega_{b,t})(1+i_t^D)}-\widetilde{\beta}\right)q_{t+1}(1-s) \\
&\quad =\frac{\varphi}{(1+\phi_\tau\Omega_{b,t})(1+i_t^D)}\left(F'(\overline{m}_{\tau,t+1})\overline{m}_{\tau,t+1}\frac{b_{\tau,t+1}-(1-s)b_{\tau,t}}{b_{\tau,t+1}}+F(\overline{m}_{\tau,t+1})\right).
\end{aligned}
$$

FOC w.r.t $k_{\tau,t+1}$ The first-order condition for capital is

$$
\begin{aligned}
1 = {} & q'(\overline{m}_{\tau,t+1})\frac{\partial \overline{m}_{\tau,t+1}}{\partial k_{\tau,t+1}}\Big(b_{\tau,t+1}-(1-s)b_{\tau,t}\Big) \\
& +\widetilde{\beta}\Bigg[-G'(\overline{m}_{\tau,t+1})\frac{\partial \overline{m}_{\tau,t+1}}{\partial k_{\tau,t+1}}(1-\chi_\tau)p_{\tau,t+1}k_{\tau,t+1}+(1-G(\overline{m}_{\tau,t+1}))p_{\tau,t+1} \\
& \qquad +sb_{\tau,t+1}F'(\overline{m}_{\tau,t+1})\overline{m}_{\tau,t+1}\frac{\partial \overline{m}_{\tau,t+1}}{\partial k_{\tau,t+1}}+1-\delta\Bigg],
\end{aligned}
$$

which can be rearranged to

$$
\begin{aligned}
1-\widetilde{\beta}(1-\delta) = {} & -q'(\overline{m}_{\tau,t+1})\frac{\overline{m}_{\tau,t+1}}{k_{\tau,t+1}}\Big(b_{\tau,t+1}-(1-s)b_{\tau,t}\Big) \\
& +\widetilde{\beta}\Bigg[G'(\overline{m}_{\tau,t+1})\overline{m}_{\tau,t+1}p_{\tau,t+1}+\big(1-G(\overline{m}_{\tau,t+1})\big)p_{\tau,t+1} \\
& \qquad -sb_{\tau,t+1}F'(\overline{m}_{\tau,t+1})\frac{\overline{m}_{\tau,t+1}}{k_{\tau,t+1}}\frac{p_{\tau,t+1}}{p_{\tau,t+1}}\Bigg],
\end{aligned}
$$

and further to (17).

B Simplified Setting: Full System of Equations

The deterministic steady state of the simplified model is characterized by the following system of equations

$$\widetilde{c}+k = q(\overline{m})b+(1-G(\overline{m}))kp-(1-F(\overline{m}))b \tag{B.1}$$

$$q'(\overline{m})\overline{m}+q(\overline{m}) = \widetilde{\beta}(1-F(\overline{m})) \tag{B.2}$$

$$1+q'(\overline{m})\overline{m}^2p = \widetilde{\beta}(1-G(\overline{m}))p \tag{B.3}$$

$$\overline{m} = \frac{b}{pk} \tag{B.4}$$

$$d = (1+\phi\omega)b \tag{B.5}$$

$$q(\overline{m}) = \beta\frac{G(\overline{m})/\overline{m}+(1-F(\overline{m}))-\varphi F(\overline{m})}{1-\phi\omega} \tag{B.6}$$

$$c = \left(\frac{1}{\beta}-1\right)d+k^\theta-pk+d-q(\overline{m})b-\Omega \tag{B.7}$$

$$p = \theta k^{\theta-1} \tag{B.8}$$

with eight unknowns $\tilde{c}, k, b, \overline{m}, c, d, p, q$. Using the uniform distributional assumption, we have $F(\overline{m}) = \frac{\overline{m}}{2}$ and $G(\overline{m}) = \frac{\overline{m}^2}{4}$. The bond price and its derivative are given by

$$q(\overline{m}) = \frac{\beta}{1-\phi\omega}\left[1 - \frac{\overline{m}}{4}(1+2\varphi)\right]$$
$$q'(\overline{m}) = -\frac{\beta}{1-\phi\omega}\frac{1+2\varphi}{4}$$

which can then be used in eq. (B.2) to obtain

$$-\frac{\beta}{1-\phi\omega}\frac{1+2\varphi}{4}\overline{m} + \frac{\beta}{1-\phi\omega}\left[1 - \frac{\overline{m}}{4}(1+2\varphi)\right] = \widetilde{\beta}\left(1 - \frac{\overline{m}}{2}\right)$$

and

$$\frac{\overline{m}}{2}\left(\widetilde{\beta} - \frac{\beta}{1-\phi\omega} - 2\beta\frac{\varphi}{1-\phi\omega}\right) = \widetilde{\beta} - \frac{\beta}{1-\phi\omega}$$

further to eq. (26)

$$\overline{m} = 2\frac{\beta - \widetilde{\beta}(1-\phi\omega)}{\beta(1+2\varphi) - \widetilde{\beta}(1-\phi\omega)}\ .$$

Note that $\overline{m} > 0$, provided $\phi\omega < 1$.

Proof of Proposition 1 Differentiating (26) with respect to the collateral policy parameter ϕ, we get:

$$\frac{\partial\overline{m}}{\partial\phi} = 2\frac{\widetilde{\beta}\omega[\beta(1+2\varphi) - \widetilde{\beta}(1-\phi\omega)] - \widetilde{\beta}\omega[\beta - \widetilde{\beta}(1-\phi\omega)]}{[\beta(1+2\varphi) - \widetilde{\beta}(1-\phi\omega)]^2} = \frac{4\beta\widetilde{\beta}\omega\varphi}{[\beta(1+2\varphi) - \widetilde{\beta}(1-\phi\omega)]^2} > 0$$

Using this in the first-order condition for capital eq. (B.3) then yields the intermediate good price:

$$1 - \frac{\beta}{1-\phi\omega}\frac{1+2\varphi}{4}\overline{m}^2 p = \widetilde{\beta}\left(1 - \frac{\overline{m}^2}{4}\right)p \Leftrightarrow p = \left[\widetilde{\beta}\left(1 - \frac{\overline{m}^2}{4}\right) + \frac{\beta}{4}\frac{1+2\varphi}{1-\phi\omega}\overline{m}^2\right]^{-1}$$

Differentiating with respect to ϕ, we get:

$$\frac{dp}{d\phi} = \frac{\partial p}{\partial\phi} + \frac{\partial p}{\partial\overline{m}}\frac{\partial\overline{m}}{\partial\phi}$$

which can be expressed in closed form as

$$\frac{dp}{d\phi} = -\left[\widetilde{\beta}\left(1-\frac{\overline{m}^2}{4}\right)+\frac{\beta}{4}\frac{1+2\varphi}{1-\phi\omega}\overline{m}^2\right]^{-2}$$
$$\left\{\frac{\beta}{4}\frac{1+2\varphi}{(1-\phi\omega)^2}\overline{m}^2\omega+\left(-\frac{\widetilde{\beta}\overline{m}}{2}+\frac{\beta}{2}\frac{1+2\varphi}{1-\phi\omega}\frac{4\beta\widetilde{\beta}\omega\varphi\overline{m}}{[\beta(1+2\varphi)-\widetilde{\beta}(1-\phi\omega)]^2}\right)\right\}$$
$$= -\underbrace{p^2\frac{\beta\overline{m}}{1-\phi\omega}}_{>0}\left\{\underbrace{\frac{\overline{m}}{4}\frac{1+2\varphi}{1-\phi\omega}}_{>0}+\underbrace{\frac{2\beta\widetilde{\beta}\omega\varphi}{\beta(1+2\varphi)-\widetilde{\beta}(1-\phi\omega)}}_{>0}\right\}<0.$$

Via (B.8) we obtain the equilibrium capital stock:

$$k = \left(\frac{p}{\theta}\right)^{\frac{1}{\theta-1}} \tag{B.9}$$

Hence:

$$\frac{dk}{d\phi} = \frac{dk}{dp}\frac{dp}{d\phi} = \underbrace{\frac{1}{\theta-1}}_{<0}\underbrace{\left(\frac{p}{\theta}\right)^{\frac{2-\theta}{\theta-1}}\frac{1}{\theta}}_{>0}\underbrace{\frac{dp}{d\phi}}_{<0}>0$$

Finally, we can use (B.4) to get the equilibrium level for b:

$$b = \overline{m}pk = \theta\overline{m}k^{\theta} \tag{B.10}$$

Differentiating with respect to ϕ

$$\frac{db}{d\phi} = \theta\left(\underbrace{k^{\theta}}_{>0}+\underbrace{\theta\overline{m}k^{\theta-1}\frac{dk}{d\overline{m}}}_{>0}\right)\underbrace{\frac{d\overline{m}}{d\phi}}_{>0}>0$$

since the sign of $\frac{dk}{d\overline{m}}$ is unambiguous:

$$\frac{dk}{d\overline{m}} = \frac{dk}{dp}\frac{dp}{d\overline{m}} = \underbrace{\frac{1}{\theta-1}}_{<0}\underbrace{\left(\frac{p}{\theta}\right)^{\frac{2-\theta}{\theta-1}}\frac{1}{\theta}}_{>0}\left\{-\underbrace{p^2\frac{\overline{m}}{2}\left(\beta\frac{1+2\varphi}{1-\phi\omega}-\widetilde{\beta}\right)}_{>0}\right\}>0$$

□

C Additional Numerical Results

C.1 The Role of Nominal Rigidities

In this section, we add nominal rigidities to the model by extending entrepreneurs, households, and firms accordingly, following standard New Keynesian models. In particular, bonds are assumed to be denominated in nominal terms, i.e. inflation has a direct effect on entrepreneurs and the supply side. Households consume a final goods basket c_t given by

$$c_t = \left(\int_0^1 c_{i,t}^{\frac{\varepsilon-1}{\varepsilon}} \, di \right)^{\frac{\varepsilon}{\varepsilon-1}} ,$$

where $\varepsilon > 1$ is the elasticity of substitution among the differentiated final goods. The demand schedule for final good i is given by

$$c_{i,t} = \left(\frac{P_{i,t}}{P_t} \right)^{-\varepsilon} c_t \; , \tag{B.11}$$

where P_t denotes the CES price index for final consumption bundle. Final good firms sell their differentiated good with a markup over their marginal costs. However, the price of firm i, $P_{i,t}$, can only be varied by paying a quadratic adjustment cost à la Rotemberg (1982) that is proportional to the nominal value of aggregate production, $P_t y_t$. Firm i's marginal costs are denoted by $\text{mc}_{i,t} \equiv \partial \mathcal{C}_t^W / \partial y_{i,t}$, where

$$\mathcal{C}_t^W(y_{i,t}) = \min_{z_{i,t}, l_{i,t}} \quad P_{z,t} z_{i,t} + W_t l_{i,t} \quad \text{s.t.} \quad y_{i,t} = (1 - \mathcal{P}_t) A_t z_{i,t}^{\theta} l_{i,t}^{1-\theta} \; ,$$

and $P_{z,t}$ is the price of the wholesale good. From the minimization problem we obtain *real* marginal costs

$$\text{mc}_t = \frac{1}{(1-\mathcal{P}_t) A_t} \left(\frac{p_{z,t}}{\theta} \right)^{\theta} \left(\frac{w_t}{1-\theta} \right)^{1-\theta} ,$$

where $p_{z,t} = P_{z,t}/P_t$ is the relative price of the wholesale good and w_t is the real wage. Hence, total nominal profits of firm i in period t are given by

$$\widehat{\Pi}_{i,t} = (P_{i,t} - \text{mc}_t P_t) \, y_{i,t} - \frac{\psi}{2} \left(\frac{P_{i,t}}{P_{i,t-1}} - 1 \right)^2 P_t y_t \; ,$$

where ψ measures the degree of the nominal rigidity. Each wholesale good firm i maximizes the expected sum of discounted profits

$$\max_{P_{i,t+s},y_{i,t+s}} \mathbb{E}_t \left[\sum_{s=0}^{\infty} \beta^s \frac{c_{t+s}^{-\gamma_C}/P_{t+s}}{c_t^{-\gamma_C}/P_t} \widehat{\Pi}_{i,t+s} \right] ,$$

subject to the demand schedule (B.11). Plugging in the demand function yields the first-order condition

$$\left(\frac{P_{i,t}}{P_t}\right)^{-\varepsilon} Y_t - \varepsilon \left(P_{i,t} - \mathrm{mc}_t P_t\right) \left(\frac{P_{i,t}}{P_t}\right)^{-\varepsilon} \frac{y_t}{P_t} - \psi \left(\frac{P_{i,t}}{P_{i,t-1}} - 1\right) \frac{P_t}{P_{i,t-1}} y_t$$
$$+ \mathbb{E}_t \left[\frac{c_{t+1}^{-\gamma_C}/P_{t+1}}{c_t^{-\gamma_C}/P_t} \psi \left(\frac{P_{i,t+1}}{P_{i,t}} - 1\right) \frac{P_{i,t+1}}{P_{i,t}^2} P_{t+1} y_{t+1} \right] = 0 .$$

In a symmetric price equilibrium, $P_{i,t} = P_t$ for all i. Using this, we rearrange and get

$$(1 - \varepsilon(1 - \mathrm{mc}_t))\, y_t + \mathbb{E}_t \left[\beta \frac{c_{t+1}^{-\gamma_C}/P_{t+1}}{c_t^{-\gamma_C}/P_t} y_{t+1} \pi_{t+1} \psi \left(\pi_{t+1} - 1\right) \pi_{t+1} \right] = \psi \left(\pi_t - 1\right) \pi_t y_t ,$$

where $\pi_t = \frac{P_t}{P_{t-1}}$. Dividing both sides by y_t and ϕ we arrive at the New Keynesian Phillips Curve

$$\mathbb{E}_t \left[\beta \frac{c_{t+1}^{-\gamma_C}/P_{t+1}}{c_t^{-\gamma_C}/P_t} \frac{y_{t+1}\pi_{t+1}}{y_t} \left(\pi_{t+1} - 1\right) \pi_{t+1} \right] + \frac{\varepsilon}{\psi} \left(\mathrm{mc}_t - \mathrm{mc}^\star\right) = \left(\pi_t - 1\right) \pi_t ,$$

where $\mathrm{mc}^\star \equiv \frac{\varepsilon - 1}{\varepsilon}$ is the steady state real marginal cost.

In addition, nominal rigidities also affect entrepreneurs, since inflation affects the default threshold $\overline{m}_{\tau,t+1} \equiv \frac{sb_{\tau,t+1}}{\pi_{t+1}(1-\chi_\tau)p_{\tau,t+1}k_{\tau,t+1}}$ and the *real per-unit* bond payoff is

$$\mathcal{R}_{\tau,t} = s\left(G(\overline{m}_{\tau,t}) \frac{\pi_t p_{\tau,t}(1-\chi_\tau)k_{\tau,t}}{sb_{\tau,t}} + 1 - F(\overline{m}_{\tau,t}) \right) - F(\overline{m}_{\tau,t})\varphi + (1-s)q_{\tau,t} . \tag{B.12}$$

Their first-order conditions are now given by

$$q'(\overline{m}_{\tau,t+1}) \frac{\overline{m}_{\tau,t+1}}{b_{\tau,t+1}} \left(b_{\tau,t+1} - (1-s)\frac{b_{\tau,t}}{\pi_t} \right) + q(\overline{m}_{\tau,t+1}) = \widetilde{\beta} \mathbb{E}_t \left[\frac{s(1 - F(\overline{m}_{\tau,t+1})) + (1-s)q_{\tau,t+1}}{\pi_{t+1}} \right] \tag{B.13}$$

and

$$1 = -q'(\overline{m}_{\tau,t+1})\frac{\overline{m}_{\tau,t+1}}{k_{\tau,t+1}}\left(b_{\tau,t+1} - (1-s)\frac{b_{\tau,t}}{\pi_t}\right) + \widetilde{\beta}(1-\delta) + \widetilde{\beta}(1-\chi_\tau)\mathbb{E}_t[p_{\tau,t+1}]\big(1 - G(\overline{m}_{\tau,t+1})\big) \,. \tag{B.14}$$

The resource constraint now also includes Rotemberg costs

$$y_t = c_t + \sum_\tau (c_{\tau,t} + i_{\tau,t}) + \Omega(\bar{b}_{t+1}) + \frac{\psi}{2}(\pi_t - 1)^2 y_t + \sum_\tau \varphi F(\overline{m}_{\tau,t})\frac{b_{\tau,t}}{\pi_t} \,. \tag{B.15}$$

To close the model, we assume that the central bank sets policy rate i_t^D according to a Taylor rule

$$i_t^D = i^D \pi_t^{\phi_\pi} \,. \tag{B.16}$$

We choose standard parameters for the final goods elasticity $\varepsilon = 6$, implying a markup of 20% in the deterministic steady state, and a Rotemberg parameter $\psi = 57.8$, consistent with Calvo parameter of 0.75. The parameter on inflation stabilization in the monetary policy rule is set to $\phi_\pi = 1.5$. Results are reported in Table C.1 and show very similar collateral policy implications.

Table C.1: Time Series Means with Nominal Rigidities

Moment	Baseline	Max Pref	Opt Coll	Only Tax	Glob Opt
Tax Parameter χ_c	0	0	0	0.07	0.07
Coll. Parameter ϕ_g	0.23	1	0.56	0.23	0.25
Coll. Parameter ϕ_c	0.23	0	0.14	0.23	0.25
Welfare Change (CE)	0%	-0.016%	0.02%	0.353%	0.353%
Conv. Leverage	39.2%	39.1%	39.0%	39.2%	39.2%
Green Leverage	39.2%	39.7%	39.8%	39.2%	39.2%
Conv. Bond Spread	99bp	142bp	114bp	100bp	98bp
Green Bond Spread	99bp	-30bp	43bp	100bp	98bp
Conv. Coll. Premium	-7bp	0bp	-5bp	-7bp	-8bp
Green Coll. Premium	-7bp	-31bp	-17bp	-7bp	-8bp
GDP	0.7455				
Change from Baseline	-	+0.1%	+0.04%	+0.35%	+0.37%
Default Cost/GDP	1.5%				
Change from Baseline	-	-0.12%	-0.08%	-0.04%	+1.58%
LM Cost/GDP	0.3%				
Change from Baseline	-	+13.5%	+2.5%	-0.7%	-6.1%
Pollution Cost/GDP	10.8%				
Change from Baseline	-	-1.0%	-0.4%	-6.8%	-6.7%
Rotemberg Cost/GDP	0.008%				
Change from Baseline	-	-1.8%	-0.9%	+2.0%	+1.6%
Green Bond Share	20.00%	21.56%	20.69%	25.60%	25.60%
Green Capital Share	20.00%	20.79%	20.32%	25.60%	25.60%

By reducing the pollution externality on final goods production, preferential treatment increases effective TFP, $(1-\mathcal{P}_t)A_t$, ceteris paribus. Hence, for the same innovation to TFP, movements in marginal costs and thereby inflation are more pronounced. However, movements in inflation affect entrepreneurs' risk choice by affecting the default probability threshold value $\overline{m}$. The increase in $\overline{m}$ counteracts the movements inflation that operate through movements in final goods firms' marginal costs.

Consider a positive innovation to TFP. If the pollution damage is reduced, then effective TFP is higher while marginal costs are lower, ceteris paribus. Hence, the corresponding decrease in inflation is more pronounced, ceteris paribus. The decrease in inflation, however, increases the default threshold $\overline{m}$. The corresponding increase in firm default rates reduces the supply of the intermediate good and thereby increases their price, counteracting the initial drop in inflation.

For any calibration that we considered, the second effect through the risk channel dominates the marginal cost channel so that reducing the pollution externality reduces inflation volatility.

C.2 Robustness Checks for Key Parameters

In Table C.2, we provide robustness checks regarding the production technology of wholesale goods producers. By assuming a Cobb-Douglas production function for wholesale good producers in eq. (10), we implicitly assume a elasticity of substitution of one between green and conventional intermediate goods. When strictly interpreting green and conventional entrepreneurs as energy producers, this elasticity is usually estimated to be larger than one. We therefore repeat our policy analysis when replacing the wholesale producers' technology by a CES-function

$$z_t = \left(\nu z_{g,t}^{\frac{\varepsilon_\nu - 1}{\varepsilon_\nu}} + (1-\nu) z_{c,t}^{\frac{\varepsilon_\nu - 1}{\varepsilon_\nu}} \right)^{\frac{\varepsilon_\nu}{\varepsilon_\nu - 1}} \tag{B.17}$$

and set the elasticity of substitution $\varepsilon_\nu = 1.6$, following the point estimate in Papageorgiou et al. (2017). The parameter ν is set to keep the green production share at 20%, consistent with the baseline. Results are shown in Table C.2. To ensure an apples-to-apples comparison, we recalibrate the parameter η_0 governing the strength of the risk-externality, such that the collateral parameter under symmetry ϕ_{sym} is optimal with respect to the welfare objective. While the main results from the Cobb-Douglas baseline carry over to the CES case, the optimal tax is much higher and optimal collateral policy implies a much larger degree of preferential treatment. This directly follows from the higher substitutability, which can also be seen from the welfare gain under maximum preferential treatment.

Table C.2: Time Series Means with $\varepsilon_\omega = 1.6$

Moment	Baseline	Max Pref	Opt Coll	Only Tax	Glob Opt
Tax Parameter χ_c	0	0	0	0.105	0.105
Coll. Parameter ϕ_g	0.23	1	0.74	0.23	0.26
Coll. Parameter ϕ_c	0.23	0	0.08	0.23	0.26
Welfare Change (CE)	0%	+0.043%	+0.058%	+0.910%	+0.911%
Conv. Leverage	39.1%	38.5%	38.7%	39.1%	39.2%
Green Leverage	39.1%	40.1%	39.9%	39.2%	39.2%
Conv. Bond Spread	103bp	140bp	128bp	104bp	101bp
Green Bond Spread	103bp	-11bp	23bp	104bp	101bp
Conv. Coll. Premium	-7bp	0bp	-2bp	-7bp	-7bp
Green Coll. Premium	-7bp	-27bp	-21bp	-7bp	-7bp
GDP	0.8068				
Change from Baseline	-	+0.19%	+0.12%	+0.88%	+0.91%
Default Cost/GDP	1.7%				
Change from Baseline	-	+0.98%	-0.09%	-0.14%	+2.12%
LM Cost/GDP	0.1%				
Change from Baseline	-	+24.3%	+18.1%	-10.4%	-42.5%
Pollution Cost/GDP	11.2%				
Change from Baseline	-	-1.4%	-1.0%	-14.5%	-14.5%
Green Bond Share	20.5%	22.3%	21.8%	32.5%	32.5%
Green Capital Share	20.5%	21.6%	21.3%	32.5%	32.5%

D Data Appendix

Table D.1 summarizes the data sources on which our empirical analysis is based. The classification of bonds as ”green” is based on publicly available lists of securities traded via various stock exchanges. Based on the list of ISINs, we retrieve bond-specific info from Datastream. Data on conventional bonds in the control group is taken from Markit. EURIBOR data are obtained through Datastream.

Table D.1: Data Sources and Ticker

Series	**Source**	**Mnemonic**
Green Bond List I	Euronext	List retrieved Nov-30-2020
Green Bond List II	FSE	List retrieved Nov-30-2020
Green Bond List III	Vienna FSE	List retrieved Nov-30-2020
Constant Maturity Ask Price	Datastream	CMPA
Constant Maturity Bid Price	Datastream	CMPB
Coupon	Datastream	C
Issue Date	Datastream	ID
Amount Outstanding	Datastream	AOS
Currency	Datastream	PCUR
Life At Issue	Datastream	LFIS
Redemption Date	Datastream	RD
EURIBOR rates (... with maturity)	Datastream	TRE6S...Y

To identify relevant speeches for our empirical analysis, we rely on a dataset published by the ECB that contains date, title (including sub-titles in the format ”TYPE by SPEAKER, ROLE, at OCCASION”), speaker and content as well as footnotes of nearly all speeches by presidents and board members since 1999.[24] We perform the following steps:

- We string-match titles and content separately for the following keywords: climate, green, sustainable, greenhouse, environment, warming, climatic, carbon, coal.
- We designate a speech for manual inspection as soon as we have one match for a title or three matches for content (variations did not change results).
- We exclude a speech if insufficient space is devoted to the topic, there is no monetary policy relation, or if we have a wrong positive (e.g. *environment* refers to low interest rates or inflation).
- We exclude speeches that address climate risk or transition risk.
- All speeches within 20 trading days of the previous speech are excluded to avoid overlapping treatment periods.

One speech was followed a press release published via Reuters on the subsequent trading day regarding an explicit announcement of preferential treatment. We do not include communication that refer to *climate risk* and *transition risk*, since these refer to improving disclosure

[24]See European Central Bank (2021). Speeches dataset. Retrieved from: https://www.ecb.europa.eu/press/key/html/downloads.en.html.

standards, the extent to which climate risk should be taken into account in credit risk assessment, and asset stranding. All these issues are important for the conduct of Central Bank policy in general, but do not specifically address bond markets. This leaves us with five speeches. Table D.2 contains details regarding the key content that motivate our classification.

Table D.2: Relevant ECB Policy Announcements

Date	Type	Link	Relevant Quotes
08-11-2018	Benoît Cœuré	ECB	• (...) the ECB, acting within its mandate, can – and should – actively support the transition to a low carbon economy (...) second, by acting accordingly, without prejudice to price stability. • Purchasing green bonds (...) could be an option, as long as the markets are deep and liquid enough.
05-02-2020	Christine Lagarde	ECB	• In keeping with this, climate change will be a key part of our ongoing strategy review. • (...) bringing climate change more fundamentally into our analysis and strategy (...) climate change is also a price stability risk.
27-02-2020	Christine Lagarde	ECB	• (...) reviewing the extent to which climate-related risks are understood and priced by the market (...) • (...) evaluate the implications for our own management of risk, in particular through our collateral framework.
17-07-2020	Isabel Schnabel	ECB	• (...) way in which we can contribute is by taking climate considerations into account when designing and implementing our monetary policy operations. • (...) Of course, Central Banks would need to be mindful of their effects on market functioning. • (...) severe risks to price stability, Central Banks are required, within their traditional mandates, to strengthen their efforts (...)
21-09-2020	Christine Lagarde	ECB	• We cannot miss this opportunity to reduce and prevent climate risks and finance the necessary green transition. • The ECB's ongoing strategy review will ensure that its monetary policy strategy is fit for purpose (...) • (...) Jean Monnet's words, (...) opportunity for Europe to take a step towards the forms of organisation of the world of tomorrow. • On 22-09-2020, Reuters reported that sustainability-linked bonds will be added to the list of eligible collateral at some unspecified date.

Since many green bonds do not show up in the *IHS Markit* database, we additionally obtain data from *Thomson Reuters Datastream*. From this dataset, we identify an appropriate untreated bond as control group, which is the conventional bond with the smallest distance to the green bond. We drop a green bond if the distance to the closest conventional bond is too high. Table D.3 contains summary statistics regarding the matching. While coupon and bid-ask spreads are very similar for both types of bonds, the spread is higher by around 5 bp for green bonds while at the same time the maturity is 1-2 years longer. For each announcement, we show summary statistics of the matched conventional-green bond sample in Table D.3.

Table D.3: Matching Green to Conventional Bonds: Summary Statistics

Date		**BA-Spread**		**Coupon**		**Spread**		**Maturity**		**Amount**	
	#	Green	Conv.	Green	Conv.	Green	Conv.	Green	Conv.	Green	Conv.
08-11-2018	80	0.34	0.33	1.08	1.05	47.50	42.20	7.6	6.0	716	719
05-02-2020	89	0.33	0.32	1.16	1.10	45.97	41.63	6.7	5.1	713	698
27-02-2020	86	0.35	0.32	1.18	1.15	51.67	44.82	6.7	5.2	696	690
17-07-2020	86	0.44	0.38	1.22	1.22	77.49	72.10	6.5	4.9	693	689
21-09-2020	79	0.38	0.36	1.18	1.15	64.94	56.37	6.3	4.5	701	709

Notes: We denote the number of matches by #. Conv. denotes a *conventional* bond. Bond yield spreads over the Euribor/Swap are in basis points. Bid-ask spread and coupon relative to a face value of 100, maturity in years. Amount outstanding is in million EUR.

In the main text, we only display the average response across treatment dates, while Table D.4 gives details on single events. We observe significantly negative premia for green bonds up to one month after the treatment events. The strongest effect is visible for ECB president Christine Lagarde's speech at February 27^{th} 2020, which included the first explicit reference to the ECB's collateral framework. Moreover, the speech delivered by Isabel Schnabel on July 17^{th} 2020 stands out, since yields on green bonds significantly increased compared to their conventional counterparts in the days following the event. However, the tone regarding future ECB environmental policy is much more modest than in other speeches. There is also no explicit prospect of preferential treatment in this speech.[25]

Table D.4: Yield Reaction around ECB Policy Announcements

Date	**Type**	**Yield Reaction**	**Standard Error**
08-11-2018	Board Member Speech	-7.9***	1.78
05-02-2020	President Speech	-4.5**	0.89
27-02-2020	President Speech	-35.4***	7.19
17-07-2020	Board Member Speech	9.9***	1.8
21-09-2020	President Speech	0.6	1.2

Notes: We display the *average* yield over 20 days after minus *average* yield over 20 trading day before the policy announcement , relative to the matched control group (in basis points). Significance levels correspond to 10 % (*), 1 % (**) and 0.1 % (***) of Welch's t-test.

We also perform our analysis for six speeches that are unrelated to environmental policy in Table D.5. We do not find any significantly negative effects and conclude that the overall

[25] For example, Central Banks "*need to be mindful of their effects on market functioning*" and are required to exert effort towards environmental concerns only "*within their traditional mandates*". Indeed, as our structural analysis in section 4 predicts, taking environmental concerns into account is not clearly motivated by the ECB mandate of price and financial stability.

impact of ECB environmental policy announcement is unlikely to be explained by a general negative trend in the greenium.

Table D.5: Yield Reaction around Non-Related ECB Policy Announcements

Date	**Speech**	**Yield Reaction**	**Standard Error**
01-10-2019	Mario Draghi (ECB)	2.64***	0.73
06-11-2019	Luis de Guindos (ECB)	1.70**	0.84
16-12-2019	Luis de Guindos (ECB)	4.25***	0.74
10-06-2020	Isabel Schnabel (ECB)	6.31***	2.64
27-08-2020	Philip R. Lane (ECB)	3.35**	0.95

Notes: We display the *average* yield over 20 days after minus *average* yield over 20 trading day before the policy announcement , relative to the matched control group (in basis points). Significance levels correspond to 10 % (*), 1 % (**) and 0.1 % (***) of Welch's t-test.