Sustainable Investing with Real-Asset Trades:

Incentives to Own and Transform Pollutive Assets

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Abstract

What impact does secondary trading of high-carbon real assets have on pollution-reduction investments? We analyze firms' optimal reform and secondary-market trading decisions in an environment where real-asset reallocation markets and transformation markets coexist. When only a reallocation market is available, value-aligned investors unintentionally weaken firms' incentives to undertake asset reforms, generating inefficiencies. Introducing a real-asset transformation market alters these incentives. Polluting firms post transformation contracts which allow other firms to contribute towards reform actions and claim impact rights. This broadens investor participation and increases real-asset reform, improving efficiency. We show that unlike other policy alternatives, such as a carbon tax or an emissions-trading system, a real-asset transformation market increases surplus for the firms that own and transform pollutive assets. Our results underscore how marketable reduction rights and use-of-proceeds forward contracts can support efficient, incentive-compatible reform of high-carbon assets.

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1 Introduction

The rise of sustainable investing has created a paradox in markets for high-carbon assets: as some environmentally-conscious investors divest from polluting firms, firms themselves have an incentive to offload pollutive real assets in secondary markets, which often flow to less transparent buyers with weaker environmental commitments, potentially undermining rather than advancing decarbonization efforts. Between 2014 and 2024, approximately USD 90 billion in petroleum assets moved from publicly listed to private companies[1]. Empirical analysis documents secondary sales of high-carbon real assets as a common response to environmental pressures. As Duchin et al. 2025 observe, such trades can "remove the option to engage with firms to reduce pollution". They further question whether such trades can have a net negative effect on the environment. This is the key motivating question for our work.

The tension between real asset trades and decarbonization efforts can be particularly relevant for industries in which real assets are long-lived. Natural gas processing plants, steel mills, and coal power plants can operate for up to 30-50 years and often change hands multiple times during their productive lifespans. In fact, secondary trades and the reallocation of real assets via over-the-counter deals play an important role in corporate restructuring processes for productive firms. Notable examples from the energy sector include RWE spinning off its renewable business into a separate entity in 2015, and E.ON's 2016 split, creating Uniper to retain ownership over all fossil fuel generation assets while the restructured E.ON shifted its focus toward clean energy sources. Another example from that same year is ENGIE announcing a €15 billion portfolio rotation program, explicitly targeting the sale of coal and oil & gas assets over a three-year period as a key component of the company's strategic shift toward low-carbon energy. We refer to such processes as *real-asset reallocation*.

At the same time, long-lived real assets undergo continuous investments and modifications that alter their characteristics, which we refer to as *real-asset transformations*. Some transformations are privately profitable. For example, installing high-efficiency boilers in steel plants improves fuel efficiency and provides fuel savings, and adding compressor units to natural gas facilities increases throughput and reduces downtime. Other transformations, however, entail net private

[1] These trade patterns have been discussed at length in industry reports, e.g. see Woodroffe, 2024.

costs despite generating large social benefits. Replacing coke-based reduction equipment with electric arc furnaces significantly reduces steel-making emissions, but is privately costly. Similarly, installing comprehensive methane leak detection equipment—fixed sensors, mobile monitoring, or satellite systems—can reveal higher-than-anticipated pollution levels, creating compliance costs for natural gas operators, yet it identifies opportunities for emission reductions that are socially valuable.

In some sectors of the economy, transforming and upgrading real assets potentially requires the involvement of many stakeholders. A prominent example are the retrofits of residential and commercial buildings, which generally include thermal insulation and renewing heating equipments, as well as other energy-efficiency related upgrades. A market-based innovation in this sector are residential and commercial property assessed clean energy loans (also called PACE and C-PACE financing programs). Homeowners, who have ownership of the underlying asset, value the upgrade itself and seek financial support from PACE lending-firms to finance the real-asset transformation. In addition to earning interest on the loans, the lending-firm gets credited towards social and environmental corporate targets, because they enable the energy-efficiency related upgrade. Thus, in exchange for their participation, the lending-firm can claim *rights to impact* — a corporate feature that is valued by investors who include socially responsible investment targets in their strategies. As more homeowners compete to secure such loans, and more lending-firms compete to originate them, a *market for real-asset transformation* emerges. Recent records of the U.S. Environmental Protection Agency (EPA) show that by 2025 more than 30 states had passed legislation to enable PACE and C-PACE programs with active involvement of the local governments.[2]

In this paper, we study how *coexisting markets for real-asset reallocation and transformation* can shape corporate incentives to own and reform high-carbon assets. We address three main research questions. First, from the perspective of investors, we examine how financial market structure influences the effectiveness of different sustainable investment strategies. Second, from the standpoint of corporate organization, we investigate the conditions under which real-asset transformation decisions are most likely to occur and how these decisions interact with firms' real-asset reallocation choices. Finally, from the viewpoint of financial-market regulation, we explore which types of contracts arise in equilibrium when we allow for co-existing markets, how they are

[2] A descriptive note on PACE and C-PACE programs can be found on this EPA website (2025).

priced, and how market composition affects firms incentives as well as the mechanisms through which transformation markets can enhance efficiency.

1.1 Main Results

We develop our contributions in an equilibrium model of risk-averse portfolio allocation and corporate decision-making, which incorporates both a secondary market for real assets and trading of contracts governing real-asset transformation. We consider an economy with three types of investors: unconstrained, value, and impact-aligned. Value-aligned investors will not buy shares of firms that operate unreformed pollutive assets, whereas impact-aligned investors will only invest in those firms that actively engage in environmental reform. Firms act to maximize their share price.[3] Firms that own pollutive assets face a corporate choice problem: they can choose to operate an unreformed pollutive real asset, engage in secondary trading, or implement a costly reform that reduces environmental impact.

When only reallocation via a secondary market for real assets is available, value-aligned investors, who exclude firms that own high-carbon assets from their portfolios, weaken corporate incentives to reform pollutive assets. As more firms engage in secondary-trading, the number of eligible firms for impact-investors decreases, resulting in a lower Sharpe ratio for impact investors, i.e., the excess return per unit of risk that they face in equilibrium decreases. Unconstrained investors, on the other hand, extract larger rent from the firms that choose to operate unreformed pollutive assets. This is due to the fact that the firms' corporate choices are endogenous: when the number of constrained investors (value or impact) increases, firms are more willing to assume secondary-trading costs and the cost of environmental reforms, which implies that the firms that *do not* pay such a cost must be willing to sell their shares at lower prices.

The introduction of a separate market for real asset transformation fundamentally changes the equilibrium structure. Because value-aligned investors will not invest in firms that operate unreformed pollutive assets, polluting firms may have an incentive to contract with other firms to undertake environmental reforms. On the other hand, because impact-aligned investors only invest in firms that engage in environmental reforms, firms that do not own pollutive assets may have an

[3] Consistently with corpoorate finance literature, firms maximize their equity value, given by the share price multiplied by the number of outstanding shares. We take the latter as constant.

incentive to contract with polluting firms to exercise reform actions and claim impact-alignment. This mechanism expand investor participation on both sides, and enhances efficiency via improved risk-sharing. Our main insight, thus, is that introducing an explicit market for transformation curbs the divestment-decarbonization tension. Our findings point to reduction-rights contracts and use-of-proceeds forward agreements as financing structures that can support efficient, incentive-compatible reform of high-carbon assets.

Our results contribute to ongoing debates over regulatory responses to secondary trading of high-carbon assets. Proposed interventions include enhanced transparency requirements for secondary trades, granting regulators approval rights over asset transfers, or even public ownership of high-carbon assets. However, screening trades without observable counterfactuals poses significant challenges for regulators, and empirical evidence from coal power plant reallocation decisions casts doubt on whether public ownership leads to greater environmental reform (Darmouni and Zhang, 2024). The mechanisms we study suggest an alternative: rather than restricting reallocation markets, introducing markets for transformation contracts can mitigate the divestment-decarbonization tension while preserving other beneficial aspects of the secondary trading channel.

1.2 Related Literature

This paper contributes to multiple strands of the literature on sustainable finance, decentralized financial markets, real-asset corporate choices, and the moral preferences of socially responsible investors. To the best of our knowledge, we are the first to propose a theory of how the presence of secondary trading channels for real assets subject to environmental reform — or the coexistence of markets for real-asset reallocation and transformation — can shape the outcomes of sustainable investing practices.

Several studies have focused on the financial implications of socially responsible investing (e.g. Hong and Kacperczyk 2009, Pedersen et al. 2021, Ľuboš Pástor et al. 2021). We contribute to this strand of the literature by showing that the introduction of a market for real asset transformation enhances investor diversification and market efficiency. In contrast with Ľuboš Pástor et al. 2021, where sustainable investors' preferences are well-aligned with positive social impact, in our setting, some investors do not differentiate between secondary trading of pollutive assets and real asset reform, with only the latter producing measurable social impact. We show that the introduction of transformation contracts partially restores this alignment.

A growing number of papers focus on climate risk, which is generally decomposed into transition risks, such as the risk of regulatory shocks on pollution; and physical risks, such as increased frequency and intensity of natural disasters. These works study how climate-risk sharing can affect asset prices across financial markets (e.g. Giglio et al. 2021, Bolton and Kacperczyk 2021). In our paper, asset prices are determined by the interaction between socially responsible investor preferences, endogenous corporate choices, and financial market structure. We assume that some investors apply exclusionary screening based on direct emissions, in line with the empirical evidence presented in Bolton and Kacperczyk 2021 — while others screen for firms that engage in environmental reform actions. We then discuss reform-action contract pricing and study how these prices affect investor returns and firms' cost of capital. Consistent with the climate-risk pricing literature, we find that firms that directly reform assets trade at a premium compared to their unreformed counterparts. This premium *increases* when transformation and reallocation markets coexist.

A separate line of research has focused on developing models to capture the real outcomes of socially responsible investing (e.g. Oehmke and Opp 2022, Huang and Kopytov 2023, Sauzet 2024, Oehmke and Opp 2025, Gupta et al. 2025, Green and Roth 2025). A common finding across these papers, mirrored here, is that environmental reform of real assets requires the presence of *impact* investors (c.f. Oehmke and Opp 2025) — when reform is costly, the presence of value-aligned investors results only in corporate reallocation decisions, without any uptake of environmental reforms. We show that when reallocation and transformation markets coexist, impact investors provide stronger incentives for firms to adopt costly reform actions, and these incentives are less negatively affected by the presence of value-aligned investors who do not distinguish between secondary trades and real asset reform. In contrast to papers that focus on entrepreneurial financing needs for new investment projects (Oehmke and Opp 2025, Green and Roth 2025), our model assumes an existing fixed-size economy to emphasize current – or legacy – real assets, which continue to play an important role in many productive industries. In that sense, our paper is closest to the work of Heinkel et al. 2001 on optimal corporate choices in the presence of socially driven investors. We enhance their model, however, to allow for heterogeneous strategies by socially driven investors, secondary trading, and a market for real asset transformation in which firms trade contracts over reform actions.

Our paper also sheds light on implementability. We show that when there are sufficiently many impact-aligned investors, trading reform options suffices, but otherwise, trading reform obligations is optimal. Related works include Pedersen et al. 2021, who find that investor optimal portfolios are implemented using four-fund separation by including an ESG-tangency portfolio. Landier and Lovo 2024 show that when there are many value-aligned investors, a single-fund is optimal for a socially responsible intermediary, and otherwise, a dual-fund approach that targets clean sectors on one hand, and direct reductions on the other, maximizes assets under management. Oehmke and Opp 2025 find that a firm-optimal financing agreement can be implemented by selling a green bond to the socially responsible fund and a regular bond to financial investors.

Finally, the moral preferences of socially driven investors is a core discussion point in this literature. Empirical work by Bonnefon et al. 2025 suggests that warm-glow effects — the non-pecuniary value of holding a portfolio in which firms do not engage in negatively perceived activities — is a more prominent concern than the social consequences of investment decisions for responsible asset managers. Our paper contributes to the discussion by analyzing how the presence of investors driven by warm-glow negatively affects sustainable investing outcomes by limiting the impact that consequentialist investors can have over firms' environmental reform decisions. The conclusions from our model are in line with the empirical findings of Duchin et al. 2025, who identify secondary trading as an economically meaningful response from firms facing environmental pressure. In our model, investors with warm-glow preferences create a disincentive for firms to invest in pollution reduction when only secondary trading is available. Instead, firms are incentivized to trade away the pollutive asset, removing the opportunity for impact-seeking investors to engage in environmental reform. A market for real asset transformation alleviates the disincentives to own pollutive assets. Our findings point towards the decentralized trading of reduction options as a market mechanism that can improve efficiency when secondary-trading frictions are present.

2 Model

We consider a static equilibrium model of risk-averse portfolio allocation and corporate decision-making, specified as follows:

Firms There are N firms selling a single divisible unit of shares each. Firms make corporate decisions to maximize their share price — determined in equilibrium — minus costs from their corporate choices. There are two types of firms:

(i) c-firms, endowed with a clean real asset that generates a normally distributed cash flow with mean μ_c and variance σ_c^2; and

(ii) d-firms, endowed with a pollutive (*dirty*) real asset that generates a normally distributed cash flow with mean μ_d and variance σ_d^2.

The number of c-firms is N_c with $0 \leq N_c \leq N$ ($N_d := N - N_c$). Covariance between the cash flows of c and d is σ_{cd}.

Investors There are I risk averse investors who are partitioned into three types:

(i) Value-aligned (v) investors, who exclude firms that operate unreformed d assets;

(ii) Impact-aligned (m) investors, who invest in firms that reduce environmental damage; and

(iii) Neutral (n) investors, who are unconstrained.

The number of investors of each type are, respectively, I_v, I_m, and I_n, with $I_v + I_m + I_n = I$. We denote the relative market share of each investor type by $\lambda_\theta = \frac{I_\theta}{I}$ for $\theta \in \{m, v, n\}$ so that $\lambda_m + \lambda_v + \lambda_n = 1$. All investors have utility functions that exhibit constant absolute risk aversion (CARA), with (a common) risk tolerance parameter τ.[4]

Corporate Choices A firm endowed with a d-asset has the opportunity to reduce the environmental damage caused by its operation at a cost of K. It can also choose to operate the *unreformed* d-asset as is at no added cost. Finally, a d-firm can sell its d-asset in a *secondary market*. We denote these corporate choices by R, U and S. When the firm decides to sell in the secondary market, we assume that the asset is acquired by an outside private buyer which provides a payment equal to the risky cash-flow of the d-asset minus a transaction cost T. Figure 1 shows that when $T \leq K$, secondary trading introduces a gap: a firm choosing to offload the asset becomes eligible for a v-investor but not for an m-investor. We define the share price of a firm that making corporate choice $y \in \{U, S, R\}$ as P_y.

[4]Note that g-investors do not distinguish between secondary-trading and real asset reforms.

Investor-Eligibility without Secondary-Trades

	U	R	A
n	✓	✓	✓
g	×	✓	✓
s	×	✓	×

Investor-Eligibility with Secondary-Trades

	U	S	R	A
n	✓	✓	✓	✓
g	×	✓	✓	✓
s	×	×	✓	×

eligible   not eligible

Figure 1: Eligibility with a Market for Real-Asset Reallocation Only

Portfolio Allocation Investors buy shares in firms depending on their corporate choices. The number of shares that a type θ investor buys in firms making corporate choice y is denoted as $x_{\theta y}$.

Riskless Asset There exists a riskless asset in perfectly elastic supply with a rate of return normalized to zero. Borrowing is allowed but short selling of firm shares is prohibited.

Market Mechanism for Real Asset Transformation With only a reallocation market, firms are allowed to keep or sell their d-asset, but cannot trade contracts over the reform actions. In other words, the opportunity to reduce environmental damage is non-transferable and thus inseparable from the d-asset itself. We relax this constraint by introducing a *real-asset transformation market.* Formally, we augment the reallocation market with an exchange in which d-firms can post – and c-firms can acquire – *transformation contracts.* A transformation contract specifies a non-negative amount π to be contributed by the c-firm towards a real-asset transformation action, in exchange for the *impact-rights* of the reform action. We denote the number of d-firms that sell contracts over their reform actions with N_β and c-firms that buy contracts involving reform actions with N_α.

Mechanism 1 (Market Mechanism for Real-Asset Transformation)**.** *The market mechanism for real-asset transformation can be described as follows:*

1. ***Posting.*** *d-firm posts a transformation contract with requested contribution π.*
2. ***Accepting.*** *c-firm decides whether to enter a posted contract.*
3. ***Transfer.*** *Upon accepting, c commits to a transfer of π to d, and d commits to transfer impact claims upon the d-asset reform.*

4. ***Disclosure.*** *Contracts are publicly observable to all firms and investors.*

The transformation market allows c-firms to actively reduce environmental damage (becoming s-eligible), as well as provide an alternative for d-firms to not operate an unreformed d-asset. Figure 2 shows how investor-eligibility changes upon the introduction of a transformation market.

Investor-Eligibility with a Transformation Market

	U	S	β	R	A	α
n	✓	✓	✓	✓	✓	✓
g	×	✓	✓	✓	✓	✓
s	×	×	×	✓	×	✓

Figure 2: Eligibility with Co-Existing Markets

Solution Concept. We focus on competitive equilibrium outcomes. A competitive equilibrium is a set of share prices $\mathbf{P} \in \mathbb{R}_{\geq 0}^{N_c+N_d}$, investor portfolio allocations $\mathbf{x} \in \mathbb{R}_{\geq 0}^{I}$, firm corporate choices $\mathbf{y} \in \{U, S, R, A, \beta, \alpha\}^{N_c+N_d}$ and vector of real-asset transformation contract prices $\pi \in \mathbb{R}^{\mathbf{N_d}}$ which jointly satisfy investor and firm rationality and incentive-compatibility and market clearing:

(i) Market for firm shares and portfolio allocation clears.

(ii) Market for secondary-trades and corporate choices clears.

(iii) Market for real-asset transformation contracts clears.

Finally the number of firms that make each corporate choice $y \in \{U, S, R, A, \beta, \alpha\}$ is denoted by $N_y \geq 0$ and is also determined in equilibrium.

Note: Absent a separate market mechanism for real asset transformation and removing the secondary trading channel makes the s and g-investors indistinguishable.[5] In this case, our model collapses to the that of Heinkel et al. 2001.

3 Corporate Choices and Share Prices in Equilibrium

We now characterize firms' share prices and optimal corporate choices in equilibrium. We provide solutions both in the case of a market for real-asset reallocation only and in the case where markets

[5] We can recover this as a limiting case by taking $T \to K$ and breaking ties in favor of environmental reform.

for reallocation and transformation coexist. We outline the main proof ideas and defer detailed computations to the Appendix.

3.1 Market for Real-Asset Reallocation Only

First, we study competitive equilibrium outcomes in the case where only a market for asset reallocation exists. In this case, the c-firms are automatically eligible for g and n-investors, but remain ineligible for the s-investors, as they own real assets that do not feature any pollution reduction opportunities. On the other hand, d-firms have three choices: (i) they can operate an unreformed pollutive asset, which makes them ineligible for v and m-investors; (ii) reform the pollutive asset, which makes them eligible for both v and m-investors; or (iii) trade the pollutive asset. In the last case, firms transfer their d-asset to an outside private buyer, and receive a payment that equals the risky cash-flow of the asset minus the transaction cost T.

Because the number of c and d-firms is fixed, the following corporate choice market clearing conditions must hold in equilibrium:

$$N_A^* = N_c, \quad N_U^* + N_S^* + N_R^* = N_d. \tag{1}$$

In the optimal corporate choice problem faced by a d-firm, secondary trading and real asset reform involve a positive cost. Thus, they will only be *firm* incentive-compatible when the resulting share price increase weakly offsets the action's cost. Because the share price decreases in the number of firms of a given type, it must be that, in equilibrium, the increase in share price *equals* the action's cost — effectively acting as a no entry & no exit condition. By this observation, the following relationships between share prices must hold in equilibrium:

$$P_S^* - P_U^* = T, \quad P_R^* - P_U^* = K. \tag{2}$$

Now, consider the optimal portfolio allocation problem faced by some investor i. When $K \geq T$, it follows from (2) that, in equilibrium, $P_U^* < P_S^* < P_R^*$. This implies that n-investors (v-investors) will only buy shares from firms of type A and U (A and S) due to *investor* incentive-compatibility: the risk-return profiles of U, S and R firms are equivalent, but in equilibrium, the share price of an

S-firms must be larger than that of a U-firm. Hence, it is never optimal for an n-investor to buy shares of an S or R-firm. By the same argument, it will never be optimal for a v-investor to buy shares in a R-firm. Then, at the portfolio allocation level, market clearing imposes the following conditions involving the portfolio allocation decisions by investors:

$$I_n x^*_{nU} = N^*_U, \quad I_v x^*_{vS} = N^*_S, \quad I_m x^*_{mR} = N^*_R, \tag{3a}$$

$$I_n x^*_{nA} + I_v x^*_{vA} = N^*_A, \tag{3b}$$

The equilibrium structure is well summarized by the clearing conditions in (3). Observe that while there is a single c-firm sub-market – $(\{n, v\}, A)$ – there are three distinct d-firm sub-markets: (n, U), (v, A) and (m, R). Moreover, d-firm sub-markets are separable across investor types. It follows that, fixing the equilibrium capital allocation, the number of firms in each category scales proportionally to the respective investor population. A large number of value-aligned investors, then, would result in more firms participating in the secondary-trading market.

Our first Lemma formalizes these observations by characterizing equilibrium corporate choices:

Lemma 3.1. *If there exists only a market for real-asset reallocation, d-firms and investors participate in three separate sub-markets: (1) unconstrained investors only invest in U firms, (2) value-aligned investors only invest in S firms, and (3) impact-aligned investors only invest in R firms. The number of d-firms choosing each corporate action $\ell \in \{U, S, R\}$ in equilibrium can be written as*

$$N^*_\ell = \max\{0, I_\theta x^*_{\theta,\ell}\} = \max\{0, \lambda_\theta(N_d + \delta^*_\ell)\},$$

for $(\theta, \ell) \in \{(n, U), (v, S), (m, R)\}$. Define $\phi := \sigma_c^2 \sigma_d^2 - \sigma_{cd}^2$. Allocative distortions in equilibrium are given by

$$\begin{aligned}
\delta^*_U &= I_m K \frac{\tau}{\sigma_d^2} + I_v T \frac{\tau}{\sigma_d^2} - \xi^*_U \frac{\sigma_{cd}}{\sigma_d^2} \\
\delta^*_S &= I_m (K - T) \frac{\tau}{\sigma_d^2} - I_n T \frac{\tau \sigma_c^2}{\phi} - \xi^*_S \frac{\sigma_{cd}}{\sigma_d^2} \\
\delta^*_R &= -I_n K \frac{\tau}{\sigma_d^2} - I_v (K - T) \frac{\tau}{\sigma_d^2} + \xi^*_R \frac{\sigma_{cd}}{\sigma_d^2},
\end{aligned}$$

satisfying $\sum_{(\theta,\ell)} I_\theta \delta^*_\ell = 0$. *Equilibrium covariance distortion terms* ξ^*_ℓ *are derived in the Appendix.*

Proof. See Appendix A.1. □

Lemma 3.1 provides insights into the size of each sub-market in equilibrium. If allocative distortion terms ξ^*_ℓ are small, then d-firms opt-in to each sub-market in proportion to investor composition λ_θ. Because $\lambda_n + \lambda_v + \lambda_m = 1$, an increase in the number of value-aligned investors incentivizes more d-firms to sell their pollutive assets in the secondary-market, reducing the size of both the sub-market of firms that engage in real-asset reform, and the sub-market of firms which operate unreformed d-assets. The allocative distortions in equilibrium are driven by the cost of corporate actions plus correlation terms. A larger cost of reform K results in fewer firms choosing reform and more firms choosing secondary-trades. Conversely, a larger cost of transaction T results in fewer firms choosing secondary-trades and more firms choosing to reform their d-assets. Finally, increases in both T or K result in more firms choosing to operate unreformed d-assets. If allocative distortions are large, an increase in the number of value-aligned investors has an additional negative effect on the number of firms that engage in real-asset reform. In particular, to the initial effect of having a smaller baseline of firms choosing the R sub-market $\frac{\partial(\lambda_m N_d)}{\partial I_v} < 0$, there is also a larger allocative penalty $\frac{\partial \xi^*_R}{\partial I_v} < 0$. Since fewer firms engage in real-asset reform, an impact-aligned investor buys fewer shares upon the introduction of an additional value-aligned investor.

Next, we characterize the equilibrium share prices for each firm category:

Lemma 3.2. *If there exists only a market for real asset reallocation, equilibrium share prices of c-firms choosing* A *and d-firm choosing* $\ell \in \{U, S, R\}$ *can be decomposed into a risk-adjusted component minus a price wedge:*

$$P^*_f = \mu_c - R_c - \omega^*_f, \quad P^*_\ell = \mu_d - R_d - \omega^*_\ell.$$

where $R_d = \frac{1}{I_\mathcal{T}}(N_d \sigma_d^2 + N_c \sigma_{cd})$ *and* $R_c = \frac{1}{I_\mathcal{T}}(N_c \sigma_c^2 + N_d \sigma_{cd})$. *Price wedges for d-firms are given by*

$$\omega^*_U = \lambda_m K + \lambda_v T, \quad \omega^*_S = \lambda_m (K - T) - \lambda_n T, \quad \omega^*_R = -\big(\lambda_v (K - T) + \lambda_n K\big),$$

and the price wedge for the c-firms is given by

$$\omega_A^* = \lambda_m \left[\frac{N_c}{I_{gn}} \frac{\sigma_c^2}{\tau} + z_A^* \frac{\sigma_{cd}}{\sigma_d^2} \right]$$

The equilibrium covariance price wedge term z_A^* is derived in the Appendix.

Proof. See Appendix A.1 □

Recall that firms maximize their share price minus the cost of their corporate choice. There are two key takeaways from Lemma 3.2. First, the shares of d-firms that directly engage in real-asset reform trade at a premium ($\omega_R^* < 0$) and the shares of a d-firm that operates an unreformed d-asset trade at a discount ($\omega_U^* > 0$) compared to the benchmark without sustainable investing constraints. The sign of the equilibrium price wedge for secondary-traders ω_S^* is ambiguous, and depends on the relative ratio of impact-aligned to unconstrained investors compared to $K/(K-T)$. When the population of impact investors is sufficiently small, $\omega_S^* < 0$. In this case, shares of secondary seller firms trade at a lower premium than R firms. Additionally, a higher share price implies a lower cost of capital in equilibrium.[6] Thus, the cost of capital of a secondary seller firm (direct reform firm) decreases as the transaction cost T (cost of reform K) increases. This is due to the fact that, in equilibrium, the increase in the share price for a S or R firm must offset the cost of trade T or the cost of reform K. Thus, a higher share of v or n investors results in a *higher* equilibrium share price (and lower cost of capital) for R firms.

The second takeaway is that the price wedge faced by the c-firms persists even in the absence of sustainable investing cost terms T or K. This is because the wedge comes from imperfect risk-sharing: as m-investors will only buy shares in firms that engage in environmental reform, under a market for real-asset reallocation only, these investors do not allocate any resources in the c-firm sub-market. The impact of such imperfect risk-sharing is larger when the c-asset cash flow is more volatile and when risk-tolerance τ is small, which gets directly reflected in the share prices.

[6] The cost of capital of a firm f can be formally defined as $\frac{\mu_f}{P_f} - 1$

3.2 Co-Existing Markets for Real-Asset Reallocation and Transformation

Now we study competitive equilibria upon the introduction of a separate market mechanism where firms trade contracts over real-asset transformation actions. Because there is no heterogeneity in the cost of reform actions, it must be that all posted transformation contracts request the same c-firm contribution in equilibrium. We can focus on the case in which, when a d-firm decides to post a transformation-contract, it does so at the clearing transformation-contract price $\pi \in \mathbb{R}$. It turns out that this market clearing price is critical to determine the structure of the equilibrium outcomes. We distinguish between a *surplus-extraction equilibrium*, where the transformation contract price is strictly larger than the cost of reform $\pi > K$, and a *cost-sharing equilibrium*, where $\pi \leq K$. In a cost-sharing equilibria, d-firms contribute a to finance the real-asset reform action, but make no impact claims. We next discuss these two equilibria:

(i) **Surplus-Extraction Equilibrium**: Suppose that the market clearing contract price is weakly larger than the cost of reform, meaning that the d-firm can extract surplus from the c-firm beyond the reform cost. Then, it must be the case that *all pollutive assets get reformed*. This is because such a contract price makes the corporate choice of operating an unreformed pollutive asset strictly dominated by posting a transformation contract. Moreover, *secondary-trading unravels*. Secondary-trading enables v-eligibility at a cost of T, whereas a transformation contract also makes the d-firm v-eligible, albeit with an additional revenue of $\pi - K \geq 0$.

(ii) **Cost-Sharing Equilibrium**: Suppose that the market clearing contract price is strictly smaller than the cost of reform. Then trading a transformation contract implements a cost-sharing mechanism because the issuing d-firm pays a reminder of $K - \pi \geq 0$ to finance the reform action and fulfill the contract. This implies a lower bound on the contract clearing price, $\pi \geq K - T$, for transformation contracts get effectively traded in equilibrium. To see why this is the case, note that if $\pi = K - T$, the d-firm contributes a payment of T towards the reform action and cedes the impact claim to the c-firm, becoming *indirectly* reformed. At this price, posting a transformation contract is *equivalent* to secondary-trading – in such equilibria, both corporate choices co-exist. For any clearing price π strictly larger than $K - T$, secondary-trading unravels: selling the d-asset in the secondary-market becomes strictly dominated by posting a transformation contract. Finally, note that when $\pi < K$ there is no clear dominance between entering the transformation market and operating an unreformed pollutive asset. Thus, in a cost-sharing equilibrium *all pollutive assets do not necessarily get reformed.*

We analyze each case separately to account for the specific corporate-choice structures.

3.2.1 Surplus-Extraction Equilibrium

Fix $\pi > K$. Since a transformation market is available, c-firms now also face a corporate choice problem. They can choose not participate in the transformation market (A-choice) or to enter a transformation contract allowing them to claim impact, in which case they contribute π towards the reform action (α-choice). In this equilibrium, the corporate choices which are sustained for d-firms are also two. They either directly engage in real asset reform or participate in the transformation market by posting a transformation contract and becoming indirectly reformed (β-choice). Operating an unreformed pollutive asset, as well as engaging in secondary-trading, are strictly dominated choices in equilibrium, and thus we have that $N_U^* = N_S^* = 0$. Because the number of c and d-firms is fixed, the corporate choice market clearing conditions in equilibrium become:

$$N_A^* + N_\alpha^* = N_c, \quad N_R^* + N_\beta^* = N_d. \tag{4}$$

Consider the optimal corporate choice faced by a c-firm. Again, because entering a transformation contract involves a positive cost for the firm, this action will only satisfy firm incentive-compatibility when the resulting share price weakly offsets the action's cost. For the d-firm, reducing environmental impact entails a direct cost as well as an *opportunity cost*: keeping the option to reduce implies that the d-firm foregoes a potential payoff of $\pi - K \geq 0$ in the transformation market. In equilibrium, the respective changes in share prices must equal these costs to guarantee a no entry & no exit condition across sub-markets. It follows that in equilibrium we must have:

$$P_\alpha^* - \pi = P_A^*, \quad P_R^* - K = P_\beta^* + \pi - K, \tag{5}$$

where P_β and P_α correspond to the share price of a firm making corporate choices β and α respectively. Compared to (2), the transformation market implies that the change in share price is not ex-ante fixed as it depends on the clearing price of the transformation market π, determined at equilibrium.

Consider, now, the optimal portfolio allocation faced by investors. From (5) we get that prices can be sorted in equilibrium: $P_\alpha > P_A$ and $P_R > P_\beta$. This implies that n and v-investors will only buy shares from firms of type A and β.[7] Conversely, m-investors will only buy shares from firms of type α and R due to the impact constraint. Market clearing then imposes the following conditions:

$$I_n x^*_{n\beta} + I_v x^*_{v\beta} = N^*_\beta, \quad I_m x^*_{mR} = N^*_R \tag{6a}$$

$$I_n x^*_{nA} + I_v x^*_{vA} = N^*_A, \quad I_m x^*_{m\alpha} = N^*_\alpha \tag{6b}$$

Compared to a case where there is only a market for real-asset reallocation (c.f. (3)), clearing conditions in (6) show a different sub-market structure. In the surplus-extraction equilibrium, there are two c-firm sub-markets, $(n \cup v, A)$ and (m, α) and two d-firm sub-markets, $(n \cup v, \beta)$ and (s, R). Our next Lemma characterizes equilibrium corporate choices under this structure for any transformation-market clearing price $\pi > K$:

Lemma 3.3. *Fix $\pi > K$. In equilibrium, investors participate in two c-firm and d-firm sub-markets: (1) unconstrained and value-aligned investors only invest in A-firms and β-firms (2) impact-aligned investors only invest in α-firms and R-firms. The number of c and d-firms choosing each corporate action $f \in \{A, \alpha\}$ and $\ell \in \{\beta, R\}$ can be written as*

$$N^*_f = \max\{0, \lambda_\theta(N_c + \delta^*_f)\}, \quad N^*_\ell = \max\{0, \lambda_\theta(N_d + \delta^*_\ell)\}$$

[7] In other words, the allocation problems of n and v investors become indistinguishable in the options-trading equilibrium.

for $(\theta, f) \in (n \cup v, A), (m, \alpha)$ *and* $(\theta, \ell) \in (n \cup v, \beta), (m, R)$*. Allocative distortions are given by:*

$$\delta_A^* = I_m \pi \frac{\tau}{\phi}(\sigma_d^2 - \sigma_{cd}), \qquad \delta_\beta^* = I_m \pi \frac{\tau}{\phi}(\sigma_c^2 - \sigma_{cd}),$$

$$\delta_\alpha^* = -I_{nv} \pi \frac{\tau}{\phi}(\sigma_d^2 - \sigma_{cd}), \qquad \delta_R^* = -I_{nv} \pi \frac{\tau}{\phi}(\sigma_c^2 - \sigma_{cd}),$$

satisfying $\sum_{(\theta,f)} \lambda_\theta \delta_f^* = 0$ *and* $\sum_{(\theta,\ell)} \lambda_\theta \delta_\ell^* = 0$.

Proof. See Appendix A.2. □

Note that value-aligned and neutral investors, in equilibrium, effectively hold equivalent positions in both c and d-firm sub-markets. The average investor position in n and v sub-markets, $\frac{N_A^*}{I_{nv}}$ and $\frac{N_\beta}{I_{nv}}^*$, is larger than the average position in m sub-markets, $\frac{N_\alpha}{I_m}^*$ and $\frac{N_R}{I_m}^*$, as implied by the sign of the allocative distortions in Lemma 3.3. The magnitude of the distortion depends directly on the transformation-contract clearing price, with both quantities jointly determined in equilibrium. Holding everything else fixed, a larger transformation-contract price results in a higher number of indirectly reformed firms and a lower number of directly reformed firms with all pollutive assets getting reformed through either channel. In contrast to Lemma 3.1, the marginal impact of an additional value-aligned investor has no effect on the number of assets that become reformed in equilibrium. As shown by our next Lemma, adding a value-aligned investor decreases the transformation-contract clearing price, increasing direct reform and lowering the volume of contract trades in the transformation-market channel.

Lemma 3.4. *In a surplus-extraction equilibrium, the transformation-contract price is given by:*

$$\pi^* = [\frac{N_c}{I_{nv}} - \frac{N_d}{I_m}]\frac{\phi}{\psi\tau}$$

where $\psi := \sigma_c^2 - 2\sigma_{cd} + \sigma_d^2$*. Thus, a surplus-extraction equilibrium exists if and only if*

$$\frac{N_c}{I_{nv}} \geq \frac{N_d}{I_m} + K\frac{\psi\tau}{\phi}.$$

Holding the cash flow distributions fixed, a surplus-extraction equilibrium exists when there is a sufficiently large (small) number of c-firms (d-firms) and m-investors ($n \cup v$-investors), the cost of reform K is sufficiently small, and investor are sufficiently risk averse.

Proof. See Appendix A.2 □

Combining Lemma 3.4 with Equation (5) we see that the transformation-contract price corresponds to the share price premia from m-eligibility, equivalent across c and d-firm sub-markets:

$$P_\alpha^* - P_A^* = P_R^* - P_\beta^* = \frac{\phi}{\psi\tau}\left[\frac{N_c}{I_{nv}} - \frac{N_d}{I_m}\right]$$

Intuitively, the market clearing transformation-contract price captures two effects:

(i) Enhancement in risk-sharing from improved diversification.

(ii) Supply-demand balance of reform actions in the transformation market.

For the risk-sharing component, note that the equilibrium transformation-contract price is the largest when risk tolerance τ is low and cash flow variance is high. Moreover, the price increases with the number of m-investors, and decreases with the number of v and n-investors. As the number of investors following an impact-aligned strategy becomes large, m-eligibility is more valuable for c-firms who are ex-ante restricted to investments only from value-aligned or unconstrained investors. The diversification enhancements yield higher equilibrium share prices, which make transformation contracts desirable for c-firms. The second key determinant for the transformation-contract price is the supply and demand balance of transformation opportunities in the transformation-market. In particular, the clearing price decreases with the number of d-firms as this implies a higher ex-ante availability of reform actions in the market. Conversely, the clearing price increases with the number of c-firms, as this creates more competition between potential buyers in the transformation-market.

Finally, we characterize the surplus-extraction equilibrium share prices:

Lemma 3.5. *In the surplus-extraction equilibrium, the share price of c-firm type f and a d-firm type ℓ can be written as a common risk-adjusted term minus a price wedge:*

$$P_f^* = \mu_c - R_c - \omega_f^*, \quad P_\ell^* = \mu_d - R_d - \omega_\ell^*$$

with equilibrium price wedges given by

$$\omega_A^* = \omega_\beta^* = \lambda_m \pi^* = \lambda_m \Big[\frac{N_c}{I_{nv}} - \frac{N_d}{I_m}\Big]\frac{\phi}{\psi\tau};$$
$$\omega_\alpha^* = \omega_R^* = -\lambda_{nv}\pi^* = -\lambda_{nv}\Big[\frac{N_c}{I_{nv}} - \frac{N_d}{I_m}\Big]\frac{\phi}{\psi\tau}$$

Proof. See Appendix A.2 □

From Lemma 3.5 we see that the shares of d-firms that engage in environmental reform trade at a premium which is larger than the premium under a market for reallocation only (c.f. Lemma 3.2). Note that this premium is the same as the one faced by the c-firms that participate in the transformation market ($\omega_\alpha^* = \omega_R^*$) — and this symmetry also holds for the case of the d-firms that sell reform-options in the transformation market and the passive c-firms, $\omega_A^* = \omega_\beta^*$, with the caveat that the shares from these firms trade at a discount ($\omega_\beta^* < 0$). Importantly, note that as opposed to Lemma 3.2, in the surplus-extraction equilibrium the share price wedges do not depend on the cost of reform K nor the cost of secondary trades T. As long as the conditions in Lemma 3.4 hold, these costs get fully absorbed by the c-firms, and the share price wedges are instead driven by the risk-sharing effects of the transformation market.

3.2.2 Cost-Sharing Equilibrium

Fix $\pi \leq K$. In this case, posting a transformation contract entails a positive cost for d-firms, which must contribute the non-negative remainder payment of $K - \pi \geq 0$ to finance the reform action. Hence, the transformation contract implements a cost-sharing mechanism between the d-firm and the c-firm, by which they jointly cover the full cost of reform. The c-firm benefits by claiming impact, becoming m-eligible. The d-firm, benefits because it ceases to operate an unreformed pollutive asset upon reform, which makes it v-eligible. It follows that to sustain a positive volume of contract trades in the transformation market, the c-firm contribution π can never fall below a threshold of $\underline{\pi} := K - T$. For $\pi < \underline{\pi}$, secondary-trading strictly dominates posting a transformation contract for the d-firm, because it enables v-eligibility at a strictly lower cost. In what follows, we focus on the interior case $\pi \in (\underline{\pi}, K)$ as it provides a more intuitive description of the equilibrium structure. We defer the corner cases — namely where $\pi = \underline{\pi}$ and $\pi = K$ — to the Appendix.

In a cost-sharing equilibrium with $\pi \in (\underline{\pi}, K)$, the c-firm optimally decides between the A-choice and the α-choice. The d-firms decide between the R-choice and the β-choice, but as opposed to a surplus-extraction equilibrium, now operating the unreformed d-asset may also be optimal in equilibrium. Because $\pi > \underline{\pi}$, the secondary market unravels.[8] Thus, a key difference with the surplus-extraction equilibrium is that not all pollutive assets are necessarily getting reformed. The equilibrium corporate choice market clearing conditions become:

$$N_A^* + N_\alpha^* = N_c, \quad N_U^* + N_R^* + N_\beta^* = N_d. \tag{7}$$

The no-entry & no-exit condition across c and d-firm sub-markets imply that the following relationships across share prices must hold in equilibrium for any $\pi \in (\underline{\pi}, K)$:

$$P_\alpha^* - \pi = P_A^*, \qquad P_R^* - K = P_U^*, \qquad P_\beta^* - (K - \pi) = P_U^*. \tag{8}$$

Note that these conditions extend those of a surplus-extraction equilibrium to account for the firms that choose to operate unreformed d-assets. Equation (8) imposes a condition which mirrors that of a case where there is only a market for real-asset reallocation (c.f. (2)) with the transformation market substituting secondary-trading. Thus, for the d-firms we have that $P_U^* < P_\beta^* < P_R^*$, and for the c-firms, we have that $P_\alpha^* > P_A^*$. This implies that n-investors only buy shares from U and A firms, v-investors only buy shares from A and β firms, and m-investors only buy shares from α and R firms. At the portfolio allocation level, market clearing imposes the following conditions in equilibrium:

$$I_n x_{nU}^* = N_U^*, \quad I_v x_{v\beta}^* = N_\beta^*, \quad I_m x_{mR}^* = N_R^* \tag{9a}$$

$$I_n x_{nA}^* + I_v x_{vA}^* = N_A^*, \quad I_m x_{m\alpha}^* = N_\alpha^* \tag{9b}$$

From (9) we observe that, in this case, the number of sub-markets is five. The sub-market structure for c-firms is that of a surplus-extraction equilibrium: $(n \cup v, A)$ and (m, α). For d-firm, the sub-market structure is that of a case where there is only a market for real-asset reallocation — (n, U),

[8] Note that when the transformation-contract price hits the lower bound, $\pi = K - T$, it might be the case that some d-firms also engage in secondary trading (S) – we discuss this case in the Appendix

(v, β) and (m, R) — but the transformation market effectively replaces secondary-trading.

Our next Lemma characterizes equilibrium corporate choices for any transformation-contract price $\pi \in (\underline{\pi}, K)$:

Lemma 3.6. *Fix $\pi \in (\underline{\pi}, K)$. In equilibrium, investors participate in five sub-markets: (1) unconstrained and value-aligned investors buy shares in A-firms, (2) impact-aligned investors buy shares in α-firms, (3) unconstrained investors buy shares in U-firms, (4) value-aligned investors buy shares in β-firms, and (5) impact-aligned investors buy shares in R-firms. The number of c and d-firms making each corporate choice $f \in \{A, \alpha\}$ and $\ell \in \{U, \beta, R\}$ can be written as*

$$N_f^* = \max\{0, \lambda_\theta(N_c + \delta_f^*)\}, \quad N_\ell^* = \max\{0, \lambda_\theta(N_d + \delta_\ell^*)\}$$

for $(\theta, f, \ell) \in (n, A, U), (v, A, \beta), (m, \alpha, R)$. Allocative distortions for c-firms are:

$$\delta_A^* = \frac{\tau}{\phi}[\sigma_d^2 I_m \pi - \sigma_{cd}\xi_A^*]; \qquad \delta_\alpha^* = \frac{\tau}{\phi}[-\sigma_d^2 I_{nv}\pi + \sigma_{cd}\xi_\alpha^*]$$

and satisfy $\sum_{(\theta,f)} I_\theta \delta_f^* = 0$. Allocative distortions for d-firm are:

$$\begin{aligned}
\delta_U^* &= \frac{\tau}{\phi}[\sigma_c^2\big(I_v(K-\pi) + I_m K\big) - \sigma_{cd}\xi_U^*] \\
\delta_\beta^* &= \frac{\tau}{\phi}[\sigma_c^2\big(I_m\pi - I_n(K-\pi)\big) - \sigma_{cd}\xi_\beta^*] \\
\delta_R^* &= \frac{\tau}{\phi}[\sigma_c^2\big(-I_v\pi - I_n K\big) + \sigma_{cd}\xi_R^*]
\end{aligned}$$

and satisfy $\sum_{(\theta,\ell)} I_\theta \delta_\ell^* = 0$. Equilibrium covariance distortion terms ξ^* are derived in the Appendix.

Proof. See Appendix A.3. □

A key difference in Lemma 3.6 as compared to Lemma 3.1 is that in the cost-sharing equilibrium, value-aligned investors incentivize d-firms to engage in the real-asset transformation market via the cost-sharing mechanism instead of using the secondary trading channel, which unravels as long as $\pi > \underline{\pi}$. The c-firm corporate choices, on the other hand, follow a similar structure to the surplus-extraction equilibrium (c.f. Lema 3.3) with N_α^* firms becoming m-eligible via indirect real-asset reforms. Again, the effect of adding one more value-aligned investor affects the transformation-contract price, which we discuss in our next Lemma.

Lemma 3.7. *In the cost-sharing equilibrium, the transformation-contract price is given by*

$$\pi^* = K\big[1 - \frac{\delta_1 + \psi}{\delta_2 + \psi}\big] + \frac{\phi}{\tau\psi}\big[\frac{N_c}{I_v} - \frac{N_d}{I_m}\big]\big[\frac{\psi}{\delta_2 + \psi}\big]$$

where

$$\delta_1 := I_n\big[\frac{\sigma_c^2}{I_m} + \frac{\sigma_d^2}{I_v}\big]; \quad \delta_2 := I_n\big[\frac{\sigma_d^2 - \sigma_{cd}}{I_v}\big]$$

An interior cost-sharing equilibrium exists if and only if $\pi^* \in (\underline{\pi}, K)$.

Proof. See Appendix A.3. □

Note that the transformation contract price differs from that in the surplus-extraction equilibrium in Lemma 3.4. However, the result in Lemma 3.7 collapses to that in Lemma 3.4 when the population of unconstrained investors goes to zero. This shows the differential role of n-investors in each case: in a surplus-extraction equilibrium, n-investors buy shares of d-firms that engage in the market for real-asset transformation due to their increased revenue from the transformation contract. Conversely, in a cost-sharing equilibrium, when a d-firm posts and accepts a transformation contract , this precludes participation from n-investors, which can make the cost-sharing mechanism unattractive. On the other hand, comparative statics with respect to value-aligned and impact-aligned investors, as well as c-firms and d-firms are equivalent: the clearing payment goes down if there are more m-investors and c-firms, and goes up if there are more v-investors or d-firms.

Finally, we characterize the equilibrium share prices:

Lemma 3.8. *In the obligations-trading equilibrium, the share price of c-firms type f and d-firms type ℓ can be written as a common risk adjusted term minus a price wedge*

$$P_f^* = \mu_c - R_c - \omega_f^*, \quad P_\ell^* = \mu_d - R_d - \omega_\ell^*$$

with equilibrium price wedges for the two c-firm types given by

$$\omega_A^* = \lambda_m \pi^*, \quad \omega_\alpha^* = -\lambda_{nv}\pi^*,$$

and equilibrium price wedge for the three d-firm types given by

$$\omega_U^* = \lambda_m K + \lambda_v (K - \pi^*), \quad \omega_\beta^* = \lambda_m \pi^* - \lambda_n (K - \pi^*), \quad \omega_R^* = -(\lambda_v \pi^* + \lambda_n K).$$

Proof. See Appendix A.3. □

The result in Lemma 3.8 again shows that the c-firm sub-market structure resembles the surplus-extraction equilibrium: the price wedges for c-firms follow the same relationship to the transformation-contract price as in Lemma 3.5. On the other hand, price wedges for d-firms follow the case of a market for real asset reallocation, with the transaction cost T replaced by d-firm transformation contract payment $K - \pi$, which is weakly smaller than T.

4 Welfare Effects of Co-Existing Markets

Having characterized competitive equilibrium outcomes under each market specification and contracting structures, we turn our attention to welfare effects. We focus on three aspects: real asset reform and secondary trading, firm surplus and investor surplus. We derive the welfare results for a symmetric case $N_c = N_d = N$ with equal variance and uncorrelated real asset returns.

First, consider the perspective of a social planner. When pollution externalities are sufficiently large, real-asset reform is socially efficient, but it is seldom the case that firms or markets internalize such effects. In our model, neither firms nor investors internalize any damages from pollution. Impact-aligned investors can enhance efficiency by providing incentives for share-price maximizing firms to engage in real-asset reform—but in the case of a market for real asset reallocation only, these incentives are curbed by the presence of value-aligned investors, who instead favor d-firms that engage in secondary market trades. Our first theorem discusses how the introduction of a separate market for real asset transformation can strengthen the incentives to own and transform pollutive assets — and change the marginal effect of value-aligned investor participation in equilibrium.

Theorem 4.1 (Incentives to Own and Transform Pollutive Assets)**.** *In the case of uncorrelated cash flows, the introduction of a separate transformation market for reform rights:*

- *Increases real asset reform in the surplus-extraction and cost-sharing equilibria.*

- *Decreases secondary trades in the surplus-extraction and cost-sharing equilibria.*

For sufficiently many firms, the marginal effect of an adding one value-aligned investor on the number of reformed real assets flips signs.

Proof. See Appendix A.4 □

Theorem 4.1 demonstrates that real-asset reform incentives are most effective under co-existing markets for real-asset reallocation and transformation. When firms are allowed to contract over reform actions, c-firms indirectly contribute towards d-asset reform under the incentive to become eligible for m-investors – a channel which is absent in the case of a market for real-asset reallocation only. In the cost-sharing equilibrium, the cost of reform is divided between a c-firm, who claims impact upon reform, and a d-firm, who ceases to operate an unreformed pollutive asset and thus has an alternative to secondary trading. For sufficiently many firms N, in both the surplus-extraction and cost-sharing equilibrium, the marginal effect of an additional v-investors is positive on the total number of reformed assets, since the d-firms prefer to engage in the reform action exchange rather than using the secondary trading channel.

Now, we discuss the effects of coexisting markets on firm surplus for both c and d-firms.

Theorem 4.2 (Co-Existing Markets and Firm Surplus)**.** *In the case of uncorrelated cash flows, the introduction of a separate transformation market for reform rights:*

- *Enhances d-firm surplus in the surplus-extraction and cost-sharing equilibria.*

- *Enhances c-firm surplus in the surplus-extraction and cost-sharing equilibria.*

Proof. See Appendix A.5 □

Theorem 4.2 shows that co-existing markets not only support incentive-compatible real-asset reform, but also unambiguously enhance firm surplus. The no-entry conditions, which are consequence of the endogenous corporate choice (c.f. Equations 2, 5 and 8) imply that c and d-firms share surplus symmetrically in each equilibrium. This metric can be pinned down as the share price of a d firm operating an unreformed real asset, or passive c firm that does not take any additional actions under reallocation only and cost-sharing equilibria. The shares of d firms that operates unreformed d assets trade at a *discount* in both cases – but the discount is *smaller* under cost-sharing than under allocation only. The same is true for a passive c-firm: the share price discount is smaller under the cost-sharing equilibrium. In the surplus-extraction equilibrium, the d firm invariant corresponds to the share price of a reformed firm minus the direct cost of reform. This quantity is again greater than its counterpart under reallocation only. What supports higher equilibrium share prices when reallocation and transformation markets co-exist? In our model, the transformation market provides a channel for firms to broaden investor participation at lower costs than under reallocation only. This enables more investor competition, yielding higher firm surplus. In Appendix C we study policy alternatives such as (1) a tax on secondary trades, (2) a carbon tax, and (3) an emissions-trading system. We show that although these alternatives can also increase real-asset reform, they all decrease d-firm surplus. This is a key point of departure with a dedicated market for real-asset transformation.

Finally, we discuss the effects of coexisting markets on investor surplus separating across the c and d sub-markets. The increase in participation (and investor competition) brought by co-existing markets induces several welfare redistribution effects over investor-types.

Theorem 4.3 (Co-Existing Markets and Investor Surplus)**.** *In the case of uncorrelated cash flows, the introduction of a separate transformation market for reform rights has the following effects on investor surplus:*

- *In c-firm sub-markets, v-surplus decreases and m-surplus decreases in the surplus-extraction and cost-sharing equilibria.*
- *In d-firm sub-markets, v-surplus increases and m-surplus decreases in the surplus-extraction and cost-sharing equilibria.*

Finally, the unconstrained n-investor surplus decreases in both sub-markets unless there is a surplus-extraction equilibrium with a sufficiently high transformation contract price.

Proof. See Appendix A.6 □

The Sharpe ratio representation of the indirect investor utility in Theorem 4.3 is useful — it shows, for instance, that with a market for asset reallocation only, n and v investors engage in larger rent-extraction over clean sub-markets due to m-investor constraints. Because the ownership of pollution is a necessary condition for positive environmental impact, m-investors avoid participation altogether, creating an advantage for n and v investors. This advantage disappears as soon as the transformation market is introduced. Conversely, the introduction of a transformation market can enhance v surplus in dirty sub-markets, providing a cost-efficient alternative for firms to become v-eligible instead of paying secondary transaction costs. Finally, in a market for asset reallocation only, n investors (who are unconstrained) take advantage of sustainable investing constraints to engage in higher d-firm sub-market rent-extraction, but this is can be curbed with the introduction of a transformation market – unless there is a surplus-extraction equilibrium with a sufficiently high transformation-contract price, where v investor constraints are not active anymore (n and v become indistinguishable) allowing both types to exploit the m-investor constraint.

5 Concluding Remarks

Our paper lays out a theory of the implications of co-existing markets for real-asset reallocation and transformation in the context of environmentally driven reform, given the presence of socially motivated investors. We show that introducing a transformation market leads to equilibrium structures that exhibit surplus-extraction or cost-sharing between pollutive and clean firms. Transformation contracts are priced as the anticipated change in share prices due to the impact claim associated with real-asset reform. If there is not enough demand to support a surplus-extraction equilibrium, transformation contracts are used by pollutive firms as a cost-sharing mechanism. In such an outcome, the transformation contract price is weakly smaller than the cost of reform – the pollutive firm contributes a remainder payment to finance the reform action. Both mechanisms expand investor participation and decrease the use of the secondary trading channel, enhancing efficiency and leading to more depth in the overall transformation of pollutive real assets as compared to a case with only a market for real asset reallocation.

Several insights arise from our theory. Our results highlights reform contracts across heterogeneous firms — such as clean and pollutive firms — as relevant structures for real-asset transformation under a heterogeneous investor base. The market for real asset transformations decouples the disincentives to own pollutive real assets from the incentives to reform them. There is some incipient empirical evidence on the use of forward reform contracts for methane abatement (Palacios et al. 2025). In this context, cooperation agreements across heterogeneous firms are frequently mentioned as valuable contractual arrangements for real-asset transformation in the oil sector. For instance, non-operated joint ventures (NOJVs), in which public firms with environmental targets help other companies, such as state-owned oil & gas companies, to reduce their emissions intensity resemble our transformation contracts (EDF 2022). An empirical analysis of such contracts would be relevant to better understand how corporate incentives interact with real-asset transformations.

Second, our model implies that firms who enter contracts for real asset reform actions should see increased investor participation via two different channels. A firm engaging in indirect reform actions over real assets becomes more attractive for an investor who directly values emissions reductions. This type of investor preferences is usually referred to as impact investing in the sustainable finance literature (Landier and Lovo 2024, Oehmke and Opp 2025). Conversely, a firm whose real assets get indirectly reformed becomes more attractive for investors who value low balance-sheet emissions. This preference type is associated with value investing. Since each of these channels is independent, our theory suggests that joint reform contracts could offer a window into whether sustainable investors and financial intermediaries follow impact or value-aligned strategies when it comes to real-asset reallocation.

Third, our model suggests that whenever secondary trading is costly, impact and value investor's strategies are de facto aligned. However, when secondary trading is available at a cost lower than the cost of real-asset reform, the presence of green investors imposes a double negative externality: corporate reallocation decisions makes achieving impact more costly for the impact investor, as well as making reform less appealing for firms that own pollutive assets. In such equilibria, secondary trading effectively "*removes the option to engage with firms to reduce pollution*" in the sense of Duchin et al. 2025. It would be relevant to empirically distinguish these cases from other settings where secondary trading might not have negative effects on investor participation or real-asset reform.

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A Missing Proofs

A.1 Market for Real-Asset Reallocation Only

For an investor type θ buying shares in c-firm type f and d-firm type ℓ, utility is given by

$$U_\theta(x_{\theta f}, x_{\theta\ell}) = x_{\theta f}\mu_c + x_{\theta\ell}\mu_d - \frac{x_{\theta f}^2\sigma_c^2 + x_{\theta\ell}^2\sigma_d^2 + 2x_{\theta f}x_{\theta\ell}\sigma_{cd}}{2\tau} - P_f x_{\theta f} - P_\ell x_{\theta\ell}. \tag{10}$$

Let $\pi_f := \mu_f - P_f$ be the mean excess return for a firm making corporate choice f. Taking the first-order conditions over (10) gives investor-optimality conditions:

$$\tau\pi_f = x_{if}\sigma_c^2 + x_{i\ell}\sigma_{cd} \tag{11a}$$

$$\tau\pi_\ell = x_{i\ell}\sigma_d^2 + x_{if}\sigma_{cd} \tag{11b}$$

Solving for x_{if} and $x_{i\ell}$ yields:

$$x_{if} = \frac{\tau}{\phi}[\sigma_d^2\pi_f - \sigma_{cd}\pi_\ell], \tag{12a}$$

$$x_{i\ell} = \frac{\tau}{\phi}[\sigma_c^2\pi_\ell - \sigma_{cd}\pi_f]. \tag{12b}$$

All else equal, when c and d cash flows are positively correlated, there are less gains from diversification and investors take weakly smaller positions in equilibrium. Recall that the active sub-market pairs in equilibrium are $\{n, A, U\}$, $\{v, A, S\}$ and $\{m, \emptyset, R\}$. Plugging (12) into the market clearing condition (3), using that the number of c and d-firms is fixed by (1) yields:

$$I_n[\sigma_d^2\pi_A - \sigma_{cd}\pi_U] + I_v[\sigma_d^2\pi_A - \sigma_{cd}\pi_S] = \frac{\phi}{\tau}N_c \tag{13a}$$

$$I_n[\sigma_c^2\pi_U - \sigma_{cd}\pi_A] + I_v[\sigma_c^2\pi_S - \sigma_{cd}\pi_A] + I_m[\sigma_c^2\pi_R] = \frac{\phi}{\tau}N_d \tag{13b}$$

Because of the no entry condition (2) the following relationship between the mean excess returns holds in equilibrium:

$$\pi_S = \pi_U - T, \quad \pi_R = \pi_U - K. \tag{14}$$

We can use (14) to rewrite (13) and recover the unconstrained investor positions:

$$I_n[\sigma_d^2\pi_A - \sigma_{cd}\pi_U] + I_v[\sigma_d^2\pi_A - \sigma_{cd}\pi_U + \sigma_{cd}T] = \frac{\phi}{\tau}N_c \tag{15a}$$

$$I_n[\sigma_c^2\pi_U - \sigma_{cd}\pi_A] + I_v[\sigma_c^2\pi_U - \sigma_c^2 T - \sigma_{cd}\pi_A] + I_m[\sigma_c^2\pi_U - \sigma_c^2 K] = \frac{\phi}{\tau}N_d \tag{15b}$$

Using (12) and market clearing we can now derive the c-firm sub-market positions:

$$x_{nA}^* = \frac{1}{I_{vn}}[N_c - \frac{\tau}{\phi}I_v\sigma_{cd}T] \tag{16a}$$

$$x_{vA}^* = \frac{1}{I_{vn}}[N_c + \frac{\tau}{\phi}I_n\sigma_{cd}T] \tag{16b}$$

From (14) we can derive d-firm position expressions for v and m-investors as a function of the unconstrained investor position:

$$x_{vS}^* = x_{nU}^* - \frac{\tau}{\phi}\sigma_c^2 T \tag{17a}$$

$$x_{mR}^* = x_{nU}^* - \frac{\tau}{\phi}[\sigma_c^2 K + \sigma_{cd}\pi_A] \tag{17b}$$

From these we can recover d-firm sub-market investor positions:

$$x_{nU}^* = \frac{1}{I}[N_d + \frac{\tau}{\phi}\big(I_v\sigma_c^2 T + I_m\sigma_c^2 K - I_m\sigma_{cd}\pi_A\big)] \tag{18a}$$

$$x_{vS}^* = \frac{1}{I}[N_d + \frac{\tau}{\phi}\big(I_m\sigma_c^2(K-T) - I_n\sigma_c^2 T - I_m\sigma_{cd}\pi_A\big)] \tag{18b}$$

$$x_{mR}^* = \frac{1}{I}[N_d + \frac{\tau}{\phi}\big(-I_v\sigma_c^2(K-T) - I_n\sigma_c^2 K + I_{nv}\sigma_{cd}\pi_A\big)] \tag{18c}$$

From (18) we can observe that correlation terms are driven by the mean excess return in the c-firm sub-market. Becase n and v-investors allocate across d and c-firm sub-markets, a positive correlation implies that higher values of π_A lead to a smaller allocation in their respective d-firm sub-markets U and S. This indirectly benefits m-investors, as more d-firms choose to engage in real-asset reform. We can rewrite the d-firm allocations as the average position plus the allocative distortions:

$$\delta_U^* := \frac{\tau}{\phi}\sigma_c^2(I_vT + I_mK) - \frac{\tau}{\phi}\sigma_{cd}\,\xi_U^*, \tag{19a}$$

$$\delta_{S^*} := \frac{\tau}{\phi}\sigma_c^2(I_m(K-T) - I_nT) - \frac{\tau}{\phi}\sigma_{cd}\,\xi_S^*, \tag{19b}$$

$$\delta_R^* := \frac{\tau}{\phi}\sigma_c^2(-I_v(K-T) - I_nK) + \frac{\tau}{\phi}\sigma_{cd}\,\xi_R^*, \tag{19c}$$

with correlation terms given by:

$$\xi_R^* := I_{nv}\pi_A^*, \quad \xi_S^* := I_m\pi_A^*, \quad \xi_U^* =: I_m\pi_A^*. \tag{19d}$$

Finally, it remains to solve explicitly for π_A. Rearranging (15) yields:

$$\pi_U\sigma_c^2 I - \pi_A\sigma_{cd}I_{nv} = \frac{\phi}{\tau}N_d + \sigma_c^2 TI_v + \sigma_c^2 KI_m \tag{20a}$$

$$\pi_A\sigma_d^2 I_{nv} - \pi_U\sigma_{cd}I_{nv} = \frac{\phi}{\tau}N_c + \sigma_{cd}TI_v \tag{20b}$$

Solving the system for π_U and π_A then yields:

$$\pi_A^* = \frac{\sigma_c^2 I[\frac{\phi}{\tau}N_c + \sigma_{cd}TI_v] + \sigma_{cd}I_{vn}[\frac{\phi}{\tau}N_d + \sigma_c^2(TI_v + KI_m)]}{\sigma_c^2\sigma_d^2 II_{vn} - \sigma_{cd}^2 I_{vn}^2} \tag{21a}$$

$$\pi_U^* = \frac{\sigma_d^2 I_{vn}[\frac{\phi}{\tau}N_d + \sigma_c^2(TI_v + KI_m)] + \sigma_{cd}I_{vn}[\frac{\phi}{\tau}N_c + \sigma_{cd}TI_v]}{\sigma_c^2\sigma_d^2 II_{vn} - \sigma_{cd}^2 I_{vn}^2}. \tag{21b}$$

which concludes the derivation.

A.2 Surplus-Extraction Equilibria with Co-Existing Markets

Recall that active sub-markets are $(\{n, v\}, A, \beta)$ and (m, α, R). Taking first order conditions over active capital allocation decisions then yields investor-optimality conditions:

$$x_{\theta f}^* = \frac{\tau}{\phi}[\pi_f\sigma_d^2 - \pi_\ell\sigma_{cd}] \quad \forall\,(\theta, f, \ell) \in (\{n, v\}, A, \beta), (m, \alpha, R), \tag{22a}$$

$$x_{\theta\ell}^* = \frac{\tau}{\phi}[\pi_\ell\sigma_c^2 - \pi_f\sigma_{cd}] \quad \forall\,(\theta, f, \ell) \in (\{n, v\}, A, \beta), (m, \alpha, R)\}. \tag{22b}$$

Plugging (22) into market-clearing conditions (4) yields:

$$I_{vn}[\sigma_c^2\pi_\beta - \sigma_{cd}\pi_A] + I_m[\sigma_c^2\pi_R - \sigma_{cd}\pi_\alpha] = N_d\frac{\phi}{\tau} \tag{23a}$$

$$I_{vn}[\sigma_d^2\pi_A - \sigma_{cd}\pi_\beta] + I_m[\sigma_d^2\pi_\alpha - \sigma_{cd}\pi_R] = N_c\frac{\phi}{\tau} \tag{23b}$$

By the no-entry & no-exit condition (5) on share prices we know that:

$$\pi_R = \pi_\beta - \pi; \quad \pi_\alpha = \pi_A - \pi, \tag{24}$$

with π the transformation-market clearing price, satisfying $\pi > K$. Using (24) to rewrite (23) in terms of π_β and π_A:

$$\sigma_c^2\pi_\beta - \sigma_{cd}\pi_A = \frac{1}{I}[N_d\frac{\phi}{\tau} + I_m\sigma_c^2\pi - I_m\sigma_{cd}\pi] \tag{25a}$$

$$\sigma_d^2\pi_A - \sigma_{cd}\pi_\beta = \frac{1}{I}[N_c\frac{\phi}{\tau} + I_m\sigma_d^2\pi - I_m\sigma_{cd}\pi] \tag{25b}$$

Then, using (22), we can solve for the equilibrium positions of n and v investors as follows:

$$x^*_{n\beta}(\pi) := \frac{1}{I}\big[N_d + \frac{\tau}{\phi}(I_m\sigma_c^2\pi - I_m\sigma_{cd}\pi)\big] \tag{26a}$$

$$x^*_{nA}(\pi) := \frac{1}{I}\big[N_c + \frac{\tau}{\phi}(I_m\sigma_d^2\pi - I_m\sigma_{cd}\pi)\big] \tag{26b}$$

Again using the corporate choice market-clearing condition (4) we get that:

$$x^*_{mR}(\pi) = \frac{N_d}{I_m} - \frac{I_{vn}}{I_m}x^*_{n\beta}(\pi), \tag{27a}$$

$$x^*_{m\alpha}(\pi) = \frac{N_c}{I_m} - \frac{I_{vn}}{I_m}x^*_{nA}(\pi). \tag{27b}$$

Replacing and rearranging yields the m investor positions:

$$x^*_{mR}(\pi) = \frac{1}{I}\big[N_d - \frac{\tau}{\phi}(I_{nv}\sigma_c^2\pi - I_{nv}\sigma_{cd}\pi)\big], \tag{28a}$$

$$x^*_{m\alpha}(\pi) = \frac{1}{I}\big[N_c - \frac{\tau}{\phi}(I_{nv}\sigma_d^2\pi - I_{nv}\sigma_{cd}\pi)\big]. \tag{28b}$$

It is straight forward to derive the equilibrium sub-market sizes under optimal corporate choices since $N^*_\alpha(\pi) = I_m x^*_{m\alpha}$, $N^*_A(\pi) = I_{nv} x^*_{nA}$, $N^*_R(\pi) = I_m x^*_{mR}$ and $N^*_\beta(\pi) = I_{nv} x^*_{n\beta}$. To study equilibrium prices we can use (22) to explicitly compute excess rents in equilibrium:

$$\pi^*_\beta(\pi) = \frac{\sigma_d^2}{\tau} x^*_{n\beta}(\pi) + \frac{\sigma_{cd}}{\tau} x^*_{nA} \tag{29}$$

$$\pi^*_A(\pi) = \frac{\sigma_c^2}{\tau} x^*_{nA}(\pi) + \frac{\sigma_{cd}}{\tau} x^*_{n\beta} \tag{30}$$

Using the definition of the excess mean returns we can solve for share prices of A and β-firms:

$$P^*_\beta(\pi) = \mu_d - \frac{1}{\tau}[\sigma_d^2 x^*_{n\beta}(\pi) + \sigma_{cd} x^*_{nA}(\pi)] \tag{31a}$$

$$P^*_A(\pi) = \mu_c - \frac{1}{\tau}[\sigma_c^2 x^*_{nA}(\pi) + \sigma_{cd} x^*_{n\beta}(\pi)] \tag{31b}$$

From (26) we can compute the inner sums:

$$\sigma_d^2 x^*_{n\beta}(\pi) - \sigma_{cd} x^*_{nA}(\pi) = \frac{1}{I}\left[\sigma_d^2 N_d + \sigma_{cd} N_c + \frac{\tau}{\phi}(I_m \sigma_c^2 \sigma_d^2 \pi - I_m \sigma_{cd}^2 \pi)\right] \tag{32a}$$

$$= \tau(R_d + \frac{1}{I} I_m \pi) \tag{32b}$$

$$\sigma_c^2 x^*_{nA}(\pi) - \sigma_{cd} x^*_{nd}(\pi) = \frac{1}{I}\left[\sigma_c^2 N_c + \sigma_{cd} N_d + \frac{\tau}{\phi}(I_m \sigma_c^2 \sigma_d^2 \pi - I_m \sigma_{cd}^2 \pi)\right] \tag{32c}$$

$$= \tau(R_c + \frac{1}{I} I_m \pi) \tag{32d}$$

Equilibrium share prices as a function of the transformation contract price for A and β-firms are:

$$P^*_\beta(\pi) = \mu_d - R_d + \frac{I_m}{I}\pi, \tag{33a}$$

$$P^*_A(\pi) = \mu_c - R_c + \frac{I_m}{I}\pi, \tag{33b}$$

and the no-entry condition (5) lets us recover the equilibrium share prices for α and R-firms:

$$P^*_R(\pi) = \mu_d - R_d - \frac{I_{nv}}{I}\pi, \tag{33c}$$

$$P^*_\alpha(\pi) = \mu_c - R_c - \frac{I_{nv}}{I}\pi. \tag{33d}$$

Finally, we can use the transformation market clearing condition to solve for the transformation-contract clearing price:

$$
\begin{aligned}
& N^*_\alpha(\pi^*) = N^*_\beta(\pi^*) \\
\iff & I_m x^*_{m\alpha}(\pi^*) = I_{nv} x^*_{n\beta}(\pi^*) \\
\iff & \lambda_m(N_c - \frac{\tau}{\phi} A\pi^*) = \lambda_{nv}(N_d + \frac{\tau}{\phi} B\pi) \\
\iff & \lambda_m N_c - \lambda_{nv} N_d = \pi^*(\frac{\tau}{\phi}(\lambda_m A + \lambda_{nv} B)) \\
\iff & \pi^* = \frac{\lambda_m N_c - \lambda_{nv} N_d}{\lambda_m A + \lambda_{nv} B} \frac{\phi}{\tau},
\end{aligned}
$$

where $A := \frac{\tau}{\phi} I_{nv}(\sigma_d^2 - \sigma_{cd})$ and $B := \frac{\tau}{\phi} I_m(\sigma_c^2 - \sigma_{cd})$. Simplifying the sum in the denominator yields the expression in the main body of the paper. In particular:

$$
\begin{aligned}
\lambda_m I_{nv}[\sigma_d^2 - \sigma_{cd}] + \lambda_{nv} I_m[\sigma_c^2 - \sigma_{cd}] &= I(\lambda_m \lambda_{nv}[\sigma_c^2 + \sigma_d^2 - 2\sigma_{cd}]) \\
&= I\lambda_m \lambda_{nv} \psi
\end{aligned}
$$

So that the transformation-contract clearing price can be written as:

$$
\pi^* = [\frac{N_c}{I_{gn}} - \frac{N_d}{I_s}] \frac{\phi}{\psi\tau}
$$

A.3 Co-Existing Markets: Cost-Sharing Equilibria

Recall that active sub-markets are (n, A, U), (v, A, β) and (m, α, R). First order conditions over active capital allocation decisions then yields investor-optimality conditions:

$$
x^*_{\theta f} = \frac{\tau}{\phi}[\pi_f \sigma_d^2 - \pi_\ell \sigma_{cd}] \quad \forall (\theta, f, \ell) \in (n, A, U), (v, A, \beta), (m, \alpha, R), \tag{34a}
$$

$$
x^*_{\theta \ell} = \frac{\tau}{\phi}[\pi_\ell \sigma_c^2 - \pi_f \sigma_{cd}] \quad \forall (\theta, f, \ell) \in (n, A, U), (v, A, \beta), (m, \alpha, R). \tag{34b}
$$

Combining (34) with corporate-choice clearing (7) and portfolio allocation clearing (9) yields:

$$
I_n[\sigma_d^2 \pi_A - \sigma_{cd} \pi_U] + I_v[\sigma_d^2 \pi_A - \sigma_{cd} \pi_\beta] + I_m[\sigma_d^2 \pi_\alpha - \sigma_{cd} \pi_R] = N_c \frac{\phi}{\tau} \tag{35}
$$

$$
I_n[\sigma_c^2 \pi_U - \sigma_{cd} \pi_A] + I_v[\sigma_c^2 \pi_\beta - \sigma_{cd} \pi_A] + I_m[\sigma_c^2 \pi_R - \sigma_{cd} \pi_\alpha] = N_d \frac{\phi}{\tau} \tag{36}
$$

The no-entry conditions (8) imply that:

$$\pi_U + K - \pi = \pi_\beta, \quad \pi_U + K = \pi_R, \quad \pi_A + \pi = \pi_\alpha \tag{37}$$

Using (37) to rewrite (35) in terms of π_A and π_U:

$$I_n[\sigma_d^2\pi_A - \sigma_{cd}\pi_U] + I_v[\sigma_d^2\pi_A - \sigma_{cd}(\pi_U - (K-\pi))] + I_m[\sigma_d^2(\pi_A - \pi) - \sigma_{cd}(\pi_U - K)] = N_c\frac{\phi}{\tau} \tag{38a}$$

$$I_n[\sigma_c^2\pi_U - \sigma_{cd}\pi_A] + I_v[\sigma_c^2(\pi_U - (K-\pi)) - \sigma_{cd}\pi_A] + I_m[\sigma_c^2(\pi - K) - \sigma_{cd}(\pi_A - \pi)] = N_d\frac{\phi}{\tau} \tag{38b}$$

We can rearrange (38) to recover the unconstrained investor positions:

$$[\sigma_d^2\pi_A - \sigma_{cd}\pi_U] = \frac{1}{I}\big(N_c\frac{\phi}{\tau} + I_m\sigma_d^2\pi - I_m\sigma_{cd}K - I_v\sigma_{cd}(K-\pi)\big) \tag{39a}$$

$$[\sigma_c^2\pi_U - \sigma_{cd}\pi_A] = \frac{1}{I}\big(N_d\frac{\phi}{\tau} + I_v\sigma_c^2(K-\pi) + I_m\sigma_c^2K - I_m\sigma_{cd}\pi\big) \tag{39b}$$

We can write the equilibrium positions as a function of π:

$$x^*_{nA}(\pi) = \frac{1}{I}\big[N_c + \frac{\tau}{\phi}[I_m\sigma_d^2\pi - I_m\sigma_{cd}K - I_v\sigma_{cd}(K-\pi)]\big]$$

$$x^*_{nU}(\pi) = \frac{1}{I}\big[N_d + \frac{\tau}{\phi}[I_v\sigma_c^2(K-\pi) + I_m\sigma_c^2K - I_m\sigma_{cd}\pi]\big]$$

From the first-order conditions now we can also derive the value-aligned investor position:

$$\begin{aligned}
x^*_{vA}(\pi) &= \frac{\tau}{\phi}[\sigma_d^2\pi_A - \sigma_{cd}\pi_\beta] = \frac{\tau}{\phi}[\sigma_d^2\pi_A - \sigma_{cd}\pi_U + \sigma_{cd}(K-\pi)] \\
&= x^*_{nA}(\pi) + \frac{\tau}{\phi}[\sigma_{cd}(K-\pi)] \\
&= \frac{1}{I}\big[N_c + \frac{\tau}{\phi}[I_m\sigma_d^2\pi - I_m\sigma_{cd}K + I_{nm}\sigma_{cd}(K-\pi)]\big] \\
x^*_{v\beta}(\pi) &= \frac{\tau}{\phi}[\sigma_c^2\pi_\beta - \sigma_{cd}\pi_A] = \frac{\tau}{\phi}[\sigma_c^2(\pi_U - (K-\pi)) + \sigma_{cd}\pi_A] \\
&= x^*_{nU}(\pi) - \frac{\tau}{\phi}[\sigma_c^2(K-\pi)] \\
&= \frac{1}{I}\big[N_d + \frac{\tau}{\phi}[-I_{nm}\sigma_c^2(K-\pi) + I_m\sigma_c^2K - I_m\sigma_{cd}\pi]\big]
\end{aligned}$$

Similarly for the impact-aligned investor:

$$
\begin{aligned}
x^*_{m\alpha}(\pi) &= \frac{\tau}{\phi}[\sigma_d^2\pi_\alpha - \sigma_{cd}\pi_R] = \frac{\tau}{\phi}[\sigma_d^2(\pi_A - \pi) - \sigma_{cd}(\pi_U - K)] \\
&= x^*_{nA}(\pi) - \frac{\tau}{\phi}[\sigma_d^2\pi - \sigma_{cd}K] \\
&= \frac{1}{I}\big[N_c + \frac{\tau}{\phi}[-I_{nv}\sigma_d^2\pi + I_{nv}\sigma_{cd}K - I_v\sigma_{cd}(K-\pi)]\big] \\
x^*_{mR}(\pi) &= \frac{\tau}{\phi}[\sigma_c^2\pi_R - \sigma_{cd}\pi_\alpha] = \frac{\tau}{\phi}[\sigma_c^2(\pi_U - K) - \sigma_{cd}(\pi_A - \pi)] \\
&= x^*_{nU}(\pi) - \frac{\tau}{\phi}[\sigma_c^2 K - \sigma_{cd}\pi] \\
&= \frac{1}{I}\big[N_d + \frac{\tau}{\phi}[I_v\sigma_c^2(K-\pi) - I_{nv}\sigma_c^2 K + I_{nv}\sigma_{cd}\pi]\big]
\end{aligned}
$$

It is straight forward to derive the sub-market equilibrium sizes under optimal corporate choices using that $N^*_\alpha(\pi) = I_m x^*_{m\alpha}$, $N^*_A(\pi) = I_n x^*_{nA} + I_v x^*_{vA}$, $N^*_R(\pi) = I_m x^*_{mR}$, $N^*_\beta(\pi) = I_v x^*_{v\beta}$ and $N^*_U(\pi) = I_n x^*_{nU}(\pi)$. This observation yields the expressions for allocative distortions and covariance terms:

$$
\begin{aligned}
\delta^*_U &= \frac{\tau}{\phi}[\sigma_c^2\big(I_v(K-\pi) + I_m K\big) - \sigma_{cd}\xi^*_U], & \xi^*_U &= I_m\pi, \\
\delta^*_\beta &= \frac{\tau}{\phi}[\sigma_c^2\big(I_m\pi - I_n(K-\pi)\big) - \sigma_{cd}\xi^*_\beta], & \xi^*_\beta &= I_m\pi, \\
\delta^*_R &= \frac{\tau}{\phi}[\sigma_c^2\big(-I_v\pi - I_n K\big) + \sigma_{cd}\xi^*_R], & \xi^*_R &= I_{nv}\pi, \\
\delta^*_\alpha &= \frac{\tau}{\phi}[-\sigma_d^2 I_{nv}\pi + \sigma_{cd}\xi^*_\alpha], & \xi^*_\alpha &= I_n K + I_v\pi, \\
\delta^*_A &= \frac{\tau}{\phi}[\sigma_d^2 I_m\pi - \sigma_{cd}\xi^*_A], & \xi^*_A &= I_m\frac{I_n K + I_v\pi}{I_{nv}}
\end{aligned}
$$

To compute the equilibrium prices we can rearrange (39) and derive mean excess return in equilibrium for A and U-firm shares:

$$
\pi^*_U(\pi) = \frac{\sigma_d^2}{\tau}x^*_{nU}(\pi) + \frac{\sigma_{cd}}{\tau}x^*_{nA}(\pi) \tag{43a}
$$

$$
\pi^*_A(\pi) = \frac{\sigma_c^2}{\tau}x^*_{nA}(\pi) + \frac{\sigma_{cd}}{\tau}x^*_{nU}(\pi) \tag{43b}
$$

This yields a direct expression for the equilibrium share prices:

$$P_U^*(\pi) = \mu_d - \frac{1}{\tau}[\sigma_d^2 x_{nU}^*(\pi) + \sigma_{cd} x_{nA}^*(\pi)] \tag{44a}$$

$$P_A^*(\pi) = \mu_c - \frac{1}{\tau}[\sigma_c^2 x_{nA}^*(\pi) + \sigma_{cd} x_{nU}^*(\pi)] \tag{44b}$$

Finally the market clearing condition for the transformation market imposes:

$$N_\beta^*(\pi) = N_\alpha^*(\pi) \tag{45a}$$

$$\iff I_g x_{g\beta}^*(\pi) = I_s x_{s\alpha}^*(\pi) \tag{45b}$$

$$\iff I_g(x_{nU}^*(\pi) - \frac{\tau}{\phi}[\sigma_c^2(K-\pi)]) = I_s(x_{nA}^*(\pi) - \frac{\tau}{\phi}[\sigma_d^2\pi - \sigma_{cd}K]) \tag{45c}$$

Expanding on the left side yields:

$$\lambda_v[N_d + \frac{\tau}{\phi}[-I_{nm}\sigma_c^2(K-\pi) + I_m\sigma_c^2 K - I_m\sigma_{cd}\pi]] \tag{45d}$$

$$= \lambda_v[N_d + \frac{\tau}{\phi}[-I_n\sigma_c^2(K-\pi) + I_m\sigma_c^2\pi - I_m\sigma_{cd}\pi]] \tag{45e}$$

Expanding on the right side yields:

$$\lambda_m[N_c + \frac{\tau}{\phi}[-I_{nv}\sigma_d^2\pi + I_{nv}\sigma_{cd}K - I_v\sigma_{cd}(K-\pi)]] \tag{45f}$$

$$= \lambda_m[N_c + \frac{\tau}{\phi}[-I_{nv}\sigma_d^2\pi + I_n\sigma_{cd}K + I_v\sigma_{cd}\pi]] \tag{45g}$$

We can define:

$$A(\pi) = [I_n\sigma_c^2 K - \pi(I_n\sigma_c^2 + I_m\sigma_c^2 - I_m\sigma_{cd})] \tag{45h}$$

$$B(\pi) = [I_n\sigma_{cd}K - \pi(I_{nv}\sigma_d^2 - I_v\sigma_{cd})] \tag{45i}$$

The market clearing condition becomes:

$$\frac{\phi}{\tau}[\lambda_v N_d - \lambda_m N_c] = \lambda_m B(\pi) + \lambda_v A(\pi), \tag{45j}$$

which yields:

$$\frac{\phi}{\tau}[\lambda_v N_d - \lambda_m N_c] - I_n(\lambda_m \sigma_{cd} K + \lambda_v \sigma_c^2 K) = -\pi[\lambda_m(I_{nv}\sigma_d^2 - I_v\sigma_{cd}) + \lambda_v(I_n\sigma_c^2 + I_m\sigma_c^2 - I_m\sigma_{cd})]. \tag{45k}$$

Finally we get that:

$$\pi = \frac{\frac{\phi}{\tau}[\lambda_m N_c - \lambda_v N_d] + I_n(\lambda_m \sigma_{cd} K + \lambda_v \sigma_c^2 K)}{[\lambda_m(I_{nv}\sigma_d^2 - I_v\sigma_{cd}) + \lambda_v(I_n\sigma_c^2 + I_m\sigma_c^2 - I_m\sigma_{cd})]} \tag{46}$$

Simplifying yields the result.

A.4 Proof of Theorem 4.1

In the case of a market for real asset reallocation only, denoted with sub-index 1, the number of reformed real assets in equilibrium is given by:

$$A^*_{R[1]} = \lambda_m(N + \xi^*_{R[1]}) = \lambda_m N - \lambda_m \frac{\tau}{\sigma^2} I_v(K - T) - \lambda_m \frac{\tau}{\sigma^2} I_n K$$

In the surplus-extraction equilibrium, denoted with sub-index 2, all assets get reformed.

$$A^*_{R[2]} - A^*_{R[1]} = \lambda_{nv} N + \lambda_m \frac{\tau}{\sigma^2} I_v(K - T) + \lambda_m \frac{\tau}{\sigma^2} I_n K > 0.$$

In a cost-sharing equilibrium (denoted with sub-index 3), the number of reformed real assets is

$$\begin{aligned}
A^*_{R[3]} &= N^*_{\beta[3]} + N^*_{R[3]} \\
&= \lambda_v(N + \frac{\tau}{\sigma^2}(I_m\pi_{[3]} - I_n(K - \pi_{[3]})) + \lambda_m(N - \frac{\tau}{\sigma^2}(I_v\pi_{[3]} + I_n K)) \\
&= \lambda_v(N - \frac{\tau}{\sigma^2} I_n(K - \pi_{[3]})) + \lambda_m(N - \frac{\tau}{\sigma^2} I_n K) \geq A^*_{R[1]}
\end{aligned}$$

where the last inequality is directly implied by $N^*_{R[3]} \geq 0$ which ensures that $N - \frac{\tau}{\sigma^2} I_n(K - \pi_{[3]}) \geq 0$. Note that secondary trades unravel in the surplus-extraction and cost-sharing equilibrium. Now, we consider the effect of adding a value-aligned investor on the number of reformed firms. It suffices to compare equilibria 1 and 3 because in a surplus-extraction equilibrium all d-assets get reformed.

First, we compare the number of unreformed firms in the base case and the cost-sharing equilibria:

$$N^*_{U[1]} = I_n x^*_{nU[1]} = \frac{I_n}{I}\big[N + \frac{\tau}{\sigma^2}\big(I_m K + I_v T\big)\big]$$
$$N^*_{U[3]} = I_n x^*_{nU[3]}(\pi_{[3]}) = \frac{I_n}{I}\big[N + \frac{\tau}{\sigma^2}\big(I_v(K - \pi_{[3]}) + I_m K\big)\big]$$

Introducing an additional value-aligned investor increases the denominator by one unit which creates downward pressure in the unreformed firms. At the same time, there is an increase in the average number of shares bought by the unconstrained investor – but this increase is weakly smaller in the cost-sharing equilibria compared to the base case for any value of $\pi \in [K - \pi, K]$. Finally, comparing the number of firms that engage in secondary trades in the base case, versus the number of firms that engage in the transformation market:

$$N^*_{S[1]} = I_v x^*_{gS[1]} = \frac{I_v}{I}\big[N + \frac{\tau}{\sigma_d^2}\big(I_m(K - T) - I_n T\big)\big]$$
$$N^*_{\beta[3]} = I_v x^*_{v\beta[3]}(\pi_{[3]}) = \frac{I_v}{I}\big[N + \frac{\tau}{\sigma^2}\big(I_m \pi_{[3]} - I_n(K - \pi_{[3]})\big)\big]$$

Introducing an additional value-aligned investor brings the market share $\frac{I_v}{I}$ closer to 1. Moreover, the inner expression is weakly larger with the transformation market for any value of $\pi \in [K-T, K]$. In the base case, the assets owned by firms in $N^*_{S[1]}$ are unreformed. With a transformation market, the assets owned by firms in $N^*_{\beta[3]}$ get reformed.

A.5 Proof of Theorem 4.2

Proof. First, we claim that aggregate firm surplus in a market for real asset reallocation only for each ex-ante firm type (c, d) is given by:

$$W_{c[1]} = N(\mu_c - R - \lambda_m \frac{N}{I_{nv}} \frac{\sigma^2}{\tau}), \qquad\qquad W_{d[1]} = N(\mu_d - R - \lambda_m K - \lambda_v T)$$

The aggregate welfare of c-firms $W_{c[1]}$ can be directly computed using Lemma 3.2 noting that all c-firms get the same utility given by the A-firm share price $P^*_{A[1]}$. A symmetric argument also holds for the aggregate welfare of d-firms $W_{d[1]}$. U-firm shares are priced at $P^*_{U[1]}$; S-firm shares are priced at $P^*_{S,[1]}$ and S-firms pay a cost of T; R-firm's shares are priced at $P^*_{R[1]}$ and

R-firms pay a cost of K. By the no-entry condition (2) all d-firms perceives the same utility of $P^*_{U[1]} = P^*_{S[1]} - T = P^*_{R[1]} - K$. Plugging the equilibrium prices yields the result. By the same rationale, in a surplus-extraction equilibrium, the aggregate c-firm utility is $W_{c[2]} = NP^*_{A[2]}$ and the aggregate d-firm utility is $W_{d[2]} = N(P^*_{R[2]} - K)$, yielding

$$W_{c[2]} = N(\mu_c - R - \lambda_m \pi_{[2]}), \qquad W_{d[2]} = N(\mu_d - R - \lambda_m K + \lambda_{nv}(\pi_{[2]} - K))$$

Further, in the cost-sharing equilibrium, c-firm and d-firm utility are given respectively by $W_{c[3]} = NP^*_{A[3]}$ and $W_{d[3]} = NP^*_{U[3]}$ yielding:

$$W_{c[3]} = N(\mu_c - R - \lambda_m \pi_{[3]}), \qquad W_{d[3]} = N(\mu_d - R - \lambda_m K - \lambda_v(K - \pi_{[3]}))$$

Then, the d-firm surplus increase follows by noting that $W_{d[2]} > W_{d[3]}$ and for any $\pi_{[3]} \in [K-T, K]$, we have $K - \pi_{[3]} \leq T$ so that $S^d_{[3]} \geq S^d_{[1]}$. The c-firm surplus increase follows by noting that $W_{c[3]} > W_{d[2]}$, and replacing $\pi_{[2]} = \frac{\sigma}{2\tau}[\frac{N}{I_{vn}} - \frac{N}{I_m}]$ into $W_{c[2]}$ to get that $W_{c[2]} \geq W_{[1]}$. □

A.6 Proof of Theorem 4.3

Proof. We focus on the investor Sharpe ratios – the net excess return relative to volatility faced by each investor in equilibrium.

$$U_\theta(x_\theta) = x_{\theta f}(\mu_c - P_f) + x_{\theta \ell}(\mu_d - P_\ell) - \frac{x^2_{\theta f}\sigma^2 + x^2_{\theta \ell}\sigma^2}{2\tau}$$

First-order conditions impose $x^*_{\theta k} = \frac{\tau}{\sigma^2}(\mu_k - P^*_k)$ for $k \in \{f, \ell\}$. The equilibrium Sharpe ratio in each sub-market corresponds to $S_k := \frac{\mu_k - P_k}{\sigma^2_k}$, which allows writing $x^*_{\theta k} = \tau S_k$. Plugging this relationship back into the utility function yields an expression for the investor's indirect utility:

$$\begin{aligned}\hat{U}_\theta &= \tau S_f(\mu_c - P^*_f) + \tau S_\ell(\mu_d - P^*_\ell) - \frac{(\tau S_f \sigma)^2 + (\tau S_\ell \sigma)^2}{2\tau} \\ &= \frac{\tau}{2}\sigma^2(S^2_f + S^2_\ell)\end{aligned}$$

Thus it suffices to study the changes in S_f and S_ℓ. First we study c-firm sub-markets. Across all equilibria it holds that both the n and v investor only buy shares in A-firms. Computing S_A for each equilibria yields:

$$S_{A[1]} = \frac{1}{\sigma^2}(R + \lambda_m \frac{N}{I_{nv}} \frac{\sigma^2}{\tau}), \qquad S_{A[2]} = \frac{1}{\sigma^2}(R + \lambda_m \pi_{[2]}) = \frac{1}{\sigma^2}(R + \lambda_m (\frac{N}{I_{nv}} - \frac{N}{I_m}) \frac{\sigma^2}{2\tau})$$
$$S_{A[3]} = \frac{1}{\sigma^2}(R + \lambda_m \pi_{[3]})$$

From the expressions we can directly conclude that $S_{A[1]} > S_{A[2]} > S_{A[3]}$ – the n and v investors see a surplus decrease due to increased competition from the m-investors – in each case, we have that a higher number of c-firms takes the α-corporate choice, leaving a smaller sub-market available for the n and v investors. It is clear that upon the introduction of a transformation market, m-investor surplus increases trivially in c-firm sub-markets: without it, m-participation is precluded, because the impact strategy prevents it from buying shares in a c-firm that does not own a pollution reduction opportunity.

Now, we study d-firm sub-markets. First, we focus on the v-investor. In the base case, the v-investor only buys shares in S-firms. In the surplus-extraction and cost-sharing equilibrium, however, it invests in β-firms. This yields the following comparisons:

$$S_{S[1]} = \frac{1}{\sigma^2}(R + \lambda_m(K - T) - \lambda_n T), \qquad S_{\beta[2]} = \frac{1}{\sigma^2}(R + \lambda_m \pi_{[2]})$$
$$S_{\beta[3]} = \frac{1}{\sigma^2}(R + \lambda_m \pi_{[3]} - \lambda_n(K - \pi_{[3]}))$$

We can directly observe, again, that $S_{\beta[2]} > S_{\beta[3]} > S_{S[1]}$ – v-investor surplus increases in the surplus-extraction and cost-sharing equilibrium compared to the base case. This is due to the value-aligned strategy being easier to comply with: in addition to secondary-trading, the d-firm can also request contributions from c-firms to become indirectly reformed. On the other side, the m-investor will hold a less competitive position, as more d-firms are attracted to the transformation market compared to secondary-trading, leaving less d-firms in the sub-market for direct reform (R-firm) which reduces m-investor surplus:

$$S_{R[1]} = \frac{1}{\sigma^2}(R - \lambda_v(K - T) - \lambda_n K), \qquad S_{R[2]} = \frac{1}{\sigma^2}(R - \lambda_{nv} \pi_{[2]})$$
$$S_{R[3]} = \frac{1}{\sigma^2}(R - \lambda_v \pi_{[3]} - \lambda_n K)$$

Finally, in the case of an n-investor, the Sharpe ratio decreases under cost-sharing — but may increase in surplus-extraction for a sufficiently high transformation-contract price:

$$S_{U[1]} = \frac{1}{\sigma^2}\big(R + \lambda_m K + \lambda_v T\big), \qquad\qquad S_{\beta[2]} = \frac{1}{\sigma^2}(R + \lambda_m \pi_{[2]})$$
$$S_{U[3]} = \frac{1}{\sigma^2}(R + \lambda_m K + \lambda_n (K - \pi_{[3]}))$$

In general, the transformation-market provides a cost-efficient alternative for firms to alleviate the v and m-investor constraints. This prevents rent-extraction from the n-investors, with the exception of a surplus-extraction equilibria, where the transformation-market gives a new channel for the n and v-investors to exploit the m-investor constraint. □

B Additional Characterizations

In this Section we study competitive equilibria for the cases in which the transformation-contract clearing price takes the critical values of $K - T$ and K.

B.1 Cost-Sharing Equilibrium with $\pi^* = K - T$

Here, the active sub-market tuples are $\{n, A, U\}$, $\{v, A, G\}$ and $\{m, \alpha, R\}$, where $G = S \cup \beta$. Using first-order conditions and corporate-choice market clearing gives:

$$I_n[\sigma_c^2 \pi_U - \sigma_{cd}\pi_A] + I_g[\sigma_c^2 \pi_G - \sigma_{cd}\pi_A] + I_s[\sigma_c^2 \pi_R - \sigma_{cd}\pi_\alpha] = N_d \frac{\phi}{\tau} \tag{47}$$
$$I_n[\sigma_d^2 \pi_A - \sigma_{cd}\pi_U] + I_g[\sigma_d^2 \pi_A - \sigma_{cd}\pi_G] + I_s[\sigma_d^2 \pi_\alpha - \sigma_{cd}\pi_R] = N_c \frac{\phi}{\tau} \tag{48}$$

We can use the no-entry condition to derive relations between excess mean returns:

$$\pi_G = \pi_U - T; \quad \pi_R = \pi_U - K; \quad \pi_\alpha = \pi_A - (K - T) \tag{49}$$

Using these relations we can rearrange the first two equations to solve for the unconstrained investor's optimal position:

$$I_n[\sigma_c^2\pi_U - \sigma_{cd}\pi_A] + I_g[\sigma_c^2(\pi_U - T) - \sigma_{cd}\pi_A] + I_s[\sigma_c^2(\pi_U - K) - \sigma_{cd}(\pi_A - (K - T))] = N_d\frac{\phi}{\tau} \quad (50)$$

$$I_n[\sigma_d^2\pi_A - \sigma_{cd}\pi_U] + I_g[\sigma_d^2\pi_A - \sigma_{cd}(\pi_U - T)] + I_s[\sigma_d^2(\pi_A - (K - T)) - \sigma_{cd}(\pi_U - K)] = N_c\frac{\phi}{\tau} \quad (51)$$

With the above we can derive the following system for π_U and π_A:

$$\sigma_c^2\pi_U - \sigma_{cd}\pi_A = \frac{1}{I}\big(N_d\frac{\phi}{\tau} + I_g\sigma_c^2 T + I_s\sigma_c^2 K - I_s\sigma_{cd}(K - T)\big) \quad (52)$$

$$\sigma_d^2\pi_A - \sigma_{cd}\pi_U = \frac{1}{I}\big(N_c\frac{\phi}{\tau} + I_s\sigma_d^2(K - T) - I_g\sigma_{cd}T - I_s\sigma_{cd}K\big) \quad (53)$$

From first-order conditions, we can directly compute the optimal positions:

$$x_{nU}^* = \frac{1}{I}\big[N_d + \frac{\tau}{\phi}\big(I_g\sigma_c^2 T + I_s\sigma_c^2 K - I_s\sigma_{cd}(K - T)\big)\big] \quad (54)$$

$$x_{nA}^* = \frac{1}{I}\big[N_c + \frac{\tau}{\phi}\big(I_s\sigma_d^2(K - T) - I_g\sigma_{cd}T - I_s\sigma_{cd}K\big)\big] \quad (55)$$

The no-entry condition also provides a connection between the position of the value-aligned investor and the unconstrained investor:

$$x_{vA}^*(\pi) = \frac{\tau}{\phi}[\sigma_d^2\pi_A - \sigma_{cd}\pi_G] = \frac{\tau}{\phi}[\sigma_d^2\pi_A - \sigma_{cd}\pi_U + \sigma_{cd}T] = x_{nA}^*(\pi) + \frac{\tau}{\phi}\sigma_{cd}T$$

$$x_{vG}^*(\pi) = \frac{\tau}{\phi}[\sigma_c^2\pi_G - \sigma_{cd}\pi_A] = \frac{\tau}{\phi}[\sigma_c^2(\pi_U - T) + \sigma_{cd}\pi_A] = x_{nU}^*(\pi) - \frac{\tau}{\phi}\sigma_c^2 T$$

Similarly for the impact-aligned investor:

$$x_{s\alpha}^*(\pi) = \frac{\tau}{\phi}[\sigma_d^2\pi_\alpha - \sigma_{cd}\pi_R] = \frac{\tau}{\phi}[\sigma_d^2(\pi_A - (K - T)) - \sigma_{cd}(\pi_U - K)] = x_{nA}^*(\pi) - \frac{\tau}{\phi}[\sigma_d^2(K - T) - \sigma_{cd}K]$$

$$x_{sR}^*(\pi) = \frac{\tau}{\phi}[\sigma_c^2\pi_R - \sigma_{cd}\pi_\alpha] = \frac{\tau}{\phi}[\sigma_c^2(\pi_U - K) - \sigma_{cd}(\pi_A - (K - T))] = x_{nU}^*(\pi) - \frac{\tau}{\phi}[\sigma_c^2 K - \sigma_{cd}(K - T)]$$

It is straight forward to derive the sub-market equilibrium sizes under optimal corporate choices using $N_\alpha^* = I_m x_{m\alpha}^*$, $N_A^* = I_{vA}x_{vA}^* + I_{nA}x_{nA}^*$, $N_R^* = I_m x_{mR}^*$, $N_G^* = I_v x_{vG}^*$ and $N_U^* = I_n x_{nU}^*$. Moreover, we have that $N_\beta^* = N_\alpha^*$ so that $N_S^* = N_G^* - N_\alpha^*$. To compute the equilibrium prices we can analyze excess mean returns in equilibrium:

$$\pi_U^* = \frac{\sigma_d^2}{\tau} x_{nU}^* + \frac{\sigma_{cd}}{\tau} x_{nA}^* \tag{56}$$

$$\pi_A^* = \frac{\sigma_c^2}{\tau} x_{nA}^* + \frac{\sigma_{cd}}{\tau} x_{nU}^* \tag{57}$$

This yields direct expressions for the equilibrium share prices:

$$P_U^* = \mu_d - \frac{1}{\tau}[\sigma_d^2 x_{nU}^* + \sigma_{cd} x_{nA}^*] \tag{58}$$

$$P_A^* = \mu_c - \frac{1}{\tau}[\sigma_c^2 x_{nA}^* + \sigma_{cd} x_{nU}^*] \tag{59}$$

Can write explicit. Then use the no-entry condition to get all the other prices. Then check the conditions for the split between S and β firms.

$$N_R^* = \frac{I_s}{I}\big[N_d - KI_{gn}\frac{\tau}{\phi}(\sigma_c^2 - \sigma_{cd}) + T(I_g\sigma_c^2 - I_g\sigma_{cd} - I_n\sigma_{cd})\frac{\tau}{\phi}\big]$$
$$N_G^* = \frac{I_g}{I}\big[N_d + (K-T)I_s\frac{\tau}{\phi}(\sigma_c^2 - \sigma_{cd}) - TI_n\frac{\tau}{\phi}\sigma_c^2\big]$$
$$N_\alpha^* = \frac{I_s}{I}\big[N_c + (K-T)I_g\frac{\tau}{\phi}(\sigma_{cd} - \sigma_d^2) + KI_n\frac{\tau}{\phi}(\sigma_{cd} - \sigma_d^2) + TI_n\frac{\tau}{\phi}\sigma_d^2\big]$$

B.2 Cost-Sharing Equilibrium with $\pi^* = K$

Flag here.

In this case, because the c-firm contribution perfectly offsets the cost of reform, it must be the case that $P_U = P_\beta$ in equilibrium. In other words, becoming eligible for a g-investor is inconsequential for a d-firm. By the same argument, it must be the case that $N_S = 0$ because otherwise d-firms would be willing to pay at least T to become eligible for a g-investor – a contradiction with the previous statement. At the same time, for the c-firms, it must be the case that $P_\alpha = P_A + K$. With this in mind, we would have that n-investors only buy shares in firms type $D := \{U, \beta\}$ and A, g-investors only buy shares in firms type β and A, and s-investors only buy shares in firms type R and α. Taking first order conditions over investor capital allocation decisions for every investor-firm pair in the active sub-markets yields the optimality conditions:

$$x_{nA} = \frac{\tau}{\phi}[(\mu_c - P_A)\sigma_d^2 - (\mu_d - P_D)\sigma_{cd}]$$
$$x_{nD} = \frac{\tau}{\phi}[(\mu_d - P_D)\sigma_c^2 - (\mu_c - P_A)\sigma_{cd}]$$
$$x_{gA} = \frac{\tau}{\phi}[(\mu_c - P_A)\sigma_d^2 - (\mu_d - P_D)\sigma_{cd}]$$
$$x_{gU'} = \frac{\tau}{\phi}[(\mu_d - P_D)\sigma_c^2 - (\mu_c - P_A)\sigma_{cd}]$$
$$x_{sA'} = \frac{\tau}{\phi}[(\mu_c - P_{A'})\sigma_d^2 - (\mu_d - P_R)\sigma_{cd}]$$
$$x_{sR} = \frac{\tau}{\phi}[(\mu_d - P_R)\sigma_c^2 - (\mu_c - P_{A'})\sigma_{cd}]$$

with $\phi = \sigma_c^2\sigma_d^2 - \sigma_{cd}^2$ and $x_{nD} = (x_{nU} + x_{nU'})$. The condition for this equilibrium to hold with positive contract trading volume is by $N_\alpha^* = N_\beta^* > 0$. Solving the resulting system yields the following equilibrium corporate choices are given by:

$$N_U^* = \frac{I_{gn}}{I}(N_d - N_c\frac{I_s}{I_{gn}} + I_sK\tau\frac{\psi}{\phi})$$
$$N_R^* = \frac{I_s}{I}(N_d - I_{gn}K\tau\frac{\sigma_c^2 - \sigma_{cd}}{\phi})$$
$$N_{A'}^* = N_{U'}^* = \frac{I_s}{I}(N_c - I_{gn}K\tau\frac{\sigma_d^2 - \sigma_{cd}}{\phi})$$
$$N_A^* = \frac{I_{gn}}{I}(N_c + I_sK\tau\frac{\sigma_d^2 - \sigma_{cd}}{\phi})$$

The equilibrium share prices are given by:

$$P_A^* = \mu_c - N_c\frac{\sigma_c^2}{I\tau} - N_d\frac{\sigma_{cd}}{I\tau} - K\frac{I_s}{I}$$
$$P_{A'}^* = \mu_c - N_c\frac{\sigma_c^2}{I\tau} - N_d\frac{\sigma_{cd}}{I\tau} + K\frac{I_{gn}}{I}$$
$$P_R^* = \mu_d - N_c\frac{\sigma_{cd}}{I\tau} - N_d\frac{\sigma_d^2}{I\tau} + K\frac{I_{gn}}{I}$$
$$P_U^* = P_{U'}^* = \mu_d - N_c\frac{\sigma_{cd}}{I\tau} - N_d\frac{\sigma_d^2}{I\tau} - K\frac{I_s}{I}$$

C Policy Comparisons

In this section, we provide an analysis of policy alternatives including a tax on secondary trades, a carbon tax and an emissions trading scheme. While all of these alternatives increase real-asset reform, as opposed to a market for real-asset transformation, they decrease d-firm surplus.

C.1 Tax on Secondary Trades

Suppose that a regulator imposes a tax over over secondary trades, making them more costly. In the context of our model, we interpret this as a change in the cost of secondary-trading. On top of the transaction cost T, we assume that the d-firm seller must pay a tax of ρ_S. First, consider the number of reformed assets in Lemma 3.1:

$$A^*_{R[1]} = N^*_{R[1]} = m_s N - m_s \frac{\tau}{\sigma^2}(I_n K + I_g(K - T)) \implies \frac{\partial A^*_{R[1]}}{\partial T} = m_s \frac{\tau}{\sigma^2} I_g > 0$$

which shows that a larger T increases real-asset reform. Now, consider d-firm surplus:

$$W_{d[1]} = N(\mu_d - R - m_s K - m_g T) \implies \frac{\partial W_{d[1]}}{\partial T} = -N m_g$$

It follows that increasing T decreases d-firm surplus. Finally, for investor surplus:

$$\begin{aligned}
S_{U,[1]} &= \frac{1}{\sigma^2}(R + m_s K + m_g T) \implies \frac{\partial S_{U,[1]}}{\partial T} = \frac{m_g}{\sigma^2} \\
S_{S,[1]} &= \frac{1}{\sigma^2}(R + m_s(K - T) - m_n T) \implies \frac{\partial S_{S,[1]}}{\partial T} = -\frac{m_s + m_n}{\sigma^2} \\
S_{R,[1]} &= \frac{1}{\sigma^2}(R - m_g(K - T) - m_n K) \implies \frac{\partial S_{R,[1]}}{\partial T} = \frac{m_g}{\sigma^2}
\end{aligned}$$

Increasing T increases n-investor and s-investor surplus and decreases g-investor surplus in d-firm sub-markets.

C.2 Carbon Tax

Suppose that a regulator imposes a carbon tax δ over firms that operate unreformed pollutive assets. We assume that upon a secondary-trade, the seller firm receives a payment equal to the risky cash-flow minus a transaction cost T and the carbon tax δ, that is, we assume that the outside private buyer fully passes on the tax to the seller. We can now characterize the new equilibrium outcome including δ. The market clearing condition in the base case is the same:

$$N_A = N_c, \quad N_U + N_R + N_S = N_d. \tag{60}$$

Considering the optimal corporate choice for a d-firm yields a modified version of (2):

$$P_U - \delta = P_S - T - \delta = P_R - K, \tag{61}$$

or $P_U = P_S - T = P_R - (K - \delta)$. For a sufficiently large carbon tax $K - \delta < T$, real-asset reform dominates secondary-trading. Suppose that $K - \delta \geq T$. Then, $P_U^* < P_S^* < P_R^*$, leading to the same market clearing condition as in (3):

$$I_n x_{nU} = N_U, \quad I_g x_{gS} = N_S, \quad I_s x_{sR} = N_R; \tag{62a}$$

$$I_n x_{nA} + I_g x_{gA} = N_A. \tag{62b}$$

Solving for the number of reformed real assets then yields:

$$\begin{aligned} A^*_{R[1]}(\delta) &= m_s N - m_s \frac{\tau}{\sigma^2}(I_n(K - \delta) + I_g(K - \delta - T)) \\ &= m_s N - m_s \frac{\tau}{\sigma^2}(I_n(K + I_g(K - \delta - T)) + m_s \frac{\tau}{\sigma^2} I_{gn} \delta \end{aligned}$$

which shows that the carbon tax increases real-asset reform. On the other hand, all d-firms perceive a symmetric utility of $P_U^* - \delta$ which implies that:

$$W_{d[1]} = N(\mu_d - R - m_s(K - \delta) - m_g T - \delta) \tag{63}$$

$$= N(\mu_d - R - m_s K + -m_g T - m_{gn}\delta) \tag{64}$$

We conclude that the carbon tax also reduces d-firm surplus.

C.3 Emissions Trading System

Suppose now that a regulator introduces an emissions trading system. The mechanism for pollution-permit allocation and trading is as follows:

1. Initially, the regulator allocates q emission permits to each one of the d-firms.
2. The d-firms can buy or sell pollution permits to accomodate their corporate choice.
    - An unreformed pollutive asset requires $q_U = q_D$ permits.
    - Secondary buyer does not reform so we assume it asks $q_S = q_D$ permits from the seller.
    - A reformed pollutive asset requires $q_R < q_D$ permits.

Note that for a sufficiently large initial allocation $q > q_D$ the equilibrium remains unchanged. Suppose instead that $q_D > q > q_R$.

First, we will see that the emissions trading system implements a transfer between the U-S and R. Let $q_b = q_D - q$ be the number of permits that a U or S firm must buy given their corporate choice. Let $q_s = q - q_R$ be the number of permits that a R firm can sell given their corporate choice. Let η be the pollution-permit clearing price. In equilibrium, we must have that:

$$P_U - \eta q_b = P_S - T - \eta q_b = P_R - K + \eta q_s$$

which can be written as:

$$P_U = P_S - T = P_R - (K - \eta(q_s + q_b))$$

Again if η is large (q is very small), reform dominates secondary-trading. Suppose that η is sufficiently small so that in equilibrium, it is still the case that $P_U < P_S < P_R$. Market clearing for pollution permits imposes that:

$$N_U^* q_b + N_S^* q_b \leq N_R^* q_s \iff (q_D - q)(N_U^* + N_S^*) \leq (N_R^*)(q - q_R)$$

If the constraint does not bind, $q_s N_R^* > q_b N_U^* + q_b N_S^*$, it must be that the pollution permit price is null, $\eta = 0$, and the equilibrium is unchanged as compared to the base case. Suppose that q is sufficiently small so that the constraint binds in equilibrium:

$$(q_D - q)(N_U^* + N_S^*) = (N_R^*)(q - q_R) \iff q_D(N_U^* + N_S^*) + q_R(N_R^*) = Nq$$
$$\iff \frac{q_D}{q}\frac{N_U + N_S}{N} + \frac{q_R}{q}\frac{N_R}{N} = 1$$

Because of corporate choice endogeneity, each d-firms perceives a symmetric utility of:

$$P_U^* - q_b\eta = P_S^* - T - q_b\eta = P_R^* - K + q_s\eta \iff P_U^* = P_S^* - T = P_R^* - K + (q_s\eta + q_b\eta)$$
$$\iff P_U^* = P_S^* - T = P_R^* - K + \eta(q_r + q_d)$$

For $P_U < P_S < P_R$ we get the same effect as with a carbon tax:

$$\begin{aligned} W_{d[1]} &= N(\mu_d - R - m_s(K - \eta(q_r + q_D)) - m_g T - \eta q_D) \\ &= N(\mu_d - R - m_s K + m_s\eta(q_r + q_D) - m_g T - \eta q_D) \\ &= N(\mu_d - R - m_s K - m_g T) + N\eta(m_s q_r - (m_g + m_n)q_D) \end{aligned}$$

We want to show that the last term is negative and that η increases as q decreases to conclude. Suppose $m_s q_R - (m_g + m_n)q_D > 0$, then:

$$m_s q_R > (m_g + m_n)q_D$$

which implies that:

$$m_s > m_g + m_n$$

However, empirical evidence suggests that impact-aligned investment should be smaller than value-aligned investment in public markets, thus, smaller than the sum of unconstrained and value-aligned investors (Bonnefon et al. 2025). Under the assumption that $m_s \leq m_g + m_n$ we get that

$m_s q_r - (m_g + m_n) q_D < 0$. In this case, any $\eta > 0$ *decreases* d-firm welfare:

$$\begin{aligned}
\frac{\partial \mathcal{S}^d_{[1]}}{\partial \eta} &= -N(m_{gn} q_D - m_s q_R) \\
&= -N m_{gn} q_D + N m_s q_R
\end{aligned}$$

Next, we show that η is increasing in the initial permit allocation, q. The market-clearing condition for pollution permits is:

$$(N^*_U(\eta) + N^*_S(\eta))(q_b - q) = N^*_R(\eta)(q - q_s)$$

Let $\zeta := \eta(q_s + q_b)$. Then the allocative distortions in equilibrium corresponding to Lemma 3.1 are given by:

$$\begin{aligned}
\xi^*_U &= I_s(K - \zeta)\frac{\tau}{\sigma^2} + I_g T \frac{\tau}{\sigma^2} \\
\xi^*_S &= I_s(K - \zeta - T)\frac{\tau}{\sigma^2} - I_n T \frac{\tau}{\sigma^2} \\
\xi^*_R &= -I_n(K - \zeta)\frac{\tau}{\sigma^2} - I_g(K - \zeta - T)\frac{\tau}{\sigma^2}
\end{aligned}$$

Computing the sum of unreformed and secondary-seller firms (permit-buyers) gives:

$$\begin{aligned}
N^*_U(\eta) + N^*_S(\eta) &= m_n(N + I_s(K - \zeta)\frac{\tau}{\sigma^2} + I_g T \frac{\tau}{\sigma^2}) + m_g(N + I_s(K - \zeta - T)\frac{\tau}{\sigma^2} - I_n T \frac{\tau}{\sigma^2}) \\
&= m_{gn} N + \frac{\tau}{\sigma^2}\big(m_n I_s(K - \zeta) + m_n I_g T + m_g I_s(K - \zeta - T) - m_g I_n T\big) \\
&= m_{gn} N + \frac{\tau}{\sigma^2} I_s\big(m_n K + m_g(K - T)\big) - \frac{\tau}{\sigma^2} I m_s m_{gn} \zeta
\end{aligned}$$

On the other side of the market, the number of reformed firms (permit-sellers) gives:

$$\begin{aligned}
N^*_R(\eta) &= m_s N - \frac{\tau}{\sigma^2} m_s\big(I_n(K - \zeta) + I_g(K - \zeta - T)\big) \\
&= m_s N - \frac{\tau}{\sigma^2} m_s\big(I_n K - I_g(K - T)\big) + \frac{\tau}{\sigma^2} I m_s m_{gn}
\end{aligned}$$

Defining the terms that are independent of η as constants, $D := N^*_U(0) + N^*_S(0)$ and $E := N^*_R(0)$, as well as $F := \frac{\tau}{\sigma^2} I m_s m_{gn} \zeta$, we can rewrite the market-clearing condition as:

$$\frac{N_U^*(\eta) + N_S^*(\eta)}{N_R^*(\eta)} = \frac{D - F\zeta}{E + F\zeta} = \frac{q - q_R}{q_D - q}$$

Solving the equation for ζ we get that:

$$\begin{aligned} (C - T\zeta)(q_D - q) &= (E + T\zeta)(q - q_R) \\ \implies \zeta^* &= \frac{C(q_D - q) - E(q - q_R)}{T[q_D - q_R]} = \end{aligned}$$

From this expression we can conclude that the permit clearing price η increases linearly as as q decreases. Note also that $C + E = N$ so the slope is:

$$\frac{\partial \zeta}{\partial q} = -\frac{N}{I m_s m_{gn} (q_D - q_R)} \frac{\sigma^2}{\tau}$$

Using that $\eta = \frac{\zeta}{q_s + q_b} = \frac{\zeta}{q_D - q_R}$ yields:

$$\frac{\partial \eta}{\partial q} = -\frac{N}{I m_s m_{gn} (q_D - q_R)^2} \frac{\sigma^2}{\tau}$$

Plugging the expressions back to compute the rate of change of d-firm surplus with respect to q we get that:

$$\frac{\partial W_{d[1]}}{\partial q} = \frac{\partial W_{d[1]}}{\partial \eta} \frac{\partial \eta}{\partial q} = \frac{N^2 (m_{gn} q_D - m_s q_R)}{I m_s m_{gn} (q_D - q_R)^2} \frac{\sigma^2}{\tau}$$

which shows that decreasing q can increase real-asset reform but it decreases d-firm surplus.