# Optimal Central Bank Collateral Policy for the Net Zero Transition*

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**Abstract**

We propose a quantitative DSGE model with environmental and financial frictions to asses how high emission taxes affect optimal central bank collateral policy. Central banks specify which assets banks can pledge as collateral to obtain short-term central bank funding. This is referred to as central bank collateral policy and involves a trade-off between supplying sufficient liquidity to banks and exposing itself to losses from accepting risky assets as collateral. Emission taxes affect this trade-off by reducing productivity in the non-financial sector, such that the corporate default rate increases and the *quality* of collateral deteriorates. High emission taxes also reduce investment, debt issuance and, hence, the amount of collateral available to banks. This decline in the *quantity* of collateral is more pronounced if emission tax shocks are very persistent or permanent. It is therefore optimal to relax collateral policy in the longer run, where the collateral *quantity* channel dominates, and to tighten collateral policy after a transitory emission tax shock, in order to offset the short run reduction in collateral *quality*.

*Keywords: Central Bank Collateral Policy, Climate Policy, Collateral Premia, Corporate Default Risk*

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# 1 Introduction

How does ambitious climate policy affect the optimal conduct of central bank collateral policy? Collateral policy specifies which assets banks can pledge to obtain central bank funding, for example corporate debt, and the valuation haircut applied to each asset. Central banks set their collateral policy wide enough to ensure that the available *quantity* of collateral allows banks to borrow from the central bank when necessary, but narrow enough to ensure that they are not overly exposed to low *quality* collateral, which might result in losses if a bank defaults on its central bank loans. This paper assesses the effect of ambitious climate policy on this basic collateral policy trade-off through the lenses of a quantitative DSGE model with environmental and financial frictions.

Higher emission taxes induce firms to reduce emissions, for example by engaging in costly emission abatement (Heutel, 2012) or by switching from an (at least currently) more productive fossil technology to a less productive clean one (Acemoglu et al., 2012). This affects macro-financial variables and optimal collateral policy through two distinct channels. On one hand, the policy-induced productivity decline renders some firms' indebtedness unsustainable. The corporate default rate increases and the *quality* of collateral deteriorates. On the other hand, firms reduce their investment in response to the policy-induced productivity decline, which is accompanied by a reduction in corporate debt outstanding and thus collateral available to banks. Climate policy affects both the *quantity* and *quality* of collateral. Whether collateral policy should be relaxed or tightened in response to emission taxes depends on the relative strength of both channels and is ultimately a quantitative question.

To answer this question, we build a quantitative DSGE model with two environmental frictions that shape optimal climate policy. Fist, firms emit carbon dioxide during the production process, which inflicts damages on the wider economy through a damage function (Nordhaus, 2008). This renders the competitive equilibrium socially inefficient and the government taxes emissions to address this externality. While emission taxes reduce emissions, they are also detrimental to productivity, output and investment. Optimal emission taxes trade off the benefits of emission reduction (lower emission damages) with its cost (lower productivity).

Additionally, there are three financial frictions which give rise to a collateral policy trade-off. First, firms finance their investment by issuing equity and by raising debt from banks. Debt financing incentives arise because firm managers are more impatient than households and thus have incentives to front-load dividend payouts. Debt issuance exposes firms to default risk, because firms receive uninsurable idiosyncratic productivity shocks and default on their debt if revenues fall short of the repayment obligation (Gomes et al., 2016). Firm revenues are lost in this case and the optimal corporate debt structure is determined by the benefits of debt issuance (dividend front-loading) and the resource costs of default. Second, banks are subject to uninsurable liquidity shocks, which are settled by borrowing from the central bank against collateral in the spirit of Bianchi and Bigio (2022) and De Fiore et al. (2024). Consistent with common practice by central banks, such borrowing is subject to eligibility standards, such as minimum requirements on ratings, and valuation haircuts which reduce the amount of funds banks can borrow per unit of corporate debt pledged. A lenient collateral policy (that sets low eligibility standards and valuation haircuts) improves welfare by increasing the *quantity* of collateral available to banks. Third, it is costly for the central bank to accept risky collateral, either because operating a collateral management system is costly (Bindseil and Papadia, 2006; Hall and Reis, 2015) or because they are averse to incurring losses from credit operations (Goncharov et al., 2023). A tight collateral policy (that sets high eligibility standards and valuation haircuts) improves welfare by ensuring a high *quality* of collateral. Optimal collateral policy balances this trade-off.[1]

An appealing feature of our model is that it accounts for behavioral responses to collateral policy by banks and firms, which go beyond these two rather mechanical effects. Specifically, the collateral eligibility of corporate debt gives rise to a collateral premium in the corporate debt price. The collateral premium increases with banks' liquidity needs and decreases with valuation haircuts. Since a high collateral premium reduces firms' overall financing cost and particularly the cost of debt financing, a lenient collateral policy stimulates investment, debt issuance and risk-taking (leverage) in the non-financial sector. These effects are consistent with the empirical literature on the transmission of collateral policy to the real economy, see for example Bekkum et al. (2018); Pelizzon et al. (2024); Huettl and Kaldorf (2024) and the references therein. This has a positive effect on output and further increases the *quantity* of collateral. At the same time, elevated risk-taking reduces the *quality* of collateral, implying larger resource losses from corporate default and larger collateral management cost incurred by the central bank. In the model, optimal collateral policy takes these endogenous responses into account.

Climate policy enters the picture because it affects firms' debt issuance and default risk, which are at the heart of the collateral policy trade-off. First, a shift to higher emission taxes reduces productivity because more resources are spent on emission abatement. Since the repayment obligation from corporate debt is predetermined in the short run, this forces some firms into bankruptcy and the aggregate default rate rises temporarily. This collateral *quality* channel is always at play, irrespective of the persistence of the emission tax increase. By contrast, the persistence has an effect on the collateral *quantity* channel. If emission tax increases are very persistent or even permanent, the expected return on capital is also depressed in future periods, so that firms reduce their investment. Importantly, emission taxes do not affect the relative benefits of debt over equity financing and firms' risk-taking decision is not affected by climate policy once firms can adjust their leverage. Consequently, debt issuance has to fall in order to keep the leverage ratio constant. This collateral *quantity* channel is particularly strong for highly persistent emission tax shocks or permanent changes to climate policy.

The model is calibrated to match important features of the corporate debt market, such as firms' leverage ratio, their default frequency, and the collateral premium on corporate debt. The parameterization of the climate block follows the environmental DSGE literature, while the parameters governing the real side are in line with the real business cycle literature. Lastly, we

[1] Tabakis and Tamura (2013) provide institutional background about the trade-offs faced by the Eurosystem when setting its collateral framework. Further details on the assessment of credit risks in the Eurosystem collateral framework are available under this link.

adopt an "inverse-optimality" approach to calibrate the central banks' collateral management costs, which is a common approach in the public economics literature going back to Christiansen and Jansen (1978), see Lockwood and Weinzierl (2016) and the references therein for recent applications of this principle. Specifically, we set the collateral management cost parameter such that the empirically observed collateral policy parameter of 65% is optimal from a utilitarian welfare perspective in the long run equilibrium with low emission taxes. To interpret this number correctly, one has to keep in mind that collateral frameworks are in practice a complicated mapping from very heterogeneous debt securities into minimum requirements on ratings and liquidity and valuation haircuts, from which our model abstracts. In practice, this would imply that banks can either use around one third of *all* outstanding corporate debt as collateral without any valuation haircut, or use all corporate debt with an uniform valuation haircut of 65%, or - more plausibly - a combination thereof. Nyborg (2017) provides a comprehensive discussion of the Eurosystem collateral framework, including eligibility criteria and valuation haircuts. Tabakis and Tamura (2013) provide a specific analysis of corporate debt as collateral.

Equipped with the calibrated model, we first consider the case of an unanticipated 10$/tCO2 emission tax shock. This reduces emissions by around six percent, but also induces GDP, consumption and investment to fall temporarily, quite similar to a negative productivity shock and consistent with empirical evidence (see Metcalf and Stock, 2023; Berthold et al., 2023; Kaenzig and Konradt, 2024; Konradt and Mangiante, 2025). The shock also increases the corporate default rate from 0.5% to 0.6% on impact, because higher taxes reduce firm revenues but do not affect their repayment obligations from legacy debt. Notably, the decline in collateral *quality* is only transitory and firms immediately adjust their leverage so that the corporate default rate reverts back to the steady state level one year after the shock. In the empirically plausible case of persistent emission tax shocks, expected productivity remains low for several years after the shock and investment declines. To keep leverage constant, this decline in investment goes hand in hand with a reduction in debt outstanding. Quantitatively, investment and the debt/GDP ratio decline by more than 0.5 percentage points, while the collateral/GDP ratio declines by around 0.2 percentage points.

If the central bank would keep collateral policy constant, the emission tax shock raises both the collateral management costs incurred by the central bank and banks' liquidity management cost. In our baseline calibration, it turns out to be optimal to increase the collateral parameter by 1.5 percentage points in response to an unanticipated 10$/tCO2 emission tax shock, which appears reasonable given its long run value of 65%. This tightening implies that the collateral *quality* channel dominates the *quantity* channel in the short run. In this model, a collateral policy tightening can be achieved either by raising valuation haircuts or by tightening eligibility criteria, such as minimum requirements on rating and liquidity, or a combination of both.

The preceding discussion already suggests that the collateral *quality* channel is active on impact, irrespective of the emission tax persistence. By contrast, the relevance of the collateral *quantity* channel is positively linked to the emission tax persistence, because the negative effects on investment and collateral availability are much stronger when productivity is persistently or permanently depressed. In our baseline calibration, emission taxes exhibits a sizable persistence.

They are still 5$/tCO2 above trend four years after the shock and the *quality* channel still dominates. Under i.i.d. tax shocks, this is even more pronounced and it is optimal to tighten collateral policy by more than six percentage points. For very persistent shocks the *quantity* channel dominates and it optimal to relax collateral policy, even though this reinforces the higher collateral management cost incurred by the central bank.

The same argument also applies to the long run implications of the climate policy *stance*. Once firms have time to adjust to a new climate policy regime, corporate default risk and the *quality* of collateral is not affected at all. Instead, only the *quantity* of collateral shrinks. To quantify the long run effects, we compute the equilibrium under current emission taxes of 23$/tCO2 and the equilibrium with the optimal emission tax of 117$/tCO2. The optimal collateral parameter declines from 65% to 59%, implying that firms can use more than 40% of all corporate debt outstanding as collateral. Reassuringly, the optimal collateral policy results are robust to various modifications of the climate block, such as higher or lower cost of switching to emission-free technologies or the extent of climate damages. There are also robust to reasonable variations in the targeted collateral premium, different assumptions on central banks' cost of accepting risky collateral and to adding nominal rigidities. Taken together our results suggest that it is a key challenge for central banks to distinguish between transitory and highly persistent (or even permanent) climate policy changes, as this distinction is a crucial determinant of the optimal collateral policy response.

**Related Literature** The interactions between central bank policies and the net zero transition have received considerable attention by policymakers recently. So far, the literature has focused on the potential role of (unconventional) monetary policy to initiate or at least support the transition to emission-free technologies. Ferrari and Nispi Landi (2023) show that green QE has a quantitatively negligible effect on aggregate emissions. Similarly, Giovanardi et al. (2023) find that green-tilted collateral policy has only a tiny effect on investment in the green sector and at the same time induces adverse side effects on financial markets. Our paper takes a different approach and quantitatively evaluates how collateral policy responds optimally when climate policy is implemented via emission taxes.

More generally, there is a rapidly evolving literature discussing how the net zero transition affects macro-financial variables that are relevant for monetary and macroprudential policies. Berthold et al. (2023) document that emission tax shocks tighten aggregate financial conditions. Carattini et al. (2023) propose a two-sector E-DSGE model to study how ambitious climate policy can lead to socially inefficient asset stranding and a credit crunch. Annicchiarico et al. (2023) study macroprudential policies if climate policy acts as an amplifier of business cycles. By contrast, McKibbin et al. (2020); Nakov and Thomas (2023); Fornaro et al. (2024); Economides and Xepapadeas (2025); and Giovanardi and Kaldorf (2024) study different aspects of climate change and monetary policy. While our paper uses a comparable quantitative environmental DSGE model, its key novelty is the analysis of optimal collateral policy in response to climate policy changes.

Our paper also contributes to the literature on central bank collateral policy. Koulischer and Struyven (2014) propose an analytically tractable model where banks have a funding choice between the private market and central bank borrowing. In their model, adverse shocks to the quantity or quality of collateral impair the transmission of conventional monetary policy. In a related setup, Cassola and Koulischer (2019) show how changes to central bank collateral policy affect banks' funding cost. By contrast, Ashcraft et al. (2011) set up a model in which central bank collateral policy affects macroeconomic outcomes by changing the prices of eligible assets. Bianchi and Bigio (2022) and De Fiore et al. (2024) study the macroeconomic implications of frictions on the interbank and sovereign bond markets. Our paper draws from this literature, in particular from using uninsurable bank liquidity shocks as modeling device, which provides an analytically and numerically tractable source of collateral demand. However, our focus is on corporate debt as collateral and how climate policy affects the collateral policy trade-off. However, it is worth noting that the "inverse-optimality" approach to calibrating the cost of accepting risky collateral can readily be applied to settings other than climate policy.

**Outline** The paper is structured as follows. Section 2 introduces a DSGE model with environmental and financial frictions. Its calibration is presented in Section 3. Section 4 considers the impact of emission tax shocks on macro-financial variables and the implications for optimal collateral policy. We turn to the long run effects of climate policy in Section 5. Section 6 demonstrates that the results are robust to varying key parameters governing environmental and financial frictions. Section 7 concludes.

## 2 Model

Time is discrete and denoted by $t = 0, 1, ...$ The representative household consumes a homogeneous final good, supplies labor to final good firms and saves in the form of bank deposits. Banks invest into defaultable corporate debt that is issued by a mass-one continuum of manufacturing firms, indexed by $j$. Manufacturers use capital to produce the intermediate good but generate carbon dioxide emissions as a by-product of their production. As customary in the real business cycle literature, investment is subject to adjustment frictions. Manufacturing firms sell their output to competitive final good producers who combine them with labor to produce the final good. The consolidated public sector consists of the central bank that extends intra-period loans to banks against eligible collateral and of a fiscal authority that levies emission taxes on manufacturing firms. For now, we abstract from nominal rigidities but show later that our quantitative results are robust to including price-setting frictions. Figure 1 presents the model structure in a stylized way.

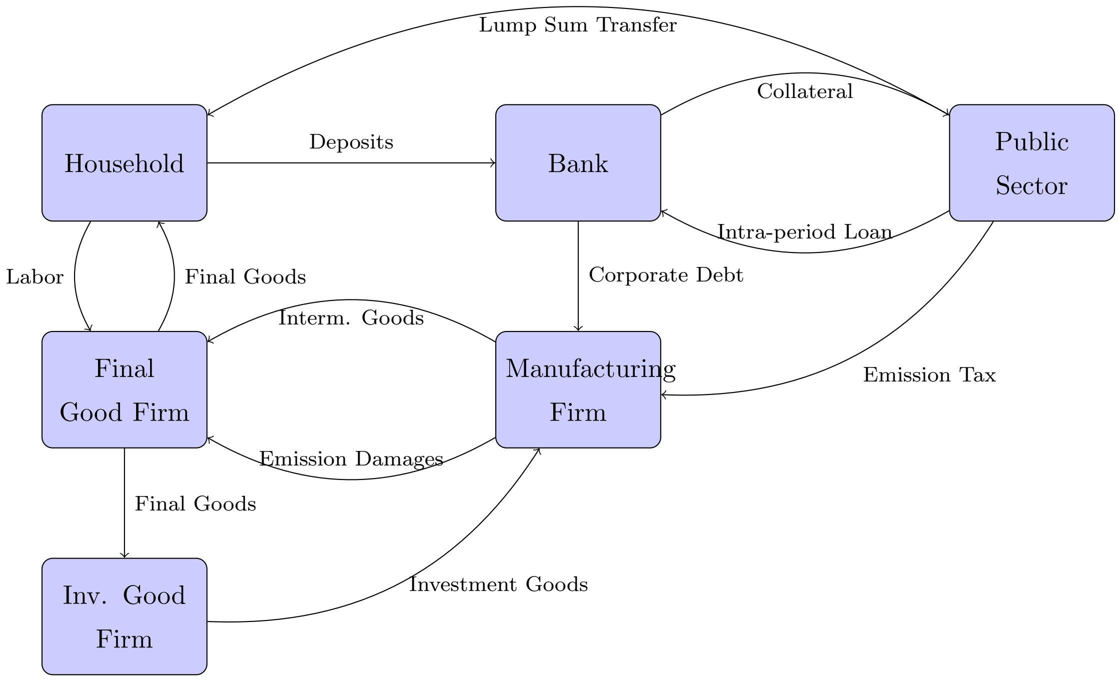


**Figure 1:** Model Structure

There are two frictions in the real sector that give rise to a climate policy trade-off that are directly inspired by the workhorse integrated assessment models used in the evaluation of climate policies. First, the emissions by the manufacturing sector are socially harmful in the sense that they reduce the productivity of the final goods sector (Nordhaus, 2008). As manufacturing firms do not internalize their adverse impact on productivity, emissions represent and externality and render the competitive equilibrium inefficient. To address this externality, emissions are taxed by the fiscal authority and manufacturing firms can reduce their emission intensity, defined as the ratio of emissions over production, at a cost (Heutel, 2012). These costs can be interpreted as productivity loss, which is consistent with recent empirical evidence by Ferriani et al. (2025) who show that green innovation is associated with a decline in aggregate productivity. Together, these two frictions shape the climate policy trade-off.

There are three frictions in the financial sector that shape the central bank collateral policy trade-off. First, each period is divided into two sub-periods and banks are subject to uninsurable idiosyncratic liquidity shocks in the first sub-period. Importantly, the corporate debt market and the goods market are only open in the second sub-period, so that banks settle liquidity shocks with the central bank using corporate debt as collateral (Bianchi and Bigio, 2022). We assume that all central bank borrowing is settled before the corporate debt market opens at the end of each period, so that banks are identical when trading with households and manufacturing firms. The within-period timing assumption is illustrated in Figure 2.

The possibility to use corporate debt as collateral implies that banks are willing to pay collateral premia on corporate debt and that the amount of corporate debt outstanding is directly welfare-relevant. Second, firms are subject to uninsurable productivity shocks, such that their

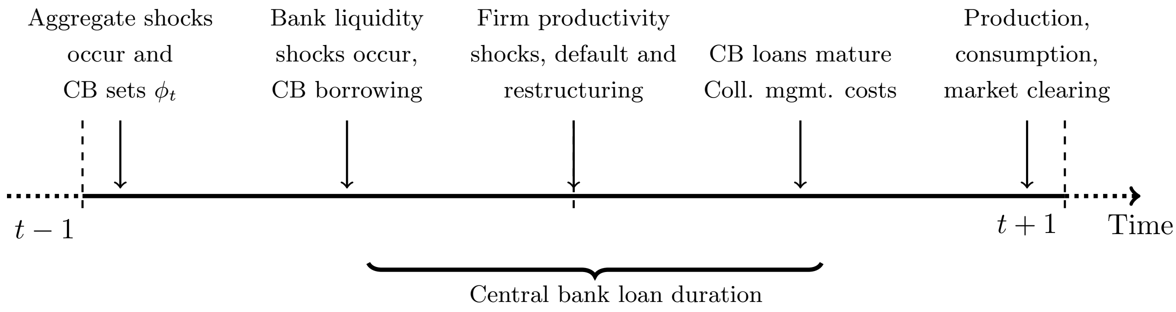


**Figure 2:** Within-period timing

debt is subject to default risk (Gomes et al., 2016). Third, corporate debt is risky when banks obtain intra-period loans from the central bank, such that the central bank is exposed to default risk from the pledged corporate debt. We assume that the exposure to risky collateral incurs an additional cost to the central bank (Bindseil and Papadia, 2006; Hall and Reis, 2015). Together these three financial frictions imply that both the *quantity* and *quality* of collateral affect welfare and the optimal collateral policy trade-off. We now describe each agent's decision problem in turn.

**Households** Households choose consumption $c_t$, labor supply $n_t$ and deposits $d_t$ to maximize lifetime utility. Deposits pay the real interest rate $i_t$, while the real wage is denoted by $w_t$. The parameter $\beta$ is the time-invariant discount factor. The maximization problem can be written recursively:

$$\begin{aligned} V_t = \max_{c_t, n_t} \quad & \log(c_t) - \zeta \frac{n_t^{1+\gamma}}{1+\gamma} + \beta \mathbb{E}_t \left[ V_{t+1} \right] \\ \text{s.t.} \quad & c_t + d_{t+1} = w_t n_t + (1 + i_{t-1}) d_t + div_t + T_t \ , \end{aligned} \tag{1}$$

where $div_t$ collects dividends from banks and firms. $T_t$ is a lump sum transfer from the government. Solving the maximization problem (1), we obtain an optimality condition for labor supply $c_t^{-1} w_t = \zeta n_t^{\gamma}$ and the Euler equation for deposits

$$1 = \mathbb{E}_t \left[ \Lambda_{t,t+1} (1 + i_t) \right] \ , \tag{2}$$

where $\Lambda_{t,t+1} \equiv \beta \frac{c_{t+1}^{-1}}{c_t^{-1}}$ is the household's stochastic discount factor (sdf).

**Banks** There is a continuum of perfectly competitive banks that collect deposits from households and hold corporate debt $b_t$ issued by manufacturing firms. The payoff per unit of debt $\mathcal{R}_t$ depends on firm decisions, in particular on corporate default, described below. The balance sheet identity is

$$(1 + i_{t-1}) d_t = \int_j \mathcal{R}_t^j b_t^j \ . \tag{3}$$

In the first sub-period period, banks draw uninsurable liquidity shocks that can be microfounded as (unmodeled) deposit withdrawals or similar demand for intra-period liquidity (Bianchi and Bigio, 2022). As the focus lies on central bank collateral frameworks, we assume that the banking sector is unable to settle all idiosyncratic liquidity shocks on the interbank market and there is demand for outside liquidity. Central bank lending is collateralized and the collateral value of each individual banks' debt portfolio, which is given by

$$\bar{b}_t = (1 - \phi_t) \int_j b_t^j \mathcal{R}_t^j dj \ , \tag{4}$$

places an upper limit on the funds that can be borrowed from the central bank. Here, $b_t^j$ is debt outstanding that firm $j$ has chosen in the previous period and $\mathcal{R}_t^j$ is the realized payoff per unit of debt issued by firm $j$, described below. $\phi_t$ is the central bank collateral parameter. Since intra-period loans are extended before firm-specific productivity shocks realize in the second sub-period, the collateral value of corporate debt is uncertain and the central bank is exposed to losses from liquidating risky collateral in the case of counterparty default. To cushion against such losses, which we describe in detail below, central banks in practice only accept sufficiently safe assets as collateral and also applies valuation haircuts to them. The policy parameter $\phi_t$ encompasses eligibility criteria and valuation haircuts in a tractable fashion. Specifically, $\phi_t = 1$ would correspond to the limit case were all assets receive a haircut of 100%, i.e. are ineligible, while $\phi_t = 0$ is the most lenient collateral framework possible under which banks could pledge the expected payoff from their entire corporate debt portfolio.

We assume that the share $\Pi \in (0, 1]$ of banks draws a liquidity deficit. Conditional on drawing a deficit, the demand of individual banks for central bank funding is denoted by $\lambda_t$ and we assume that is exponentially distributed with rate parameter $l_1$.[2] If the collateral value of a banks portfolio falls short of the demand for central bank funding, banks need to acquire funds from other, more expensive sources, for example from issuing equity and bank bonds, borrowing on the unsecured money market, or by attracting new deposits. We summarize the cost associated with all these (unmodeled) funding sources in the parameter $\zeta$.

The expected cost from liquidity management are hence obtained from evaluating the cdf of the exponential distribution at $\bar{b}_t$ and multiplying this by the probability of receiving the negative liquidity shock $\Pi$ and the cost of acquiring funding $\zeta$: $\mathcal{L}(\bar{b}_t) = \Pi \cdot \zeta \cdot \exp\{-l_1 \bar{b}_t\}$. Since our calibration strategy is tailored to macroeconomic moments, the parameter combination $\Pi \cdot \zeta$ is observationally equivalent and we re-parameterize the cost function as follows:

$$\mathcal{L}(\bar{b}_t) = \frac{l_0}{l_1} \exp\{-l_1 \bar{b}_t\} \ . \tag{5}$$

[2]Note that our calibration is annual, such that central bank lending in this model also includes long term refinancing operations. Funding needs can vary drastically between banks over the course of hone year, such that it is reasonable to assume that some banks actually exhaust their collateral over such an horizon. This would arguably be less likely over a daily horizon.

Bank dividends in period $t$ are reduced by the liquidity management cost:

$$div_t = \int_j \mathcal{R}_t^j b_t^j dj - (1+i_{t-1})d_t + d_{t+1} - \int_j q(\overline{m}_{t+1}^j) b_{t+1}^j dj - \mathcal{L}(\bar{b}_t) \tag{6}$$

We follow Cúrdia and Woodford (2011) and assume that banks can invest into corporate dent as long as their are able to repay depositors in expectations. Solving the shareholder value maximization problem subject to this solvency constraint $(1+i_t)d_{t+1} = \int_j \mathbb{E}_t[\mathcal{R}_{t+1}^j b_{t+1}^j]dj$ then yields a break-even condition for corporate debt:

$$q_t^j = \frac{\mathbb{E}_t[\mathcal{R}_{t+1}^j(1+(1-\phi_{t+1})\Omega_{t+1})]}{1+i_t} \,. \tag{7}$$

The expression $\Omega_{t+1} \equiv -\frac{\partial \mathcal{L}_{t+1}}{\partial \bar{b}_{t+1}}$ is a wedge in the debt pricing condition that stems from the collateral benefits that corporate debt provides to banks at the beginning of the next period, when bank-specific liquidity shocks occur, see again the timing assumption in Figure 2. This wedge is weighted by next period's collateral value of bonds $1-\phi_{t+1}$. It is worth noting that banks price default risk competitively. Banks take the future payoff $\mathcal{R}_{t+1}^j$ from investing into the debt of firm $j$ as given. In the context of firms that are sufficiently large to issue marketable debt that is eligible as collateral with the central bank, abstracting from relationship lending or bargaining power of banks vis-a-vis firms appears to be a reasonable assumption.

**Manufacturing Firms: Technology** Manufacturing firms use capital to produce the homogeneous intermediate good $z_t^j$ which they sell to final goods producers, taken as given the price $p_t^Z$. Their production function is linear and subject to idiosyncratic productivity shocks $z_t^j = m_t^j k_t^j$. The manufacturing sector generates socially harmful emissions $e_t = (1-\nu_t)\int_j z_t^j dj$ each period as a by-product of the production process. Period emissions accumulate into the stock of emissions according to

$$E_t = e_t + (1-\delta_E)E_{t-1} \,,$$

where $\delta_E$ is the decay rate of atmospheric carbon dioxide. Emission are taxed at a potentially time-varying rate $\tau_t$ and firms can reduce their emission intensity $\nu_t$ by paying a cost that is proportional to production $z_t^j$ (Heutel, 2012). The emission tax bill incurred by firm $j$ in period $t$ is given by $\tau_t(1-\nu_t)z_t^j$. Abatement costs are proportional to output and increase in the share of abated emissions $\frac{a_0}{a_1+1}\nu_t^{a_1+1} z_t^j$ with $a_0$, $a_1 > 0$.

Each period, firms choose their abatement effort to minimize the sum of the emission tax bill and abatement costs. Solving this static cost minimization problem yields the optimal abatement effort:

$$\nu_t^* = \left(\frac{\tau_t}{a_0}\right)^{\frac{1}{a_1}} \,. \tag{8}$$

We define the climate policy *compliance cost* $\xi_t$ per unit of output $z_t^j$ as:

$$\xi_t \equiv \tau_t \left(1 - \left(\frac{\tau_t}{a_0}\right)^{\frac{1}{a_1}}\right) + \frac{a_0}{a_1+1}\left(\frac{\tau_t}{a_0}\right)^{\frac{a_1+1}{a_1}} \ . \tag{9}$$

Note that under full abatement ($\tau_t = a_0$), the emission tax in the first part of equation (9) is zero, but firms still pay the abatement cost reflected in the second part of equation (9). The total abatement cost are a resource loss that enters the market clearing condition for final goods:

$$\mathcal{A}_t = \frac{a_0}{a_1+1}\left(\frac{\tau_t}{a_0}\right)^{\frac{a_1+1}{a_1}} \int_j z_t^j dj \ . \tag{10}$$

The pre-unit compliance cost (9) and the total abatement cost (10) are both increasing in the emission tax rate $\tau_t$. It is worth noting that one can also interpret $\nu_t^*$ as the share of manufacturing firms that uses a clean technology, see Kaldorf and Rottner (2025) for details on this interpretation.

**Manufacturing Firms: Financial Frictions** Capital is financed through a combination of equity, modeled as a transfer from households, and corporate debt $b_t^j$ to banks. We assume that firms are operated on behalf of the household by impatient managers with discount factor $\widetilde{\beta} < \beta$. The relative impatience of firm managers implies that they have a preference to front-load dividend payments. This generates a motive to raise additional funds from banks via debt issuance. As customary in the literature, aggregate risk is shared perfectly between the representative household and firm owners, such that firm-owners sdf is given by $\widetilde{\Lambda}_{t,t+1} \equiv \widetilde{\beta}\frac{c_{t+1}^{-1}}{c_t^{-1}}$.

Corporate debt is long term. A fraction $\chi$ of debt outstanding matures each period, while the remainder $1-\chi$ is rolled over at the current market price. After the realization of the idiosyncratic productivity shock, an individual firm defaults if revenues $(p_t^Z - \xi_t)m_t^j k_t^j$ fall short of the repayment obligation $\chi b_t^j$. The threshold productivity shock realization is defined as

$$\overline{m}_t^j \equiv \frac{\chi b_t^j}{(p_t^Z - \xi_t)k_t^j} \tag{11}$$

We assume that $m_t$ is log-normally distributed with standard deviation $\varsigma_m$ and mean $\mu_m = -\frac{1}{2}\varsigma_m^2$ to ensure that idiosyncratic productivity has an expected value of one. It is worth noting that an unanticipated increase in emission taxes increases the compliance cost $\xi_t$ and hence the threshold productivity shock below firms default. The associated increase in the *aggregate* default rate $F(\overline{m}_t)$ reflects the collateral *quality* channel.

Integrating out the idiosyncratic productivity shock, the expected payoff per unit of debt in the next period is given by

$$\mathcal{R}_{t+1}^j = \chi\big(1 - F(\overline{m}_{t+1}^j)\big) + (1-\chi)q(\overline{m}_{t+2}^j) \ , \tag{12}$$

where $F(\cdot)$ is the cdf of the log normal distribution. Note that $\mathcal{R}^j_{t+1}$ is still a random variable, as we have only integrated out the idiosyncratic shock in equation (12), but there is aggregate risk. Following Gomes et al. (2016), we assume that firms are restructured immediately, such that the credit status of individual firms does not enter as a state variable and the pricing of the non-maturing share of debt $(1-\chi)$ is unaffected by a default event. This appears to be a plausible assumption in an annual calibration. Together with the assumption that idiosyncratic productivity shocks are i.i.d., this implies that the mass of firms is constant over time, and it allows us to aggregate manufacturing firms into a representative agent and we drop the superscript $j$ in the following. It also implies that the shareholder value maximization problem of the representative firm reduces to the following two-period consideration:

$$\begin{aligned}\max_{k_{t+1},b_{t+1},\overline{m}_{t+1}} & -\psi_t k_{t+1} + q(\overline{m}_{t+1})\Big(b_{t+1}-(1-\chi)b_t\Big) \\ & + \mathbb{E}_t\Bigg[\widetilde{\Lambda}_{t,t+1}\cdot\Bigg\{\int_{\overline{m}_{t+1}}^{\infty}(p^Z_{t+1}-\xi_{t+1})mk_{t+1}-\chi b_{t+1}dF(m) \\ & \qquad + \psi_{t+1}(1-\delta_K)k_{t+1} + q(\overline{m}_{t+2})\Big(b_{t+2}-(1-\chi)b_{t+1}\Big)\Bigg\}\Bigg],\end{aligned}$$

subject to the default threshold (11) and the pricing schedule on corporate debt. The pricing schedule is obtained from substituting the debt payoff (12) into the bond pricing condition (7):

$$q(\overline{m}_{t+1}) = \mathbb{E}_t\left[\Big\{\chi\big(1-F(\overline{m}_{t+1})\big)+(1-\chi)q(\overline{m}_{t+2})\Big\}\cdot\frac{(1+(1-\phi_{t+1})\Omega_{t+1})}{1+i_t}\right].$$

As firm managers maximize dividends subject to a pricing *schedule* offered by banks, they take into account that a change in their debt issuance affects the debt price through the default probability in future periods. This is a common assumption in models with equilibrium default, see for example Khan et al. (2020) and Ottonello and Winberry (2020) for models with heterogeneous firms, or Gomes et al. (2016) and Jungherr and Schott (2022) for models with representative firms. Denoting the Lagrange-multiplier on the default threshold (11) by $\mu_t$, the first-order condition for debt issuance is

$$q(\overline{m}_{t+1}) - \mu_t\frac{\overline{m}_{t+1}}{b_{t+1}} = \mathbb{E}_t\left[\widetilde{\Lambda}_{t,t+1}\Big\{\chi(1-F(\overline{m}_{t+1}))+(1-\chi)q(\overline{m}_{t+2})\Big\}\right], \tag{13}$$

The LHS collects the additional dividends from issuing one unit of debt, where $\mu_t\frac{\overline{m}_{t+1}}{b_{t+1}}$ is a debt dilution term, while the RHS summarizes the expected repayment obligation $\chi(1-F(\overline{m}_{t+1}))$ and the rollover of the non-maturing share $(1-\chi)q(\overline{m}_{t+2})$.[3] Optimal investment balances the cost of purchasing capital in period $t$ (LHS) with its benefits, i.e. the re-sale value of undepreciated capital $\psi_{t+1}(1-\delta_K)$ and production revenues conditional on not defaulting $(p^Z_{t+1}-\xi_{t+1})\big(1-$

[3] The dilution term can be seen most clearly for one period debt, where equation (15) reduces to $\mu_t = -q'(\overline{m}_{t+1})b_{t+1}$.

$G(\overline{m}_{t+1})$):

$$\psi_t - \mu_t \frac{\overline{m}_{t+1}}{k_{t+1}} = \mathbb{E}_t \left[ \widetilde{\Lambda}_{t,t+1} \left\{ \psi_{t+1}(1-\delta_K) + (p^Z_{t+1} - \xi_{t+1})\big(1 - G(\overline{m}_{t+1})\big) \right\} \right] . \tag{14}$$

Furthermore, note that the expected compliance cost $\xi_{t+1}$ directly enters the first-order condition for capital by reducing the expected payoff from production revenues. The risk choice $\overline{m}_{t+1}$ solves

$$-\mu_t - q'(\overline{m}_{t+1})\Big(b_{t+1} - (1-\chi)b_t\Big) = \mathbb{E}_t \left[ \widetilde{\Lambda}_{t,t+1} \left\{ \Big(b_{t+2} - (1-\chi)b_{t+1}\Big) q'(\overline{m}_{t+2}) \frac{\partial \overline{m}_{t+2}}{\partial \overline{m}_{t+1}} \right\} \right] . \tag{15}$$

To fully characterize the solution to the firm problem, we take the derivative of banks' debt pricing condition (7) with respect to the risk choice:

$$q'(\overline{m}_{t+1}) = \mathbb{E}_t \left[ \left\{ -\chi F'(\overline{m}_{t+1}) + (1-\chi) \frac{\partial \overline{m}_{t+2}}{\partial \overline{m}_{t+1}} q'(\overline{m}_{t+2}) \right\} \cdot \frac{1 + (1-\phi_{t+1})\Omega_{t+1}}{1+i_t} \right] . \tag{16}$$

Crucially, the risk choice is not affected by emission taxes as the benefits (dividend front-loading) and costs (resource losses of corporate default) do not depend on $\xi_{t+1}$. The collateral *quantity* channel hence arises from the negative effect of $\xi_{t+1}$ on optimal investment (14) and the absence of an effect on $\overline{m}_{t+1}$, such that $b_{t+1}$ has to decline as well to satisfy the constraint (11).

It is also important to recognize that the risk choice in the following period $\overline{m}_{t+2}$ is relevant for the pricing of debt and for today's risk choice because debt is long term. The expression $\frac{\partial \overline{m}_{t+2}}{\partial \overline{m}_{t+1}}$ is the slope of the unknown policy function for the risk choice (Gomes et al., 2016). We solve for the slope by adding an additional equilibrium condition related to the Lagrange multiplier $\lambda_t$ on the default threshold $\overline{m}_{t+1}$. Re-arranging the first-order condition for debt issuance (13) for the multiplier $\mu_t$,

$$\mu_t = \frac{b_{t+1}}{\overline{m}_{t+1}} q(\overline{m}_{t+1}) - \mathbb{E}_t \left[ \widetilde{\Lambda}_{t,t+1} \frac{b_{t+1}}{\overline{m}_{t+1}} \left\{ \chi(1 - F(\overline{m}_{t+1})) + (1-\chi) q(\overline{m}_{t+2}) \right\} \right] ,$$

and further differentiating with respect to $\overline{m}_{t+1}$ yields

$$q(\overline{m}_{t+1}) + \overline{m}_{t+1} q'(\overline{m}_{t+1}) = \mathbb{E}_t \left[ \widetilde{\Lambda}_{t,t+1} \left\{ \chi(1-F(\overline{m}_{t+1})) + (1-\chi) \left( q(\overline{m}_{t+2}) + q'(\overline{m}_{t+2}) \overline{m}_{t+1} \frac{\partial \overline{m}_{t+2}}{\partial \overline{m}_{t+1}} \right) \right\} \right] , \tag{17}$$

which, together with the risk choice (15), jointly determines the multiplier $\mu_t$ on the default threshold $\overline{m}_{t+1}$ and the slope of the policy function for the risk choice. Intuitively, Equation (17) requires that the additional dividends financed by debt issuance in the *current* period (LHS) equal the discounted repayment obligation $\chi(1 - F(\overline{m}_{t+1}))$ and the effect on addition dividends financed by debt issuance in the *next* period (RHS). The expressions $\overline{m}_{t+1} q'(\overline{m}_{t+1})$ and $\overline{m}_{t+1} q'(\overline{m}_{t+2}) \frac{\partial \overline{m}_{t+2}}{\partial \overline{m}_{t+1}}$ are debt dilution terms that capture the decline in the debt price associated with more debt issuance. The aggregate losses from corporate default are given by

$$\mathcal{F}_t = \int_0^{\overline{m}_t} m_t k_t dF(m_t) , \tag{18}$$

i.e. current production by manufacturing firms, weighted by the aggregate productivity of all defaulting firms. This term directly enters the final goods market clearing condition as resource losses from corporate default.[4]

**Final Good and Capital Good Firms** There is a continuum of perfectly competitive final good producers that combine labor and intermediate goods in using a Cobb-Douglas technology, subject to aggregate productivity shocks

$$y_t = A_t \exp\{-\Psi_E e_t\} z_t^{\theta} n_t^{1-\theta} \; . \tag{19}$$

Here, $A_t$ is exogenous TFP and the term $\exp\{-\Psi_E E_t\}$ reflects damages from socially harmful emissions. Denoting the intermediate good price by $p_t^Z$ and normalizing the final good price to one, the first-order conditions are standard:

$$w_t = (1-\theta)\frac{n_t}{y_t} \; , \tag{20}$$

$$p_t^Z = \theta \frac{z_t}{y_t} \; . \tag{21}$$

The capital good that manufacturing firms acquire to build up their capital stock is produced by a representative investment good firms. The capital price is denoted by $\psi_t$. Capital good firms convert $\big(1 + \frac{\Psi_I}{2}(\frac{i_t}{i_{t-1}})\big)$ units of the final good into one unit of the investment good, such that the profit maximization problem

$$\max_{\{i_t^s\}_{t=0}^{\infty}} \; \mathbb{E}_0 \left[ \sum_{t=0}^{\infty} \beta^t \frac{c_t^{-\gamma_C}}{c_0^{-\gamma_C}} \left\{ \psi_t i_t - \left(1 + \frac{\Psi_I}{2}\left(\frac{i_t}{i_{t-1}} - 1\right)^2\right) i_t \right\} \right]$$

yields the first-order condition linking equilibrium investment to the price of capital:

$$\psi_t = 1 + \frac{\Psi_I}{2}\Big(\frac{i_t}{i_{t-1}} - 1\Big)^2 + \Psi_I\Big(\frac{i_t}{i_{t-1}} - 1\Big)\frac{i_t}{i_{t-1}} - \mathbb{E}_t\left[\Lambda_{t,t+1}\Psi_I\Big(\frac{i_{t+1}}{i_t} - 1\Big)\Big(\frac{i_{t+1}}{i_t}\Big)^2\right] \; . \tag{22}$$

**Public Policy and Closing the Model** Emission taxes are set exogenously and we allow for some degree of policy uncertainty as source of transition risk. This is operationalized by assuming that they follow an AR(1) process:

$$\tau_t = (1-\rho_\tau)\tau^{SS} + \rho_\tau \tau_{t-1} + \sigma_\tau \epsilon_t^\tau \; . \tag{23}$$

we consider a wide range of long run emission taxes up to their welfare-maximizing level in the quantitative analysis.

The central bank extends intra-period loans to banks at a zero interest rate against collateral. Following Bindseil and Papadia (2006) and Hall and Reis (2015), accepting risky debt as

[4]We implicitly assume that final good producers purchase $\int_0^\infty m_t dF(m_t) z_t = z_t$ intermediate goods each period, since the idiosyncratic productivity integrates to one by assumption, while the default costs are paid in terms of the final good. Alternatively, one could assume that intermediate good supply of defaulters is zero and assume away direct default costs entering the final goods market clearing condition. This would imply a very similar resource losses but introduce a slightly more cumbersome market clearing condition for intermediate goods.

collateral is costly for at least three reasons. First, central banks need to operate a credit risk management system, which is not directly related to their typical monetary policy activities. Second, in the case of a counterparty default, the central bank needs to liquidate the pledged collateral, potentially at a loss. Third, the central bank might generally be averse to losses, in particular from lending operations with the private sector (Goncharov et al., 2023). To operationalize these different microfoundations in a parsimonious way, we impose a quadratic cost function $\mathcal{C}_t$ from accepting risky collateral:

$$\mathcal{C}_t = c_0 \cdot \big(\mathcal{B}_t\big)^2 \quad \text{where} \quad \mathcal{B}_t \equiv \bar{b}_t \cdot F(\overline{m}_t) \ . \tag{24}$$

Its single argument $\mathcal{B}_t$ measures the exposure to losses from intra-period loans to banks and contains two parts. First, it depends as the potential size of loans banks can obtain, which is given by the eligible collateral $\bar{b}_t$. Second, it depends on the riskiness of the underlying collateral, i.e. the potential loan size is weighted by default rate $F(\overline{m}_t)$ of the pledged collateral. We focus on the contemporaneous default rate because central bank losses realize in the second sub-period, when the intra-period central bank loans mature.

We allow collateral policy to respond to emission taxes, which we operationalize this by a simple rule in the spirit of Schmitt-Grohe and Uribe (2007):

$$\phi_t = \phi^{SS} + \varphi_\tau \cdot \mathcal{S} \cdot (\tau_t - \tau^{SS}) \ . \tag{25}$$

Here, the auxiliary constant $\mathcal{S}$ converts model emission taxes, which are in abstract units, into US dollars per tonne of carbon dioxide (\$/tCO2) and makes them easily interpretable. We describe this conversion factor in the calibration section. It is worth noting that the model should be interpreted in trend-deviations, like all real business cycle models. An emission tax shock thus represents a temporary tightening or loosening of climate policy over the short to medium run, for example due to an election. The model is not intended to capture shorter run effects of climate policy such as the macro-financial effects of energy price volatility.

The model is closed by assuming that the central bank rebates its net profits to households in lump sum fashion. Market clearing for final goods requires:

$$y_t = c_t + i_t \cdot \Big(1 + \frac{\Psi_I}{2}\big(\frac{i_t}{i_{t-1}} - 1\big)^2\Big) + \mathcal{A}_t + \mathcal{C}_t + \mathcal{F}_t + \mathcal{L}_t \ . \tag{26}$$

From the goods market clearing condition and the final good production function, we observe that five frictions affect household consumption and welfare. On the real side of the model, these are emission damages and productivity losses associated with emission abatement. On the financial side, these are collateral management costs incurred by the central bank, resources losses from corporate default, and liquidity management costs incurred by banks. Lastly, exogenous TFP follows an AR(1) process in logs:

$$\log(A_t) = \rho_A \log(A_{t-1}) + \sigma_A \epsilon_t^A \ . \tag{27}$$

The model is solved and simulated using a second order approximation around the deterministic steady state. For the rest of the paper, we adopt a utilitarian welfare criterion, i.e. optimal policy maximizes households value function (1), evaluated at the competitive equilibrium for a given climate and collateral policy.

# 3 Calibration

Each model period corresponds to one year. Parameters governing households and the production technology are set to conventional values used in the real business cycle literature. To calibrate parameters concerning financial frictions, in particular debt issuance, default risk and the collateral premium, we follow recent estimates from the empirical literature. The collateral policy parameter in the equilibrium with low emission taxes is informed using an "inverse-optimality" approach that is increasingly common in the public economics literature. Lastly, parameters in the climate block are in line with smaller scale environmental DSGE models. We describe each group of parameters in turn. The full parameterization is summarized in Table 1.

**Households and Production Sector** As the calibration is annual, we set $\beta = 0.99$, implying a real risk-free rate of 1% p.a. The Frisch elasticity of labor supply $\gamma$ is set to its conventional value of one, while the weight on labor supply disutility $\zeta = 9$ is set such that it implies a steady state labor supply of $n^{SS} = 0.33$. The depreciation rate of physical capital $\delta_K = 0.1$ and the Cobb-Douglas coefficient in the final goods production $\theta = 1/3$ are set to standard values used in the real business cycle literature. Lastly, the investment adjustment cost parameter $\Psi_I = 0.5$ is commonly used in smaller scale DSGE models and delivers an empirically plausible excess volatility of investment over GDP, see the second row of Table 2.

**Financial Sector** Setting the maturity parameter to $\chi = 0.2$ implies an average debt maturity of five years. The curvature parameter $l_1$ in banks' liquidity management cost is normalized to one. We inform the scale parameter $l_0 = 0.004$ using recent empirical estimates of the collateral premium. The model-implied collateral premium is defined as the yield differential between the traded debt security and a counterfactual security with the same payoffs but without the collateral premium $(1 - \phi_{t+1})\Omega_{t+1}$. Similar to the price of the traded security (7), the counterfactual security is priced using the following recursion:

$$\widetilde{q}(\overline{m}_{t+1}) = \frac{\chi\big(1 - F(\overline{m}_{t+1})\big) + (1-\chi)\widetilde{q}(\overline{m}_{t+2})}{1 + i_t} . \tag{28}$$

Based on the random maturity structure of corporate debt, the yield to maturity for the traded security is defined implicitly through the relationship $q(\overline{m}_{t+1}) = \frac{\chi + (1-\chi)q(\overline{m}_{t+2})}{1+r_t}$. Note that the yield on the traded security contains both a default risk premium and a collateral premium. Re-arranging gives $r_t = \frac{\chi}{q(\overline{m}_{t+1})} - \chi$. In a similar fashion, we obtain the yield to maturity for the counterfactual debt security $\widetilde{r}_t = \frac{\chi}{\widetilde{q}(\overline{m}_{t+1})} - \chi$. The collateral premium is then defined as $\widetilde{r}_t - r_t$ and we target a value of 12 basis points, in line with recent empirical work by Bekkum et al.

| Parameter | Value | Source |
| --- | --- | --- |
| *Households* | | |
| Household discount factor $\beta$ | 0.99 | Standard |
| Labor supply curvature $\gamma$ | 1 | Frisch elasticity of one |
| Labor supply weight $\zeta$ | 8.5 | $n^{SS} = 0.33$ |
| *Technology* | | |
| Cobb-Douglas coefficient $\alpha$ | 1/3 | Standard |
| Capital depreciation rate $\delta_K$ | 0.1 | Standard |
| Inv. adj. parameter $\Psi_I$ | 0.5 | Standard |
| TFP persistence $\rho_A$ | 0.8 | Standard |
| TFP shock vol $\sigma_A$ | 0.01 | Standard |
| *Climate Block* | | |
| Abatement cost parameter $a_0$ | 0.03 | Full Abatement Tax 220$/tCO2 |
| Abatement cost parameter $a_1$ | 1.6 | Heutel (2012) |
| Emission damage parameter $\Psi_E$ | 3E-04 | 3% Damage/GDP under current tax |
| Emission decay $\delta_E$ | 0.01 | Consistent with Heutel (2012) |
| Emission tax level $\tau^{SS}$ | 0.003 | 23$/tCO2 global average tax |
| Emission tax persistence $\rho_\tau$ | 0.8 | Standard |
| Emission tax shock vol $\sigma_\tau$ | 0.00013 | Berthold et al. (2023) |
| *Financial Markets* | | |
| Share of maturing debt $\chi$ | 0.2 | Five year maturity |
| Firm-owner discount factor $\widetilde{\beta}$ | 0.975 | Target: Firm leverage 35% |
| St. dev. firm risk $\varsigma_m$ | 0.2 | Target: Firm default rate 0.5% |
| Liquidity management cost scale $l_0$ | 0.004 | Collateral premium 12bps |
| Liquidity management cost curvature $l_1$ | 1 | Normalization |
| Long run collateral parameter $\phi^{SS}$ | 0.65 | Eurosystem data |
| Collateral default cost scale $c_0$ | 360 | Inverse optimality of $\phi^{SS}$ |

**Table 1:** Baseline Calibration

(2018), Mesonnier et al. (2021), Pelizzon et al. (2024), or Huettl and Kaldorf (2024). We set the firm discount factor $\widetilde{\beta} = 0.975$ and the standard deviation of the idiosyncratic shock to $\varsigma_m = 0.2$ to jointly match a corporate leverage ratio of 35% and a default frequency of 0.5% per annum.

**Collateral Policy** The parameters related to central bank collateral policy, i.e. $c_0$ in the cost function of accepting risky collateral and the long run collateral policy parameter $\phi^{SS}$ are challenging to calibrate for two reasons. First, the collateral framework is a complicated mapping from a portfolio of very heterogeneous debt securities, such as bonds and loans, with different maturities and liquidity attributes, into the collateral value of this portfolio. The collateral value of any security is zero if it is ineligible and one if it can be pledged without a haircut. Since our macro model abstracts from such heterogeneity, $\phi^{SS}$ reflects the average haircut of the entire portfolio of corporate debt held by banks and is best interpreted as the collateral policy *stance*. Under this interpretation $\phi^{SS}$ encompasses both eligibility criteria such as minimum rating requirements, and valuation haircuts applied to eligible assets. This simplification allows us to solve for the optimal collateral policy *stance*, both in the long run and in response to persistent shocks.

We use publicly available macro-financial variables and apply institutional details from the Eurosystem haircut schedule to obtain a data moment for $\bar{b}_t$. Using Eurosystem data from 2015 to 2024, the ratio of total eligible assets over the balance sheet size of the banking sector corresponds to 45% on average.[5] This would imply a collateral parameter of $\phi^{SS} = 55\%$. As there are no consolidated data on average haircuts of the eligible collateral available, we add a discretionary valuation haircut of 10%, which reduces the collateral value of banks portfolio. As of 2025, bonds issued by non-financial corporation with a residual maturity of 5-7 years and a BBB-rating receive a 15% haircut in the Eurosystem collateral framework, while bonds with a A-rating or higher get a 5% haircut. Lower rated bonds are not eligible. Investment grade corporate bonds appear to be representative of the assets accepted as collateral by the Eurosystem and they are also similar to the corporate debt used in the model.[6] This leaves us with an average collateral parameter of $\phi^{SS} = 65\%$.

As a second challenge, the cost of accepting risky collateral by the central bank are unobservable and can not easily be inferred from macro-financial variables. To overcome this challenge, we take an "inverse optimality" approach inspired by the public economics literature that goes back at least to Christiansen and Jansen (1978). Recent examples include Lockwood and Weinzierl (2016), Chang et al. (2018), and Wu (2021) and we also refer to the references therein. A comparable approach is applied to central bank collateral policy by Giovanardi et al. (2023).[7] Under this "inverse-optimality" approach, the scale parameter in the collateral management cost (24) is set to $c_0 = 360$, such that the collateral policy parameter $\Phi^{SS}$ is optimal from a utilitarian welfare perspective. We show in Section 6 that the key quantitative results are robust to reasonable variations of $\phi^{SS}$ and $c_0$.

**Climate Block** Following Heutel (2012), the curvature parameter of the abatement cost function is set to $a_1 = 1.6$. The level parameter $a_0$ is set to 0.03 such that an emission tax of 230\$/tCO2 induces full abatement of emissions. This value is in line with Bilal and Kaenzig (2025) and Environmental Defense Fund (2021). To make the model-implied emission tax $\tau$ interpretable, it is converted into an emission price $p^e$, expressed in \$/tCO2, that can be related to the social cost of carbon. This price is related to the emission tax through $p^e \cdot \frac{e^{\text{world}}}{y^{\text{world}}} = \tau \cdot \frac{e^{\text{model}}}{y^{\text{model}}}$, such that we can convert the emission tax from model units into \$/tCO2 using the following

[5]For the size of the banking sector, we use total assets reported my all MFIs in the euro area, which is publicly available under this link. Eurosystem collateral data are available under this link.

[6]The haircuts applicable to different asset classes in the Eurosystem are available under this link.

[7]If the liquidity shock can be partially settled on the interbank market, the central banks' exposure would be smaller than $\bar{b}_t$. Under this interpretation, we would need to re-calibrate $c_0$. As the empirical strategy is based on eligibility premia and corporate debt supply at the macro level, this is observationally equivalent to the setting where all liquidity shocks are settled with the central bank directly.

| Moment | Model | Data | Source |
|---|---|---|---|
| Relative vol consumption $\sigma(c)/\sigma(y)$ | 0.83 | 0.96 | Euro area data |
| Relative vol investment $\sigma(i)/\sigma(y)$ | 1.73 | 1.90 | Euro area data |
| Correlation Consumption-GDP $corr(c, y)$ | 0.97 | 0.91 | Euro area data |
| Correlation Investment-GDP $corr(i, y)$ | 0.95 | 0.86 | Euro area data |
| Correlation Emissions-GDP $corr(e, y)$ | 0.55 | 0.76 | Euro area data |
| Correlation Default-GDP $corr(F(\overline{m}_t), y)$ | -0.44 | -0.55 | Kuehn and Schmid (2014) |
| Correlation Debt-GDP $corr(b_t, y_t)$ | 0.98 | 0.65 | Jungherr and Schott (2022) |

**Table 2: Model Fit:** All model-implied moments are computed based on a second-order approximation around the deterministic steady state and expressed in relative deviations from their steady state value. The long run emission tax is fixed at 23\$/tCO2 and the standard deviation of emission tax shocks is set to $\sigma_\tau = 0.0013$. All euro area data moments are based on real data, are logged and de-trended using an one-sided HP-filter with smoothing parameter of 6.25.

relationship:

$$p^e = \frac{y^{\text{world}}/y^{\text{model}}}{e^{\text{world}}/e^{\text{model}}} \cdot \tau \equiv \mathcal{S} \cdot \tau \; . \tag{29}$$

The conversion rate $\mathcal{S} = 7600$ is informed by the ratio of model output ($y^{model} = 0.521011$ in the long run equilibrium without emission taxes) to global GDP ($y^{world} = 105$ billion USD in 2022) and model emissions ($e^{model} = 1.41922$ in the long run equilibrium without emission taxes) to global emissions ($e^{world} = 37.5$ GtCO2 in 2022). The emission tax is set to 23\$/tCO2, which corresponds to the global average of emission taxes and emission permit prices in 2022. We set the standard deviation of emission tax shocks to $\sigma_\tau = 0.00013$, such that a one standard deviation shock corresponds to 1\$/tCO2. This value corresponds to the empirical estimate by Berthold et al. (2023). The persistence parameter in the emission tax process (23) is set to $\rho_\tau = 0.8$. This it would imply that four years after the shock, emission taxes are still above trend by 50% of the initial shock size. This appears to be a reasonable value given the typical length of electoral cycles. However, we vary the persistence parameter over a large grid in the quantitative analysis.

Lastly, we set the decay rate of carbon dioxide to $\delta_E$ to one percent per annum and the emission damage parameter is set to $\Psi_E$ = 3E-04, which implies a damage/GDP ratio of 3%, in line with comparable E-DSGE models such as Heutel (2012). As we show in Section 6, the magnitude of climate damages is not an important parameter as far as optimal collateral policy is concerned, though it is obviously pivotal for optimal climate policy.

**Model Fit** Table 2 illustrates that the model is capable of replicating key macro-financial dynamics that are important for the interplay of collateral and climate policies. Reassuringly, the excess volatilities of consumption and investment over GDP, as well as their correlations with GDP are in line with their data counterparts, suggesting that standard business cycle dynamics are captured well by the model. Emissions are strongly pro-cyclical, which is an important empirical finding in environmental macroeconomics, see also the discussion in Giovanardi and

Kaldorf (2024) and the references therein. By contrast, corporate default risk is counter-cyclical, i.e. it spikes during recessions, which is a well studied fact in macro-finance, see for example Kuehn and Schmid (2014) and the references therein. Corporate debt issuance is somewhat more pro-cyclical than in the data, as the model features only two exogenous shocks (TFP and emission taxes) that are directly linked to the production side and no financial shocks. Consequently, debt issuance closely follows investment demand, such that it is also highly correlated with output.

It is worth noting that neither the emission tax level nor the volatility of its stochastic component does not materially affect time series volatilities in the model. The main reason is that the variance of emission tax shocks is too small in practice (Berthold et al., 2023) to have a large effect on the second moments reported in Table 2. While Table 2 demonstrates the model's ability to replicate the dynamics of key macro-financial variables, we will show in the next section that the model also delivers empirically plausible effects of climate policy on macro-financial variables.

## 4 Optimal Collateral Policy in the Short Run

Using the calibrated model, we start with discussing the short run effect of climate policy on macro-financial variables and the implications for optimal collateral policy. As customary in the literature, short run changes to climate policy are operationalized using emission tax shocks. Figure 3 displays the impulse response of key welfare-relevant variables to a 10\$/tCO2 emission tax shock, where we pick an intentionally large shock size for illustrative purposes. The dotted blue line refers to the (constant) baseline collateral policy $\phi_t = \phi^{SS}$. Since our calibration is annual, the baseline persistence of $\rho_\tau = 0.8$ implies that the tax is 5\$/tCO2 above trend four years after the shock and still around 1\$/tCO2 above trend after ten years.

**Emission Tax Shocks** The top middle panel of Figure 3 shows that the emission tax shock induces a 6 percentage points increase in the share of abated emissions. The effect is closely aligned with empirical results by Metcalf and Stock (2023).[8] While this is clearly a desirable outcome from a climate policy perspective, the emission tax shock implies a sudden and persistent increase in the climate policy compliance cost $\xi_t$, see equation (9). This affects the default risk and debt issuance in the non-financial sector, which in turn determines the optimal collateral policy response.

On one hand, the top right panel shows that the corporate default rate raises by around 6 basis points, which can be interpreted as a materialization of transition risk. This directly follows from the default threshold (11), where legacy debt $b_t$ and capital $k_t$ are predetermined and the compliance cost $\xi_t$ enters the denominator. Consequently, emission tax shocks reduce the *quality* of collateral. Notably, the corporate default rate only increases on impact, as firms can immediately adjust their risk-taking behavior after defaulters are restructured and the corporate debt market opens.

[8] Their empirical approach considers a 40\$/tCO2 emission tax shock that covers 30% of all emissions. Since the emission taxes in our model apply to all emissions, the aggregate effects are of very similar magnitude.

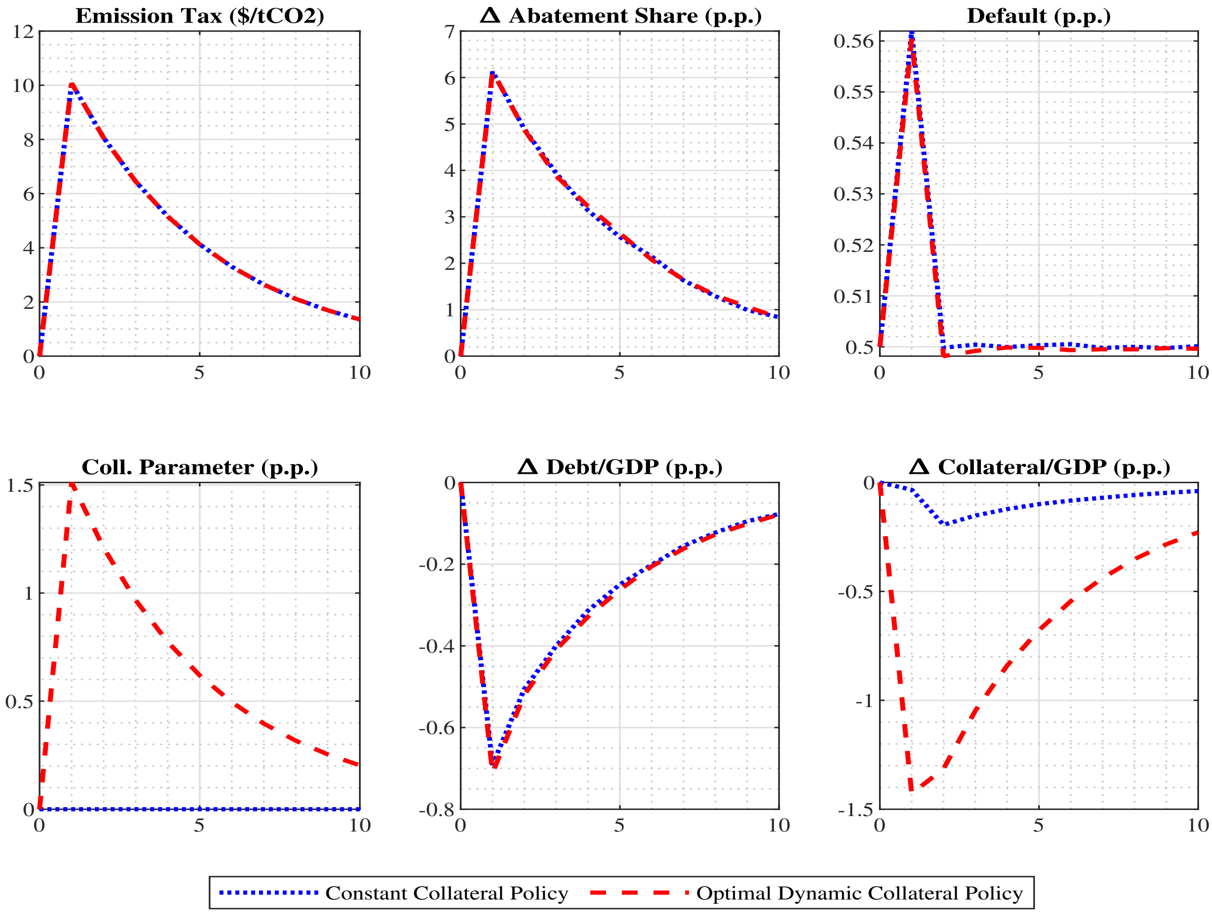


**Figure 3: IRF to 10$/tCO2 Emission Tax Shock**. This figure displays the impulse response to a 10$/tCO2 emission tax shock on key macro-financial variables. The top row displays the change in the share of abated emissions $\nu_t^*$ and the corporate default rate $F(\overline{m}_t)$, both expressed in percentage points. The bottom row shows the absolute change in the collateral parameter $\phi_t$ and changes in the debt and collateral to GDP ratio, all in percentage points. The dotted blue line refers to constant collateral policy, the dashed red line to optimal dynamic collateral policy.

On the other hand, the compliance cost remain high if the emission tax shock is persistent, which reduces firms' expected return on capital. It follows from the first-order condition for capital, equation (14), that firms invest less and that production in the manufacturing sector declines very persistently. These recessionary effects of climate policy surprises are well documented in the empirical literature (see for example Kaenzig and Konradt, 2024 or Konradt and Mangiante, 2025). We show the response of investment and manufacturing output in greater detail in Figure A.1 in Appendix A. As far as collateral policy is concerned, recall that the emission tax shock does not affect firms' risk choice, as $\xi_t$ does not enter equation (15) independently. Intuitively, emission taxes do not make debt financing more or less attractive to firms. Consequently, firms not only reduce investment, but also their debt outstanding. Quantitatively, the corporate debt/GDP ratio declines by more than half a percentage point, while the collateral/GDP ratio declines by around 0.2 percentage points. Emission taxes reduce the *quantity* of collateral. Naturally, the magnitude of this effect crucially depends on the persistence of the shock and we will revisit this issue at the end of this section.

**Collateral Policy Implications** How should collateral policy respond optimally to the negative collateral *quantity* and *quality* effects? We focus on optimal collateral policy rules, i.e. we maximize welfare over $\varphi_\tau$ in equation (25). For the baseline tax shock persistence of $\rho_\tau = 0.8$, the collateral parameter $\phi_t$ optimally increases by 1.80 percentage points on impact in response to a a 10$/tCO2 shock. By the design of the collateral policy rule, it remains above its steady state value until the emission tax has reverted back to trend. In practice, this can be achieved either by increasing valuation haircuts or by tightening eligibility criteria, such as minimum requirements on rating and liquidity, or a combination of both.

The dashed red line in Figure 3 displays the macro-financial implications of the optimal collateral policy adjustment to a 10$/tCO2 tax shock. Since collateral policy does not enter the first-order condition for abatement (8), the abatement share is unchanged (top middle panel). In a similar vein, the increase of the default rate on impact cannot be affected by collateral policy, as debt and investment were chosen in the previous period (top right panel). However, by tightening collateral policy, the default rate is slightly lower in the periods after the shock. Tighter collateral policy reduces banks' pricing of corporate debt, similar to a negative credit supply shock, so that temporarily tightened collateral policy provides (small) disciplining incentives to manufacturing firms by reducing the benefits from issuing debt. This is also reflected by the slightly more pronounced decline in the debt/GDP ratio. Mechanically, the collateral/GDP ratio is considerably smaller if collateral policy is tight. In Figure A.1 in Appendix A, we show that such a contractionary policy substantially reduces the collateral management cost incurred by the central bank, which goes hand in hand with a temporary increase in banks' liquidity management cost.

**The Role of Emission Tax Persistence** Is it always optimal to tighten collateral policy in the short run? An unexpected emission tax increase affects the corporate default rate on impact, which increases both the direct resource losses of default and central banks' collateral management cost. This collateral *quality* channel operates irrespective of the emission tax persistence and would prescribe a temporary tightening of collateral policy. The collateral *quantity* channel works in the opposite direction, as the decline in available collateral also has a negative welfare effect due to banks' liquidity management cost that directly enter the resource constraint. When is this channel active? The *quantity* of collateral hardly responds if shocks are i.i.d., since the expected emission tax in the period after the shock corresponds to the long run mean ($\xi_{t+1} = \xi$). It gains relevance as the persistence of the shock, and thus the persistence of compliance cost in future periods, increases.

The net effect is again a quantitative question. Figure 4 shows the quantitative implications of varying the persistence parameter $\rho_\tau$ in the emission tax process (23) and re-optimizing the response parameter $\varphi_\tau$ each time. For the case of i.i.d. shocks ($\rho_\tau = 0$), optimal collateral policy is very restrictive as $\phi_t$ increases by more than 6 percentage points in response to a 10$/tCO2 shock. The absence of a collateral *quantity* effect renders it optimal to drastically increase $\phi_t$. For very persistent shocks ($\rho_\tau > 0.95$), the negative collateral *quantity* effect exceeds the negative *quality* effects in welfare terms, such that it is optimal to temporarily relax

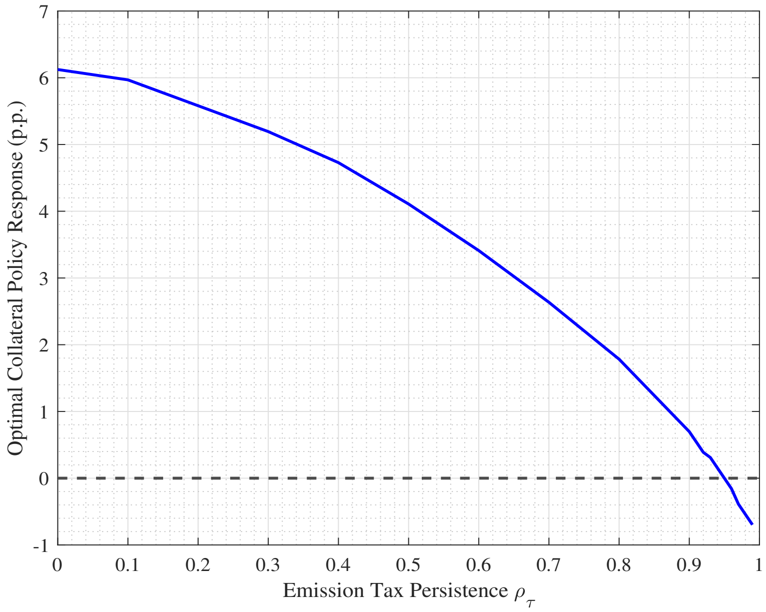


**Figure 4: Optimal Collateral Policy: The Role of Emission Tax Persistence**. This figure displays the optimal collateral policy response $\varphi_\tau$, expressed in percentage points, to a 10\$/tCO2 emission tax shock for different degrees of persistence $\rho_\tau$ in the emission tax rate. The long run tax is fixed at the current level of 23\$/tCO2.

the collateral framework. For empirically plausible levels of persistence, foe example our baseline value of $\rho_\tau = 0.8$, the effect is moderately positive. Differentiating between transitory and very persistent climate policy changes can be an important practical issue for policymakers.

# 5 Optimal Collateral Policy in the Long Run

In the previous section, we have seen that the persistence of climate policy is a key determinant for the optimal collateral policy response. If emission tax shocks are highly persistent, the collateral *quantity* channel dominates, as firms strongly reduce their debt outstanding, while the *quality* channel is relatively less relevant. Building on this observation, this section discusses the long run effects of emission taxes on the macroeconomy and before turning to the implications for the long run collateral policy trade-off.

**Long Run Effects of Emission Taxes** Figure 5 shows how increasing emission taxes from their current level of 23\$/tCO2 up to 140\$/tCO2 affects key welfare-relevant variables. The share of abated emissions $\nu_t^*$ is a key metric for the climate impact of any emission tax and is shown in the left panel of Figure 5. As customary in the literature (Golosov et al., 2014), we focus on the welfare-maximizing tax in the following, which is given by 117\$/tCO2. In this case, around 60% of emissions are abated. Alternatively under the interpretation of $\nu_t^*$ as technology choice, 60% of all firms operate the clean technology. The welfare gain of this policy amounts to around 0.4% in consumption equivalents. For further details, we refer to Figure A.2 in Appendix A, where we also display the effect of emission taxes on additional welfare-relevant variables. Emissions would continue to decline up to the full abatement tax level of 230\$/tCO2, but so would the productivity losses from abatement. Due to the convex functional form assumption on abatement costs (10), the marginal productivity losses increase in the emission tax, while the marginal climate benefit declines due to the exponential damage function specification.

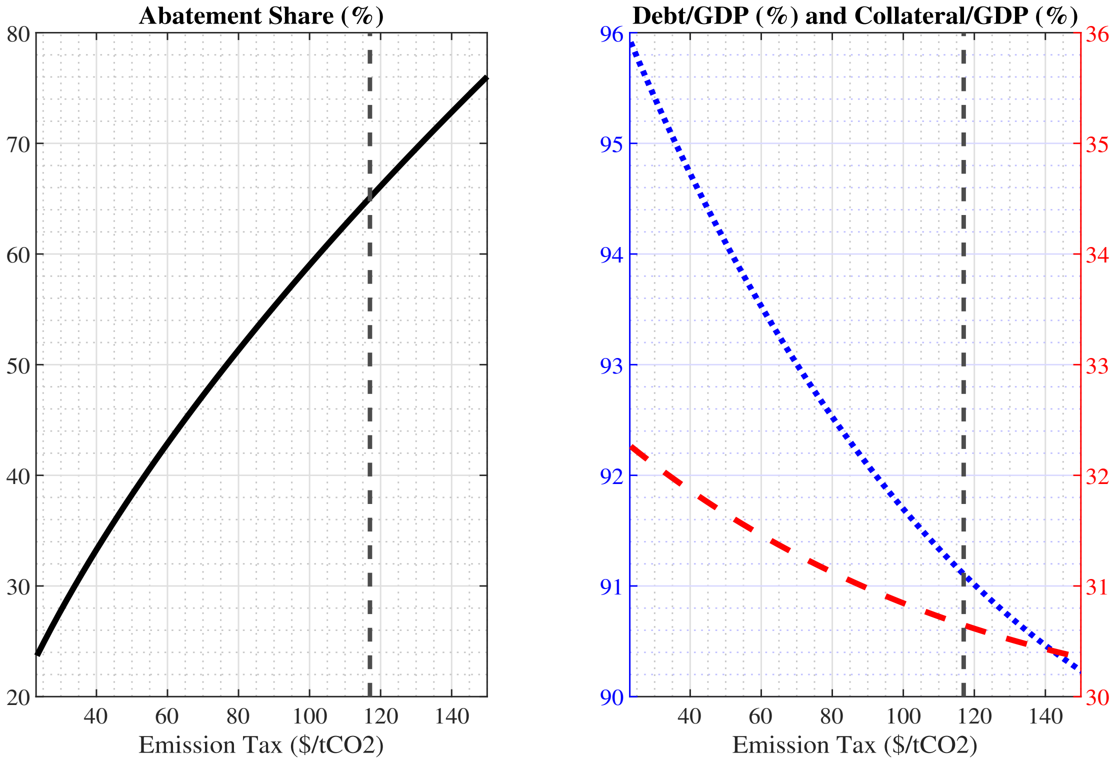


**Figure 5: Long Run Effects of Emission Taxes**. This figure displays the effects of long run emission taxes on the share of abated emissions $\nu_t^*$ (in %, left panel), the ratio of corporate debt $b_t$ to GDP (in %, left axis, dotted blue line in the right panel), and the ratio of collateral $\bar{b}_t$ to GDP (in %, right axis, dashed red line in the right panel). The emission tax on the x-axis is expressed in $/tCO2, its optimal level of 117$/tCO2 is indicated by the dashed black line.

The right panel of Figure 5 displays how changes in the emission tax affect debt issuance in the manufacturing sector and, thereby, the availability of collateral. The corporate debt/GDP ratio declines from 96% to around 90% (dotted blue line). The dashed red line shows that this induces the collateral/GDP ratio to decline from 32% to 30%. Since only around one third of all corporate debt can be pledged with the central bank ($\phi^{SS} = 0.65$), the effect of emission taxes on collateral is around one third of the effect of overall corporate debt. Ambitious climate policy has a sizable negative collateral *quantity* effect. It turns out that only this collateral *quantity* effect is present in the long run. By contrast, the corporate default rate and the *quality* of collateral are independent of the climate policy regime in the long run, which is again an implication form the risk-taking decision (15), which only depends on the benefits of debt issuance (front-loading of dividend payouts) and its costs (resources losses from corporate default) and not on the emission tax level.

While firms do not adjust their risk-taking, the emission tax directly affects the first-order condition for investment (14). Recall that higher taxes increase the climate policy compliance cost $\xi_{t+1}$ that and thereby the revenues from selling output. Similar to a secular productivity decline, this reduces the incentives to accumulate capital. Quantitatively, capital declines by around five percent under the optimal emission tax of 117\$/tCO2, relative to the current tax of 23\$/tCO2. This is accompanied by a proportional reduction in loan demand, such that firms indebtedness and default risk remains constant. This is shown in greater detail in Figure A.2, where we also report the effects of emission taxes on all welfare-relevant cost terms.

**Long Run Effects of Collateral Policy** To understand the implications of climate policy for optimal collateral policy, we first show how the collateral parameter $\phi^{SS}$ affects the macroeconomy. The dashed red line in Figure 6 refers to the case with status quo emission taxes (23\$/tCO2). The top left panel shows the amount of available collateral $\bar{b}_t = (1 - \phi_t)\mathcal{R}_t b_t$, which is directly affected by modification to the collateral parameter. For instance, setting $\phi^{SS}$ = 90% would imply a collateral/GDP ratio of slightly less than 10%. As we have discussed in the calibration section, changes to the collateral policy *stance* could be implemented by only allowing the 10% least risky corporate debt securities as collateral without applying any valuation haircut, by accepting all corporate debt but attaching an haircut of 90% to all of them, or any combination of these two extremes.

The top right panel demonstrates that lenient collateral policy incentivizes firms to issue more debt, which translates into higher corporate default rates, see the bottom left panel. These endogenous responses by the manufacturing sector follow from the first-order condition for debt issuance (13) and its risk choice (15). A lower collateral haircut parameter $\phi^{SS}$ increases banks' valuation of corporate debt. This works like an increase in credit supply which, in our model, corresponds to a shift in the debt price schedule. Firms respond to this credit supply expansion by increasing their debt issuance, investment, and risk-taking. We also refer to Giovanardi et al., 2023 for a more detailed discussion of this effect and to Bekkum et al. (2018) for empirical evidence of this effect.

If collateral policy is lenient, higher default rates increase both the direct resource losses from corporate default and the collateral management cost incurred by the central bank, which is detrimental to welfare. At the same time, this increases collateral availability to banks, inducing a decline in liquidity management costs and an increase in welfare. Figure A.3 in Appendix A shows in more details how collateral policy affects these cost functions. As the dashed red line in the bottom right panel of Figure 6 shows, the baseline calibration implies that a collateral parameter of $\phi^{SS} = 65\%$ is optimal in the long run with low emission taxes, by the very definition of the "inverse-optimal" calibration strategy.

The effects of collateral policy on investment and GDP appear to be quite small when compared to the effects of monetary policy shocks (Smets and Wouters, 2007). However, one has to keep in mind that the collateral premium is macroeconomically relevant but comparatively modest. Specifically, it is calibrated to 12bps in the baseline calibration, but we show in Section 6 that the implications of emission taxes for collateral policy are very similar also for a larger collateral premium of 25bps. As the top right panel of Figure A.3 shows, the collateral premium in the debt pricing condition expands to around 25bps collateral policy is very lenient ($\phi^{SS} < 10\%$), while it vanishes if collateral policy is maximally tight ($\phi^{SS}$ approaching 100%).

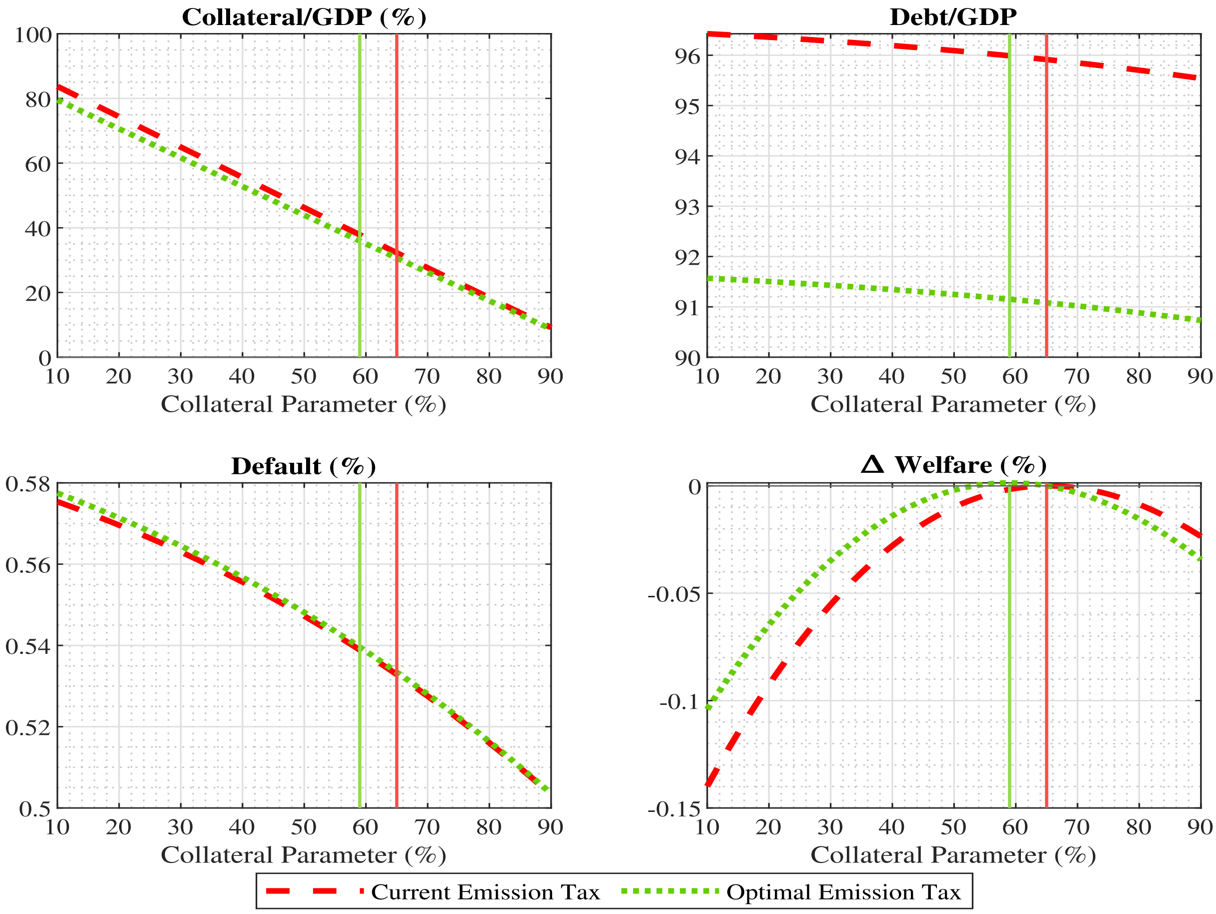


**Figure 6: Optimal Long Run Collateral Policy**. This figure displays the effects of varying the collateral parameter $\phi^{SS}$ on the ratio of collateral $\bar{b}_t$ to GDP (in %, top left), the ratio of corporate debt $b_t$ to GDP (in %, top right), the corporate default rate $F(\overline{m}_t)$ (in percentage points, bottom left). In the bottom right, we express the welfare gain of collateral policy relative to the baseline collateral parameter $\phi^{SS} = 65\%$ in consumption equivalents:

$$gain^{CE,policy} \equiv \exp\{(1-\beta)(V^{policy} - V^{baseline})\} - 1 \, .$$

The dashed red line refers to the current 23\$/tCO2 emission tax, the dotted green line to the optimal emission tax of 117\$/tCO2. The collateral parameter $\phi^{SS}$ on the x-axis is expressed in percentage points.

Against this background, the macro and welfare implications of changes to collateral policy appear quantitatively reasonable.

**Collateral Policy Implications** Having discussed how the different environmental and financial frictions shape optimal emission taxes and optimal collateral policy, respectively, we now turn to their interaction. How do emission taxes affect macro-financial variables which are relevant for optimal collateral policy in the long run? The dotted green line in Figure 6 reflects the optimal emission tax of 117\$/tCO2. Comparing this to the dashed red line in the top panel, we see that collateral policy naturally has a very similar mechanical impact on the collateral/GDP ratio and also induces a very similar endogenous corporate debt supply response. The key difference is that the level of corporate debt/GDP is much lower under optimal taxes.

We have seen that climate policy has no long run impact on the default rate, see Figure A.2.

Hence, the *quality* of collateral is unchanged. At the same time, emission taxes reduce the *quantity* of collateral, as we have discussed for the case of transitory emission tax shocks. As the bottom right panel of Figure 6 demonstrates, the welfare optimum is reached for a smaller collateral policy parameter of $\Phi^{SS} = 59\%$. This is a sizable effect, as it would imply that an additional 6% of *all outstanding* corporate debt are made eligible as collateral, or that all eligible assets receive a drastically lower haircut, or a combination thereof. Again, our macroeconomic framework does not provide guidance whether this should be implemented via lenient eligibility criteria or lower valuation haircuts.[9]

An interesting further implication of this model is that the welfare relevance of collateral supply also feeds back into optimal climate policy. Intuitively, welfare maximizing emission taxes take into account that they inflict an additional welfare loss by reducing collateral supply. This resembles the findings of Doettling and Rola-Janicka (2023), who show that optimal emission taxes decline in the extent of financial frictions. To approximate of the effect size in our model, we re-optimize the optimal emission tax if the collateral framework is adjusted to its more lenient long run level of $\phi^{SS} = 59\%$. In this case, the optimal emission tax rises slightly from 117\$/tCO2 to 118\$/tCO2. The effect is not large, which should not come as a surprise, given the smaller welfare relevance of financial frictions in comparison to climate damages. This "facilitator role" of appropriate collateral policy also resonates with Oehmke and Opp (2025), who derive a similar result in a model of bank capital regulation.

# 6 Robustness

This section presents several robustness checks for the quantitative results presented in Section 4 and Section 5. First, we discuss the role of emission damages and abatement costs, i.e. the two key parameters governing environmental frictions. The second set of robustness checks concerns macro-financial parameters. We consider a higher target for the collateral premium, which is supported by some empirical studies, and for the central bank cost of accepting risky collateral, which we calibrated using an "inverse-optimality" approach. Lastly, we extend the model by nominal rigidities in order to shed light on the plausibility of the model's short run dynamics in response to emission tax shocks.

**Emission Damages** As a first robustness check, we consider larger emission damages, which are subject to considerable uncertainty in practice (Friedl et al., 2023). Specifically, we double the emission damage parameter to $\Psi_E = 6\text{E-}04$, so that it is optimal to increase the emission tax to the full abatement level (230\$/tCO2). We slightly recalibrate the central bank cost function parameter to $c_0 = 290$ which ensures that $\phi^{SS} = 65\%$ is optimal under low emission taxes. Since full abatement taxes are optimal under this larger damage parameter, the compliance cost $\xi_t$ are substantially larger as well. This induces a comparatively stronger decline in investment and debt outstanding, such that it is optimal to relax collateral policy by more ($\phi^{SS} = 50\%$),

[9] The effects for the (sub-optimal) full abatement tax are slightly larger, as collateral supply declines even further in this case. We obtain a slightly lower optimal long run collateral parameter $\Phi^{SS} = 58\%$ in this case.

see Table 3. By contrast, the optimal response $\varphi_\tau = 1.85\%$ hardly changes compared to the baseline, since short run dynamics are not materially affected by long run emission damages.

**Abatement Cost** There is also substantial uncertainty surrounding the costs of abating emissions and adopting emission-free technologies. In the baseline parameterization, we have calibrated the parameter $a_0$ based on abatement cost curves applicable to the US and Europe following Bilal and Kaenzig (2025). The resulting parameter might underestimate the abatement costs at a global level, in particular in economies that are currently relying on fossil energy heavily. Likewise, they might overestimate the abatement cost in the presence of technological change directed at emission reducing activities. Therefore, we provide a robustness check of the optimal collateral policy results with respect to different abatement cost levels.

Choosing a higher abatement cost parameter $a_0 = 0.04$ implies that a much larger emission tax of 310\$/tCO2 is necessary to induce net zero emissions. However, the considerably larger abatement cost reduce the *optimal* emission tax to 61\$/tCO2, as the point where marginal abatement cost equal marginal emission damages is reached for a much lower $\nu_t*$. It turns out that this diminishes the long run compliance cost $\xi_t$ in the first-order condition for investment (14), such that capital and debt outstanding decline less in the long run equilibrium compared to the baseline calibration. The optimal long run collateral parameter under the optimal emission tax is slightly larger at $\phi^{SS} = 62\%$, see the middle panel of Table 3. Conversely, the optimal collateral policy response to emission tax shocks is larger due to a more pronounced collateral *quality* channel. There is a larger impact effect on corporate default risk and the central banks' collateral management cost, because compliance cost $\xi_t$ are also more responsive to a 10\$/tCO2 emission tax shock.

Conversely, setting $a_0 = 0.02$ strongly reduces the marginal cost of abatement and the optimal emission tax is much larger at 155\$/tCO2, which induces net zero emissions. Quantitatively, the wedge $\xi_t$ under optimal climate policy is quite similar to the baseline calibration so that the optimal long run collateral policy parameter $\phi^{SS}$ does not change visibly. However, a 10\$/tCO2 tax shock has a smaller effect on the contemporaneous default frequency, such that the collateral *quality* channel is muted in comparison to the collateral *quantity* channel. This renders a weaker response parameter $\phi_\tau$ optimal.

**Collateral Premium** In the baseline calibration, we used a collateral premium of 12bps, which is consistent with recent empirical literature. Some papers, however, find a considerably larger collateral premium. Using Chinese data, Chen et al. (2023) and Fang et al. (2025) report a collateral premium around 50bps. In the fourth row of Table 3, we show that the implications of emission taxes for optimal collateral policy are robust to increasing the scale parameter of liquidity management costs to $l_0 = 0.008$, which implies a collateral premium of 25bps, which strikes a middle-ground between the high premium found in Chinese data and the smaller estimate based on euro area data. As before, we adjust the scale parameter of collateral default costs to render the long run collateral parameter $\phi^{SS} = 65\%$ optimal. This is the case for $c_0 = 560$.

| | Optimal $\phi^{SS}$ with current tax | Optimal $\phi^{SS}$ with optimal tax | Optimal response $\varphi_\tau$ to 10\$/tCO2 tax shock |
|---|---|---|---|
| Baseline calibration | 65 | 59 | 1.80 |
| *Climate parameters* | | | |
| Higher damages $\Psi_E = 6\text{E-}04$ | 65 | 50 | 1.85 |
| Lower abatement cost $a_0 = 0.02$ | 65 | 59 | 1.55 |
| Higher abatement cost $a_0 = 0.04$ | 65 | 62 | 1.90 |
| *Macro-financial parameters* | | | |
| Higher coll. premium $l_0 = 0.008$ | 65 | 59 | 1.50 |
| Lower coll. mgmt. cost $c_0 = 300$ | 60 | 53 | 2.00 |
| Higher coll. mgmt. cost $c_0 = 420$ | 70 | 64 | 1.55 |
| Nominal rigidities | 65 | 59 | 1.05 |

**Table 3: Robustness.** This table reports the optimal long run collateral parameter in the long run equilibrium with small emission taxes (23$/tCO2, first column) and under optimal emission taxes (second column) for various parameter changes and the extension with nominal rigidities. The third column reports the optimal collateral policy response $\varphi_\tau$ to a 10$/tCO2 emission tax shock as defined in equation (25), based a long run tax of 23$/tCO2. All results are based on long simulations of a second order approximation around the deterministic steady state. The long run collateral parameter $\phi^{SS}$ and its response to a 10$/tCO2 emission tax shock $\varphi_\tau$ are expressed in percentage points.

Naturally, changes to parameters in the financial sector also affect the climate policy trade-off. A larger collateral premium allows firms to permanently increase investment, which in turn has a positive effect on GDP and emission damages. The optimal emission tax is slightly larger in this case at 124$/tCO2, compared to 117$/tCO2 in the baseline. Under optimal emission taxes, the optimal collateral parameter does not visibly change from the baseline calibration with low emission taxes. The dynamic response $\varphi_\tau = 1.5\%$ is less pronounced than in the baseline. Tightening collateral policy too much would induce a sub-optimally large increase in banks' liquidity management cost after an emission tax shock.

**Collateral Management Costs** In order to obtain a data moment for the long run collateral parameter $\phi^{SS}$, we have used the ratio of all eligible assets in the Eurosystem over the size of the euro area banking sector. While this approach appears to the most pragmatic way to aggregate the fairly complicated Eurosystem collateral framework into a single number that can be related to macro-financial variables, it is naturally subject to certain biases that could go in either direction.

On one hand, the numerator in the ratio could overstate the amount of eligible assets, as we have uniformly reduced the value of all eligible assets reported by the ECB by a 5% valuation haircut. This would corresponded to the valuation haircut of high quality corporate bonds with a five year residual maturity. In practice, a sizable share of eligible assets is riskier than that, either because they are not traded on liquid markets or have a lower rating. To show that the results are robust to such a bias, we recalibrate $c_0 = 420$ which ensures that $\phi^{SS} = 70\%$ is optimal in the long run equilibrium with small emission taxes. Note that collateral premia would be slightly smaller in this situation due to the higher collateral parameter, which endogenously reduces debt issuance, investment and real activity. The optimal collateral parameter under optimal taxes is 64% and the difference of six percentage points coincides with the optimal reduction in the baseline calibration.

On the other hand, the denominator, i.e. the total assets in the banking sector, could be biased upwards as well if banks extend credit to each other, for example by holding bonds issued by other banks. To take this potential bias into account, we set $\phi^{SS} = 60\%$ and again recalibrate $c_0 = 300$ to render $\phi^{SS}$ optimal. Naturally, the collateral premium is slightly larger in this case. Again, the optimal collateral policy relaxation is very similar to the baseline and $\phi^{SS}$ declines by seven percentage points.

While the robustness checks of our main results with respect to changes in the parameter $c_0$ are motivated by potential measurement error, they also provide a certain robustness with respect to the "inverse-optimality" approach to calibrating the parameter $c_0$. Indeed, our quantitative DSGE model does not assess the optimality of the status quo collateral framework. We are rather interested in the optimal *response* of collateral policy to changes in emission taxes, which is very robust to the initial collateral framework imposed in the quantitative analysis.

**Nominal Rigidities** Up to this point, we have studied the collateral policy trade-off in a real model. While the basic trade-off between collateral *quantity* and *quality* is arguably unaffected by nominal rigidities in the long run, two aspects are worth noting. First, corporate debt is usually in nominal terms and, hence, default risk and debt issuance are affected by inflation. Second, the empirical literature has robustly found that emission taxes are inflationary (Berthold et al., 2023; Kaenzig and Konradt, 2024; Konradt and Mangiante, 2025). This is particularly relevant for the collateral *quality* channel, since firms as issuers of nominal debt benefit from short run inflation and might default less often in response to an emission tax shock. Gomes et al. (2016) show that in the presence of long-term debt (like in our model), the reduction of the real debt burden to negative and inflationary shocks (such as emission tax shocks) softens the effects on investment, production and, hence, debt issuance. In the context of collateral policy, this channel might mitigate the collateral *quantity* channel.

To quantify the relevance of nominal debt, we augment the model by monopolistic competition, price adjustment frictions (Rotemberg, 1982) and a Taylor rule for the nominal interest rate. This also affects the pricing of corporate debt and the first-order conditions for debt issuance and the risk choice. The analytical steps and details on the calibration are deferred to Appendix B. As the last row of Table 3 shows, the optimal reduction of $\phi^{SS}$ is identical to the baseline, since nominal rigidities by design have no long run effects. In the short run, we observe a much weaker response to the same emission tax shock, consistent with the notion that nominal rigidities substantially mitigate the collateral *quality* channel and the central bank finds it optimal to shift the policy response in favor of the collateral *quantity* channel.

# 7 Conclusion

We propose a quantitative DSGE model with environmental and financial frictions to evaluate how climate policy affects optimal central bank collateral policy. Optimal climate policy is determined by climate damages and productivity losses associated with emission abatement or a switch to emission-free technologies. Optimal collateral policy balances the positive effects of increasing collateral supply to banks with losses from exposure to risky collateral incurred by the central bank and adverse risk-taking effects on the corporate debt market. We calibrate this model to macro-financial variables from the Eurosystem. While most frictions and their quantification are in line with the macro-climate and the macro-finance literature, we use an "inverse optimality" approach to calibrate the central bank's cost of accepting risky collateral in the equilibrium with current emission taxes. The optimal collateral policy parameter can be interpreted as average haircut on all corporate debt outstanding and corresponds to 65% in the baseline calibration.

We use the calibrated model as a laboratory and show that climate policy affects the collateral policy trade-off through two distinct channels. First, higher emission taxes decrease productivity, which increase the corporate default frequency in the short run. This effect is not present in the long run, when firms have time to adjust their investment, debt issuance and leverage. Consequently, climate policy only temporarily decreases the *quality* of collateral. Second, emission taxes do not change the benefits of issuing debt or equity, i.e. they do not affect firms' optimal leverage. The reduction in investment associated with the productivity decline hence goes hand in hand with a reduction in debt issuance. Climate policy decreases the *quantity* of collateral and the persistence of climate policy crucially determines which of the two effects dominates.

It turns out that the collateral *quality* channel dominates for transitory emission tax shocks if they have an empirically plausible persistence. In the baseline calibration, for instance, it is optimal to temporarily tighten collateral policy in response to a 10$/tCO2 emission tax shock by almost two percentage points. This is sizable, given that the long run collateral parameter is calibrated to 65%. The results are even stronger for i.i.d. tax shocks. By contrast, for very persistent shocks or permanent emission tax increases, relaxing collateral policy improves welfare as the *quantity* channel is the dominating force. The optimal collateral parameter would decline to 59% in the long run equilibrium with optimal emission taxes. These results are robust to plausible modifications of the climate block, the collateral premium, central bank cost from accepting risky debt as collateral, and to adding nominal rigidities. From a practical point of view, it is crucial for central banks to assess the persistence of any given climate policy change, as the optimal response to a rather transitory emission tax shock differs greatly from the optimal response to a very persistent or even permanent shift in climate policies.

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# A Additional Quantitative Results

This section provides additional quantitative results. First, we consider the short run effects of emission tax shocks. We then turn to the effects of climate policy over the long run before discussing the implications for optimal collateral policy.

## A.1 Effects of Emission Tax Shocks

Figure A.1 displays the results of subjecting the economy to a 10$/tCO2 emission tax shock. The negative effect of emission taxes on productivity reduces investment, which exhibits a hump shape due to adjustment costs. Output in the manufacturing sector declines very persistently, with a peak response six years after the shock. These results are consistent with a large and growing body of empirical literature on the effects of climate policy and green innovation on macroeconomic outcomes, see Berthold et al. (2023); Kaenzig and Konradt (2024); Konradt and Mangiante (2025); or Ferriani et al. (2025) among others.

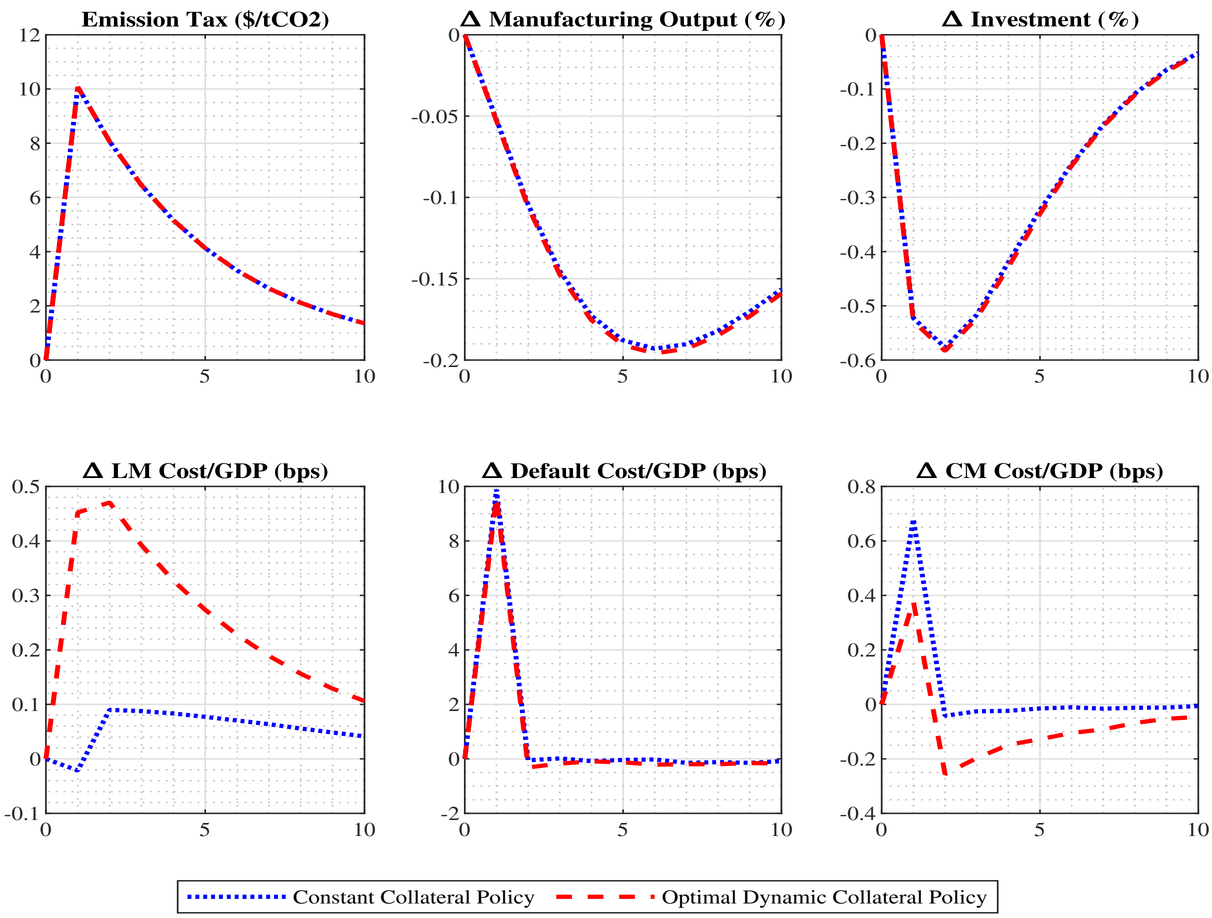


**Figure A.1: IRF to 10$/tCO2 Emission Tax Shock.** This figure displays the effects of a 10$/tCO2 emission tax shock on additional welfare-relevant macro-financial variables. First row: change in manufacturing output $z_t$ and investment $i_t$, both in percent. Second row: liquidity management cost (5), resource losses of default (18) and collateral management cost (24) (all in % relative to the tax-free benchmark). Time on the x-axis is expressed in years.

Concerning the key welfare-relevant cost terms, the bottom row shows that liquidity management costs increase moderately if collateral policy remains constant. The tiny decline on impact is due to the comparatively large GDP response in the denominator. When collateral policy responds dynamically to the shock, the increase is much more pronounced. The middle panel in the bottom row of Figure A.1 suggests that the resource losses of corporate default spike on impact, irrespective of collateral policy and generally inherit the shape of the corporate default rate. The central bank collateral management cost similarly increase on impact, but much less so if policy tightens in response to the shock. Once firms can adjust the indebtedness, the collateral management cost actually fall below their long run level under optimal collateral policy. These patterns in the bottom row would naturally revert for very persistent emission tax shocks, where it is optimal to temporarily relax $\phi_t$.

## A.2 Long Run Effects of Emission Taxes

Figure A.2 displays the effects of long run emission taxes of additional welfare-relevant macro-financial variables, complementing Figure 5. As we have discussed in the main text, optimal emission taxes reduce total capital by around 5%, but do not affect the corporate default rate. The second row shows that GDP and labor decline initially, which reflects the negative productivity effects of emission taxes, but GDP is larger under the optimal tax. Consumption is monotonically increasing in the emission tax level.

The third row of Figure A.2 show how banks' liquidity management cost, resource losses from corporate default, and collateral management cost respond to climate policy. The shape of these cost functions in the second row essential traces the effect of emission taxes on the change in capital. Any reduction in capital goes hand in hand with a reduction in debt issuance, which increases banks' liquidity management cost $\mathcal{L}(\bar{b}_t)$. It mechanically reduces the cost of corporate default $\mathcal{F}_t$ and the collateral management cost $\mathcal{C}_t$ incurred by the central bank. The bottom left panel shows that emission damages quite obviously decline in the emission tax level, while the abatement cost increase. Emission damages would vanish for any tax exceeding 230$/tCO2. For the optimal tax of 117$/tCO2, damages and costs are equal at around 1.5% of GDP.

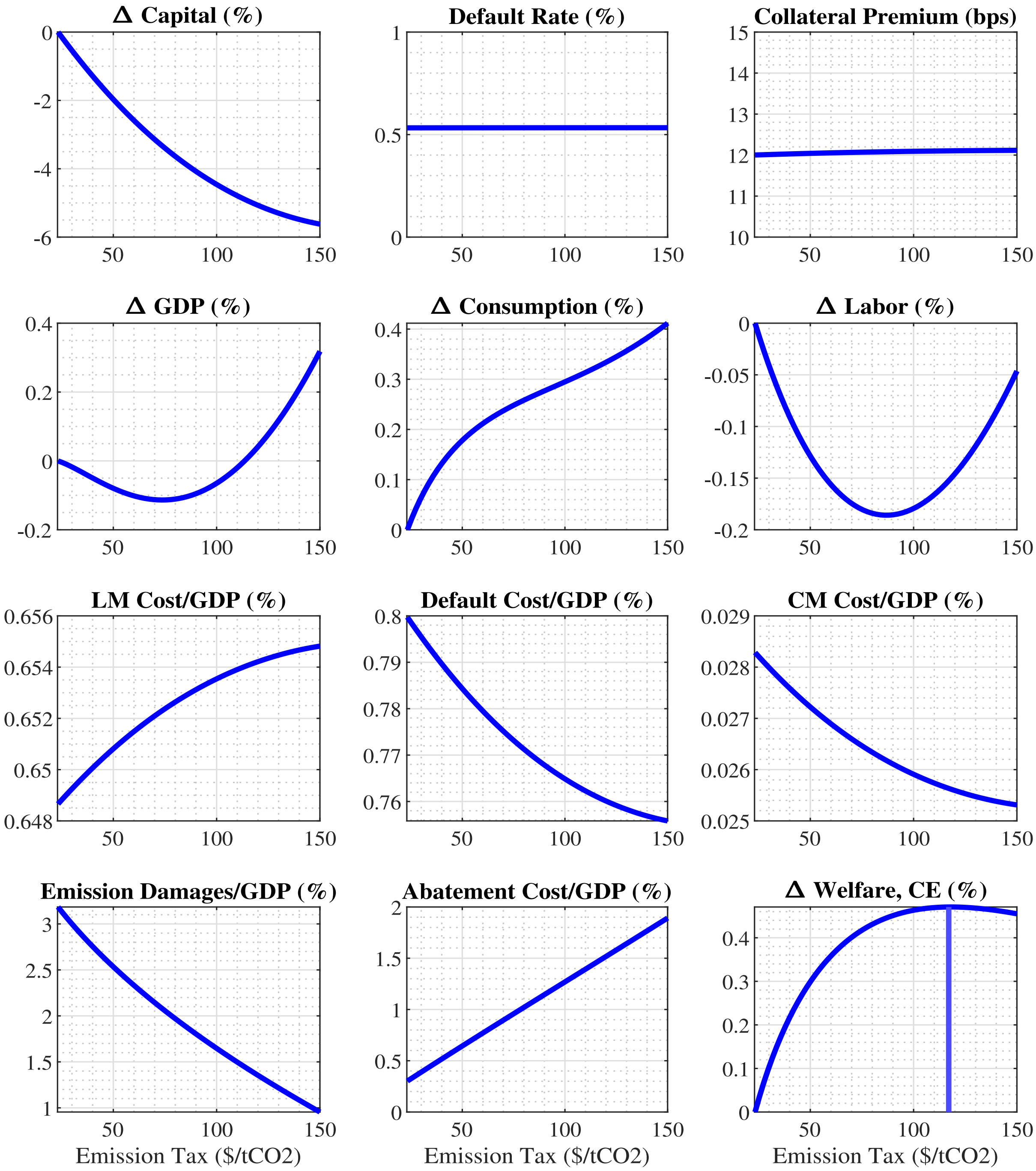


**Figure A.2: Long Run Effects of Emission Taxes**. This figure displays the effects of long run emission taxes on additional welfare-relevant macro-financial variables. First row: change in capital (in % relative to current emission taxes), corporate default rate (in %) and the collateral premium (in basis points). Second row: change in GDP, consumption and labor (all in % relative to current emission taxes). Third row: liquidity management cost (5), resource losses from corporate default (18) and collateral management cost (24) (all relative to GDP in percentage points). Fourth row: climate damage/GDP $1 - \exp\{\Psi_E e_t\}$ and abatement cost/GDP in percentage points. The welfare change in the bottom right is computed relative to the long run with the baseline collateral parameter of $\phi^{SS} = 65\%$ (bottom right). We express the welfare gain of any given emission tax relative to the optimal emission tax of 117\$/tCO2 in consumption equivalents:

$$gain^{CE,policy} \equiv \exp\{(1-\beta)(V^{policy} - V^{baseline})\} - 1 \,.$$

The emission tax on the x-axis is expressed in \$/tCO2.

### A.3 Long Run Effects of Collateral Policy

In Figure A.3, we show how macro-financial variables respond to changes in the collateral parameter $\phi^{SS}$. We consider the current emission tax (23\$/tCO2, dashed red line) and the optimal tax (117\$/tCO2, dotted green line). Mechanically, the collateral premium declines to zero if haircuts approach 100%. As the marginal benefit of holding collateral is positive but decreasing, the collateral premium increases by less than one for one as haircuts approach zero. Investment and default risk decline if collateral policy is very lenient ($\phi^{SS}$ approaching zero). Relative to the baseline with $\phi^{SS} = 65\%$, capital would increase by more than 0.5% if all assets would be accepted without valuation haircuts and GDP would expand by around 0.25%. These investment effects stem from the higher prices of corporate debt if eligibility requirements and/or collateral haircuts are low. This reduces firms' cost of capital which increases investment. At the same time, it makes debt issuance more attractive which increases the default rate.

Importantly, the transmission of collateral policy to macro-financial variables is largely independent of the climate policy regime, i.e. the dotted green and dashed red lines mostly overlap. Put differently, all macro variables in the first two rows exhibit the same response to a reduction of $\phi^{SS}$ by 10 percentage points, irrespective of the emission tax level. The notable exception is consumption, which is affected slightly differently and this differential shape is directly connected to the welfare-relevant cost functions, which are shown in the third and fourth row of Figure A.3.

Naturally, abatement costs and emission damages do not depend on the collateral policy regime in place. Lenient collateral policy reduces the liquidity management cost for banks but at the same time increases resource losses from corporate default (related to the risk-taking effects) and strongly increases the collateral management cost incurred by the central bank. The key difference under optimal emission taxes is that there is less capital and less corporate debt outstanding. Therefore, liquidity management costs are slightly larger, while corporate default losses $\int_0^{\overline{m}_t} m_t k_t dF(m_t)$ are smaller for any collateral policy parameter. The collateral management cost $c_0 \cdot (\bar{b}_t F(\overline{m}_t))^2$ are smaller for any $\phi^{SS}$ as well since debt outstanding enters them directly. Putting these pieces together, consumption and welfare exhibit a different shape, depending on the climate policy regime.

The bottom right panel summarizes how long run collateral policy affects welfare. The maximum is attained for a lower collateral parameter ($\phi^{SS} = 59\%$) under optimal emission taxes than in the long run equilibrium with low emission taxes ($\phi^{SS} = 65\%$). Again, this is not due to a change in the *transmission* of collateral policy to macro-financial variables due to emission taxes, but because emission taxes have permanent effects on macro-financial variables that are relevant for optimal collateral policy.

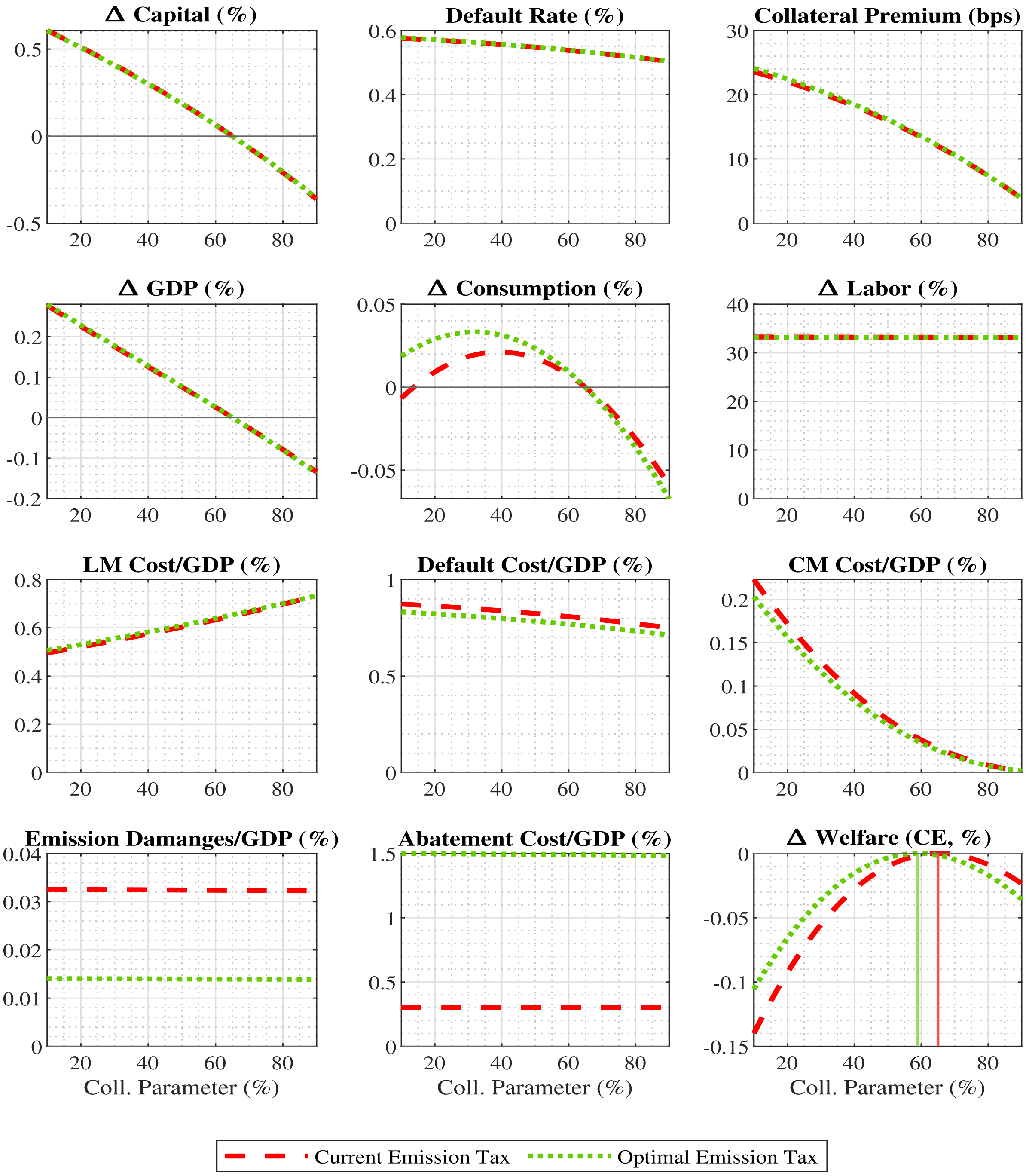


**Figure A.3: Long Run Effects of Collateral Policy**. This figure displays the effects of long run collateral policy on additional welfare-relevant macro-financial variables. First row: change in capital (in % relative to current emission taxes), corporate default rate (in %) and the collateral premium (in basis points). Second row: change in GDP, consumption and labor (all in % relative to current emission taxes). Third row: liquidity management cost (5), resource losses from corporate default (18) and collateral management cost (24) (all relative to GDP in percentage points). Fourth row: climate damage/GDP $1 - \exp\{\Psi_E e_t\}$ and abatement cost/GDP in percentage points. In the bottom right, we express the welfare gain of collateral policy relative to the baseline collateral parameter $\phi^{SS} = 65\%$ in consumption equivalents:

$$gain^{CE,policy} \equiv \exp\{(1-\beta)(V^{policy} - V^{baseline})\} - 1 \,.$$

The collateral parameter $\phi^{SS}$ on the x-axis is expressed in percentage points. The dashed red line corresponds to the current emission tax of 23\$/tCO2, while the dotted green line refers to the optimal emission tax of 117\$/tCO2.

## B Extension with Nominal Rigidities

In this section, we collect all equilibrium conditions that are either added or modified in the presence of nominal rigidities. The key frictions are monopolistic competition in the final good sector and price setting frictions following Rotemberg (1982). Under monopolistic competition, we first solve the cost minimization problem of final good firms, yielding the following demand conditions for intermediate goods and labor:

$$
\begin{aligned}
&mc_t \theta \frac{y_t}{z_t} = p_t^Z \ , \\
&mc_t (1-\theta) \frac{y_t}{n_t} = w_t \ ,
\end{aligned}
$$

where $mc_t$ is the real marginal cost of production for the final good. In the following, $\epsilon$ denotes the elasticity of substitution in the final goods basket and $\Psi_P$ is the price adjustment cost parameter. Each final good producer $i$ sets its price to maximize

$$
\max \mathbb{E}_0 \left[ \sum_{t=0}^{\infty} \beta^t \frac{c_t^{-1}}{c_0^{-1}} \left\{ \left( \frac{P_t(i)}{P_t} \right)^{-\epsilon} \left( \frac{P_t(i)}{P_t} - mc_t \right) y_t - \frac{\Psi_P}{2} \left( \frac{P_t(i)}{P_{t-1}(i)} \right)^{-\epsilon} \left( \frac{P_t(i)}{P_t} - 1 \right)^2 y_t \right\} \right] .
$$

The New Keynesian Philips curve is obtained from solving this maximization problem and imposing symmetry across firms.

$$
\mathbb{E}_t \left[ \Lambda_{t,t+1} \frac{y_{t+1}}{y_t} \left( \pi_{t+1} - 1 \right) \pi_{t+1} \right] + \frac{\epsilon}{\Psi_P} \left( \mathrm{mc}_t - \frac{\epsilon - 1}{\epsilon} \right) = \left( \pi_t - 1 \right) \pi_t \ .
$$

As customary in the New Keynesian model, the interest rate $i_t$ is *nominal* and that households' Euler equation becomes

$$
1 = \mathbb{E}_t \left[ \Lambda_{t,t+1} \frac{1 + i_t}{\pi_{t+1}} \right] ,
$$

and banks' solvency constraint is now given by

$$
\frac{1 + i_{t-1}}{\pi_t} d_t = \mathcal{R}_t b_t \ .
$$

This also has implications for the pricing of corporate debt, as the repayment obligation next period is in nominal terms and its real value is diluted by inflation. The *real* per-unit payoff from investing into corporate debt is given by

$$
\mathcal{R}_{t+1}^j = \frac{\chi \big( 1 - F(\overline{m}_{t+1}^j) \big)}{\pi_{t+1}} + (1 - \chi) q(\overline{m}_{t+2}^j) \ ,
$$

while the debt pricing *schedule* becomes

$$
q(\overline{m}_{t+1}) = \mathbb{E}_t \left[ \left\{ \frac{\chi \big( 1 - F(\overline{m}_{t+1}) \big)}{\pi_{t+1}} + (1 - \chi) q(\overline{m}_{t+2}) \right\} \cdot \frac{\big(1 + (1 - \phi_{t+1}) \Omega_{t+1}\big) \cdot \pi_{t+1}}{1 + i_t} \right] .
$$

Here, expected inflation enters in the numerator, as $i_t$ is a nominal interest rate. Its derivative with respect to the risk choice reads

$$q'(\overline{m}_{t+1}) = \mathbb{E}_t\left[\left\{-\frac{\chi F'(\overline{m}_{t+1})}{\pi_{t+1}} + (1-\chi)\frac{\partial \overline{m}_{t+2}}{\partial \overline{m}_{t+1}} q'(\overline{m}_{t+2})\right\} \cdot \frac{\big(1+(1-\phi_{t+1})\Omega_{t+1}\big)\pi_{t+1}}{1+i_t}\right] .$$

At the same time, debt dilution also affects the default threshold for manufacturing firms $\overline{m}_t \equiv \frac{\chi b_t^j}{\pi_t(p_t^Z - \xi_t)k_t^j}$. Adding these elements to the shareholder value maximization problem, the first-order conditions for debt issuance

$$q(\overline{m}_{t+1}) - \mu_t \frac{\overline{m}_{t+1}}{b_{t+1}} = \mathbb{E}_t\left[\frac{\widetilde{\Lambda}_{t,t+1}}{\pi_{t+1}}\left\{\chi(1-F(\overline{m}_{t+1})) + (1-\chi)q(\overline{m}_{t+2})\right\}\right] ,$$

and the risk choice

$$-\mu_t - q'(\overline{m}_{t+1})\Big(b_{t+1} - (1-\chi)b_t\Big) = \mathbb{E}_t\left[\widetilde{\Lambda}_{t,t+1}\left\{\Big(b_{t+2} - (1-\chi)\frac{b_{t+1}}{\pi_{t+1}}\Big)q'(\overline{m}_{t+2})\frac{\partial \overline{m}_{t+2}}{\partial \overline{m}_{t+1}}\right\}\right] ,$$

take these debt dilution effects into account, respectively. The additional condition on the slope of the policy function for $\overline{m}_{t+1}$ is now given by

$$q(\overline{m}_{t+1}) + \overline{m}_{t+1}q'(\overline{m}_{t+1}) = \mathbb{E}_t\left[\frac{\widetilde{\Lambda}_{t,t+1}}{\pi_{t+1}}\left\{\chi(1-F(\overline{m}_{t+1})) + (1-\chi)\left(q(\overline{m}_{t+2}) + q'(\overline{m}_{t+2})\overline{m}_{t+1}\frac{\partial \overline{m}_{t+2}}{\partial \overline{m}_{t+1}}\right)\right\}\right] .$$

To close the model, we impose a standard Taylor-type rule for the nominal interest rate

$$1 + i_t = 1/\beta + \phi_\pi \cdot (\pi_t - 1) , \tag{B.30}$$

and take into account that price adjustment costs enter the market clearing condition for final goods:

$$y_t = c_t + i_t \cdot \left(1 + \frac{\Psi_I}{2}\left(\frac{i_t}{i_{t-1}} - 1\right)^2\right) + \mathcal{A}_t + \mathcal{C}_t + \mathcal{F}_t + \mathcal{L}_t + \frac{\Psi_P}{2}(\pi_t - 1)^2 . \tag{B.31}$$

The parameterization of nominal rigidities follows the New Keynesian literature, taking into account that the model is calibrated to annual data. We set the demand elasticity of final goods to $\epsilon = 6$, implying a markup of 20%. Following Giovanardi and Kaldorf (2025), we set the Rotemberg price adjustment parameter to $\Psi_P = 4.5$ and the response of the nominal interest rate to inflation in equation (B.30) to $\phi_\pi = 2$. Emission tax shocks are inflationary on impact in this context, although this naturally depends on the central banks' interest rate response.