european corporate governance institute

ecgi

Dynamic Green Disclosure Requirements

Finance Working Paper N° 1058/2025
Revised November 2026

Deeksha Gupta
Johns Hopkins University
Jan Starmans
Stockholm School of Economics and ECGI

© Deeksha Gupta and Jan Starmans 2026. All rights reserved. Short sections of text, not to exceed two paragraphs, may be quoted without explicit permission provided that full credit, including © notice, is given to the source.

This paper can be downloaded without charge from:
https://doi.org/10.67929/ecgi-fin-1058-2025

european corporate governance institute

ECGI Working Paper Series in Finance

Dynamic Green Disclosure Requirements

Working Paper N° 1058/2025
November 2026

Deeksha Gupta
Jan Starmans

© Deeksha Gupta and Jan Starmans 2026. All rights reserved. Short sections of text, not to exceed two paragraphs, may be quoted without explicit permission provided that full credit, including © notice, is given to the source.

Abstract

This paper studies the design of green disclosure requirements. We show that dynamic green disclosure requirements that become more stringent over time can dominate full transparency. Less stringent initial requirements can overcome roadblocks in the green transition, while more stringent requirements later induce additional reform. Dynamic requirements may slow down the green transition for some firms but can increase the number of firms that eventually reform, highlighting a novel trade-off between the pace and breadth of the green transition. Our results apply to recent policies mandating green disclosures, many of which become more stringent over time.

Keywords: Socially responsible investing, sustainable investing, ESG, disclosure, non-financial reporting, greenwashing

JEL Classification: G14, G18, G32, G38, M14

Deeksha Gupta

Johns Hopkins University
ORCID 0000-0001-9291-8182

Jan Starmans

Stockholm School of Economics and ECGI
ORCID 0000-0003-4583-9515

Dynamic Green Disclosure Requirements*

Deeksha Gupta† Jan Starmans‡

November 13, 2026

Abstract

This paper studies the design of green disclosure requirements. We show that dynamic green disclosure requirements that become more stringent over time can dominate full transparency. Less stringent initial requirements can overcome roadblocks in the green transition, while more stringent requirements later induce additional reform. Dynamic requirements may slow down the green transition for some firms but can increase the number of firms that eventually reform, highlighting a novel trade-off between the pace and breadth of the green transition. Our results apply to recent policies mandating green disclosures, many of which become more stringent over time.

Keywords: Socially responsible investing, sustainable investing, ESG, disclosure, non-financial reporting, greenwashing.
JEL Classifications: G14, G18, G32, G38, M14.

*We would like to thank Patrick Augustin, Ehsan Azarmsa, Bo Becker, Sebastien Betermier, Bruno Biais, Max Bruche, Alvin Chen, Adrien d'Avernas, Rosa Ferrer (discussant), Thomas Geelen, Mariassunta Giannetti, Jillian Grennan, Ai He, Jakub Hajda (discussant), Lucie Lu (discussant), Andrey Malenko, Vincent Maurin, Lakshmi Naaraayanan, Marcus Opp, Dmitry Orlov (discussant), Markus Parlasca, Lin Peng (discussant), Alessio Piccolo, Alejandro Rivera, Magdalena Rola-Janicka, Jan Schneemeier (discussant), Alex Stomper (discussant), Per Strömberg, Katrin Tinn, Zhe Wang, Sumudu W. Watugala, Yan Xiong (discussant), Olivier-David Zerbib, Elaine Zhang (discussant), and Pavel Zryumov, seminar participants at Humboldt University Berlin, the Stockholm School of Economics, the E-axes Forum Webinar on Climate Finance and Economics, the University of Vienna, the University of Maryland, and the Federal Reserve Board, as well as conference participants at the 2023 HEC-HKUST Workshop on Impact and Sustainable Finance, the 2024 Climate Finance Workshop at King's College London Business School, the 2024 CSFN Conference on Governance and Sustainability, the 2024 NTHU-UNSW Symposium on Sustainable Finance and Economics, the 2024 Workshop on Financial Regulation Going Green at the House of Finance at Goethe University Frankfurt, the 2024 Early Career Women in Finance Conference, the 2024 Conference in Sustainable Finance at the University of Luxembourg, the 2024 Holden Conference in Finance and Real Estate, the 2024 CIVICA Advancing Climate Economics Conference at IE University, and the 2025 Midwest Finance Association Annual Meeting, for their helpful comments and suggestions.

†Carey Business School, Johns Hopkins University. Email: deeksha.gupta@jhu.edu.
‡Department of Finance, Stockholm School of Economics. Email: jan.starmans@hhs.se.

Green disclosure requirements, which require companies to publicly report their sustainability efforts and environmental impact, have emerged as a prominent policy tool as the urgency to address climate change has intensified. These requirements represent one of the most significant shifts in corporate reporting in decades, with jurisdictions worldwide implementing sweeping new sustainability disclosure mandates. For instance, the European Union's Corporate Sustainability Reporting Directive (CSRD) requires large firms to report detailed sustainability information. Advocates of green disclosure regulation emphasize its importance in promoting transparency in financial markets to help support the economy's green transition. For example, the European Union describes the Sustainable Finance Disclosure Regulation (SFDR) as a "transparency framework" that helps "investors who seek to put their money into companies and projects supporting sustainability objectives to make informed choices" with the main objective to "help Europe make the shift to a net-zero economy." Intuitively, by giving investors relevant information, green disclosure requirements may enable the efficient allocation of green capital, which may, in turn, incentivize firms to adopt more sustainable practices.

As regulators worldwide implement extensive green disclosure requirements, they face fundamental questions about their design. For example, how do these requirements affect stock prices and firm investment in green technologies? Should the requirements be as strict as possible to generate maximum transparency, or could there be benefits to limiting transparency? Should the requirements evolve and become stricter over time, like the EU's SFDR, or should regulators impose strict requirements from the outset? Further, how should factors such as the cost of investments in green technology and investors' green preferences affect the design? Despite the importance of these questions in policy, research on green disclosure regulation is still in its early stages, and its efficacy and optimal design remain open questions.

In this paper, we build a parsimonious dynamic framework to address these questions by studying the optimal design of green disclosure requirements to support firms' green transition in a setting with socially responsible investors who value firms' greenness. We model a firm's green transition as a multi-step process without imposing specific assumptions about the costs and benefits of each transition step. This approach allows us to capture the complex and dynamic nature of firms' green transition.

Our analysis yields three key insights. First, we show that when at least one step of the green transition is sufficiently costly, dynamic green disclosure requirements that become more strin-

gent over time can dominate full transparency. Limiting transparency initially by pooling firms with different levels of greenness in a single disclosure category can overcome roadblocks in the green transition, while more stringent requirements in the future can incentivize additional reform. Which firms should initially be pooled together and how quickly requirements should become more stringent depend on which step of the green transition is a roadblock. Second, the anticipation of more stringent future requirements shapes firms' transition incentives today. This anticipation can amplify or dampen early transition incentives, depending on which firms are pooled initially. Finally, temporarily limiting transparency involves a novel trade-off between the pace and the breadth of the green transition. Less stringent initial requirements can increase the number of firms that eventually reform, but they may slow down reform for some firms.

More specifically, we consider an infinite-horizon environment in which a continuum of firms is born at the beginning of the first period. A representative socially responsible investor is endowed with each firm's shares. Each firm is initially one of three types—dirty, low-type green, or high-type green. All firms generate a random per-period profit with the same expected value. In addition, each firm generates a social benefit at the end of each period, which is highest for high-type green firms and lowest for dirty firms. A complete green transition involves first paying a cost to adopt a green technology, which transitions a dirty firm to a low-type green firm, and then paying a cost to scale the green technology, which transitions a low-type green firm to a high-type green firm. We assume that a complete green transition is socially optimal.

Adoption may capture a firm's investment in relevant human capital for the green transition while scaling may involve deploying the expertise to improve sustainability across all products and throughout the whole supply chain.[1] Our framework accommodates both cases where scaling is more costly than adoption, consistent with standard diminishing returns to scale, and cases where adoption is more costly. Our model therefore allows us to capture settings in which early or later steps can create roadblocks in the green transition.

The central friction in our model is that the investor cannot observe a firm's type in the absence of green disclosure requirements. A firm is operated by a manager who knows the firm's type and makes investment decisions to maximize the investor's valuation of the firm. The investor internalizes only a fraction of the firms' social benefits, so that greener firms command higher valuations,

[1] Our model also applies to investment funds targeted by disclosure regulations such as the SFDR. In this context, adoption may involve building an investment team capable of developing active engagement strategies to promote sustainability within portfolio companies, and scaling may involve implementing these strategies across all portfolio companies and asset classes.

but the investor does not fully account for the social value of the green transition. Such preferences have several interpretations and can capture investors who inherently care about externalities, are concerned about physical or transition risks, or value the additional profits generated by pro-social consumers.[2] A regulator aims to maximize the expected discounted aggregate social surplus in the economy and can introduce green disclosure requirements at the beginning of the first period. Under strict green disclosure, all firms disclose their type at the end of each period, whereas under lax green disclosure, two of the three firm types are grouped in a single disclosure category. The regulator chooses the initial requirements and commits to when, if ever, they become strict.

We start by characterizing firms' adoption and scaling decisions under strict green disclosure. The notion that increased transparency creates incentives for the green transition is present in our framework. A low-type green firm scales the green technology if the gain in the investor's valuation from scaling exceeds the scaling cost. A dirty firm has an additional consideration when deciding whether to adopt the green technology, since adopting also gives rise to the option to scale. This option value of scaling, which captures the prospect of further valuation increases, can serve as an additional incentive to adopt and arises because of the multi-step nature of the green transition process. Strict green disclosure implements the first best when the investor's preference for greenness is sufficiently strong. Otherwise, at least one step of the green transition is a roadblock.

Next, we consider static lax green disclosure requirements, which pool two firm types permanently. Because the investor cannot distinguish between the pooled firms, the investor values them at a weighted average of their valuations, which over-values the dirtier type and under-values the greener type. Under "pooling at the top" (a category with low-type and high-type green firms), low-type green firms are over-valued, so adoption captures a mis-valuation subsidy. This strengthens adoption incentives but eliminates scaling incentives, because scaling incurs a cost without raising the investor's valuation. Under "pooling at the bottom" (a category with dirty and low-type green firms), low-type green firms are instead under-valued and bear a mis-valuation tax, which

[2]Investors may value green firms for their own sake, as in Heinkel et al. (2001), Pastor et al. (2021), and Pedersen et al. (2021), or may commit to paying a premium for greenness in order to have an impact, as in Gupta et al. (2025). A growing body of evidence suggests that moral and ethical considerations shape investors' financial decisions (e.g., Riedl and Smeets, 2017; Bauer et al., 2021; Humphrey et al., 2021; Zhang, 2021; Baker et al., 2022; Zhang, 2022; Bonnefon et al., 2022; Heeb et al., 2022; Kräussl et al., 2023; Giglio et al., 2025). Alternatively, the greenium may reflect concerns about physical or transition risks (e.g., Bolton and Kacperczyk, 2021b, 2022), in which case adoption and scaling can be read as measures that reduce a firm's climate risk exposure. Finally, the greenium may reflect higher profits from pro-social consumers who are willing to pay more for green products (e.g., Albuquerque et al., 2019; Aghion et al., 2023; Meier et al., 2023). Since consumers base their purchasing decisions on the information available to them, firms grouped in the same disclosure category would then attract the same additional demand.

they can escape by scaling. This strengthens scaling incentives but weakens adoption incentives, because adoption alone does not change a dirty firm's green disclosure category and therefore does not raise its valuation. Taken together, these results establish a pecking order for each transition step when at least one step of the green transition is a roadblock. Pooling at the top generates the most adoption but the least scaling, while pooling at the bottom generates the most scaling but the least adoption, with strict green disclosure lying in between on both margins.

We then turn to dynamic green disclosure requirements, under which the regulator starts with lax green disclosure and switches to strict green disclosure in a committed future period. The anticipated switch raises the investor's valuation of the pooled firms, because the investor expects some of them to continue their transition once their types are revealed. This option value of future reform arises under both forms of pooling, but with opposite consequences. Under pooling at the top, a higher pooled valuation increases the mis-valuation subsidy and amplifies adoption. Under pooling at the bottom, it erodes the mis-valuation tax and dampens scaling. A faster switch generates a larger option value as future reform is discounted less, so an earlier switch generates more adoption under pooling at the top but less scaling under pooling at the bottom.

This asymmetry has two key implications. First, dynamic pooling at the top has an amplification effect, generating more adoption and more scaling than either of its components. More firms adopt when lax green disclosure is expected to be temporary rather than permanent, and more firms eventually scale under delayed strict green disclosure, because the initial lax phase creates a larger pool of low-type green firms that scale once requirements become strict. Dynamic pooling at the bottom has no counterpart to this amplification, because the anticipated switch weakens, rather than strengthens, the incentive that the lax phase is meant to create. Second, the optimal timing of the switch differs across the two forms of pooling. Under pooling at the top, the regulator switches to strict green disclosure as soon as possible. Under pooling at the bottom, the regulator may need to delay the switch to preserve the tax that induces scaling.

Finally, we characterize the optimal green disclosure requirements. Each dynamic green disclosure requirement may broaden the green transition, relative to strict green disclosure, but at the cost of slowing the transition of a subset of firms. Dynamic pooling at the top can induce more dirty firms to adopt, and eventually scale, but delays scaling by initially low-type green firms until the switch. Pooling at the bottom can induce more low-type green firms to scale but may delay adoption by dirty firms. The regulator therefore faces a trade-off between the pace and the breadth

of the green transition, and a dynamic requirement is optimal only if the gain in breadth outweighs the loss in pace. The characteristics of the green transition technology determine whether a dynamic requirement can be optimal and, if so, which one. If neither step of the green transition is a roadblock, strict green disclosure is optimal. If at least one step is a roadblock, a dynamic requirement can be optimal. Dynamic pooling at the top can be optimal when adoption is the only roadblock, pooling at the bottom can be optimal when scaling is the only roadblock, and either can be optimal when both steps are roadblocks.

Many recent policy initiatives are designed to become more stringent over time, such as California's climate disclosure laws, the EU's SFDR, and the UK's ongoing proposals. For example, the SFDR initially required financial market participants to comply with less stringent "Level 1" disclosure requirements starting in March 2021. About two years later, in January 2023, the SFDR entered its "Level 2" phase in which disclosure requirements became more stringent, and entities were required to reveal more detailed information to investors (Deloitte, 2022). While practical motivations for this dynamic implementation may include political and administrative constraints, our model suggests that this approach may optimally encourage investments necessary for the economy's green transition. Consistent with our predictions, research finds decreased emission intensity during the SFDR's less stringent initial phase (Spaans et al., 2024). Our analysis suggests that the anticipation of stricter requirements may itself have affected incentives to become greener during the first phase.

An important insight of our analysis is that the regulator may enhance the green transition by temporarily making less green firms indistinguishable from greener firms. This notion of government-mandated greenwashing differs from the traditional concept of firms intentionally misrepresenting their level of greenness. Amid growing concerns about greenwashing tricking investors,[3] this insight adds nuance by highlighting potential social benefits of obfuscation. An important empirical implication is that obfuscation does not necessarily indicate a lack of genuine reform. In our model, under pooling at the top, dirty firms may enhance their social value while appearing greener than they are, and this ability to obfuscate is key to motivating reform. This contrasts with studies interpreting greenwashing as a lack of genuine reform (e.g., Dumitrescu et al., 2022; Duchin et al., 2025).

Our analysis has several broader implications. First, we map the roadblocks that shape the

[3] See, for example, "A Broken System Needs Urgent Repairs," The Economist, 21 July 2022.

optimal requirements to observable industry characteristics based on whether the main cost of the transition lies in developing green capabilities or in deploying them across the firm. Second, because the anticipation of future requirements shapes firms' incentives in the present, the design of dynamic requirements raises questions of commitment and of the information environment. We discuss when the regulator needs to commit to a regulatory path and how information about firm greenness from other sources, such as voluntary disclosure or historical records, changes the effectiveness of lax requirements. Third, our framework maps to the extensive margin of the green transition, in which adoption corresponds to the exit of dirty firms and scaling to the entry of green firms. Finally, our framework suggests that green disclosure requirements can complement carbon taxes when political constraints keep the tax below its Pigouvian level, with the tax setting the price of emissions and the disclosure requirement determining the tax base by defining how finely the tax distinguishes between firms.

Related Literature: Our paper contributes to the theoretical literature studying how socially responsible investors impact firm decisions.[4] Closest to our paper is Gupta et al. (2025), who study the pace of the green transition in a dynamic setting in which firms choose when to reform and show how investors with broad impact preferences may slow down the green transition by incentivizing strategic delay in firm reform. We contribute to this literature by studying how green disclosure requirements affect both the pace and the breadth of the green transition in a dynamic environment with socially responsible investors.

A small group of papers examine green disclosure in static settings (e.g., Lyon and Maxwell, 2011; Wu et al., 2020; Aghamolla and Byeong-Je, 2023; Chen and Schneemeier, 2023; Chen, 2023; Xue, 2025; Friedman et al., 2025; Inderst and Opp, 2025; Jiang and Xiong, 2025; Mahieux et al., 2025; Banerjee and Prokopev, 2026; Smith, 2026). For example, Banerjee and Prokopev (2026) show that mandatory disclosure of firms' climate-risk exposure can reduce investor welfare because it lowers the adoption of green projects that help investors hedge climate risk, Chen and Schneemeier (2023) study how voluntary green disclosure affects traders' incentives to acquire information and trade on private information in a setting with feedback effects, and Inderst and Opp

[4]See, e.g., Heinkel et al. (2001); Hart and Zingales (2017); Davies and Van Wesep (2018); Chowdhry et al. (2019); Morgan and Tumlinson (2019); Green and Roth (2025); Matsusaka and Shu (2021); Pastor et al. (2021); Roth (2021); Barbalau and Zeni (2022); Broccardo et al. (2022); Gollier and Pouget (2022); Huang and Kopytov (2022); Allen et al. (2023); De Angelis et al. (2023); Döttling and Rola-Janicka (2023); Edmans et al. (2022); Geelen et al. (2022); Jagannathan et al. (2022); Jin and Noe (2023); Landier and Lovo (2024); Levit et al. (2024); Bisceglia et al. (2023); Malenko and Malenko (2026); Döttling et al. (2024); Gryglewicz et al. (2024); Oehmke and Opp (2024); Gupta et al. (2025).

(2025) study when green certification adds value as a policy tool if the regulator also has access to carbon taxes or minimum requirements on green production. In contrast to this literature on static green disclosure, we consider a dynamic environment where the green transition is a multi-step process, showing how disclosure requirements optimally evolve over time and how current requirements interact with firms' anticipation of future requirements. A notable exception to the focus on static settings is Cartellier et al. (2025), who analyze firms' environmental communication in a dynamic setting. In their framework, the information environment is fixed. Firms can inflate their environmental ratings above fundamentals, and the dynamics arise from the gradual revelation of past misrating, which investors penalize, generating a market-discipline force that curbs greenwashing. In our framework, the regulator designs a dynamic information environment by choosing when to switch to strict green disclosure. As a result, the two papers deliver different results. In Cartellier et al. (2025), more transparency curbs misrating by firms, whereas in our setting, coarse disclosure mandated by the regulator can be socially beneficial because it incentivizes firm reform.

Beyond green disclosure, we relate to the literature on the benefits of coarse information in shaping incentives, which has been studied in the context of career and reputational concerns (e.g., Holmström, 1999; Dewatripont et al., 1999; Bar-Isaac and Deb, 2020; Hörner and Lambert, 2020), grades and ratings (e.g., Harbaugh and Rasmusen, 2018; Biswas et al., 2023), product certification (e.g., Albano and Lizzeri, 2001), agency problems (e.g., Ely and Szydlowski, 2020), and bank stress tests (e.g., Goldstein and Leitner, 2018; Orlov et al., 2023).[5] For example, in Dewatripont et al. (1999), an agent exerts effort to influence the market's belief about his talent, and a coarse pass or fail signal of his performance can induce more effort than a precise signal. In Ely and Szydlowski (2020), a principal commits to withhold information about the difficulty of a task until a fixed date in order to sustain the agent's effort. In Orlov et al. (2023), a coarse first stress test allows the regulator to recapitalize weak banks while they are still pooled with stronger banks, before a second test reveals their quality. In these papers, agents' types are either exogenous or chosen once in response to the information structure, whether static or dynamic. In contrast, firms in our setting respond to disclosure requirements that change over time by choosing whether and when to change

[5]Coarse information can also be valuable because it allows a certifier or rating agency to extract rents (e.g., Lizzeri, 1999; Doherty et al., 2012; Kartasheva and Yilmaz, 2020; Ali et al., 2022). In addition, coarse information can arise in equilibrium from the strategic behavior of agents with exogenous types, for example from firms' decisions to share information with competitors (Vives, 1984), from the reports of a rating agency that cannot commit to its ratings (Goel and Thakor, 2015), or from competition between ESG rating agencies (Azarmsa and Shapiro, 2023).

their type, possibly more than once. The distribution of firm types therefore changes over time in response to disclosure requirements. The resulting interaction between current disclosure requirements and the option value of future reform is the source of our main results. Because investors expect some firms in the pooled disclosure category to change their type once disclosure becomes strict, the anticipated switch raises the valuation of the pooled disclosure category, which amplifies the mis-valuation subsidy under pooling at the top but erodes the mis-valuation tax under pooling at the bottom, in turn affecting whether firms want to initially change their type. This asymmetry determines the timing of the switch to strict green disclosure, the severity of the trade-off between the pace and the breadth of the green transition, and the role of the regulator's commitment to the timing of the switch.

We also relate to a literature examining how regulators facilitate firms' green transition in the presence of financial frictions or green shareholders. Existing work focuses on standard policies like carbon taxes, carbon trading schemes, and emissions caps (e.g., Biais and Landier, 2022; Huang and Kopytov, 2022; Bustamante and Zucchi, 2022, 2024; Döttling and Rola-Janicka, 2023; Biais et al., 2026). For example, Döttling and Rola-Janicka (2023) show that optimal emission taxes deviate from the Pigouvian benchmark when firms are financially constrained, and Bustamante and Zucchi (2022, 2024) show that carbon pricing tilts firms toward short-lived abatement rather than green innovation. In contrast, we study green disclosure requirements as a new policy tool.

A growing body of empirical work examines the financial and real effects of green disclosure (e.g., Jouvenot and Krueger, 2019; Bolton and Kacperczyk, 2021a; Christensen et al., 2022; Giannetti et al., 2023; Ilhan et al., 2023; Emiris et al., 2026; Krueger et al., 2024; Spaans et al., 2024; Badenhoop and Mücke, 2025). These papers support our assumptions about disclosure and socially responsible investing and provide empirical support for key predictions. Emiris et al. (2026) and Spaans et al. (2024) show that investors respond to mandatory green disclosure by increasing green fund investment. Additionally, Spaans et al. (2024) find funds reduce their emission intensity during SFDR's initial lax stage, supporting our prediction that lax green disclosure can encourage funds to become greener.

1 Model

We consider an infinite-horizon environment, where a period is denoted by $t \in \mathbb{N}_0 := \{0, 1, \ldots\}$. At the beginning of period $t = 0$, a unit continuum of firms is born, and a risk-neutral representative investor with time-discount factor $\beta \in (0,1)$ is endowed with each firm's shares. There are three types of firms: dirty firms (d), low-type green firms (g_L), and high-type green firms (g_H), with initial masses $\mu_d > 0$, $\mu_{g_L} > 0$, and $\mu_{g_H} > 0$, where $\mu_d + \mu_{g_L} + \mu_{g_H} = 1$.[6] Each firm generates a random and independent profit $\tilde{\pi}$ with expected value $\pi := \mathbb{E}[\tilde{\pi}] > 0$ at the end of each period, which is independent of its type, and a type-dependent social benefit b_i, where $i \in \{d, g_L, g_H\}$. The social benefit can be positive (e.g., carbon capturing) or negative (e.g., carbon emissions), with the only requirement being that $b_{g_H} > b_{g_L} > b_d$. We denote $\Delta_a = b_{g_L} - b_d > 0$ and $\Delta_s = b_{g_H} - b_{g_L} > 0$.

There is a green transition technology that allows firms to change their type and increase the social benefit they generate. A dirty firm can adopt the green technology by paying a one-time adoption cost $\kappa_a > 0$ to become a low-type green firm and a low-type green firm can scale the green technology by paying a one-time scaling cost $\kappa_s > 0$ to become a high-type green firm. Dirty firms can, but do not have to, adopt and scale the green technology in the same period. Both adoption and scaling are irreversible.[7]

The expected discounted social surplus generated by a firm of type $i \in \{d, g_L, g_H\}$ that never changes its type is $\sum_{t=0}^{\infty} \beta^t (\pi + b_i) = \frac{\pi + b_i}{1-\beta}$. We assume it is socially optimal for firms to adopt and scale the green technology: $\frac{\Delta_a}{1-\beta} > \kappa_a$ and $\frac{\Delta_s}{1-\beta} > \kappa_s$. In particular, adoption alone, even without further scaling, is socially preferable to not adopting. We also assume that it is not socially desirable to shut down a dirty firm: $\frac{\pi + b_d}{1-\beta} > 0$.

A firm's social benefit impacts the representative investor's utility and, therefore, firm valuations. Specifically, the investor's per-period expected utility from a type i firm under full information is $\pi + \lambda b_i$, where $\lambda \in (0,1]$ captures the degree to which the investor internalizes the social benefit. A representative investor is a simple and tractable way to model a premium for green firms,[8] consistent with evidence that greener firms have higher market valuations (e.g., Bolton and Kacperczyk, 2021b; Eskildsen et al., 2024).

Each firm is operated by a manager who makes adoption and scaling decisions to maximize the

[6] In Section 5, we discuss microfoundations that can give rise to an initial distribution of firm types.

[7] In Section 5, we discuss the implications of partial reversibility for our results.

[8] A number of papers derive this premium as an equilibrium result in asset pricing models with both financial and socially responsible investors (e.g., Heinkel et al., 2001; Pastor et al., 2021; Pedersen et al., 2021).

investor's expected end-of-period valuation, that is, the firm's valuation based on the investor's information set. Such preferences can be micro-founded by managerial concerns arising from stock-based compensation and are a standard assumption in the sustainable finance literature (e.g., Pastor et al., 2021).[9] For example, under full information, the end-of-period $t = 0$ valuation of a low-type green firm that scales the green technology in period $t = 0$ is $\hat{\pi} - \kappa_s + \lambda b_{g_H} + \frac{\beta}{1-\beta}(\pi + \lambda b_{g_H})$, where $\hat{\pi}$ is the realized and π the expected profit. Intuitively, this captures the investor's valuation on the day of the firm's earnings announcement. The expected end-of-period valuation is thus $\frac{\pi+\lambda b_{g_H}}{1-\beta} - \kappa_s$.[10] Therefore, under full information, a low-type green firm scales the green technology if and only if $\frac{\lambda\Delta_s}{1-\beta} \geq \kappa_s$. We define the direct valuation gains from adoption and scaling as $V_a := \frac{\lambda\Delta_a}{1-\beta} - \kappa_a$ and $V_s := \frac{\lambda\Delta_s}{1-\beta} - \kappa_s$, which depend on the degree to which the investor internalizes the social benefit, λ.

The central friction is that the investor cannot observe firms' types and their adoption and scaling decisions without green disclosure requirements. In practice, green investments may not be easily discernible from financial statements and may require specific sustainability disclosure. Indeed, firm greenness is difficult for outsiders to assess, as reflected in the substantial disagreement among ESG rating providers (e.g., Berg et al., 2022; Christensen et al., 2022), and closing this information gap is the stated rationale for mandatory green disclosure (e.g., Carattini et al., 2022). Consistent with this view, investors demand such disclosure through shareholder proposals (e.g., Fisch and Robertson, 2024), and trading activity and valuations change following green disclosure events (e.g., Bolton and Kacperczyk, 2021a; Parise and Rubin, 2023; Emiris et al., 2026; Krueger et al., 2024; Spaans et al., 2024).[11] Specifically, we assume that the investor observes only the realization of the random variable $\tilde{\pi} - \kappa$ at the end of a period, where $\kappa \in \{\kappa_a, \kappa_s, \kappa_a + \kappa_s, 0\}$, but not its components. For simplicity, we assume that $\tilde{\pi}$ is sufficiently noisy, such that observing $\tilde{\pi} - \kappa$ does not allow the investor to draw inference about κ.[12] In addition, while managers are informed

[9] In Section 5, we discuss additional implications that would arise if the manager cared about future changes in firm valuation based on their private information.

[10] We assume that a firm's manager makes adoption and scaling decisions before the random profit is realized. The manager's decisions would be identical if the manager made adoption and scaling decisions after profits are realized but before they are reported to the investor.

[11] The assumption that the investor knows the distribution of firm types but not individual realizations is standard in the disclosure literature (e.g., Grossman, 1981; Milgrom, 1981; Verrecchia, 1983; Dye, 1985) and in the information-design literature (e.g., Kamenica and Gentzkow, 2011).

[12] To illustrate this more formally, consider a scenario without green disclosure where all dirty firms adopt the green technology and assume profits are normally distributed. The inference problem of distinguishing dirty from initially green firms then becomes one of two normal distributions with known common variance σ^2 and means π and $\pi - \kappa_a$. With probability $1 - \mu_d$, a draw is made from $N(\pi, \sigma^2)$, and with probability μ_d, from $N(\pi - \kappa_a, \sigma^2)$. After observing

about the firm's type and actions, they cannot credibly convey this information to the investor. In Appendix D.1, with an accompanying discussion in Section 5, we extend the model to allow for voluntary green disclosure and for leakage of information about firm types independent of green disclosure requirements. We show that our results continue to hold as long as such disclosure remains incomplete and does not perfectly reveal every firm type in the economy.

A regulator can establish green disclosure requirements, which determine the investor's information set regarding firm types. Under strict green disclosure, all firms' types are revealed at the end of each period. Under lax green disclosure, two of the three firm types are pooled in a single disclosure category, giving rise to three possible requirements: (i) pooling low-type and high-type green firms (pooling at the top); (ii) pooling dirty and low-type green firms (pooling at the bottom); and (iii) pooling dirty and high-type green firms (pooling at the extremes).[13]

The regulator establishes disclosure requirements at the beginning of period $t = 0$ and commits ex ante to the path of disclosure requirements in all future periods.[14] A disclosure requirement consists of initial requirements and, possibly, a later switch to stricter requirements. Under dynamic green disclosure requirements, the regulator implements lax green disclosure in period $t = 0$ and chooses a period $t = \tau$, with $\tau \geq 1$, when requirements switch to strict green disclosure. The case $\tau = \infty$ corresponds to static green disclosure requirements, which remain fixed in all future periods. The investor has perfect recall, and, as such, a firm's sequence of past disclosure categories is part of the investor's information set in every period. As we show in Appendix C.2, a switch in the opposite direction, from strict to lax green disclosure, is therefore inconsequential, since the disclosure history continues to reveal each firm's type. This type of dynamic disclosure aligns with real-world implementations, such as the EU's SFDR, which initially required funds to classify themselves on the basis of limited information before introducing stricter requirements.

The regulator's objective is to maximize the expected discounted aggregate social surplus. We adopt the convention that the regulator implements strict green disclosure whenever indifferent between strict green disclosure and another disclosure requirement. This convention establishes

a realization, the posterior probability of having drawn from either distribution can be updated using Bayes' Rule. As $\sigma^2 \to \infty$, the posterior probabilities converge to the prior probabilities because the observation becomes uninformative, and the prior dominates.

[13] We rule out pooling all three firm types together, which is equivalent to no disclosure. If all firms share a common valuation, neither adoption nor scaling is privately profitable, and welfare equals the no-transition benchmark, which strict green disclosure weakly dominates.

[14] In Appendix D.3, we analyze the case without commitment to future disclosure requirements. We discuss this analysis in Section 5.

full transparency as the natural benchmark. Firm classifications are disclosed at the end of each period, so firms can adopt or scale before their type is disclosed. In particular, initial firm types are not disclosed at the beginning of period $t = 0$.[15] We discuss the implications of historical disclosure in Section 5.

The regulator moves first and chooses the green disclosure requirements to maximize the expected discounted aggregate social surplus, anticipating the behavior of managers and the investor that the requirements induce. Throughout, we study equilibria in which each manager chooses adoption and scaling decisions to maximize the firm's expected end-of-period valuation, the investor forms beliefs about each firm's type from its disclosure history using Bayes' rule, and valuations reflect these beliefs. Firms are atomistic and take the valuations assigned to disclosure histories as given. When the green disclosure requirements admit several such equilibria among managers and the investor, the regulator selects the welfare-maximizing one.[16] Appendix B defines the game formally and specifies beliefs for disclosure histories that are not reached in equilibrium.

2 Strict Green Disclosure

Under strict green disclosure requirements, the investor observes a firm's type at the end of each period and can therefore distinguish among the three firm types.

Lemma 1. *Under strict green disclosure requirements, a low-type green firm scales the green technology in period $t = 0$ if and only if $V_s \geq 0$. A dirty firm adopts the green technology in period $t = 0$ if and only if*

$$V_a + \max\{V_s, 0\} \geq 0, \tag{1}$$

and, if it adopts, also scales in period $t = 0$ if and only if $V_s \geq 0$. No firm adopts or scales in any period $t \geq 1$.

Lemma 1 shows that a low-type green firm scales whenever the valuation gain weakly exceeds the scaling cost, $V_s \geq 0$. Adoption incentives differ fundamentally. Because the green transition

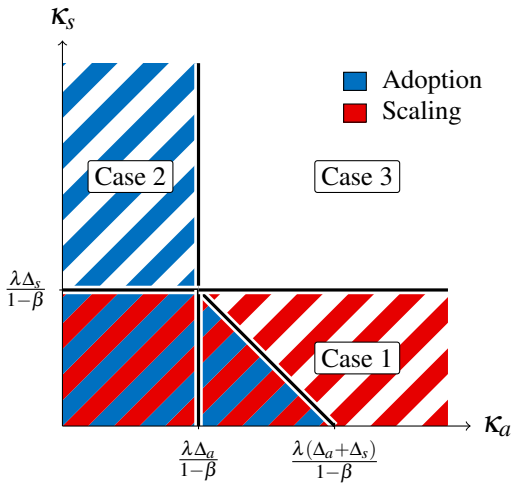
[15] If all initial types were disclosed, the investor would infer each firm's type in every later period from its initial type and its disclosure history, making lax green disclosure ineffective. This follows the same logic that makes switches from strict to lax green disclosure inconsequential in Appendix C.2. Disclosing all initial firm types would therefore not improve on the requirements we study.

[16] For example, the regulator can accompany the disclosure requirement with guidance recommending the transition, consistent with the coordinating role of policy in settings with strategic complementarities (e.g., Cooper and John, 1988; Murphy et al., 1989).

is a multi-step process in which firms must adopt before they can scale, adoption gives rise to the option to scale. Two forces therefore drive adoption: the valuation gain from adoption alone, V_a, and the option value of scaling, $\max\{V_s, 0\}$.

Figure 1 plots adoption and scaling decisions as functions of their costs. In the region with both blue and red stripes, all firms complete the green transition: dirty firms adopt and scale, and low-type green firms scale. Within this region, the rectangular subregion (adoption cost below $\frac{\lambda\Delta_a}{1-\beta}$) is where the valuation gain from adoption alone covers the adoption cost, while the triangular subregion (adoption cost between $\frac{\lambda\Delta_a}{1-\beta}$ and $\frac{\lambda(\Delta_a+\Delta_s)}{1-\beta}$) is where the option value of subsequent scaling drives adoption. In the single-color regions, only one transition step occurs. In the region with only blue stripes, adoption costs are low enough for dirty firms to adopt, but scaling costs are too high for low-type green firms to scale. In the region with only red stripes, scaling costs are low enough for low-type green firms to scale, but adoption costs are too high for dirty firms to adopt.

Figure 1: Adoption and Scaling under Strict Green Disclosure Requirements



Notes: The figure plots adoption and scaling decisions under strict green disclosure requirements as a function of the adoption cost κ_a and the scaling cost κ_s. The blue-striped region shows the parameter set in which initially dirty firms adopt the green technology. The red-striped region shows the parameter set in which low-type green firms scale (initially low-type green firms and dirty firms that adopt). The unshaded region corresponds to parameters under which no firm adopts or scales. Outside the region with both blue and red stripes, the labels indicate the three roadblock configurations that we introduce below following Assumption 1: adoption is the only roadblock (Case 1), scaling is the only roadblock (Case 2), and both margins are roadblocks (Case 3).

In the region with both blue and red stripes, strict green disclosure requirements implement the first best. An increase in the investor's preference for the social benefit, λ, expands this region along both axes, since a higher valuation of greener firms widens the range of adoption and scaling

costs over which firms reform.

Corollary 1. *Strict green disclosure requirements implement the first best, in which every dirty firm adopts and scales and every low-type green firm scales the green technology in period $t = 0$, if and only if $\lambda \geq \overline{\lambda}$, where*

$$\overline{\lambda} := (1-\beta)\max\left\{\frac{\kappa_s}{\Delta_s}, \frac{\kappa_a+\kappa_s}{\Delta_a+\Delta_s}\right\} \in (0,1). \tag{2}$$

The result follows from our assumption that adoption and scaling are socially optimal. At $\lambda = 1$, the investor fully internalizes the social benefits, so under full information, firms adopt and scale, and strict green disclosure implements the first best. By continuity, the same holds for any sufficiently high λ. No other disclosure requirement can then strictly improve upon strict green disclosure, and the regulator implements it by our convention. We therefore focus on $\lambda < \overline{\lambda}$, the region outside the blue-and-red striped area in Figure 1, where strict disclosure leaves at least one transition margin—adoption or scaling—as a roadblock.

Assumption 1. $\lambda < \overline{\lambda}$.

We maintain Assumption 1 throughout Section 3, where we analyze lax green disclosure requirements, and return to the case $\lambda \geq \overline{\lambda}$ in Section 4, where we characterize the globally optimal green disclosure requirement. Under Assumption 1, exactly three configurations of the valuation gains are possible, and we refer to them throughout the analysis. In Case 1, adoption is the only roadblock: $V_s \geq 0$ and $V_a + V_s < 0$ (which implies $V_a < 0$), corresponding to the region with only red stripes in Figure 1. In Case 2, scaling is the only roadblock: $V_s < 0$ and $V_a \geq 0$, corresponding to the region with only blue stripes. In Case 3, both margins are roadblocks: $V_a < 0$ and $V_s < 0$, corresponding to the unshaded region.

Whether $\lambda < \overline{\lambda}$ depends on the extent of investor concern about firms' greenness, captured by λ, and the green transition technology, which determines the level of $\overline{\lambda}$. The evidence that greenness is priced (e.g., Eskildsen et al., 2024), that firm valuations do not fully reflect the social costs and benefits of the green transition (e.g., Piazzesi et al., 2025; Pedersen, 2026), and that the greenium varies across markets (e.g., Eskildsen et al., 2024) suggests that λ is positive, below one, and heterogeneous. The threshold $\overline{\lambda}$, in turn, weakly increases with the adoption cost κ_a and strictly with the scaling cost κ_s (Corollary 1). These costs likely differ across industries. For example, $\overline{\lambda}$ may be particularly high in heavily polluting capital-intensive industries, in which the green

transition requires replacing existing production processes. This heterogeneity suggests that green disclosure requirements should be industry-specific, with strict green disclosure requirements being optimal in industries with low transition costs. We map our framework to observable industry characteristics in Appendix D.4, with an accompanying discussion in Section 5.

3 Lax Green Disclosure

Lax green disclosure requirements pool two of the three firm types in a single disclosure category: pooling at the top (low- and high-type green firms), pooling at the bottom (dirty and low-type green firms), and pooling at the extremes (dirty and high-type green firms). In this section, we characterize firms' adoption and scaling decisions under each requirement. Section 3.1 studies static lax green disclosure requirements, which remain in place in all future periods ($\tau = \infty$). Section 3.2 studies dynamic green disclosure requirements, under which the regulator switches to strict green disclosure in period $t = \tau$. Section 4 builds on these results to characterize the optimal green disclosure requirements.

We characterize reform in period $t = 0$ and, under dynamic pooling at the top and at the bottom, in period $t = \tau$. Appendix B shows that this is without loss of generality for pooling at the top and for the welfare-maximizing equilibria we characterize under pooling at the bottom. Under pooling at the extremes, we do not characterize equilibrium. Instead, we show that it is weakly dominated by strict green disclosure for any timing of reform (Lemma 4).

Let $\phi_a \in [0,1]$ denote the fraction of dirty firms that adopt, $\phi_{a,s} \in [0, 1-\phi_a]$ the fraction of dirty firms that adopt and scale, and $\phi_s \in [0,1]$ the fraction of low-type green firms that scale in period $t = 0$. The post-transition measures at the end of period $t = 0$ are $\tilde{\mu}_d = (1-\phi_a-\phi_{a,s})\mu_d$, $\tilde{\mu}_{g_L} = \phi_a\mu_d + (1-\phi_s)\mu_{g_L}$, and $\tilde{\mu}_{g_H} = \phi_{a,s}\mu_d + \phi_s\mu_{g_L} + \mu_{g_H}$. For a pooled disclosure category containing types i and j, let $\theta_i = \tilde{\mu}_i/(\tilde{\mu}_i + \tilde{\mu}_j)$ denote type i's share in the pooled disclosure category.

3.1 Static Lax Green Disclosure

Under static lax green disclosure requirements, no firm reforms after period $t = 0$, so the composition of the pooled disclosure category is constant over time. The investor's expected end-of-period valuation of a firm in the pooled disclosure category, gross of any adoption or scaling costs incurred

in period $t = 0$, is

$$\frac{\pi + \theta_i \lambda b_i + \theta_j \lambda b_j}{1 - \beta}, \tag{3}$$

a weighted average of the full-information valuations of the pooled firm types. Pooling thus creates a mis-valuation relative to strict green disclosure. The lower-type firm in the pooled disclosure category is over-valued, and the higher-type firm is under-valued. As we show below, this mis-valuation can either strengthen or weaken firms' incentives to adopt and scale the green technology.

To characterize firms' adoption and scaling decisions under each disclosure requirement, we proceed in four steps. First, we characterize firms' transition incentives under static pooling at the top and at the bottom, taking the period $t = 0$ transition shares $(\phi_a, \phi_{a,s}, \phi_s)$ as given. Second, we show that pooling at the extremes is weakly dominated by strict green disclosure. Third, we determine the equilibrium transition shares $(\phi_a, \phi_{a,s}, \phi_s)$ under the two remaining lax green disclosure requirements: pooling at the top and at the bottom. Finally, we summarize the key insights from the analysis by establishing pecking orders of the disclosure regimes for adoption and for scaling.

3.1.1 Adoption and Scaling Incentives under Static Pooling at the Top and at the Bottom

We begin by characterizing firms' adoption and scaling incentives under static pooling at the top.

Lemma 2 (Adoption and Scaling Incentives under Static Pooling at the Top)**.** *Fix the period-$t = 0$ transition shares $(\phi_a, \phi_{a,s}, \phi_s)$. Under static pooling at the top, a low-type green firm has no incentive to scale.*

A dirty firm has no incentive to adopt and scale jointly and has an incentive to adopt if and only if

$$V_a + \theta_{g_H} \frac{\lambda \Delta_s}{1 - \beta} \;\geq\; 0, \tag{4}$$

where θ_{g_H} is the share of high-type green firms in the pooled disclosure category.

Lemma 2 shows that pooling at the top strengthens adoption incentives while eliminating scaling incentives. Because low- and high-type green firms are in the same pooled disclosure category and thus have the same valuation, scaling is costly but yields no valuation gain. For the same reason, a dirty firm never adopts and scales jointly, because scaling adds a cost without adding a valuation gain over adoption alone.

Although it eliminates scaling incentives, pooling at the top strengthens adoption incentives

relative to strict green disclosure. Under pooling at the top, a dirty firm's adoption decision includes a mis-valuation subsidy, $\theta_{g_H} \frac{\lambda \Delta_s}{1-\beta} > 0$, which arises because a firm that adopts enters the pooled disclosure category with high-type green firms and captures part of their higher valuation. This subsidy increases with the share of high-type green firms.

Next, we characterize adoption and scaling incentives under pooling at the bottom.

Lemma 3 (Adoption and Scaling Incentives under Static Pooling at the Bottom)**.** *Fix the period-$t = 0$ transition shares $(\phi_a, \phi_{a,s}, \phi_s)$. Under static pooling at the bottom, a low-type green firm has an incentive to scale if and only if*

$$V_s + \theta_d \frac{\lambda \Delta_a}{1-\beta} \;\geq\; 0, \tag{5}$$

where θ_d and $\theta_{g_L} = 1 - \theta_d$ are the shares of dirty and low-type green firms in the pooled disclosure category, with $\theta_d = 1$ and $\theta_{g_L} = 0$ when $\phi_{a,s} = \phi_s = 1$.

A dirty firm has no incentive to adopt without scaling and has an incentive to adopt and scale jointly if and only if

$$V_a + V_s - \theta_{g_L} \frac{\lambda \Delta_a}{1-\beta} \;\geq\; 0. \tag{6}$$

Lemma 3 shows that pooling at the bottom creates a mis-valuation tax on low-type green firms, which strengthens scaling incentives. Pooling at the bottom adds $\theta_d \frac{\lambda \Delta_a}{1-\beta}$ to the valuation gain from scaling. Intuitively, because the investor cannot distinguish low-type green firms from dirty firms in the pooled disclosure category, low-type green firms are under-valued. They bear a mis-valuation tax that increases with the share of dirty firms in the pooled disclosure category, θ_d. By scaling, a low-type green firm becomes high-type green, exits the pooled disclosure category, and avoids this mis-valuation tax.

While strengthening scaling incentives, pooling at the bottom weakens adoption incentives relative to strict green disclosure. Under pooling at the bottom, dirty firms never adopt without scaling because adoption alone would leave them in the pooled disclosure category with no valuation gain while incurring the adoption cost. A dirty firm therefore transitions only by adopting and scaling jointly. The joint transition bundles adoption with potentially unprofitable scaling, weakening adoption incentives.

Taken together, Lemmas 2 and 3 reveal an asymmetric mis-valuation structure. Each requirement strengthens one transition margin and weakens the other. The asymmetry arises from the multi-step nature of the green transition and reflects the intermediate position of low-type green

firms. Pooling at the top inflates the valuation of low-type green firms, making it more attractive to become a low-type green firm by adopting, while eliminating scaling incentives. Pooling at the bottom deflates that valuation, making it more attractive to remain a dirty firm by not adopting, and to become a high-type green firm by scaling. Pooling at the top therefore strengthens adoption and weakens scaling, while pooling at the bottom does the opposite. After determining the equilibrium transition shares, we formalize this asymmetry in Corollary 2 by ranking the disclosure regimes for adoption and for scaling, establishing a pecking order along each margin.

3.1.2 Pooling at the Extremes

Unlike static pooling at the top and at the bottom, which each strengthen one transition margin, static pooling at the extremes weakens both relative to strict green disclosure.

Lemma 4 (Dominance of Strict Disclosure over Pooling at the Extremes)**.** *Pooling at the extremes is weakly dominated by strict green disclosure, in the sense that it generates weakly lower social welfare in any equilibrium.*

Lemma 4 shows that pooling at the extremes generates weakly lower welfare than strict green disclosure. This result arises because pooling at the extremes weakens both transition margins. Adoption incentives weaken because a dirty firm in the pooled disclosure category enjoys a mis-valuation subsidy from being pooled with high-type green firms, which it forfeits by adopting. Moreover, dirty firms never adopt and scale jointly, since the joint transition would leave them in the same pooled disclosure category while incurring a cost. Scaling incentives weaken in turn because a low-type green firm that scales enters the pooled disclosure category at a valuation diluted by dirty firms, rather than at the full high-type green valuation under strict green disclosure. We can therefore exclude pooling at the extremes from the analysis that follows.

3.1.3 Equilibrium under Static Pooling at the Top and at the Bottom

Lemmas 2 and 3 characterize firms' transition incentives taking the period $t = 0$ transition shares $(\phi_a, \phi_{a,s}, \phi_s)$ as given. We now determine the equilibrium transition shares, starting with pooling at the top.

Proposition 1 (Equilibrium under Static Pooling at the Top)**.** *Under static pooling at the top, the equilibrium is unique. No firm scales the green technology ($\phi^*_{a,s} = \phi^*_s = 0$), and there exist two*

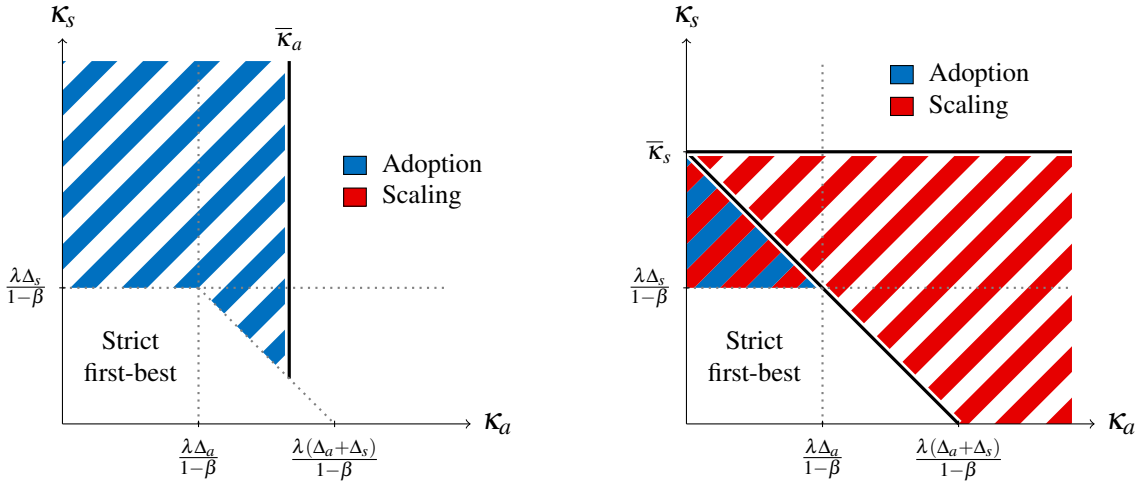
thresholds $\underline{\kappa}_a$ and $\overline{\kappa}_a$, where $\frac{\lambda\Delta_a}{1-\beta} < \underline{\kappa}_a < \overline{\kappa}_a$, such that (i) if $\kappa_a \leq \underline{\kappa}_a$, all dirty firms adopt ($\phi_a^* = 1$); (ii) if $\kappa_a \in (\underline{\kappa}_a, \overline{\kappa}_a)$, a fraction of dirty firms adopt ($\phi_a^* \in (0,1)$), which is strictly decreasing in κ_a; and (iii) if $\kappa_a \geq \overline{\kappa}_a$, no dirty firm adopts ($\phi_a^* = 0$).

Proposition 1 shows how the incentives of Lemma 2 translate into equilibrium. No firm scales the green technology, and the mis-valuation subsidy expands the adoption region relative to strict green disclosure. In particular, under pooling at the top, a positive fraction of dirty firms adopt for all $\kappa_a < \overline{\kappa}_a$, whereas strict green disclosure generates adoption only for $\kappa_a \leq \frac{\lambda\Delta_a}{1-\beta} < \overline{\kappa}_a$. The equilibrium analysis also highlights that adoption decisions are strategic substitutes. As more dirty firms adopt, they enter the pooled disclosure category as low-type green firms, reducing the share of high-type green firms, θ_{g_H}, and with it the mis-valuation subsidy captured by adoption. Only a fraction of dirty firms therefore adopt at intermediate adoption costs, with the equilibrium adoption fraction ϕ_a^* strictly decreasing in κ_a. Panel (a) of Figure 2 illustrates the equilibrium: the blue-striped region extends up to $\overline{\kappa}_a$, strictly beyond the adoption region under strict green disclosure in Figure 1. In addition, there is no red-striped region, since no firm scales.

Proposition 2 (Equilibrium under Static Pooling at the Bottom)**.** *Under static pooling at the bottom, no dirty firm adopts without scaling ($\phi_a^* = 0$), and there exist two thresholds $\underline{\kappa}_s$ and $\overline{\kappa}_s$, with $\underline{\kappa}_s < \overline{\kappa}_s = \frac{\lambda(\Delta_a+\Delta_s)}{1-\beta}$, such that (i) if $\kappa_s \leq \underline{\kappa}_s$, in the welfare-maximizing equilibrium all dirty firms adopt and scale and all low-type green firms scale ($\phi_{a,s}^* = \phi_s^* = 1$); (ii) if $\kappa_s \in (\underline{\kappa}_s, \overline{\kappa}_s]$, in the welfare-maximizing equilibrium only low-type green firms scale ($\phi_{a,s}^* = 0$ and $\phi_s^* = 1$); and (iii) if $\kappa_s > \overline{\kappa}_s$, no firm scales in the unique equilibrium ($\phi_{a,s}^* = \phi_s^* = 0$).*

Proposition 2 shows how the incentives of Lemma 3 translate into equilibrium. No dirty firm adopts without scaling, and the mis-valuation tax expands the scaling region relative to strict green disclosure. In particular, low-type green firms scale the green technology for all $\kappa_s \leq \overline{\kappa}_s$, whereas strict green disclosure generates scaling only for $\kappa_s \leq \frac{\lambda\Delta_s}{1-\beta} < \overline{\kappa}_s$. Adoption, by contrast, arises only on a subset of the adoption region under strict green disclosure, because adoption is now bundled with privately unprofitable scaling when $V_s < 0$. Notably, when the joint cost $\kappa_a + \kappa_s$ lies below $\overline{\kappa}_s$, dirty firms adopt and scale jointly, and the equilibrium attains the first best. Panel (b) of Figure 2 illustrates the equilibrium: the red-striped region, in which low-type green firms scale, extends up to $\overline{\kappa}_s$, strictly beyond the scaling region under strict green disclosure in Figure 1. The blue-striped region, in which dirty firms adopt, shrinks relative to the adoption region under strict green disclosure. Still, the first-best region expands relative to strict green disclosure: the triangle

Figure 2: Adoption and Scaling under Static Green Disclosure Requirements



(a) Pooling at the Top **(b)** Pooling at the Bottom

Notes: Panel (a): Pooling at the top. The blue-striped region shows the parameter set in which at least a fraction of dirty firms adopt: all dirty firms adopt for low κ_a and a partial fraction adopts as κ_a approaches the lax adoption threshold $\overline{\kappa}_a$. **Panel (b): Pooling at the bottom.** The red-striped region shows the parameter set in which low-type green firms scale. The triangle in the upper left with both blue and red stripes shows the parameter set in which both adoption and scaling occur, implementing the first-best. Gray dotted lines mark the adoption and scaling thresholds under strict green disclosure from Figure 1. The unshaded bottom-left region marks parameters where strict green disclosure already achieves the first best.

with both blue and red stripes marks the parameter region in which pooling at the bottom attains the first best but strict green disclosure does not.

In contrast to adoption decisions under pooling at the top, scaling decisions are strategic complements. As more low-type green firms scale and exit the pooled disclosure category, the share of dirty firms, θ_d, rises, and with it the mis-valuation tax escaped by scaling. This complementarity can give rise to multiple equilibria, in which case the regulator selects the welfare-maximizing equilibrium.

3.1.4 Adoption and Scaling Pecking Orders

In this section, we organize the preceding results and establish pecking orders across the three static disclosure regimes for adoption and for scaling. Relative to strict green disclosure, static pooling at the top strengthens adoption at the cost of scaling, while static pooling at the bottom strengthens scaling at the cost of adoption. The following corollary combines Propositions 1 and 2 to establish a pecking order along each margin.

Corollary 2 (Adoption and Scaling Pecking Orders)**.** *In equilibrium, static pooling at the top generates weakly more adoption than strict green disclosure, which in turn generates weakly more adoption than static pooling at the bottom. For scaling, the pecking order reverses: static pooling at the bottom generates weakly more scaling than strict green disclosure, which in turn generates weakly more scaling than static pooling at the top. Each comparison is strict for some transition costs.*

3.2 Dynamic Green Disclosure

We now study dynamic green disclosure requirements, under which the regulator implements lax green disclosure in period $t = 0$ and commits to switching to strict green disclosure at the beginning of period $t = \tau$. As in the static analysis, dynamic pooling at the extremes is weakly dominated by strict green disclosure, which we show in Appendix C. We therefore restrict attention to dynamic pooling at the top and at the bottom.

To characterize firms' adoption and scaling decisions under each disclosure requirement, we proceed in three steps. First, we characterize firms' transition incentives under dynamic pooling at the top and at the bottom, taking the period $t = 0$ transition shares $(\phi_a, \phi_{a,s}, \phi_s)$ and the switching period τ as given. Second, we determine the equilibrium transition shares $(\phi_a, \phi_{a,s}, \phi_s)$ as a function of the switching period τ. Finally, we summarize the analysis by comparing each dynamic requirement with its static counterpart, revealing an asymmetry in how the anticipated switch to strict green disclosure shapes transition incentives. Throughout, we treat the switching period τ as given. The regulator's optimal choice of τ is determined as part of the optimal-disclosure analysis in Section 4.

3.2.1 Adoption and Scaling Incentives under Dynamic Pooling at the Top and at the Bottom

Under dynamic green disclosure requirements, firms make transition decisions in period $t = 0$, under lax green disclosure, and again in period $t = \tau$, when the switch to strict green disclosure reveals the types of firms in the pooled disclosure category. There are two additional forces that occur under dynamic requirements relative to static ones. First, additional transition can occur upon the switch to strict green disclosure. Because green disclosure is strict from period $t = \tau$ onward, transition incentives in period $t = \tau$ are the same as those under strict green disclosure (Lemma 1).

Second, the additional transition under strict green disclosure affects transition incentives under lax green disclosure. When valuing the pooled disclosure category in period $t = 0$, the investor anticipates the period-$t = \tau$ transitions of the firms in the pool, so the pooled valuation increases because it embeds the option value of future transitions.

We begin with dynamic pooling at the top, under which the pooled disclosure category comprises high-type green firms, which face no further transition decision, and low-type green firms, which scale in period $t = \tau$ if and only if $V_s \geq 0$. Relative to its static counterpart, the pooled valuation under pooling at the top therefore embeds one additional term, the option value of future scaling. The expected end-of-period $t = 0$ valuation of a firm in the pooled disclosure category, gross of any adoption or scaling costs incurred in period $t = 0$, is

$$\frac{\pi + \theta_{g_L}\lambda b_{g_L} + \theta_{g_H}\lambda b_{g_H}}{1-\beta} \; + \; \beta^{\tau}\,\theta_{g_L}\max\{V_s, 0\}, \tag{7}$$

where the first term is the static pooled valuation (3) and the second term is the option value of future scaling, weighted by the probability θ_{g_L} that the firm in the pooled disclosure category is a low-type green firm and discounted by β^{τ} because scaling occurs after the switch in period $t = \tau$.

Lemma 5 (Adoption and Scaling Incentives under Dynamic Pooling at the Top in Period $t = 0$)**.** *Fix the period-$t = 0$ transition shares $(\phi_a, \phi_{a,s}, \phi_s)$ and the switching period $\tau \geq 1$. Under dynamic pooling at the top, a low-type green firm has no incentive to scale in period $t = 0$.*

A dirty firm has no incentive to adopt and scale jointly in period $t = 0$ and has an incentive to adopt in period $t = 0$ if and only if

$$V_a + \theta_{g_H}\frac{\lambda\Delta_s}{1-\beta} + \beta^{\tau}\,\theta_{g_L}\max\{V_s, 0\} \;\geq\; 0, \tag{8}$$

where θ_{g_H} and $\theta_{g_L} = 1 - \theta_{g_H}$ are the shares of high-type and low-type green firms in the pooled disclosure category.

Lemma 5 shows that the anticipated switch to strict green disclosure strengthens adoption incentives relative to static pooling at the top. Holding the period-$t = 0$ transition shares fixed, the adoption incentive (8) exceeds its static counterpart (4) by the option value of future scaling, $\beta^{\tau}\theta_{g_L}\max\{V_s, 0\}$, increasing the mis-valuation subsidy captured by adoption.

Under dynamic pooling at the bottom, the pooled disclosure category comprises dirty firms, which retain the option to adopt upon the switch, and low-type green firms, which retain the option

to scale upon the switch. The expected end-of-period $t = 0$ valuation of a firm in the pooled disclosure category, gross of any adoption or scaling costs incurred in period $t = 0$, is

$$\frac{\pi + \theta_d \lambda b_d + \theta_{g_L} \lambda b_{g_L}}{1-\beta} \; + \; \beta^{\tau} \left(\theta_d \max\{V_a, 0\} + \theta_{g_L} \max\{V_s, 0\} \right), \tag{9}$$

where the first term is the static pooled valuation (3) and the second term is the option value of future reform, weighted by the probabilities θ_d and θ_{g_L} that the firm in the pooled disclosure category is a dirty or a low-type green firm and discounted by β^{τ} because reform occurs only in period $t = \tau$.[17]

Lemma 6 (Adoption and Scaling Incentives under Dynamic Pooling at the Bottom in Period $t = 0$)**.** *Fix the period-$t = 0$ transition shares $(\phi_a, \phi_{a,s}, \phi_s)$ and the switching period $\tau \geq 1$. Under dynamic pooling at the bottom, a low-type green firm has an incentive to scale in period $t = 0$ if and only if*

$$V_s + \theta_d \frac{\lambda \Delta_a}{1-\beta} - \beta^{\tau} \left(\theta_d \max\{V_a, 0\} + \theta_{g_L} \max\{V_s, 0\} \right) \; \geq \; 0, \tag{10}$$

where θ_d and $\theta_{g_L} = 1 - \theta_d$ are the shares of dirty and low-type green firms in the pooled disclosure category, with $\theta_d = 1$ and $\theta_{g_L} = 0$ when $\phi_{a,s} = \phi_s = 1$.

A dirty firm has no incentive to adopt without scaling in period $t = 0$ and has an incentive to adopt and scale jointly in period $t = 0$ if and only if

$$V_a + V_s - \theta_{g_L} \frac{\lambda \Delta_a}{1-\beta} - \beta^{\tau} \left(\theta_d \max\{V_a, 0\} + \theta_{g_L} \max\{V_s, 0\} \right) \; \geq \; 0. \tag{11}$$

Lemma 6 shows that the anticipated switch to strict green disclosure weakens scaling incentives relative to static pooling at the bottom. Holding the period-$t = 0$ transition shares fixed, the scaling incentive (10) and the joint adoption-and-scaling incentive (11) fall short of their static counterparts (5) and (6) by the option value of future reform. The prospect of reform in period $t = \tau$ raises the pooled valuation, making it less costly to remain in the pooled disclosure category, eroding the mis-valuation tax escaped by scaling.

[17] A dirty firm that adopts in period $t = \tau$ does not scale, since under Assumption 1 adoption under strict green disclosure occurs only in Case 2, where $V_s < 0$. Its option value is therefore $\max\{V_a, 0\}$.

3.2.2 Equilibrium under Dynamic Pooling at the Top and at the Bottom

Lemmas 5 and 6 characterize firms' transition incentives taking the period $t = 0$ transition shares $(\phi_a, \phi_{a,s}, \phi_s)$ and the switching period τ as given. We now determine the equilibrium transition shares as functions of τ, denoted $(\phi_a^*(\tau), \phi_{a,s}^*(\tau), \phi_s^*(\tau))$, under each requirement, starting with dynamic pooling at the top.

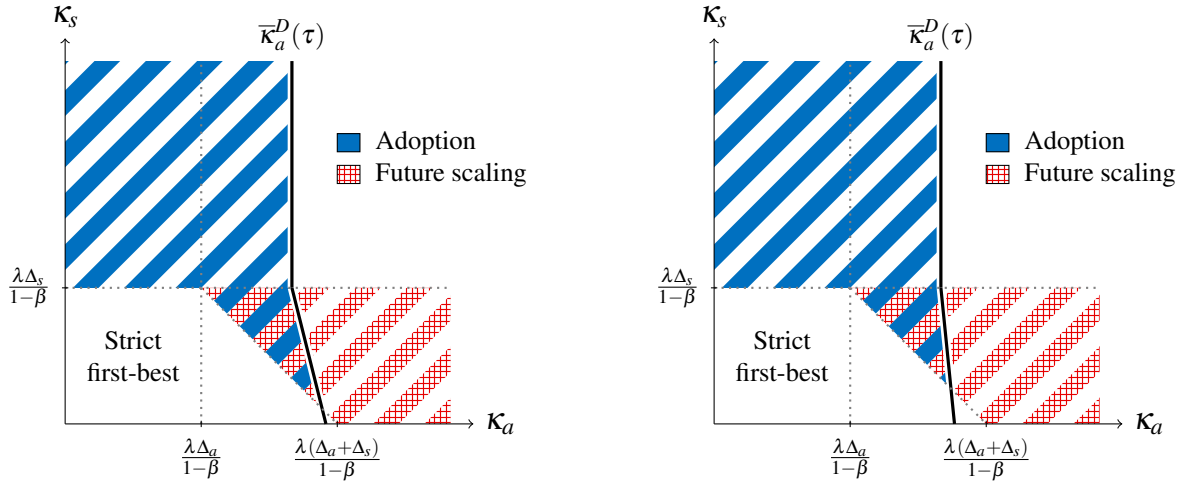
Proposition 3 (Equilibrium under Dynamic Pooling at the Top)**.** *Fix the switching period $\tau \geq 1$. Under dynamic pooling at the top, the equilibrium is unique. No firm scales in period $t = 0$ ($\phi_{a,s}^*(\tau) = \phi_s^*(\tau) = 0$), and there exist two thresholds $\underline{\kappa}_a^D(\tau)$ and $\overline{\kappa}_a^D(\tau)$, where $\frac{\lambda \Delta_a}{1-\beta} < \underline{\kappa}_a^D(\tau) < \overline{\kappa}_a^D(\tau)$, such that (i) if $\kappa_a \leq \underline{\kappa}_a^D(\tau)$, all dirty firms adopt in period $t = 0$ ($\phi_a^*(\tau) = 1$); (ii) if $\kappa_a \in (\underline{\kappa}_a^D(\tau), \overline{\kappa}_a^D(\tau))$, a fraction of dirty firms adopt in period $t = 0$ ($\phi_a^*(\tau) \in (0,1)$), which is strictly decreasing in κ_a; and (iii) if $\kappa_a \geq \overline{\kappa}_a^D(\tau)$, no dirty firm adopts in period $t = 0$ ($\phi_a^*(\tau) = 0$). In period $t = \tau$, no dirty firm adopts, and low-type green firms, both initially low-type green firms and dirty firms that adopted in period $t = 0$, scale in Case 1 ($V_s \geq 0$).*

Proposition 3 shows that, for any switching period $\tau \geq 1$, the equilibrium under dynamic pooling at the top inherits the threshold structure of its static counterpart (Proposition 1). No firm scales in period $t = 0$, and adoption decreases with the adoption cost, with thresholds that now depend on the switching period τ. In period $t = \tau$, low-type green firms (both initially low-type green firms and dirty firms that adopted in period $t = 0$) scale in Case 1. Figure 3 illustrates the equilibrium: blue stripes mark the region in which dirty firms adopt in period $t = 0$, and hatched red stripes mark the region in which low-type green firms scale in period $t = \tau$ upon the switch.

Corollary 3. *The equilibrium thresholds and transition shares from Proposition 3 have the following properties: (i) the thresholds $\underline{\kappa}_a^D(\tau)$ and $\overline{\kappa}_a^D(\tau)$ are weakly decreasing in τ and weakly exceed their static counterparts $\underline{\kappa}_a$ and $\overline{\kappa}_a$ from Proposition 1, with strict inequalities if and only if $V_s > 0$; (ii) the equilibrium fraction of dirty firms that adopt in period $t = 0$ satisfies $\phi_a^*(\tau) \geq \phi_a^*(\tau')$ for any $\tau < \tau'$, with strict inequality if and only if $V_s > 0$ and $\kappa_a \in (\underline{\kappa}_a^D(\tau'), \overline{\kappa}_a^D(\tau))$, and weakly exceeds its static counterpart ϕ_a^* from Proposition 1, with strict inequality if and only if $V_s > 0$ and $\kappa_a \in (\underline{\kappa}_a, \overline{\kappa}_a^D(\tau))$.*

Corollary 3 shows that dynamic pooling at the top amplifies adoption relative to its static counterpart. Both adoption thresholds shift outward, and equilibrium adoption weakly exceeds its static counterpart. The amplification reflects the option value of future scaling embedded in the pooled

Figure 3: Adoption and Scaling under Dynamic Pooling at the Top



(a) Small τ **(b)** Large τ

Notes: Both panels plot adoption and scaling decisions under dynamic pooling at the top in the (κ_a, κ_s) plane, with the only difference being the value of the switching period τ. Blue stripes indicate that dirty firms adopt in period $t = 0$. Hatched red stripes indicate that low-type green firms scale in period $t = \tau$ upon the switch to strict green disclosure. The adoption threshold $\overline{\kappa}_a^D(\tau)$ from Proposition 3 is drawn as a solid black line. It coincides with its static counterpart $\overline{\kappa}_a$ for $\kappa_s \geq \frac{\lambda\Delta_s}{1-\beta}$ and exceeds it for $\kappa_s < \frac{\lambda\Delta_s}{1-\beta}$, by more in Panel (a), with a small switching period, than in Panel (b), with a large switching period. Gray dotted lines mark the adoption and scaling thresholds under strict green disclosure from Figure 1. The unshaded bottom-left region marks parameters where strict green disclosure already achieves the first best.

valuation, and its size is governed by the discount factor β^τ. An earlier switch discounts future scaling by less, shifts the thresholds further outward, and generates more adoption. The two panels of Figure 3 illustrate this dependence on the switching period by contrasting a small switching period, in which the dynamic adoption threshold $\overline{\kappa}_a^D(\tau)$ extends beyond its static counterpart (Panel a), with a larger switching period, in which it remains closer to the static threshold (Panel b).

Next, we characterize the equilibrium under dynamic pooling at the bottom.

Proposition 4 (Equilibrium under Dynamic Pooling at the Bottom)**.** *Fix the switching period $\tau \geq 1$. Under dynamic pooling at the bottom, no dirty firm adopts without scaling in period $t = 0$ ($\phi_a^*(\tau) = 0$), and there exist two thresholds $\overline{\kappa}_s^D(\tau)$ and $\underline{\kappa}_s^D(\tau)$, with $\underline{\kappa}_s^D(\tau) < \overline{\kappa}_s^D(\tau)$, such that (i) if $\kappa_s \leq \underline{\kappa}_s^D(\tau)$, in the welfare-maximizing equilibrium all dirty firms adopt and scale and all low-type green firms scale in period $t = 0$ ($\phi_{a,s}^*(\tau) = \phi_s^*(\tau) = 1$); (ii) if $\kappa_s \in (\underline{\kappa}_s^D(\tau), \overline{\kappa}_s^D(\tau)]$, in the welfare-maximizing equilibrium only low-type green firms scale in period $t = 0$ ($\phi_{a,s}^*(\tau) = 0$ and $\phi_s^*(\tau) = 1$); and (iii) if $\kappa_s > \overline{\kappa}_s^D(\tau)$, no firm scales the green technology in period $t = 0$ in the unique equilibrium ($\phi_{a,s}^*(\tau) = \phi_s^*(\tau) = 0$). In period $t = \tau$, no low-type green firm scales, and the*

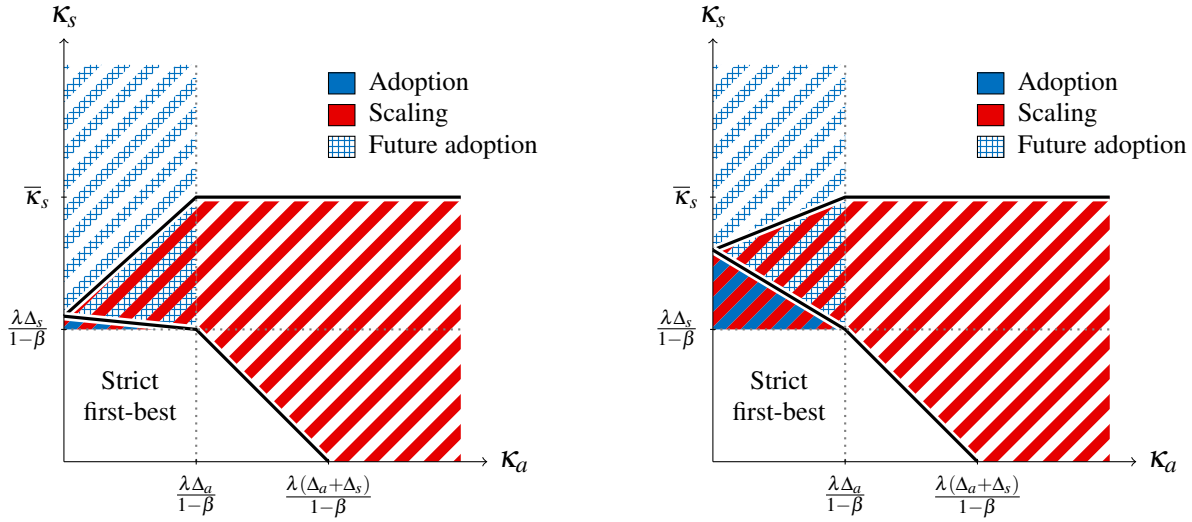
remaining dirty firms adopt in Case 2 ($V_a \geq 0$).

Proposition 4 shows that, for any switching period $\tau \geq 1$, the equilibrium under dynamic pooling at the bottom inherits the threshold structure of its static counterpart (Proposition 2). No dirty firm adopts without scaling in period $t = 0$, and scaling decreases with the scaling cost, with thresholds that now depend on the switching period τ. In period $t = \tau$, dirty firms remaining in the pooled disclosure category adopt the green technology in Case 2. Figure 4 illustrates the equilibrium decisions: the combined solid blue and red stripes mark the region in which all dirty firms adopt and scale and all low-type green firms scale in period $t = 0$, attaining the first best; the red stripes mark the region in which only low-type green firms scale in period $t = 0$; and the hatched blue stripes mark the region in which dirty firms adopt in period $t = \tau$ upon the switch.

Corollary 4. *The equilibrium thresholds and transition shares from Proposition 4 have the following properties: (i) the thresholds $\underline{\kappa}_s^D(\tau)$ and $\overline{\kappa}_s^D(\tau)$ are weakly increasing in τ and weakly below their static counterparts $\underline{\kappa}_s$ and $\overline{\kappa}_s$ from Proposition 2, with strict inequalities if and only if $V_a > 0$; (ii) the equilibrium fraction of low-type green firms that scale in period $t = 0$ satisfies $\phi_s^*(\tau) \leq \phi_s^*(\tau')$ for any $\tau < \tau'$, with strict inequality if and only if $V_a > 0$ and $\kappa_s \in (\overline{\kappa}_s^D(\tau), \overline{\kappa}_s^D(\tau')]$, and weakly falls below its static counterpart ϕ_s^* from Proposition 2, with strict inequality if and only if $V_a > 0$ and $\kappa_s \in (\overline{\kappa}_s^D(\tau), \overline{\kappa}_s]$; (iii) the equilibrium fraction of dirty firms that adopt and scale in period $t = 0$ satisfies $\phi_{a,s}^*(\tau) \leq \phi_{a,s}^*(\tau')$ for any $\tau < \tau'$, with strict inequality if and only if $V_a > 0$ and $\kappa_s \in (\underline{\kappa}_s^D(\tau), \underline{\kappa}_s^D(\tau')]$, and weakly falls below its static counterpart $\phi_{a,s}^*$, with strict inequality if and only if $V_a > 0$ and $\kappa_s \in (\underline{\kappa}_s^D(\tau), \underline{\kappa}_s]$.*

Corollary 4 shows that dynamic pooling at the bottom dampens scaling relative to its static counterpart, in contrast to the amplification under dynamic pooling at the top. Both scaling thresholds shift inward, and equilibrium scaling and joint adoption-and-scaling weakly fall below their static counterparts. The dampening reflects the option value of future adoption embedded in the pooled valuation, and its size is governed by the discount factor β^τ. An earlier switch discounts future adoption by less, shifts the thresholds further inward, and generates less scaling. The two panels of Figure 4 illustrate this dependence on the switching period by contrasting a small switching period, in which the dynamic scaling thresholds $\underline{\kappa}_s^D(\tau)$ and $\overline{\kappa}_s^D(\tau)$ fall far below their static counterparts (Panel a), with a larger switching period, in which they remain closer to the static thresholds (Panel b).

Figure 4: Adoption and Scaling under Dynamic Pooling at the Bottom



(a) Small τ **(b)** Large τ

Notes: Both panels plot adoption and scaling decisions under dynamic pooling at the bottom in the (κ_a, κ_s) plane, with the only difference being the value of the switching period τ. Combined blue and red stripes indicate that all dirty firms adopt and scale and all low-type green firms scale in period $t = 0$. Red stripes alone indicate that only low-type green firms scale in period $t = 0$. Hatched blue stripes indicate that dirty firms adopt in period $t = \tau$ upon the switch to strict green disclosure. The scaling thresholds $\overline{\kappa}_s^D(\tau)$ and $\underline{\kappa}_s^D(\tau)$ from Proposition 4 are drawn as solid black lines. They coincide with their static counterparts $\overline{\kappa}_s$ and $\underline{\kappa}_s$ for $\kappa_a \geq \frac{\lambda\Delta_a}{1-\beta}$ and fall below them for $\kappa_a < \frac{\lambda\Delta_a}{1-\beta}$, by more in Panel (a), with a small switching period, than in Panel (b), with a large switching period. Gray dotted lines mark the adoption and scaling thresholds under strict green disclosure from Figure 1. The unshaded bottom-left region marks parameters where strict green disclosure already achieves the first best.

3.2.3 Amplification Under Dynamic Green Disclosure

We now summarize the key insights from the preceding analysis by comparing the two dynamic lax green disclosure requirements with their static counterparts and with strict green disclosure. The comparison reveals an asymmetry between pooling at the top and at the bottom in how the anticipated switch to strict green disclosure shapes transition incentives.

Under dynamic pooling at the top, the anticipated switch to strict green disclosure makes lax green disclosure more effective. By preserving the option value of scaling, the anticipated switch enhances the mis-valuation subsidy captured by adoption during the initial period of lax green disclosure (Corollary 3). As such, lax green disclosure requirements promote adoption more effectively when they are expected to be temporary rather than permanent. In addition, initial lax green disclosure enhances the impact of later strict green disclosure by increasing the number of firms that eventually scale the green technology. This amplification can generate more adoption

and more scaling than either component, static pooling at the top or strict green disclosure, alone.

By contrast, under dynamic pooling at the bottom, the anticipated switch to strict green disclosure makes lax green disclosure less effective. By preserving the option value of adoption, the anticipated switch erodes the mis-valuation tax escaped by scaling during the initial period of lax green disclosure (Corollary 4). As such, lax green disclosure requirements incentivize scaling less effectively when they are expected to be temporary rather than permanent. In addition, initial lax green disclosure does not enhance the impact of strict green disclosure by increasing the measure of dirty firms that adopt. Dynamic pooling at the bottom therefore generates no counterpart to the amplification effect under dynamic pooling at the top. The following corollary formalizes these comparisons in terms of long-run adoption and scaling.

Corollary 5 (Long-Run Adoption and Scaling)**.** *Fix the switching period $\tau \geq 1$. In the long run, dynamic pooling at the top generates weakly more adoption than static pooling at the top, with strict inequality if and only if $V_s > 0$ and $\kappa_a \in (\underline{\kappa}_a, \overline{\kappa}_a^D(\tau))$, and weakly more scaling than strict green disclosure, with strict inequality if and only if $V_s \geq 0$ and $\kappa_a < \overline{\kappa}_a^D(\tau)$. Dynamic pooling at the bottom generates the same adoption as strict green disclosure, and weakly less scaling than static pooling at the bottom, with strict inequality if and only if $V_a > 0$ and $\kappa_s \in (\underline{\kappa}_s^D(\tau), \underline{\kappa}_s] \cup (\overline{\kappa}_s^D(\tau), \overline{\kappa}_s]$.*

Corollary 5 compares the breadth of the green transition, the long-run masses of firms that adopt and scale, across disclosure requirements. Dynamic pooling at the top is the only requirement that amplifies both transition margins. However, dynamic pooling at the top is not necessarily superior to strict green disclosure because it delays scaling by low-type green firms, which scale only in period $t = \tau$ rather than in period $t = 0$. Similarly, although dynamic pooling at the bottom generates the same long-run adoption as strict green disclosure, this adoption occurs weakly later. Unless dirty firms adopt and scale jointly in period $t = 0$, they adopt only in period $t = \tau$. The timing of reform thus generates a trade-off between the pace and the breadth of the green transition under different disclosure requirements. In the next section, we explore this trade-off and characterize optimal green disclosure requirements.

4 Optimal Green Disclosure Requirements

We now characterize the optimal green disclosure requirements. The regulator chooses both the green disclosure requirement and, under an initial lax green disclosure requirement, the switching

period τ, where $\tau = \infty$ corresponds to the static requirement.[18] Under dynamic pooling at the bottom, an early switch may undo the reform that the static requirement generates in period $t = 0$ (Corollary 4). A sufficiently late switch preserves this reform. We denote by $\underline{\tau}^D := \min\{\tau \geq 1 : (\phi^*_{a,s}(\tau), \phi^*_s(\tau)) = (\phi^*_{a,s}, \phi^*_s)\}$ the earliest such switching period, that is, the smallest $\tau \geq 1$ for which the period-$t = 0$ transition shares under the dynamic requirement, $\phi^*_{a,s}(\tau)$ and $\phi^*_s(\tau)$, coincide with those under the static requirement, $\phi^*_{a,s}$ and ϕ^*_s.

Proposition 5 (Optimal Green Disclosure Requirements)**.** *The optimal green disclosure requirements depend on which transition margin constitutes a roadblock under strict green disclosure.*

Case 0: no roadblock *($V_s \geq 0$* ***and*** *$V_a + V_s \geq 0$****, equivalently*** *$\lambda \geq \overline{\lambda}$).* *Strict green disclosure implements the first best, and the regulator implements strict green disclosure.*

Case 1: adoption is the only roadblock *($V_s \geq 0$* ***and*** *$V_a + V_s < 0$).* *Pooling at the bottom is weakly dominated by strict green disclosure. The regulator implements dynamic pooling at the top with switching period $\tau = 1$ if $\kappa_a < \overline{\kappa}^D_a(1)$ and*

$$\underbrace{\phi^*_a(1)\,\mu_d\left(\tfrac{\Delta_a}{1-\beta} - \kappa_a\right)}_{\substack{\text{Social value of}\\ \text{adoption}}} + \underbrace{\beta\,\phi^*_a(1)\,\mu_d\left(\tfrac{\Delta_s}{1-\beta} - \kappa_s\right)}_{\substack{\text{Social value of adopters'}\\ \text{subsequent scaling}}} > \underbrace{(1-\beta)\,\mu_{g_L}\left(\tfrac{\Delta_s}{1-\beta} - \kappa_s\right)}_{\substack{\text{Social loss from}\\ \text{delayed scaling}}}, \tag{12}$$

where $\overline{\kappa}^D_a(1)$ and $\phi^*_a(1)$ are the adoption threshold and the equilibrium adoption share from Proposition 3. Otherwise, the regulator implements strict green disclosure.

Case 2: scaling is the only roadblock *($V_s < 0$* ***and*** *$V_a \geq 0$).* *Pooling at the top is weakly dominated by strict green disclosure. The regulator implements pooling at the bottom with switching period $\underline{\tau}^D$ if $\kappa_a + \kappa_s \leq \overline{\kappa}_s$, attaining the first best, or if $\kappa_s \leq \overline{\kappa}_s < \kappa_a + \kappa_s$ and*

$$\underbrace{\mu_{g_L}\left(\tfrac{\Delta_s}{1-\beta} - \kappa_s\right)}_{\substack{\text{Social value of}\\ \text{scaling}}} > \underbrace{\left(1 - \beta^{\underline{\tau}^D}\right)\mu_d\left(\tfrac{\Delta_a}{1-\beta} - \kappa_a\right)}_{\substack{\text{Social loss from}\\ \text{delayed adoption}}}, \tag{13}$$

where $\overline{\kappa}_s$ is the scaling threshold under static pooling at the bottom (Proposition 2). Otherwise, the regulator implements strict green disclosure.

Case 3: both margins are roadblocks *($V_a < 0$* ***and*** *$V_s < 0$).* *Strict green disclosure generates no reform, and each dynamic lax requirement coincides with its static counterpart. Pooling at the*

[18] The optimal switching period is not always unique, and we adopt the convention that the regulator implements the earliest optimal switching period.

top generates adoption if and only if $\kappa_a < \overline{\kappa}_a$, and pooling at the bottom generates scaling if and only if $\kappa_s \leq \overline{\kappa}_s$, where $\overline{\kappa}_a$ and $\overline{\kappa}_s$ are the adoption and scaling thresholds under static pooling at the top and at the bottom (Propositions 1 and 2). If neither lax requirement generates reform, the regulator implements strict green disclosure. Otherwise, the regulator implements pooling at the top if

$$\underbrace{\phi_a^* \mu_d \left(\frac{\Delta_a}{1-\beta} - \kappa_a \right)}_{\substack{\textit{Social value of adoption} \\ \textit{under pooling at the top}}} \geq \underbrace{\mu_{g_L} \left(\frac{\Delta_s}{1-\beta} - \kappa_s \right) \mathbb{1}_{\{\kappa_s \leq \overline{\kappa}_s\}}}_{\substack{\textit{Social value of scaling} \\ \textit{under pooling at the bottom}}}, \tag{14}$$

where ϕ_a^* is the equilibrium adoption share under static pooling at the top (Proposition 1), and pooling at the bottom otherwise.[19]

Proposition 5 shows that, unless strict green disclosure implements the first best (Case 0), the regulator's choice reduces to three candidates: strict green disclosure, dynamic pooling at the top with an immediate switch, and pooling at the bottom with switching period $\underline{\tau}^D$. The optimal timing of the switch can differ across the two lax requirements, reflecting the asymmetry established in Section 3.2.3. Under pooling at the top, the timing of the switch involves no trade-off. An earlier switch both strengthens the amplification of adoption (Corollary 3), broadening the green transition, and shortens the delay before low-type green firms scale, accelerating the green transition, so the regulator switches as soon as possible. Under pooling at the bottom, by contrast, an earlier switch accelerates the adoption that dirty firms undertake upon the switch, but it also raises the option value of future adoption embedded in the pooled valuation, dampening scaling in period $t = 0$ (Corollary 4). Delaying the switch to $\underline{\tau}^D$ preserves period-$t = 0$ reform that makes pooling at the bottom attractive in the first place, while inducing adoption upon the switch as early as possible.

The comparison among the three candidates depends on the trade-off between the pace and the breadth of the green transition. If adoption is the only roadblock (Case 1), strict green disclosure generates scaling by low-type green firms in period $t = 0$ but no adoption. Dynamic pooling at the top can increase the breadth of the green transition by increasing adoption and subsequent scaling by the additional adopters. However, the increase in breadth comes at the cost of a loss in pace because low-type green firms scale later than under strict green disclosure. Dynamic pooling at the top is optimal if the social value of any additional adoption and subsequent scaling outweighs the cost of delaying scaling.

[19] When the regulator is indifferent between the two lax green disclosure requirements, we adopt the convention that the regulator implements pooling at the top.

If scaling is the only roadblock (Case 2), strict green disclosure generates adoption by all dirty firms in period $t = 0$ but no scaling. Dynamic pooling at the bottom can increase the breadth of the green transition by increasing scaling but may come at the cost of a loss in pace if dirty firms delay adoption. When the joint cost of adoption and scaling is sufficiently low, the mis-valuation tax induces low-type green firms to scale and dirty firms to adopt and scale jointly in period $t = 0$, so pooling at the bottom implements the first best and is optimal. When the joint transition is too costly for dirty firms but scaling remains within reach, the regulator must delay the switch to period $\underline{\tau}^D$ to preserve scaling in period $t = 0$, and dirty firms adopt only upon the switch. Pooling at the bottom is optimal if the social value of the additional scaling outweighs the cost of the delayed adoption.

Finally, if both margins are roadblocks (Case 3), strict green disclosure generates no reform, and the trade-off collapses to just the breadth dimension. Because no firm would reform upon a switch to strict green disclosure, the option values embedded in the pooled valuation vanish, and each dynamic requirement coincides with its static counterpart. The regulator therefore compares the breadth of the two static lax requirements. Pooling at the top may generate adoption, while pooling at the bottom may generate scaling. The regulator implements the requirement whose margin generates the larger social surplus.

5 Extensions and Robustness

This section presents extensions of the baseline model and discusses the robustness of our main results to alternative assumptions.

Voluntary Disclosure and Information Leakage: In our baseline model, the investor learns about firm types only through green disclosure requirements. In Appendix D.1, we relax this assumption along two dimensions. First, we allow a subset of firms to voluntarily disclose their type, for example through a third-party certification or an audited sustainability report. Second, we allow information about a subset of firms to leak to the investor independently of green disclosure requirements, for example through media coverage or analyst research.

We show that voluntary disclosure and information leakage weaken the effectiveness of lax green disclosure requirements, but leave our results qualitatively unchanged as long as public information remains incomplete. In particular, they weaken adoption incentives under pooling at

the top and scaling incentives under pooling at the bottom (Proposition D.1). Voluntary disclosure weakens lax green disclosure requirements because the firms with the strongest incentive to voluntarily disclose their type are those that are under-valued in the pooled disclosure category. Under pooling at the top, high-type green firms are under-valued. Their disclosure reduces the share of high-type green firms in the pooled disclosure category and with it the mis-valuation subsidy captured by adoption. Under pooling at the bottom, low-type green firms are under-valued and bear the mis-valuation tax. Voluntary disclosure allows them to avoid the mis-valuation tax without scaling and therefore substitutes for the reform the requirement is designed to induce.

Information leakage weakens lax green disclosure requirements through a different channel. Unlike voluntary disclosure, leakage is not strategic. A fraction of firms of every type is revealed, rather than mostly the firms that are under-valued in the pooled disclosure category. Revealed firms reform as they would under strict green disclosure. Revealed dirty firms no longer capture the mis-valuation subsidy under pooling at the top, and revealed low-type green firms no longer bear the mis-valuation tax under pooling at the bottom, so leakage reduces adoption under the former and scaling under the latter (Proposition D.2).

The welfare the regulator can attain weakly falls under both voluntary disclosure and information leakage (Corollary 6). A regulator who implements lax green disclosure requirements therefore has an incentive to limit the flow of type-revealing information before the switch to strict green disclosure.

Both extensions are illustrative. They capture, in a simple and stylized way, how information revealed by other means, whether strategically by firms or through non-strategic leakage, interacts with our mechanism. They abstract from other important features of such information revelation, such as firms' endogenous acquisition of a disclosure technology and reputational incentives.

Initial Distribution of Firm Types: The baseline model takes the initial masses of dirty, low-type green, and high-type green firms as given. The initial distribution captures the reality that firms already differed in their greenness when policymakers began to consider green disclosure requirements. Several factors, unrelated to green disclosure, may have led firms to improve greenness even without observable benefits for stakeholders. For example, this may reflect advantageous technology shocks or pro-social preferences of corporate insiders such as managers, leading to investment in the green technology even if external stakeholders such as investors do not observe firms' greenness.

In Appendix D.2, we show that our framework can capture such heterogeneity by adding a pre-period $t = -1$, in which all firms are initially dirty and some become green for reasons unrelated to green disclosure. We keep the pre-period deliberately stylized to illustrate, in a tractable and simple way, the idea that the initial distribution of firm types can be independent of the disclosure requirements firms face later. In this pre-period, there are no green disclosure requirements, and firms draw random transition costs, or benefits, capturing temporary shocks to technology or managerial preferences for green investment. From period $t = 0$ onward, the model is as in the baseline.

We show that firms with transition benefits adopt or scale in period $t = -1$ so that the economy enters period $t = 0$ with the initial distribution of firm types of the baseline model (Proposition D.3). Intuitively, without green disclosure requirements, the investor cannot distinguish between firms so the investor's market valuation of different firm types does not drive adoption or scaling. However, some firms reform because they receive an alternative benefit, such as higher realized profits from a green investment opportunity or a non-pecuniary managerial benefit. Importantly, the reform decisions in period $t = -1$ hold irrespective of the disclosure requirements that firms and the investor expect from period $t = 0$ onward. Because the investor cannot distinguish between firms in period $t = -1$, expectations about future requirements affect the valuation of all firms equally and therefore do not affect the gain from reforming. The analysis of the baseline model therefore applies unchanged from period $t = 0$ onward.

Green Disclosure Requirements Without Commitment: In Appendix D.3 we analyze dynamic green disclosure requirements when the regulator cannot commit to the switching period τ. The key insight is that once firms have undertaken their initial transitions, the regulator wants to switch to strict green disclosure requirements as quickly as possible if additional reform occurs upon the switch. Proposition D.4 shows that the regulator switches to strict green disclosure in period $t = 1$. Welfare under dynamic pooling at the top is the same as that with commitment. However, welfare under dynamic pooling at the bottom can be lower. Intuitively, under pooling at the top, period $t = 1$ is also the switching period the regulator chooses with commitment (Proposition 5) because of the amplification effect (Corollary 3), so commitment is immaterial. Under pooling at the bottom, the regulator may need to commit to a delayed switch $\underline{\tau}^D > 1$ (Proposition 5) to preserve period-$t = 0$ scaling (Corollary 4). Whenever the regulator implements pooling at the bottom with $\underline{\tau}^D > 1$, the lack of commitment lowers welfare.

Industry Characteristics: Our characterization of optimal green disclosure requirements depends on which transition margin is a roadblock under strict green disclosure. In Appendix D.4, we map this characterization to observable industry characteristics by parameterizing the industry technology so that reform reduces a dirty firm's externality, $b_d < 0$, by a fraction γ_a upon adoption and by a further fraction γ_s upon scaling. An industry is sensitive to green disclosure requirements when investors care about firm greenness and when the green technology creates substantial dispersion in externalities across firm types. Under our parameterization, the valuation gains from adoption and scaling are proportional to $|b_d|$, so heavier polluters are more sensitive to green disclosure requirements, but only to the extent that the green technology can substantially reduce their externality, as captured by γ_a and γ_s.

Among sensitive industries, the optimal requirement depends on transition costs relative to the valuation gains. When both adoption and scaling costs are low, as in office-based services whose emissions stem mainly from purchased electricity, strict green disclosure implements the first best. Dynamic pooling at the top can be optimal when adoption is a roadblock, which may be the case when developing the knowledge and capabilities to go green is costly. The automobile industry fits this case, since incumbents must build new expertise in batteries, electric motors, and software, but can deploy a first electric platform across product lines at relatively low cost. Dynamic pooling at the bottom can be optimal when scaling is a roadblock, which may be the case when knowledge is available but deploying it throughout the firm is costly. Consumer-facing industries such as apparel and packaged food fit this case, since their emissions lie mainly upstream in supply chains that are costly to re-source, certify, and monitor.

Managers' Objective Function: We assume that managers maximize the expected end-of-period firm valuation. Alternatively, they could care about both the current valuation and anticipated future changes in valuation. For static green disclosure requirements, these assumptions are equivalent since valuations do not change after the first period.

Under dynamic green disclosure requirements, however, these assumptions can cause subtle differences in the manager's problem. For example, under dynamic pooling at the top, when $\kappa_s > \frac{\lambda\Delta_s}{1-\beta}$ and no scaling occurs upon the switch to strict green disclosure, the expected end-of-period $t = 0$ valuation of low-type green firms is the same under dynamic and static green disclosure requirements. However, the manager of a low-type green firm anticipates that the firm's valuation will drop when requirements switch to strict, since the manager knows the firm's type while the

investor does not. If managers care about such future drops, the regulator would have a reason to choose a large τ to preserve adoption incentives, mimicking static requirements.

Similarly, the manager of a firm in the pooled green disclosure category that will reform upon the switch to strict green disclosure anticipates paying the transition cost in the future, whereas the investor assigns a probability to this event based on the share of that firm's type in the category. If managers care about future valuation changes, this also affects transition incentives, and the regulator would adjust τ accordingly. While this force may change the relative welfare benefits of different requirements, our qualitative results about which requirements are optimal depending on which, if any, transition margin is a roadblock in the green transition should continue to hold.

Historical Green Disclosure: In our model, since types are disclosed at the end of each period, there is no disclosure at the beginning of period $t = 0$, and firms can adopt or scale before their type is disclosed. Disclosing all initial firm types at the beginning of period $t = 0$ would not improve on the requirements we study, since the investor would then infer each firm's type in every later period from its initial type and its disclosure history.

Effective green disclosure design must consider not only whether to require disclosure of current environmental performance but also whether to mandate disclosure of green investments and historical environmental performance. As shown in Appendices C.2 and D.1, starting with strict green disclosure can render lax green disclosure ineffective and information leakage weakens the effectiveness of lax green disclosure requirements. Indeed, Emiris et al. (2026) find that the SFDR's initial lax stage yielded larger investor responses for funds without prior sustainability ratings, consistent with lax disclosure requirements being more effective when historical information is limited.

The absence of credible historical information about firm greenness from other sources, such as public news or voluntary disclosure, appears to be the empirically relevant case, as regulators cite a lack of historical data and a significant degree of information asymmetry regarding the greenness of firms as reasons for regulatory intervention on disclosure in financial markets.

Reversible Green Technology: In our baseline model, we assume that investments in the green transition are irreversible. This assumption is reasonable because resources invested in green innovation may be hard to recover, particularly when fixed costs are high. Nevertheless, some investments may be partially reversible. For example, hiring specialized labor to scale a firm's green technology may be reversed by reducing the workforce. In our model, reversibility would

be attractive for firms that are under-valued in the pooled green disclosure category, potentially reducing the effectiveness of lax green disclosure requirements. Our qualitative results about the optimality of lax green disclosure requirements should hold as long as there are some costs to reversing the green transition for a subset of firms.

Heterogeneous Profitability: In our baseline model, expected profits are the same for all firm types. This assumption isolates the valuation channel of green disclosure from differences in profitability across types. If expected profits differed across types, two additional forces would arise. First, profitability differences would affect firm valuations through a cash-flow channel. Under strict green disclosure, this channel is isomorphic to a shift in κ_a or κ_s, so that if green firms were less profitable, roadblocks would become more likely. Under lax green disclosure, the profit difference is pooled like the social benefit and acts like a shift in Δ_a or Δ_s, which leaves the direction of the mis-valuation subsidy and tax unchanged as long as profit differences do not reverse the ordering of full-information valuations across firm types. Second, profit realizations would become informative signals about firm types, and the investor would partially learn firms' types even in the absence of green disclosure. The information leakage extension in Appendix D.1.2 captures this force in reduced form. Although the extension abstracts from the details of learning from profits, it captures the main qualitative effect of heterogeneous profitability on our mechanism.

6 Discussion

In this section, we conclude by discussing some additional implications of our analysis. These discussions and insights are broad in scope and intended to be suggestive rather than conclusive.

Firm Entry and Exit: Our analysis is cast in terms of the intensive margin, in which an existing firm undertakes successive steps of the green transition, but each step also has a natural extensive-margin interpretation. We can reinterpret a dirty firm as one that produces negative externalities, a low-type green firm as one that produces no externalities, and a high-type green firm as one that produces positive externalities. Under this reading, adoption corresponds to a firm exiting the "dirty" product market and thereby ceasing to impose negative externalities, and scaling corresponds to a firm entering the "green" product market and generating positive externalities. Disclosure requirements then act on entry and exit incentives analogously to the way they act

on adoption and scaling in our baseline model, with the measure of low-type green firms, μ_{g_L}, reinterpreted as the initial size of the pool of potential green entrants.

Under this interpretation, lax green disclosure requirements can be optimal if either the exit of dirty firms (adoption) or the entry of green firms (scaling) is a roadblock under strict green disclosure. Dynamic pooling at the top can induce dirty firms to exit early but delays green entry until the switch to strict green disclosure. Dynamic pooling at the bottom can induce early green entry but may delay the exit of dirty firms until the switch. The optimal requirement follows the characterization in Proposition 5.

The pooling mechanism in our framework requires that all three firm types are priced in capital markets. In particular, the intermediate low-type green category must be a priced object, over-valued under pooling at the top and under-valued under pooling at the bottom, for the mis-valuation that drives transitions under lax green disclosure to arise. This is the case, for example, for a green start-up that has raised capital and is priced by investors but has not yet begun production. Another natural interpretation is a firm with multiple product lines, for example a conglomerate such as Procter & Gamble, where our model describes entry into and exit from a given product line rather than entry and exit of the firm itself. Exiting a product line that relies on polluting production processes is analogous to adoption, while launching a green product line is analogous to scaling. In the intermediate low-type green state, the firm operates neither line and generates no externalities.

Size of Dirty Firms: Our model holds the scale of each firm's activity, and hence the scale of the externality it generates, fixed, so that disclosure operates only through the transition incentives it creates. In practice, disclosure may also mitigate externalities by reducing the size of dirty firms. If a lower valuation raises a dirty firm's cost of capital and thereby reduces its scale, disclosure reduces the externality the firm generates. While we do not model this size channel, it is instructive to consider how it would interact with our results. This size channel creates an additional reason to disclose dirty firms, potentially pushing against lax green disclosure. Importantly, however, this argument is only an impediment for requirements that conceal the identity of dirty firms. Under pooling at the bottom, dirty firms are pooled with low-type green firms and are over-valued. Concealment could then also expand dirty production, generating an additional cost to pooling at the bottom. Under pooling at the top, by contrast, dirty firms remain separately identified, so the size channel would continue to operate. The additional size channel could in fact strengthen the case for pooling at the top, since this requirement generates the strongest incentives for dirty firms

to reform.

Changing Fundamentals: Our analysis takes the transition costs κ_a and κ_s and the investor's preference parameter λ as time-invariant. In practice, these fundamentals need not be static. Technological innovation that lowers the adoption cost κ_a or the scaling cost κ_s, or shifts in investor preferences that move λ, may mean that a transition step that is a roadblock today is no longer one in the future. While we do not model such changes formally, the logic of our analysis suggests that anticipated changes in fundamentals would work asymmetrically across the two forms of pooling, in the same way as the anticipated switch to strict green disclosure does in our baseline model. An anticipated drop in κ_s (or increase in λ) that leads firms to scale in the future would raise the pooled valuation under pooling at the top and thereby strengthen the mis-valuation subsidy, similar to the mechanism of a faster anticipated switch to strict green disclosure. By contrast, an anticipated drop in κ_a (or increase in λ) that leads firms to adopt in the future would raise the pooled valuation under pooling at the bottom and thereby erode the mis-valuation tax. We therefore expect anticipated changes in fundamentals to affect the optimal switching time and the welfare gain from a given lax requirement, rather than the qualitative case for lax green disclosure when a roadblock exists today.

Relationship to Carbon Taxes: A Pigouvian carbon tax under full transparency can implement the first-best allocation in our framework. In practice, however, informational, financial, or technological frictions and political economy constraints often prevent effective carbon taxation (e.g., Acemoglu et al., 2012; Tirole, 2012; Carattini et al., 2019; Douenne and Fabre, 2022; Döttling and Rola-Janicka, 2023; Oehmke and Opp, 2024). Green disclosure regulation may be easier to implement because it shifts who bears the cost of the transition. Whereas the cost of carbon taxation tends to fall on consumers, and often on poorer households (e.g., Känzig, 2023), green disclosure places it on investors who pay a premium for greener firms. Green disclosure thus relies on investors' willingness to pay for greenness, and it is most valuable when this willingness to pay is present but the political capacity to raise carbon taxes is limited.

Our model also admits a natural mapping between green disclosure and carbon taxation. The parameter λ can be interpreted as a carbon tax rate and b_i as (the negative of) a firm's emissions. For a firm with a negative externality ($b_i < 0$), $\lambda b_i < 0$ is then the carbon tax payment that reduces its per-period profit π, and for a firm with a positive externality ($b_i > 0$), $\lambda b_i > 0$ is a subsidy. Under strict green disclosure, each firm is taxed on its own emissions, as under a standard carbon

tax. Under lax green disclosure, firms in the pooled green disclosure category are instead taxed on the average emissions of that category, corresponding to $\theta_i b_i + \theta_j b_j$. The carbon tax rate thus sets the price of emissions, whereas the disclosure requirement determines the tax base to which this rate applies, that is, how finely the tax distinguishes between firms with different emissions.

Our results then carry over directly. If the carbon tax rate is high enough that $\lambda \geq \overline{\lambda}$, Corollary 1 implies that a fully granular tax base implements the first best, so a coarser base cannot improve on it. If the politically feasible tax rate satisfies $\lambda < \overline{\lambda}$, a granular tax base would leave at least one transition margin as a roadblock, and coarsening the base can complement the tax. A coarse green tax bracket can help when the first step of the transition is the roadblock, and a coarse dirty tax bracket can help when completing the transition is the roadblock. Moreover, our dynamic results suggest that the tax base should become more granular over time. A coarse green tax bracket that is announced to be refined later can generate more decarbonization than either a permanently coarse or a permanently granular base, because the anticipated refinement preserves the option value of completing the transition. In particular, taxation and disclosure can complement each other. The tax sets the price of emissions, and disclosure shapes how it applies across firm types and over time.

References

Acemoglu, Daron, Philippe Aghion, Leonardo Bursztyn, and David Hemous, 2012, The Environment and Directed Technical Change, *American Economic Review* 102, 131–66.

Aghamolla, Cyrus, and An Byeong-Je, 2023, Mandatory vs. Voluntary ESG Disclosure, Efficiency, and Real Effects, Working Paper.

Aghion, Philippe, Roland Benabou, Ralf Martin, and Alexandra Roulet, 2023, Environmental Preferences and Technological Choices: Is Market Competition Clean or Dirty?, *American Economic Review: Insights* 5, 1–20.

Aghion, Philippe, Antoine Dechezleprêtre, David Hémous, Ralf Martin, and John Van Reenen, 2016, Carbon Taxes, Path Dependency, and Directed Technical Change: Evidence from the Auto Industry, *Journal of Political Economy* 124, 1–51.

Albano, Gian Luigi, and Alessandro Lizzeri, 2001, Strategic Certification and Provision of Quality, *International Economic Review* 42, 267–283.

Albuquerque, Rui, Yrjö Koskinen, and Chendi Zhang, 2019, Corporate Social Responsibility and Firm Risk: Theory and Empirical Evidence, *Management Science* 65, 4451–4469.

Ali, S. Nageeb, Nima Haghpanah, Xiao Lin, and Ron Siegel, 2022, How to Sell Hard Information, *Quarterly Journal of Economics* 137, 619–678.

Allen, Franklin, Adelina Barbalau, and Federica Zeni, 2023, Reducing Carbon using Regulatory and Financial Market Tools, Working Paper.

Arkolakis, Costas, and Conor Walsh, 2024, The Economic Impacts of Clean Energy, *Brookings Papers on Economic Activity* 2024, 161–238.

Azarmsa, Ehsan, and Joel D. Shapiro, 2023, The Market for ESG Ratings, Working Paper.

Badenhoop, Nikolai, and Christian Mücke, 2025, Do Investors Care about Sustainable Investment Targets? An Assessment Using the Sustainable Finance Disclosure Regulation, Working Paper.

Baker, Malcolm, Mark L. Egan, and Suproteem K. Sarkar, 2022, How Do Investors Value ESG?, Working Paper.

Banerjee, Snehal, and Filipp Prokopev, 2026, When Climate-Risk Disclosures Reduce Green Investment and Welfare, Working Paper.

Bar-Isaac, Heski, and Joyee Deb, 2020, Reputation with Opportunities for Coasting, *Journal of the European Economic Association* 19, 200–236.

Barbalau, Adelina, and Federica Zeni, 2022, The Optimal Design of Green Securities, Working Paper.

Bauer, Rob, Tobias Ruof, and Paul Smeets, 2021, Get Real! Individuals Prefer More Sustainable Investments, *Review of Financial Studies* 34, 3976–4043.

Berg, Florian, Julian F. Kölbel, and Roberto Rigobon, 2022, Aggregate Confusion: The Divergence of ESG Rating, *Review of Finance,* forthcoming.

Biais, Bruno, Johan Hombert, Daniel Schmidt, and Pierre-Olivier Weill, 2026, Cap and Trade with Imperfect Hedging, Working Paper.

Biais, Bruno, and Augustin Landier, 2022, Emission Caps and Investment in Green Technologies, Working Paper.

Bisceglia, Michele, Alessio Piccolo, and Jan Schneemeier, 2023, Externalities of Responsible Investments, Working Paper.

Biswas, Sonny, Kostas Koufopoulos, and Anjan V. Thakor, 2023, Can Information Imprecision Be Valuable? The Case of Credit Ratings, Working Paper.

BloombergNEF, 2026, Corporate Clean Energy Buying Fell in 2025 After Nearly a Decade of Growth.

Bolton, Patrick, and Marcin Kacperczyk, 2021a, Carbon Disclosure and the Cost of Capital, Working Paper.

Bolton, Patrick, and Marcin Kacperczyk, 2021b, Do Investors Care About Carbon Risk?, *Journal of Financial Economics* 142, 517–549.

Bolton, Patrick, and Marcin Kacperczyk, 2022, Global Pricing of Carbon-Transition Risk, Working Paper.

Bonnefon, Jean-Francois, Augustin Landier, Parinitha Sastry, and David Thesmar, 2022, Do Investors Care About Corporate Externalities? Experimental Evidence, Working Paper.

Broccardo, Eleonora, Oliver D. Hart, and Luigi Zingales, 2022, Exit versus Voice, *Journal of Political Economy* 130, 3101–3145.

Bustamante, Maria Cecilia, and Francesca Zucchi, 2022, Dynamic Carbon Emission Management, Working Paper.

Bustamante, Maria Cecilia, and Francesca Zucchi, 2024, Financially Constrained Carbon Management, Working Paper.

Carattini, Stefano, Edgar Hertwich, Givi Melkadze, and Jeffrey G. Shrader, 2022, Mandatory Disclosure is Key to Address Climate Risks, *Science* 378, 352–354.

Carattini, Stefano, Steffen Kallbekken, and Anton Orlov, 2019, How to Win Public Support for a Global Carbon Tax, *Nature* 565, 289–291.

Cartellier, Fanny, Peter Tankov, and Olivier David Zerbib, 2025, Can Investors Curb Greenwashing?, *Journal of Economic Dynamics and Control* 180, 105195.

Chen, Hui, and Jan Schneemeier, 2023, Responsible Investors and Stock Market Feedback, Working Paper.

Chen, Huiyao, 2023, Talk or Walk the Talk? The Real Impact of ESG Investing, Working Paper.

Chowdhry, Bhagwan, Shaun William Davies, and Brian Waters, 2019, Investing for Impact, *Review of Financial Studies* 32, 864–904.

Christensen, Dane M., George Serafeim, and Anywhere Sikochi, 2022, Why is Corporate Virtue in the Eye of The Beholder? The Case of ESG Ratings, *Accounting Review* 97, 147–175.

Cooper, Russell, and Andrew John, 1988, Coordinating Coordination Failures in Keynesian Models, *Quarterly Journal of Economics* 103, 441–463.

Davies, Shaun William, and Edward Dickersin Van Wesep, 2018, The Unintended Consequences of Divestment, *Journal of Financial Economics* 128, 558–575.

De Angelis, Tiziano, Peter Tankov, and Olivier David Zerbib, 2023, Climate Impact Investing, *Management Science* 69, 7669–7692.

Deloitte, 2022, SFDR Compliance: A Look into Current Status, Challenges, and Possible Solutions, Deloitte Article.

Dewatripont, Mathias, Ian Jewitt, and Jean Tirole, 1999, The Economics of Career Concerns, Part I: Comparing Information Structures, *Review of Economic Studies* 66, 183–198.

Doherty, Neil A., Anastasia V. Kartasheva, and Richard D. Phillips, 2012, Information Effect of Entry into Credit Ratings Market: The Case of Insurers' Ratings, *Journal of Financial Economics* 106, 308–330.

Döttling, Robin, Doron Levit, Nadya Malenko, and Magdalena Rola-Janicka, 2024, Voting on Public Goods: Citizens vs. Shareholders, Working Paper.

Douenne, Thomas, and Adrien Fabre, 2022, Yellow Vests, Pessimistic Beliefs, and Carbon Tax Aversion, *American Economic Journal: Economic Policy* 14, 81–110.

Duchin, Ran, Janet Gao, and Qiping Xu, 2025, Sustainability or Greenwashing: Evidence from the Asset Market for Industrial Pollution, *Journal of Finance* 80, 699–754.

Dumitrescu, Ariadna, Javier Gil-Bazo, and Feng Zhou, 2022, Defining Greenwashing, Working Paper.

Dye, Ronald A., 1985, Disclosure of Nonproprietary Information, *Journal of Accounting Research* 23, 123–145.

Döttling, Robin, and Magdalena Rola-Janicka, 2023, Too Levered for Pigou: Carbon Pricing, Financial Constraints, and Leverage Regulation, Working Paper.

Edmans, Alex, Doron Levit, and Jan Schneemeier, 2022, Socially Responsible Divestment, Working Paper.

Electrek, 2022, Ford to Release Second Electric Car Based on VW's MEB Platform, March 14, 2022.

Ely, Jeffrey C., and Martin Szydlowski, 2020, Moving the Goalposts, *Journal of Political Economy* 128, 468–506.

Emiris, Marina, Joanna Harris, and Francois Koulischer, 2026, Regulating ESG Disclosure: Capital Allocation and Investor Heterogeneity, Working Paper.

Eskildsen, Marc, Markus Ibert, Theis Ingerslev Jensen, and Lasse Heje Pedersen, 2024, In Search of the True Greenium, Working Paper.

Fisch, Jill, and Adriana Z. Robertson, 2024, Shareholder Proposals and the Debate Over Sustainability Disclosure, in Luca Enriques, and Giovanni Strampelli, Eds., *Board-Shareholder Dialogue: Policy Debate, Legal Constraints and Best Practices*, 475–501 (Cambridge University Press).

Friedman, Henry L., Mirko S. Heinle, and Irina Luneva, 2025, Implications of Introducing Investor-Focused ESG Reporting, Working Paper.

Geelen, Thomas, Jakub Hajda, and Jan Starmans, 2022, Sustainable Organizations, Working Paper.

Giannetti, Mariassunta, Martina Jasova, Maria Loumioti, and Caterina Mendicino, 2023, 'Glossy Green' Banks: The Disconnect Between Environmental Disclosures and Lending Activities, Working Paper.

Giglio, Stefano, Matteo Maggiori, Johannes Stroebel, Zhenhao Tan, Stephen Utkus, and Xiao Xu, 2025, Four Facts about ESG Beliefs and Investor Portfolios, *Journal of Financial Economics* 164, 103984.

Goel, Anand M., and Anjan V. Thakor, 2015, Information Reliability and Welfare: A Theory of Coarse Credit Ratings, *Journal of Financial Economics* 115, 541–557.

Goldstein, Itay, and Yaron Leitner, 2018, Stress Tests and Information Disclosure, *Journal of Economic Theory* 177, 34–69.

Gollier, Christian, and Sébastien Pouget, 2022, Investment Strategies and Corporate Behaviour with Socially Responsible Investors: A Theory of Active Ownership, *Economica* 89, 997–1023.

Green, Daniel, and Benjamin Roth, 2025, The Allocation of Socially Responsible Capital, *Journal of Finance* 80, 755–781.

Grossman, Sanford J., 1981, The Informational Role of Warranties and Private Disclosure about Product Quality, *Journal of Law and Economics* 24, 461–483.

Gryglewicz, Sebastian, Simon Mayer, and Erwan Morellec, 2024, Investor Activism and the Green Transition, Working Paper.

Gupta, Deeksha, Alexandr Kopytov, and Jan Starmans, 2025, The Pace of Change: Socially Responsible Investing in Private Markets, *Review of Financial Studies,* 39, 30–78.

Harbaugh, Rick, and Eric Rasmusen, 2018, Coarse Grades: Informing the Public by Withholding Information, *American Economic Journal: Microeconomics* 10, 210–235.

Hart, Oliver, and Luigi Zingales, 2017, Companies Should Maximize Shareholder Welfare Not Market Value, *Journal of Law, Finance, and Accounting* 2, 247–274.

Heeb, Florian, Julian F. Kölbel, Falko Paetzold, and Stefan Zeisberger, 2022, Do Investors Care about Impact?, *Review of Financial Studies* 36, 1737–1787.

Heinkel, Robert, Alan Kraus, and Josef Zechner, 2001, The Effect of Green Investment on Corporate Behavior, *Journal of Financial and Quantitative Analysis* 36, 431–449.

Hertwich, Edgar G., and Richard Wood, 2018, The Growing Importance of Scope 3 Greenhouse Gas Emissions from Industry, *Environmental Research Letters* 13, 104013.

Holmström, Bengt, 1999, Managerial Incentive Problems: A Dynamic Perspective, *Review of Economic Studies* 66, 169–182.

Huang, Shiyang, and Alexandr Kopytov, 2022, Sustainable Finance under Regulation, Working Paper.

Humphrey, Jacquelyn, Shimon Kogan, Jacob Sagi, and Laura Starks, 2021, The Asymmetry in Responsible Investing Preferences, Working Paper.

Hörner, Johannes, and Nicolas S. Lambert, 2020, Motivational Ratings, *Review of Economic Studies* 88, 1892–1935.

Ilhan, Emirhan, Philipp Krueger, Zacharias Sautner, and Laura T. Starks, 2023, Climate Risk Disclosure and Institutional Investors, *Review of Financial Studies* 36, 2617–2650.

Inderst, Roman, and Marcus M. Opp, 2025, Sustainable Finance Versus Environmental Policy: Does Greenwashing Justify a Taxonomy for Sustainable Investments?, *Journal of Financial Economics* 163, 103954.

Jagannathan, Ravi, Soohun Kim, Robert McDonald, and Shixiang Xia, 2022, Environmental Activism, Endogenous Risk, and Stock Prices, Working Paper.

Jiang, Xu, and Yan Xiong, 2025, Disclosure Standards for Corporate Social Responsibility, Working Paper.

Jin, Dunhong, and Thomas H. Noe, 2023, Making Sure Your Vote Does not Count: ESG Activism, Pseudo-Green Shareholders, and Insincere Proxy Voting, Working Paper.

Jouvenot, Valentin, and Philipp Krueger, 2019, Mandatory Corporate Carbon Disclosure: Evidence from a Natural Experiment, Working Paper.

Kamenica, Emir, and Matthew Gentzkow, 2011, Bayesian Persuasion, *American Economic Review* 101, 2590–2615.

Känzig, Diego R., 2023, The Unequal Economic Consequences of Carbon Pricing, NBER Working Paper 31221.

Kartasheva, Anastasia V., and Bilge Yilmaz, 2020, Precision of Ratings, Working Paper.

Krueger, Philipp, Zacharias Sautner, Dragon Yongjun Tang, and Rui Zhong, 2024, The Effects of Mandatory ESG Disclosure Around the World, *Journal of Accounting Research* 62, 1795–1847.

Kräussl, Roman, Tobi Oladiran, and Denitsa Stefanova, 2023, A Review on ESG Investing: Investors' Expectations, Beliefs and Perceptions, *Journal of Economic Surveys,* forthcoming.

Landier, Augustin, and Stefano Lovo, 2024, Socially Responsible Finance: How to Optimize Impact, *Review of Financial Studies* 38, 1211–1258.

Levit, Doron, Nadya Malenko, and Ernst G. Maug, 2024, Trading and Shareholder Democracy, *Journal of Finance* 79, 257–304.

Lizzeri, Alessandro, 1999, Information Revelation and Certification Intermediaries, *RAND Journal of Economics* 30, 214–231.

Lyon, Thomas P., and John W. Maxwell, 2011, Greenwash: Corporate Environmental Disclosure under Threat of Audit, *Journal of Economics & Management Strategy* 20, 3–41.

Mahieux, Lucas, Haresh Sapra, and Gaoqing Zhang, 2025, Measuring Greenhouse Gas Emissions: What Are the Costs and Benefits?, *Journal of Accounting Research* 63, 1063–1105.

Malenko, Andrey, and Nadya Malenko, 2026, Voting Choice, *Review of Financial Studies,* forthcoming.

Matsusaka, John G., and Chong Shu, 2021, A Theory of Proxy Advice when Investors Have Social Goals, Working Paper.

McKinsey & Company and Global Fashion Agenda, 2020, Fashion on Climate: How the Fashion Industry Can Urgently Act to Reduce Its Greenhouse Gas Emissions.

Meier, Jean-Marie, Henri Servaes, Jiaying Wei, and Steven Chong Xiao, 2023, Do Consumers Care About ESG? Evidence from Barcode-Level Sales Data, Working Paper.

Milgrom, Paul R., 1981, Good News and Bad News: Representation Theorems and Applications, *Bell Journal of Economics* 12, 380–391.

Morgan, John, and Justin Tumlinson, 2019, Corporate Provision of Public Goods, *Management Science* 65, 4489–4504.

Murphy, Kevin M., Andrei Shleifer, and Robert W. Vishny, 1989, Industrialization and the Big Push, *Journal of Political Economy* 97, 1003–1026.

Nestlé, 2020, Focusing on Regenerative Agriculture and Moving to Renewable Electricity, Nestlé Redoubles Efforts to Combat Climate Change, Press release, December 3, 2020.

Oehmke, Martin, and Marcus M. Opp, 2024, A Theory of Socially Responsible Investment, *Review of Economic Studies* 92, 1193–1225.

Orlov, Dmitry, Pavel Zryumov, and Andrzej Skrzypacz, 2023, The Design of Macroprudential Stress Tests, *Review of Financial Studies* 36, 4460–4501.

Parise, Gianpaolo, and Mirco Rubin, 2023, Green Window Dressing, Working Paper.

Pastor, Lubos, Robert F. Stambaugh, and Lucian A. Taylor, 2021, Sustainable Investing in Equilibrium, *Journal of Financial Economics* 142, 550–571.

Pedersen, Lasse Heje, 2026, Can Sustainable Finance Save the Planet?, *Journal of Finance: Insights and Perspectives,* forthcoming.

Pedersen, Lasse Heje, Shaun Fitzgibbons, and Lukasz Pomorski, 2021, Responsible Investing: The ESG-Efficient Frontier, *Journal of Financial Economics* 142, 572–597.

Piazzesi, Monika, Lautaro Chittaro, Marcelo Sena, and Martin Schneider, 2025, Asset Returns as Carbon Taxes, Working Paper.

Poore, Joseph, and Thomas Nemecek, 2018, Reducing Food's Environmental Impacts Through Producers and Consumers, *Science* 360, 987–992.

Reuters, 2023, Volkswagen Plans Job Cuts, Further Launch Delays at Software Unit, October 27, 2023.

Riedl, Arno, and Paul Smeets, 2017, Why Do Investors Hold Socially Responsible Mutual Funds?, *Journal of Finance* 72, 2505–2550.

Roth, Benjamin, 2021, Impact Investing: A Theory of Financing Social Enterprises, Working Paper.

Smith, Kevin, 2026, Climate Risk Disclosure and Risk Sharing in Financial Markets, *Review of Financial Studies,* Forthcoming.

Spaans, Lara, Jeroen Derwall, Joop Huij, and Kees Koedijk, 2024, Sustainable Finance Disclosure Regulation: Voluntary Signaling or Mandatory Disclosure?, Working Paper.

The European Commission, n.d., Sustainability-related disclosure in the financial services sector, `https://finance.ec.europa.eu/sustainable-finance/disclosures/sustainability-related-disclosure-financial-services-sector_en`, Accessed: August 2023.

Tirole, Jean, 2012, Some Political Economy of Global Warming, *Economics of Energy and Environmental Policy* 1, 121–132.

Verrecchia, Robert E., 1983, Discretionary Disclosure, *Journal of Accounting and Economics* 5, 179–194.

Villena, Verónica H., and Dennis A. Gioia, 2020, A More Sustainable Supply Chain, *Harvard Business Review* 98, 84–93.

Vives, Xavier, 1984, Duopoly Information Equilibrium: Cournot and Bertrand, *Journal of Economic Theory* 34, 71–94.

Volkswagen Group, 2022, Volkswagen and Ford expand collaboration on MEB electric platform, Press release, March 14, 2022.

Way, Rupert, Matthew C. Ives, Penny Mealy, and J. Doyne Farmer, 2022, Empirically Grounded Technology Forecasts and the Energy Transition, *Joule* 6, 2057–2082.

Wu, Yue, Kaifu Zhang, and Jinhong Xie, 2020, Bad Greenwashing, Good Greenwashing: Corporate Social Responsibility and Information Transparency, *Management Science* 66, 3095–3112.

Xue, Hao, 2025, ESG Disclosure, Market Forces, and Investment Efficiency, *Accounting Review* 100, 439–467.

Zhang, Ye, 2021, Impact Investing and Venture Capital Industry: Experimental Evidence, Working Paper.

Zhang, Ye, 2022, Startups' Strategies for Green Funding Adoption, Working Paper.

A Proofs: Baseline Model

A.1 Strict Green Disclosure Requirements

Proof of Lemma 1. Consider first the scaling decision of a low-type green firm. The investor's end-of-period $t = 0$ valuation of an initially low-type green firm that scales the green technology in period $t = 0$ is given by $\hat{\pi} - \kappa_s + \lambda b_{g_H} + \frac{\beta}{1-\beta}(\pi + \lambda b_{g_H})$, where $\hat{\pi}$ denotes the realization and π the expectation of the random profit $\tilde{\pi}$. The investor's end-of-period $t = 0$ valuation of an initially low-type green firm that does not scale the green technology in period $t = 0$, and, as the footnote below shows, never scales thereafter, is given by $\hat{\pi} + \lambda b_{g_L} + \frac{\beta}{1-\beta}(\pi + \lambda b_{g_L})$. Scaling and adoption decisions are made before profits are realized, so the manager maximizes the expected end-of-period valuation. An initially low-type green firm never delays scaling,[20] and thus scales the green technology in period $t = 0$ if and only if $\frac{\pi+\lambda b_{g_H}}{1-\beta} - \kappa_s \geq \frac{\pi+\lambda b_{g_L}}{1-\beta} \iff \frac{\lambda\Delta_s}{1-\beta} \geq \kappa_s \iff V_s \geq 0$.

Consider next the adoption decision of a dirty firm. Anticipating the scaling decision above, a dirty firm that adopts the green technology in period $t = 0$ has expected end-of-period $t = 0$ valuation $\frac{\pi}{1-\beta} - \kappa_a + \max\left\{\frac{\lambda b_{g_L}}{1-\beta}, \frac{\lambda b_{g_H}}{1-\beta} - \kappa_s\right\}$, which can be rewritten as $\frac{\pi+\lambda b_{g_L}}{1-\beta} - \kappa_a + \max\left\{\frac{\lambda\Delta_s}{1-\beta} - \kappa_s,\ 0\right\}$. A dirty firm that never adopts the green technology has expected end-of-period $t = 0$ valuation $\frac{\pi+\lambda b_d}{1-\beta}$. Adopting in a later period $T \geq 1$ and scaling optimally thereafter yields $\frac{\pi+\lambda b_d}{1-\beta} +$

[20] Scaling is a one-time cost κ_s that permanently raises the firm's per-period valuation by $\lambda\Delta_s$, so scaling in period T is worth $\beta^T\left(\frac{\lambda\Delta_s}{1-\beta} - \kappa_s\right)$, the perpetuity of the flow gain net of the cost, discounted back to period $t = 0$. Deferring one period saves $(1-\beta)\kappa_s$ in discounted cost but forgoes a period of flow gain $\lambda\Delta_s$, so the firm never delays when $V_s \geq 0$ and never scales otherwise.

$\beta^T (V_a + \max\{V_s, 0\})$, which is dominated by adopting in period $t = 0$ if $V_a + \max\{V_s, 0\} \geq 0$ and by never adopting otherwise. A dirty firm therefore adopts the green technology in period $t = 0$ if and only if $\frac{\pi+\lambda b_{g_L}}{1-\beta} - \kappa_a + \max\left\{\frac{\lambda\Delta_s}{1-\beta} - \kappa_s,\ 0\right\} \geq \frac{\pi+\lambda b_d}{1-\beta}$, which can be rewritten as inequality (1). ■

Proof of Corollary 1. Each transition has strictly positive social surplus (since $\frac{\Delta_a}{1-\beta} > \kappa_a$ and $\frac{\Delta_s}{1-\beta} > \kappa_s$), so any delay is socially costly. As such, strict green disclosure requirements implement the first best if and only if every low-type green firm scales and every dirty firm adopts and scales in period $t = 0$. By Lemma 1, this holds if and only if $V_s \geq 0$ and $V_a + \max\{V_s, 0\} \geq 0$. Given $V_s \geq 0$, the second condition reduces to $V_a + V_s \geq 0$. Substituting the definitions of V_a and V_s, we have $V_s \geq 0$ if and only if $\lambda \geq (1-\beta)\frac{\kappa_s}{\Delta_s}$, and $V_a + V_s \geq 0$ if and only if $\lambda \geq (1-\beta)\frac{\kappa_a+\kappa_s}{\Delta_a+\Delta_s}$. Both conditions therefore hold if and only if $\lambda \geq \overline{\lambda}$, with $\overline{\lambda}$ as defined in (2). Finally, $\overline{\lambda} > 0$ because $\kappa_a > 0$ and $\kappa_s > 0$, and $\overline{\lambda} < 1$ because $\frac{\Delta_s}{1-\beta} > \kappa_s$ and $\frac{\Delta_a}{1-\beta} > \kappa_a$ imply $(1-\beta)\frac{\kappa_s}{\Delta_s} < 1$ and $(1-\beta)\frac{\kappa_a+\kappa_s}{\Delta_a+\Delta_s} < 1$. ■

A.2 Static Lax Green Disclosure Requirements

As in the main text, we maintain Assumption 1 from this subsection onward and refer to the three roadblock configurations of Section 2. Throughout this subsection, we characterize reform in period $t = 0$, taking as given that no firm reforms in any later period. The composition of each disclosure category is then constant after period $t = 0$, and a firm that does not reform in period $t = 0$ keeps its period-$t = 0$ valuation. The results in this subsection therefore characterize equilibria of the game in which firms can reform only in period $t = 0$. Lemma B.2 in Appendix B then establishes that these equilibria are also equilibria of the game in which firms can reform in every period, and that no equilibrium of that game features reform in a later period under pooling at the top, and no welfare-maximizing equilibrium does under pooling at the bottom. The restriction is therefore without loss of generality under pooling at the top and for the welfare-maximizing equilibria we characterize under pooling at the bottom. The proof of Lemma 4 does not rely on this restriction, since it shows that pooling at the extremes is weakly dominated by strict green disclosure for any timing of reform.

Proof of Lemma 2. Under pooling at the top, low-type and high-type green firms are in the pooled disclosure category, and dirty firms are separately identified. Fix transition shares $(\phi_a, \phi_{a,s}, \phi_s)$. By Lemma B.1, no low-type green firm scales and no dirty firm adopts and scales jointly.

Since no firm has an incentive to scale, a dirty firm that adopts enters the pooled disclosure category as a low-type green firm and remains there. Using equation (3), the expected end-of-period $t = 0$ valuation of a firm in the pooled disclosure category is $\frac{\pi+\theta_{g_L}\lambda b_{g_L}+\theta_{g_H}\lambda b_{g_H}}{1-\beta} - \kappa$, where $\kappa \in \{0, \kappa_a\}$ and $\theta_{g_L} = 1 - \theta_{g_H}$. A dirty firm that does not adopt is separately identified with expected end-of-period $t = 0$ valuation $\frac{\pi+\lambda b_d}{1-\beta}$. A dirty firm therefore has an incentive to adopt if

and only if $\frac{\pi+\theta_{g_L}\lambda b_{g_L}+\theta_{g_H}\lambda b_{g_H}}{1-\beta} - \kappa_a \geq \frac{\pi+\lambda b_d}{1-\beta}$, which, using $\theta_{g_L}+\theta_{g_H}=1$, $b_{g_L}-b_d=\Delta_a$, and $b_{g_H}-b_{g_L}=\Delta_s$, can be rewritten as inequality (4). ■

Proof of Lemma 3. Under pooling at the bottom, dirty and low-type green firms are in the pooled disclosure category, and high-type green firms are separately identified. Fix transition shares $(\phi_a, \phi_{a,s}, \phi_s)$. By Lemma B.1, no dirty firm adopts without scaling, so no firm in the pooled disclosure category at the end of period $t=0$ incurs a reform cost in period $t=0$. Using equation (3), the expected end-of-period $t=0$ valuation of a firm in the pooled disclosure category is $\frac{\pi+\theta_d\lambda b_d+\theta_{g_L}\lambda b_{g_L}}{1-\beta}$, where $\theta_{g_L}=1-\theta_d$. If no firm remains in the pooled disclosure category, that is, if $\phi_{a,s}=\phi_s=1$, we adopt the convention that $\theta_d=1$, evaluating the valuation of the empty pooled disclosure category under the off-equilibrium belief that a firm in it is a dirty firm. This belief is consistent with the D1 criterion refinement, as dirty firms have the strongest incentive to remain in the pooled disclosure category: exiting requires paying both the adoption and scaling costs, whereas low-type green firms pay only the scaling cost. A low-type green firm that scales exits the pooled disclosure category and is separately identified as a high-type green firm with expected end-of-period $t=0$ valuation $\frac{\pi+\lambda b_{g_H}}{1-\beta} - \kappa_s$. A low-type green firm therefore has an incentive to scale if and only if $\frac{\pi+\lambda b_{g_H}}{1-\beta} - \kappa_s \geq \frac{\pi+\theta_d\lambda b_d+\theta_{g_L}\lambda b_{g_L}}{1-\beta}$, which, using $\theta_d+\theta_{g_L}=1$, $b_{g_H}-b_{g_L}=\Delta_s$, and $b_{g_L}-b_d=\Delta_a$, can be rewritten as inequality (5).

Consider next a dirty firm that adopts and scales jointly. Such a firm exits the pooled disclosure category and is separately identified as a high-type green firm with expected end-of-period $t=0$ valuation $\frac{\pi+\lambda b_{g_H}}{1-\beta} - \kappa_a - \kappa_s$. A dirty firm therefore has an incentive to adopt and scale jointly if and only if $\frac{\pi+\lambda b_{g_H}}{1-\beta} - \kappa_a - \kappa_s \geq \frac{\pi+\theta_d\lambda b_d+\theta_{g_L}\lambda b_{g_L}}{1-\beta}$, which, using $\theta_d+\theta_{g_L}=1$, $b_{g_H}-b_{g_L}=\Delta_s$, and $b_{g_L}-b_d=\Delta_a$, can be rewritten as inequality (6). ■

Proof of Lemma 4. Under pooling at the extremes, dirty and high-type green firms are in the pooled disclosure category, and low-type green firms are separately identified. By Lemma B.1, no dirty firm adopts and scales jointly. By Lemma B.2, adoption can occur in any period only in Case 2, and scaling only in Case 1. Under strict green disclosure, by contrast, all dirty firms adopt in period $t=0$ in Case 2 and all low-type green firms scale in period $t=0$ in Case 1 (Lemma 1). Any transition that occurs under pooling at the extremes in any period therefore also occurs under strict green disclosure, where it occurs in period $t=0$.

It follows that any transition that occurs under pooling at the extremes, in any period, also occurs under strict green disclosure, where it occurs in period $t=0$. Conversely, a transition that strict green disclosure implements in period $t=0$ occurs under pooling at the extremes weakly later or not at all. In any equilibrium, the mass of dirty firms that adopt and the mass of low-type green firms that scale under pooling at the extremes are therefore weakly lower than under strict green disclosure, and any transition that does occur is weakly delayed. By the model primitives,

$\frac{\Delta_a}{1-\beta} > \kappa_a$ and $\frac{\Delta_s}{1-\beta} > \kappa_s$, each transition carries strictly positive social value, and delaying it from period $t = 0$ to a period $t \geq 1$ reduces its contribution to the expected discounted social surplus by the fraction $1 - \beta^t > 0$. Aggregating across firms, social welfare under pooling at the extremes is weakly lower than under strict green disclosure in any equilibrium, so pooling at the extremes is weakly dominated by strict green disclosure.[21] ■

Proof of Proposition 1. By Lemma 2, no low-type green firm scales and no dirty firm adopts and scales jointly, so $\phi_s^* = \phi_{a,s}^* = 0$ under pooling at the top. The active margin is adoption by dirty firms. The post-transition shares in the pooled disclosure category are $\theta_{g_L}(\phi_a) = \frac{\phi_a \mu_d + \mu_{g_L}}{\phi_a \mu_d + \mu_{g_L} + \mu_{g_H}}$ and $\theta_{g_H}(\phi_a) = \frac{\mu_{g_H}}{\phi_a \mu_d + \mu_{g_L} + \mu_{g_H}}$. By Lemma 2, a dirty firm has an incentive to adopt if and only if

$$\frac{\lambda \Delta_a}{1-\beta} - \kappa_a + \theta_{g_H}(\phi_a) \frac{\lambda \Delta_s}{1-\beta} \;\geq\; 0, \tag{15}$$

and the left-hand side is strictly decreasing in ϕ_a.

Consider first an equilibrium with $\phi_a = 0$. Evaluating inequality (15) at $\phi_a = 0$, such an equilibrium requires

$$\kappa_a \;\geq\; \overline{\kappa}_a \;:=\; \frac{\lambda \Delta_a}{1-\beta} + \frac{\mu_{g_H}}{\mu_{g_L} + \mu_{g_H}} \frac{\lambda \Delta_s}{1-\beta}.$$

Consider next an equilibrium with $\phi_a = 1$. Evaluating inequality (15) at $\phi_a = 1$, such an equilibrium requires

$$\kappa_a \;\leq\; \underline{\kappa}_a \;:=\; \frac{\lambda \Delta_a}{1-\beta} + \frac{\mu_{g_H}}{\mu_d + \mu_{g_L} + \mu_{g_H}} \frac{\lambda \Delta_s}{1-\beta}.$$

Since $\mu_d > 0$, $\underline{\kappa}_a < \overline{\kappa}_a$, and since $\frac{\mu_{g_H}}{\mu_d + \mu_{g_L} + \mu_{g_H}} \frac{\lambda \Delta_s}{1-\beta} > 0$, $\underline{\kappa}_a > \frac{\lambda \Delta_a}{1-\beta}$. Because the left-hand side of inequality (15) is strictly decreasing in ϕ_a, these conditions are also sufficient, and the equilibrium is unique in each case.

If $\kappa_a \in (\underline{\kappa}_a, \overline{\kappa}_a)$, neither $\phi_a = 0$ nor $\phi_a = 1$ is an equilibrium. Since the left-hand side of inequality (15) is continuous and strictly decreasing in ϕ_a, there exists a unique $\phi_a \in (0,1)$ satisfying the indifference condition

$$\frac{\lambda \Delta_a}{1-\beta} + \frac{\mu_{g_H}}{\phi_a \mu_d + \mu_{g_L} + \mu_{g_H}} \frac{\lambda \Delta_s}{1-\beta} \;=\; \kappa_a,$$

which yields

$$\phi_a \;=\; \frac{1}{\mu_d} \left(\frac{\mu_{g_H} \lambda \Delta_s}{(1-\beta)\kappa_a - \lambda \Delta_a} - \mu_{g_L} - \mu_{g_H} \right) \;\in\; (0,1).$$

Since the denominator $(1-\beta)\kappa_a - \lambda \Delta_a$ is positive and strictly increasing in κ_a, ϕ_a is strictly

[21] An equilibrium under pooling at the extremes exists. Through the composition of the pooled disclosure category, adoption decisions are strategic substitutes and scaling decisions are strategic complements under pooling at the extremes, and existence follows as in the proofs of Propositions 1 and 2.

decreasing in κ_a. ■

Proof of Proposition 2. By Lemma 3, no dirty firm adopts without also scaling under pooling at the bottom, so $\phi_a^* = 0$ and the active margins are $\phi_{a,s}$ and ϕ_s. The equilibrium scaling and joint adopt-and-scale incentive conditions are

$$\frac{\lambda\Delta_s}{1-\beta} + \theta_d(\phi_{a,s},\phi_s)\frac{\lambda\Delta_a}{1-\beta} \;\geq\; \kappa_s, \tag{16}$$

$$\theta_d(\phi_{a,s},\phi_s)\frac{\lambda\Delta_a}{1-\beta} + \frac{\lambda\Delta_s}{1-\beta} \;\geq\; \kappa_a + \kappa_s. \tag{17}$$

Let $\underline{\kappa}_s := \max\{0, \overline{\kappa}_s - \kappa_a\}$. The threshold $\overline{\kappa}_s$ is the largest possible value of the left-hand sides of (16) and (17), attained at $\theta_d = 1$, and, since $\kappa_s > 0$, the condition $\kappa_s \leq \underline{\kappa}_s$ is equivalent to $\kappa_a + \kappa_s \leq \overline{\kappa}_s$. Since $\overline{\kappa}_s > 0$ and $\kappa_a > 0$, both arguments of the maximum in $\underline{\kappa}_s$ lie strictly below $\overline{\kappa}_s$, so $\underline{\kappa}_s < \overline{\kappa}_s$.

Case (i): $\kappa_s \leq \underline{\kappa}_s$. Consider the candidate equilibrium $\phi_{a,s} = \phi_s = 1$. In this equilibrium, the pooled disclosure category has zero mass, and we evaluate unilateral deviations under the off-equilibrium belief that a firm remaining in the pooled disclosure category is a dirty firm with probability one, $\theta_d = 1$. A low-type green firm that does not scale receives expected end-of-period $t = 0$ valuation $\frac{\pi+\lambda b_d}{1-\beta}$, and does not deviate if and only if $\frac{\pi+\lambda b_{g_H}}{1-\beta} - \kappa_s \geq \frac{\pi+\lambda b_d}{1-\beta} \iff \kappa_s \leq \overline{\kappa}_s$, which holds because $\kappa_s \leq \underline{\kappa}_s \leq \overline{\kappa}_s$. A dirty firm that deviates to not adopting and scaling receives expected end-of-period $t = 0$ valuation $\frac{\pi+\lambda b_d}{1-\beta}$, and does not deviate if and only if $\frac{\pi+\lambda b_{g_H}}{1-\beta} - \kappa_a - \kappa_s \geq \frac{\pi+\lambda b_d}{1-\beta} \iff \kappa_a + \kappa_s \leq \overline{\kappa}_s$, which holds by the case condition. Thus, $\phi_{a,s} = \phi_s = 1$ is an equilibrium. Because the expected discounted social surplus is strictly increasing in both adoption and scaling under the assumption that the green transition is socially optimal, every other equilibrium generates strictly lower welfare, so this is the welfare-maximizing equilibrium.

Case (ii): $\kappa_s \in (\underline{\kappa}_s, \overline{\kappa}_s]$. The case condition is equivalent to $\kappa_s \leq \overline{\kappa}_s < \kappa_a + \kappa_s$. Because $\kappa_a + \kappa_s > \overline{\kappa}_s$, inequality (17) fails for every $(\phi_{a,s},\phi_s)$, so $\phi_{a,s} = 0$ in any equilibrium. Consider the candidate equilibrium $\phi_{a,s} = 0, \phi_s = 1$. In this equilibrium, $\theta_d(0,1) = 1$, so the scaling incentive condition (16) reduces to $\kappa_s \leq \overline{\kappa}_s$, which holds. A dirty firm in the pooled disclosure category has expected end-of-period $t = 0$ valuation $\frac{\pi+\lambda b_d}{1-\beta}$ and does not deviate to adopting and scaling because inequality (17) fails. Thus, $\phi_{a,s} = 0, \phi_s = 1$ is an equilibrium. Because expected discounted social surplus is strictly increasing in ϕ_s when $\phi_{a,s} = 0$ and $\frac{\Delta_s}{1-\beta} > \kappa_s$, and every equilibrium has $\phi_{a,s} = 0$, every other equilibrium generates strictly lower welfare, so this is the welfare-maximizing equilibrium.

Case (iii): $\kappa_s > \overline{\kappa}_s$. Inequality (16) fails for every $(\phi_{a,s},\phi_s) \in [0,1]^2$, and hence so does inequality (17). The unique equilibrium has $\phi_{a,s} = \phi_s = 0$. ■

Proof of Corollary 2. When $\lambda < \overline{\lambda}$, the option value of scaling does not drive adoption under strict

green disclosure, so by Lemma 1, the fraction of dirty firms that adopt under strict green disclosure, ϕ_a^{strict}, satisfies $\phi_a^{\text{strict}} = 1$ in Case 2, and $\phi_a^{\text{strict}} = 0$ in Cases 1 and 3. The fraction of low-type green firms that scale under strict green disclosure, ϕ_s^{strict}, satisfies $\phi_s^{\text{strict}} = 1$ in Case 1, and $\phi_s^{\text{strict}} = 0$ in Cases 2 and 3.

Adoption pecking order: By Proposition 1, the fraction of dirty firms that adopt under pooling at the top, ϕ_a^{top}, is equal to one if and only if $\kappa_a \leq \underline{\kappa}_a = \frac{\lambda\Delta_a}{1-\beta} + \frac{\mu_{g_H}}{\mu_d+\mu_{g_L}+\mu_{g_H}} \frac{\lambda\Delta_s}{1-\beta} > \frac{\lambda\Delta_a}{1-\beta}$. In Case 2, $\kappa_a \leq \frac{\lambda\Delta_a}{1-\beta} < \underline{\kappa}_a$, so every dirty firm that adopts under strict green disclosure also adopts under pooling at the top. Hence $\phi_a^{\text{top}} \geq \phi_a^{\text{strict}}$. By Proposition 2, the fraction of dirty firms that adopt under pooling at the bottom equals $\phi_{a,s}^{\text{bottom}}$, which equals 1 in case (i) in which $\kappa_a + \kappa_s \leq \overline{\kappa}_s$, and equals 0 otherwise. If $\phi_{a,s}^{\text{bottom}} = 1$, then $\kappa_a + \kappa_s \leq \frac{\lambda(\Delta_a+\Delta_s)}{1-\beta}$, which implies $\kappa_a \leq \frac{\lambda\Delta_a}{1-\beta} + \left(\frac{\lambda\Delta_s}{1-\beta} - \kappa_s\right)$, so condition (1) is satisfied and $\phi_a^{\text{strict}} = 1$. Hence $\phi_a^{\text{strict}} \geq \phi_{a,s}^{\text{bottom}}$. Taken together, we have $\phi_a^{\text{top}} \geq \phi_a^{\text{strict}} \geq \phi_{a,s}^{\text{bottom}}$.

Scaling pecking order: By Lemma 2, the fraction of low-type green firms that scale under pooling at the top is zero, so $\phi_s^{\text{strict}} \geq \phi_s^{\text{top}} = 0$. By Proposition 2, the fraction of low-type green firms that scale under pooling at the bottom, ϕ_s^{bottom}, equals 1 whenever $\kappa_s \leq \overline{\kappa}_s$, and equals 0 otherwise. In Case 1, $\kappa_s \leq \frac{\lambda\Delta_s}{1-\beta} < \overline{\kappa}_s$, so every low-type green firm that scales under strict green disclosure also scales under pooling at the bottom, so $\phi_s^{\text{bottom}} \geq \phi_s^{\text{strict}}$. Taken together, we have $\phi_s^{\text{bottom}} \geq \phi_s^{\text{strict}} \geq \phi_s^{\text{top}} = 0$. Dirty firms that adopt and scale add to scaling under pooling at the bottom in case (i), whereas no dirty firm scales under strict green disclosure (Lemma 1 and Assumption 1) or under pooling at the top (Lemma 2), so the ordering holds for the total mass of firms that scale as well.

Strictness: For adoption, if $\kappa_a \in \left(\frac{\lambda\Delta_a}{1-\beta}, \overline{\kappa}_a\right)$, then $\phi_a^{\text{strict}} = 0$, while $\phi_a^{\text{top}} > 0$; and if $\kappa_a \leq \frac{\lambda\Delta_a}{1-\beta}$ and $\kappa_a + \kappa_s > \overline{\kappa}_s$, then $\phi_a^{\text{strict}} = 1$, while $\phi_{a,s}^{\text{bottom}} = 0$. For scaling, if $\kappa_s \in \left(\frac{\lambda\Delta_s}{1-\beta}, \overline{\kappa}_s\right]$, then $\phi_s^{\text{strict}} = 0$, while $\phi_s^{\text{bottom}} = 1$; and if $\kappa_s \leq \frac{\lambda\Delta_s}{1-\beta}$, then $\phi_s^{\text{strict}} = 1$, while $\phi_s^{\text{top}} = 0$. Hence each comparison in the two pecking orders is strict for some transition costs. ■

A.3 Dynamic Green Disclosure Requirements

Throughout this subsection, we characterize reform in period $t = 0$ and in period $t = \tau$, taking as given that no firm reforms in any other period. The results in this subsection therefore characterize equilibria of the game in which firms can reform only in these two periods. Lemma B.3 in Appendix B then establishes that these equilibria are also equilibria of the game in which firms can reform in every period, and that no equilibrium of that game features reform in any other period under pooling at the top, and no welfare-maximizing equilibrium does under pooling at the bottom. The restriction is therefore without loss of generality under pooling at the top and for the welfare-maximizing equilibria we characterize under dynamic pooling at the bottom.

Proof of Lemma 5. Under dynamic pooling at the top, low- and high-type green firms are pooled in periods $t \in \{0,\ldots,\tau-1\}$, and dirty firms are separately identified. In period $t=\tau$, the regulator switches to strict green disclosure, and firms in the pooled disclosure category are revealed. Fix transition shares $(\phi_a,\phi_{a,s},\phi_s)$. By Lemma 1, a revealed low-type green firm scales in period $t=\tau$ in Case 1, and does not scale in Cases 2 and 3, and a dirty firm, which is separately identified throughout, adopts in period $t=\tau$ in Case 2, and does not adopt in Cases 1 and 3. Since $V_s<0$ in Case 2, a dirty firm never adopts and scales jointly in period $t=\tau$, and its valuation gain from adoption in period $t=\tau$ is $\max\{V_a,0\}$.

Step 1: Pool valuation: A pool firm obtains the flow valuation $\pi+\theta_{g_L}\lambda b_{g_L}+\theta_{g_H}\lambda b_{g_H}$ in each period $t\in\{0,\ldots,\tau-1\}$. In period $t=\tau$, a revealed high-type green firm has continuation value $\frac{\pi+\lambda b_{g_H}}{1-\beta}$, while a revealed low-type green firm has continuation value $\frac{\pi+\lambda b_{g_L}}{1-\beta}+\max\{V_s,0\}$. Dirty firms are never in the pooled disclosure category, so adoption in period $t=\tau$ leaves pool members' continuation values unchanged. Discounting and summing yields equation (7).

Step 2: Scaling in period $t=0$: By Lemma B.1, no low-type green firm scales in period $t=0$, and no dirty firm adopts and scales jointly in period $t=0$.

Step 3: Adoption in period $t=0$: A dirty firm chooses between adopting in period $t=0$, entering the pooled disclosure category with expected end-of-period $t=0$ valuation (7) less κ_a, and not adopting, remaining separately identified with expected end-of-period $t=0$ valuation $\frac{\pi+\lambda b_d}{1-\beta}+\beta^\tau\max\{V_a,0\}$, where the second term is the option value of adopting in period $t=\tau$ under strict green disclosure. The firm has an incentive to adopt in period $t=0$ if and only if

$$\frac{\pi+\theta_{g_L}\lambda b_{g_L}+\theta_{g_H}\lambda b_{g_H}}{1-\beta}+\beta^\tau\theta_{g_L}\max\{V_s,0\}-\kappa_a \;\geq\; \frac{\pi+\lambda b_d}{1-\beta}+\beta^\tau\max\{V_a,0\},$$

which, using $\theta_{g_L}+\theta_{g_H}=1$, $b_{g_L}-b_d=\Delta_a$, and $b_{g_H}-b_{g_L}=\Delta_s$, rearranges to

$$V_a+\theta_{g_H}\frac{\lambda\Delta_s}{1-\beta}+\beta^\tau\,\theta_{g_L}\max\{V_s,0\} \;\geq\; \beta^\tau\max\{V_a,0\}. \tag{18}$$

This condition is equivalent to (8). The two conditions, (8) and (18), differ only in the term $\beta^\tau\max\{V_a,0\}$ on the right-hand side, which equals zero in Cases 1 and 3 and $\beta^\tau V_a$ in Case 2. In Cases 1 and 3, the two conditions therefore coincide. In Case 2, the left-hand side of (18) is at least $V_a+\theta_{g_H}\frac{\lambda\Delta_s}{1-\beta}$, which strictly exceeds V_a because $\theta_{g_H}>0$, as $\mu_{g_H}>0$. Since $V_a\geq\beta^\tau V_a\geq 0$, the left-hand side then exceeds the right-hand side of both conditions, so both hold. In either case, (8) holds if and only if (18) holds. ■

Proof of Lemma 6. Under dynamic pooling at the bottom, dirty and low-type green firms are pooled in periods $t\in\{0,\ldots,\tau-1\}$, and high-type green firms are separately identified. In period $t=\tau$, the regulator switches to strict green disclosure, and firms in the pooled disclosure

category are revealed. Fix transition shares $(\phi_a, \phi_{a,s}, \phi_s)$. By Lemma 1, a revealed low-type green firm scales in period $t = \tau$ in Case 1, and does not scale in Cases 2 and 3, and a revealed dirty firm adopts in period $t = \tau$ in Case 2, and does not adopt in Cases 1 and 3. Since $V_s < 0$ in Case 2, a revealed dirty firm never adopts and scales jointly, and its valuation gain from adoption in period $t = \tau$ is $\max\{V_a, 0\}$.

Step 1: Pool valuation: A pool firm obtains the flow valuation $\pi + \theta_d \lambda b_d + \theta_{g_L} \lambda b_{g_L}$ in each period $t \in \{0, \ldots, \tau - 1\}$. In period $t = \tau$, a revealed dirty firm has continuation value $\frac{\pi + \lambda b_d}{1-\beta} + \max\{V_a, 0\}$, and a revealed low-type green firm has continuation value $\frac{\pi + \lambda b_{g_L}}{1-\beta} + \max\{V_s, 0\}$. Discounting and summing yields equation (9). If no firm remains in the pooled disclosure category, that is, if $\phi_{a,s} = \phi_s = 1$, we adopt the convention that $\theta_d = 1$, evaluating the valuation of the empty pooled disclosure category under the off-equilibrium belief that a firm in it is a dirty firm, for the same reason as in the proof of Lemma 3.

Step 2: Scaling in period $t = 0$: A firm that scales in period $t = 0$ exits the pooled disclosure category as a high-type green firm with expected end-of-period $t = 0$ valuation $\frac{\pi + \lambda b_{g_H}}{1-\beta} - \kappa_s$, while a firm that does not scale remains in the pooled disclosure category with expected end-of-period $t = 0$ valuation (9). The firm has an incentive to scale if and only if

$$\frac{\pi + \lambda b_{g_H}}{1-\beta} - \kappa_s \;\geq\; \frac{\pi + \theta_d \lambda b_d + \theta_{g_L} \lambda b_{g_L}}{1-\beta} + \beta^\tau \left(\theta_d \max\{V_a, 0\} + \theta_{g_L} \max\{V_s, 0\}\right),$$

which, using $\theta_d + \theta_{g_L} = 1$, $b_{g_H} - b_{g_L} = \Delta_s$, and $b_{g_L} - b_d = \Delta_a$, rearranges to (10).

Step 3: Adoption in period $t = 0$: By Lemma B.1, no dirty firm adopts without scaling in period $t = 0$. A dirty firm that adopts and scales jointly exits the pooled disclosure category as a high-type green firm with expected end-of-period $t = 0$ valuation $\frac{\pi + \lambda b_{g_H}}{1-\beta} - \kappa_a - \kappa_s$. The firm has an incentive to adopt and scale jointly if and only if

$$\frac{\pi + \lambda b_{g_H}}{1-\beta} - \kappa_a - \kappa_s \;\geq\; \frac{\pi + \theta_d \lambda b_d + \theta_{g_L} \lambda b_{g_L}}{1-\beta} + \beta^\tau \left(\theta_d \max\{V_a, 0\} + \theta_{g_L} \max\{V_s, 0\}\right),$$

which rearranges to (11). ■

Proof of Proposition 3. By Lemma 5, no low-type green firm has an incentive to scale and no dirty firm has an incentive to adopt and scale jointly in period $t = 0$, for any transition shares, so $\phi^*_{a,s}(\tau) = \phi^*_s(\tau) = 0$ and the active margin in period $t = 0$ is adoption by dirty firms. Setting $\phi_{a,s} = \phi_s = 0$ in Lemma 5, the post-transition shares in the pooled disclosure category are $\theta_{g_H}(\phi_a) = \frac{\mu_{g_H}}{\phi_a \mu_d + \mu_{g_L} + \mu_{g_H}}$ and $\theta_{g_L}(\phi_a) = \frac{\phi_a \mu_d + \mu_{g_L}}{\phi_a \mu_d + \mu_{g_L} + \mu_{g_H}}$.

Step 1: Threshold structure for given τ: Define

$$f(\phi_a;\tau) \;:=\; \frac{\lambda\Delta_a}{1-\beta} + \theta_{g_H}(\phi_a)\frac{\lambda\Delta_s}{1-\beta} + \beta^\tau\,\theta_{g_L}(\phi_a)\max\{V_s,0\}.$$

By Lemma 5, a dirty firm has an incentive to adopt in period $t=0$ if and only if $f(\phi_a;\tau)\geq\kappa_a$. Since $\max\{V_s,0\}\leq\frac{\lambda\Delta_s}{1-\beta}$ and $\beta^\tau<1$,

$$\frac{\partial f}{\partial\phi_a} \;=\; \frac{\mu_d\mu_{g_H}}{(\phi_a\mu_d+\mu_{g_L}+\mu_{g_H})^2}\left[\beta^\tau\max\{V_s,0\}-\frac{\lambda\Delta_s}{1-\beta}\right] \;<\; 0,$$

so $f(\cdot;\tau)$ is continuous and strictly decreasing in ϕ_a. Setting $\overline{\kappa}_a^D(\tau):=f(0;\tau)$ and $\underline{\kappa}_a^D(\tau):=f(1;\tau)$, strict monotonicity gives $\underline{\kappa}_a^D(\tau)<\overline{\kappa}_a^D(\tau)$. The three cases follow as in the proof of Proposition 1: $\phi_a^*(\tau)=1$ if and only if $\kappa_a\leq\underline{\kappa}_a^D(\tau)$; $\phi_a^*(\tau)=0$ if and only if $\kappa_a\geq\overline{\kappa}_a^D(\tau)$; and for $\kappa_a\in(\underline{\kappa}_a^D(\tau),\overline{\kappa}_a^D(\tau))$ there exists a unique interior $\phi_a^*(\tau)\in(0,1)$ solving $f(\phi_a;\tau)=\kappa_a$, which is strictly decreasing in κ_a.

Step 2: Comparison with the static thresholds: Direct substitution using the definitions of $\overline{\kappa}_a$ and $\underline{\kappa}_a$ in the proof of Proposition 1 gives $\overline{\kappa}_a^D(\tau)=\overline{\kappa}_a+\beta^\tau\,\theta_{g_L}(0)\max\{V_s,0\}$ and $\underline{\kappa}_a^D(\tau)=\underline{\kappa}_a+\beta^\tau\,\theta_{g_L}(1)\max\{V_s,0\}$. In particular, $\underline{\kappa}_a^D(\tau)\geq\underline{\kappa}_a>\frac{\lambda\Delta_a}{1-\beta}$.

Step 3: Behavior in period $t=\tau$: In period $t=\tau$, the switch to strict green disclosure reveals the types of firms in the pooled disclosure category. By Lemma 1, a revealed low-type green firm (including a dirty firm that adopted in period $t=0$) scales in period $t=\tau$ in Case 1, and does not scale in Cases 2 and 3, and a dirty firm adopts in period $t=\tau$ in Case 2, and does not adopt in Cases 1 and 3. In Case 2, $\kappa_a\leq\frac{\lambda\Delta_a}{1-\beta}<\underline{\kappa}_a^D(\tau)$ by Step 2, so $\phi_a^*(\tau)=1$: all dirty firms adopt in period $t=0$ and none remain in period $t=\tau$. If instead $\phi_a^*(\tau)<1$, then $\kappa_a>\underline{\kappa}_a^D(\tau)>\frac{\lambda\Delta_a}{1-\beta}$, so Case 1 or Case 3 applies and no remaining dirty firm has an incentive to adopt in period $t=\tau$. Hence no dirty firm adopts in period $t=\tau$. ■

Proof of Corollary 3. **Step 1: Thresholds:** From Step 2 of the proof of Proposition 3, $\overline{\kappa}_a^D(\tau)=\overline{\kappa}_a+\beta^\tau\,\theta_{g_L}(0)\max\{V_s,0\}$ and $\underline{\kappa}_a^D(\tau)=\underline{\kappa}_a+\beta^\tau\,\theta_{g_L}(1)\max\{V_s,0\}$. Since $\theta_{g_L}(0)>0$ and $\theta_{g_L}(1)>0$, both shifts are non-negative, and strictly positive if and only if $V_s>0$. Hence both thresholds weakly exceed their static counterparts, with strict inequalities if and only if $V_s>0$. Since β^τ is strictly decreasing in τ, both thresholds are weakly decreasing in τ, strictly so if and only if $V_s>0$.

Step 2: Equilibrium adoption: Fix $\tau<\tau'$ and let f be defined as in Step 1 of the proof of Proposition 3. For any $\phi_a\in[0,1]$, $\theta_{g_L}(\phi_a)>0$ since $\mu_{g_L}>0$, so

$$f(\phi_a;\tau)-f(\phi_a;\tau') \;=\; \left(\beta^\tau-\beta^{\tau'}\right)\theta_{g_L}(\phi_a)\max\{V_s,0\} \;\geq\; 0,$$

with strict inequality if and only if $V_s>0$. If $V_s\leq 0$, then $f(\cdot;\tau)=f(\cdot;\tau')$ and $\phi_a^*(\tau)=\phi_a^*(\tau')$.

If $\kappa_a \leq \underline{\kappa}_a^D(\tau')$, then $\kappa_a \leq \underline{\kappa}_a^D(\tau)$ by Step 1, so $\phi_a^*(\tau) = \phi_a^*(\tau') = 1$; if $\kappa_a \geq \overline{\kappa}_a^D(\tau)$, then $\kappa_a \geq \overline{\kappa}_a^D(\tau')$, so $\phi_a^*(\tau) = \phi_a^*(\tau') = 0$. Now suppose $V_s > 0$ and $\kappa_a \in (\underline{\kappa}_a^D(\tau'), \overline{\kappa}_a^D(\tau))$. By Proposition 3, $\phi_a^*(\tau') < 1$ and $\phi_a^*(\tau) > 0$. If $\phi_a^*(\tau) = 1$ or $\phi_a^*(\tau') = 0$, then $\phi_a^*(\tau) > \phi_a^*(\tau')$ directly. Otherwise, both are interior and satisfy $f(\phi_a^*(\tau);\tau) = \kappa_a = f(\phi_a^*(\tau');\tau') < f(\phi_a^*(\tau');\tau)$, and since $f(\cdot;\tau)$ is strictly decreasing in ϕ_a, $\phi_a^*(\tau) > \phi_a^*(\tau')$. Taken together, $\phi_a^*(\tau) \geq \phi_a^*(\tau')$, with strict inequality if and only if $V_s > 0$ and $\kappa_a \in (\underline{\kappa}_a^D(\tau'), \overline{\kappa}_a^D(\tau))$.

The comparison with the static counterpart ϕ_a^* follows from the same argument: replacing $f(\cdot;\tau')$ with the static adoption incentive $\frac{\lambda\Delta_a}{1-\beta} + \theta_{g_H}(\cdot)\frac{\lambda\Delta_s}{1-\beta}$ from the proof of Proposition 1, the pointwise difference is $\beta^\tau \theta_{g_L}(\cdot)\max\{V_s, 0\}$, and the corresponding thresholds are $\underline{\kappa}_a$ and $\overline{\kappa}_a$, yielding $\phi_a^*(\tau) \geq \phi_a^*$, with strict inequality if and only if $V_s > 0$ and $\kappa_a \in (\underline{\kappa}_a, \overline{\kappa}_a^D(\tau))$. ■

Proof of Proposition 4. By Lemma 6, no dirty firm has an incentive to adopt without scaling in period $t = 0$, for any transition shares, so $\phi_a^*(\tau) = 0$ and the active margins in period $t = 0$ are $\phi_{a,s}$ and ϕ_s, governed by conditions (10) and (11). In period $t = \tau$, the switch to strict green disclosure reveals the types of firms in the pooled disclosure category. By Lemma 1, a revealed low-type green firm scales in period $t = \tau$ in Case 1, and does not scale in Cases 2 and 3, and a revealed dirty firm adopts in period $t = \tau$ in Case 2, and does not adopt in Cases 1 and 3. Since $V_s < 0$ in Case 2, a revealed dirty firm never adopts and scales jointly, and no firm that adopts in period $t = \tau$ subsequently scales.

Step 1: Threshold structure for given τ: Conditions (10) and (11) depend on the transition shares only through the share of dirty firms in the pooled disclosure category, θ_d, and both left-hand sides are strictly increasing in θ_d, with common slope $\frac{\lambda\Delta_a}{1-\beta} - \beta^\tau \max\{V_a, 0\} + \beta^\tau \max\{V_s, 0\} > 0$, since $\beta^\tau \max\{V_a, 0\} < \frac{\lambda\Delta_a}{1-\beta}$. Both conditions are therefore most permissive at $\theta_d = 1$. Define $\overline{\kappa}_s^D(\tau) := \overline{\kappa}_s - \beta^\tau \max\{V_a, 0\}$ and $\underline{\kappa}_s^D(\tau) := \max\{0, \overline{\kappa}_s^D(\tau) - \kappa_a\}$. At $\theta_d = 1$, the scaling condition (10) reduces to $\kappa_s \leq \overline{\kappa}_s^D(\tau)$, and the joint adoption-and-scaling condition (11) reduces to $\kappa_a + \kappa_s \leq \overline{\kappa}_s^D(\tau)$, equivalently $\kappa_s \leq \underline{\kappa}_s^D(\tau)$. Since $\beta^\tau \max\{V_a, 0\} < \frac{\lambda\Delta_a}{1-\beta}$, we have $\overline{\kappa}_s^D(\tau) > \frac{\lambda\Delta_s}{1-\beta} > 0$, and hence, since $\kappa_a > 0$, $\underline{\kappa}_s^D(\tau) < \overline{\kappa}_s^D(\tau)$.

Step 2: Welfare ranking: Relative to remaining in the pooled disclosure category, a dirty firm that adopts and scales in period $t = 0$ raises expected discounted social surplus by $\frac{\Delta_a + \Delta_s}{1-\beta} - \kappa_a - \kappa_s$ in Cases 1 and 3, in which it would otherwise never adopt, and by $(1-\beta^\tau)\left(\frac{\Delta_a}{1-\beta} - \kappa_a\right) + \frac{\Delta_s}{1-\beta} - \kappa_s$ in Case 2, in which it would otherwise adopt in period $t = \tau$. A low-type green firm that scales in period $t = 0$ raises it by $\frac{\Delta_s}{1-\beta} - \kappa_s$ in Cases 2 and 3, in which it would otherwise never scale, and by $(1-\beta^\tau)\left(\frac{\Delta_s}{1-\beta} - \kappa_s\right)$ in Case 1, in which it would otherwise scale in period $t = \tau$. All four gains are strictly positive by the model primitives and $\beta^\tau < 1$. Expected discounted social surplus is therefore strictly increasing in both period-$t = 0$ transition shares, and an equilibrium with weakly larger shares generates weakly higher welfare.

Step 3: Case analysis: Case (i): $\kappa_s \leq \underline{\kappa}_s^D(\tau)$. Consider the candidate equilibrium $\phi_{a,s} = \phi_s = 1$. The pooled disclosure category has zero mass, so $\theta_d = 1$ by the convention in Lemma 6, reflecting the off-equilibrium belief that a firm remaining in the pooled disclosure category is a dirty firm. By Step 1, the joint adoption-and-scaling condition holds because $\kappa_s \leq \underline{\kappa}_s^D(\tau)$, and the scaling condition holds because $\kappa_s \leq \underline{\kappa}_s^D(\tau) \leq \overline{\kappa}_s^D(\tau)$, so neither a dirty firm nor a low-type green firm deviates. Thus, $\phi_{a,s}^*(\tau) = \phi_s^*(\tau) = 1$ is an equilibrium, and because its transition shares are maximal, Step 2 implies that every other equilibrium generates strictly lower welfare, so this is the welfare-maximizing equilibrium.

Case (ii): $\kappa_s \in (\underline{\kappa}_s^D(\tau), \overline{\kappa}_s^D(\tau)]$. Because $\kappa_a + \kappa_s > \overline{\kappa}_s^D(\tau)$, the joint adoption-and-scaling condition fails for every $(\phi_{a,s}, \phi_s)$ by Step 1, so $\phi_{a,s}^*(\tau) = 0$ in any equilibrium. Consider the candidate equilibrium $\phi_{a,s} = 0, \phi_s = 1$. The pooled disclosure category then contains exactly the dirty firms, so $\theta_d = 1$, and the scaling condition holds because $\kappa_s \leq \overline{\kappa}_s^D(\tau)$. A dirty firm does not deviate to adopting and scaling jointly because the joint condition fails. Thus, $\phi_{a,s}^*(\tau) = 0, \phi_s^*(\tau) = 1$ is an equilibrium, and because $\phi_{a,s} = 0$ in any equilibrium and $\phi_s = 1$ is maximal, Step 2 implies that every other equilibrium generates strictly lower welfare, so this is the welfare-maximizing equilibrium.

Case (iii): $\kappa_s > \overline{\kappa}_s^D(\tau)$. By Step 1, the scaling condition fails for every $(\phi_{a,s}, \phi_s)$, and the joint adoption-and-scaling condition fails a fortiori since $\kappa_a > 0$. The unique equilibrium is $\phi_{a,s}^*(\tau) = \phi_s^*(\tau) = 0$.

Step 4: Behavior in period $t = \tau$: No low-type green firm scales in period $t = \tau$. In cases (i) and (ii), all low-type green firms scale in period $t = 0$. In case (iii), $\kappa_s > \overline{\kappa}_s^D(\tau) > \frac{\lambda \Delta_s}{1-\beta}$ by Step 1, so Case 2 or Case 3 applies, in which no revealed low-type green firm scales, and no firm that adopts in period $t = \tau$ subsequently scales. The remaining dirty firms (all dirty firms in cases (ii) and (iii), and none in case (i)) adopt in period $t = \tau$ in Case 2, and do not adopt in Cases 1 and 3. ■

Proof of Corollary 4. **Step 1: Thresholds:** From Step 1 of the proof of Proposition 4, $\overline{\kappa}_s^D(\tau) = \overline{\kappa}_s - \beta^\tau \max\{V_a, 0\}$ and $\underline{\kappa}_s^D(\tau) = \max\{0, \overline{\kappa}_s^D(\tau) - \kappa_a\}$. If $V_a \leq 0$, then $\max\{V_a, 0\} = 0$, so $\overline{\kappa}_s^D(\tau) = \overline{\kappa}_s$ and $\underline{\kappa}_s^D(\tau) = \underline{\kappa}_s$ for every τ, and all comparisons hold with equality. Suppose $V_a > 0$. Since β^τ is strictly decreasing in τ, $\overline{\kappa}_s^D(\tau)$ is strictly increasing in τ and strictly below $\overline{\kappa}_s$. Moreover, $V_a > 0$ is equivalent to $\kappa_a < \frac{\lambda \Delta_a}{1-\beta}$, so for any τ,

$$\overline{\kappa}_s^D(\tau) - \kappa_a \;=\; \overline{\kappa}_s - \beta^\tau V_a - \kappa_a \;>\; \overline{\kappa}_s - V_a - \kappa_a \;=\; \frac{\lambda \Delta_s}{1-\beta} \;>\; 0,$$

and the floor in $\underline{\kappa}_s^D(\tau) = \max\{0, \overline{\kappa}_s^D(\tau) - \kappa_a\}$ never binds: $\underline{\kappa}_s^D(\tau) = \overline{\kappa}_s^D(\tau) - \kappa_a$ and, likewise, $\underline{\kappa}_s = \overline{\kappa}_s - \kappa_a$. Hence $\underline{\kappa}_s^D(\tau)$ is strictly increasing in τ and strictly below $\underline{\kappa}_s$. Both thresholds are therefore weakly increasing in τ and weakly below their static counterparts, with strict inequalities if and only if $V_a > 0$.

Step 2: Equilibrium transition shares: By Proposition 4, the welfare-maximizing equilibrium shares are $\phi_s^*(\tau) = \mathbb{1}_{\{\kappa_s \leq \overline{\kappa}_s^D(\tau)\}}$ and $\phi_{a,s}^*(\tau) = \mathbb{1}_{\{\kappa_s \leq \underline{\kappa}_s^D(\tau)\}}$, and by Proposition 2, their static counterparts are $\phi_s^* = \mathbb{1}_{\{\kappa_s \leq \overline{\kappa}_s\}}$ and $\phi_{a,s}^* = \mathbb{1}_{\{\kappa_s \leq \underline{\kappa}_s\}}$. Fix $\tau < \tau'$. Since $\overline{\kappa}_s^D(\tau) \leq \overline{\kappa}_s^D(\tau')$ by Step 1, $\phi_s^*(\tau) \leq \phi_s^*(\tau')$, with strict inequality if and only if $\kappa_s \in (\overline{\kappa}_s^D(\tau), \overline{\kappa}_s^D(\tau')]$; by Step 1, this interval is nonempty if and only if $V_a > 0$, so strict inequality holds if and only if $V_a > 0$ and $\kappa_s \in (\overline{\kappa}_s^D(\tau), \overline{\kappa}_s^D(\tau')]$. The same argument with $\overline{\kappa}_s$ in place of $\overline{\kappa}_s^D(\tau')$ gives $\phi_s^*(\tau) \leq \phi_s^*$, with strict inequality if and only if $V_a > 0$ and $\kappa_s \in (\overline{\kappa}_s^D(\tau), \overline{\kappa}_s]$. Analogously, $\phi_{a,s}^*(\tau) \leq \phi_{a,s}^*(\tau')$ and $\phi_{a,s}^*(\tau) \leq \phi_{a,s}^*$, with strict inequalities if and only if $V_a > 0$ and, respectively, $\kappa_s \in (\underline{\kappa}_s^D(\tau), \underline{\kappa}_s^D(\tau')]$ and $\kappa_s \in (\underline{\kappa}_s^D(\tau), \underline{\kappa}_s]$. ■

Proof of Corollary 5. For each regime, let α and σ denote the long-run masses of firms that have adopted and scaled, respectively, with a superscript identifying the regime: S for strict, T for static pooling at the top, B for static pooling at the bottom, DT for dynamic pooling at the top, and DB for dynamic pooling at the bottom. We establish the four claims of the corollary in turn.

Step 1: Dynamic pooling at the top, adoption: Under static and dynamic pooling at the top, all adoption takes place in period $t = 0$. In Cases 2 and 3, $V_s < 0$ implies that the dynamic thresholds coincide with their static counterparts (Corollary 3), so $\phi_a^*(\tau) = \phi_a^*$ and $\alpha^{DT} = \alpha^T$. In Case 1, Corollary 3 establishes that $\phi_a^*(\tau)$ weakly exceeds ϕ_a^*, with strict inequality if and only if $V_s > 0$ and $\kappa_a \in (\underline{\kappa}_a, \overline{\kappa}_a^D(\tau))$. Combining the three cases, $\alpha^{DT} = \mu_d \phi_a^*(\tau) \geq \mu_d \phi_a^* = \alpha^T$, with strict inequality if and only if Case 1 applies with $V_s > 0$ and $\kappa_a \in (\underline{\kappa}_a, \overline{\kappa}_a^D(\tau))$.

Step 2: Dynamic pooling at the top, scaling: Under both strict and dynamic pooling at the top, every eventual low-type green firm—originally low-type green or formerly dirty firm that has adopted—scales if and only if $V_s \geq 0$, giving $\sigma^R = (\mu_{g_L} + \alpha^R)\mathbb{1}_{\{V_s \geq 0\}}$ for $R \in \{S, DT\}$. In Cases 2 and 3, $V_s < 0$ implies $\sigma^{DT} = \sigma^S = 0$. In Case 1, $V_a + V_s < 0$ rules out adoption under strict green disclosure (Lemma 1), so $\alpha^S = 0$ and $\sigma^{DT} - \sigma^S = \alpha^{DT} = \mu_d \phi_a^*(\tau)$, which is strictly positive if and only if $\kappa_a < \overline{\kappa}_a^D(\tau)$ (Proposition 3). Combining the three cases, $\sigma^{DT} \geq \sigma^S$, with strict inequality if and only if Case 1 applies and $\kappa_a < \overline{\kappa}_a^D(\tau)$.

Step 3: Dynamic pooling at the bottom, adoption: Under dynamic pooling at the bottom, dirty firms either jointly adopt and scale in period $t = 0$ or remain in the pool and—when types are revealed in period $t = \tau$—adopt under strict if and only if $V_a \geq 0$. In Case 2, $V_a \geq 0$ delivers eventual adoption by all dirty firms (the joint adopters in period $t = 0$ together with the remainder in period $t = \tau$), so $\alpha^{DB} = \mu_d$; the same condition makes $\alpha^S = \mu_d$. In Cases 1 and 3, $V_a + V_s < 0$ rules out joint adoption-and-scaling under any $\tau \geq 1$ because the dynamic joint threshold weakly shifts inward of $\overline{\kappa}_s$ (Proposition 4 and Corollary 4), and $V_a < 0$ rules out period-$t = \tau$ adoption. Both regimes therefore deliver $\alpha^{DB} = 0 = \alpha^S$. Combining the three cases, $\alpha^{DB} = \alpha^S$.

Step 4: Dynamic pooling at the bottom, scaling: In Cases 1 and 3, $V_a < 0$ shuts off the dampening channel (Corollary 4): the dynamic period-$t = 0$ thresholds coincide with their static

counterparts, period-$t = 0$ scaling decisions are identical, and there is no further scaling in period $t = \tau$ (Proposition 4). Hence $\sigma^{DB} = \sigma^{B}$ in Cases 1 and 3. In Case 2, $V_s < 0$ rules out scaling in period $t = \tau$ under both regimes, so $\sigma^{B} = \mu_d \mathbb{1}_{\{\kappa_s \le \underline{\kappa}_s\}} + \mu_{g_L} \mathbb{1}_{\{\kappa_s \le \overline{\kappa}_s\}}$ and $\sigma^{DB} = \mu_d \mathbb{1}_{\{\kappa_s \le \underline{\kappa}_s^D(\tau)\}} + \mu_{g_L} \mathbb{1}_{\{\kappa_s \le \overline{\kappa}_s^D(\tau)\}}$ (Propositions 2 and 4). Since $\underline{\kappa}_s^D(\tau) \le \underline{\kappa}_s$ and $\overline{\kappa}_s^D(\tau) \le \overline{\kappa}_s$ (Corollary 4), the difference $\sigma^{B} - \sigma^{DB}$ is nonnegative and strictly positive if and only if $\kappa_s \in (\underline{\kappa}_s^D(\tau), \underline{\kappa}_s] \cup (\overline{\kappa}_s^D(\tau), \overline{\kappa}_s]$, and these intervals are nonempty if and only if $V_a > 0$ (Corollary 4). Combining the three cases, $\sigma^{DB} \le \sigma^{B}$, with strict inequality if and only if Case 2 applies with $V_a > 0$ and $\kappa_s \in (\underline{\kappa}_s^D(\tau), \underline{\kappa}_s] \cup (\overline{\kappa}_s^D(\tau), \overline{\kappa}_s]$. ■

A.4 Optimal Green Disclosure Requirements

Throughout this subsection, welfare denotes the expected discounted aggregate social surplus net of the no-transition benchmark, defined as the expected discounted aggregate social surplus when no firm ever adopts or scales. Since aggregate surplus depends only on firms' fundamental values and the transition costs incurred, not on firm valuations, the no-transition benchmark is identical across green disclosure requirements. Each welfare expression below therefore equals the discounted social surplus generated by the green transitions that the corresponding disclosure requirement induces, and maximizing this welfare gain is equivalent to maximizing welfare. We define

$$G_a := \mu_d \left(\tfrac{\Delta_a}{1-\beta} - \kappa_a \right), \quad G_s := \mu_{g_L} \left(\tfrac{\Delta_s}{1-\beta} - \kappa_s \right), \quad G_{a,s} := \mu_d \left(\tfrac{\Delta_a + \Delta_s}{1-\beta} - \kappa_a - \kappa_s \right), \tag{19}$$

as the social surplus gains from all dirty firms adopting, all initially low-type green firms scaling, and all dirty firms adopting and scaling jointly. Since $\frac{\Delta_a}{1-\beta} > \kappa_a$ and $\frac{\Delta_s}{1-\beta} > \kappa_s$, all three are strictly positive, and $G_{a,s} = G_a + \mu_d(\frac{\Delta_s}{1-\beta} - \kappa_s) > G_a$. A transition in period t contributes its surplus discounted by β^t, and we set $\beta^\infty := 0$, so that all expressions below cover the static requirement at $\tau = \infty$, with $\phi_a^*(\infty) = \phi_a^*$, $\underline{\kappa}_s^D(\infty) = \underline{\kappa}_s$, and $\overline{\kappa}_s^D(\infty) = \overline{\kappa}_s$.

By Lemma 1, welfare under strict green disclosure is $W^S = G_s$ in Case 1, $W^S = G_a$ in Case 2, and $W^S = 0$ in Case 3. By Proposition 3, welfare under pooling at the top with switching period τ is

$$W^{DT}(\tau) \;=\; \phi_a^*(\tau)\, G_a \;+\; \beta^\tau (\mu_{g_L} + \phi_a^*(\tau)\mu_d) \left(\tfrac{\Delta_s}{1-\beta} - \kappa_s \right) \mathbb{1}_{\{V_s \ge 0\}}, \tag{20}$$

where the first term reflects adoption in period $t = 0$ and the second term scaling in period $t = \tau$ by initially low-type green firms and by adopters, which occurs in Case 1 only. No dirty firm adopts in period $t = \tau$ (Proposition 3), so no further term arises. By Proposition 4, welfare under pooling at the bottom with switching period τ in the welfare-maximizing equilibrium is

$$W^{DB}(\tau) \;=\; \mathbb{1}_{\{\kappa_s \le \underline{\kappa}_s^D(\tau)\}} (G_{a,s} + G_s) \;+\; \mathbb{1}_{\{\underline{\kappa}_s^D(\tau) < \kappa_s \le \overline{\kappa}_s^D(\tau)\}} G_s \;+\; \beta^\tau G_a \mathbb{1}_{\{V_a \ge 0\}} \mathbb{1}_{\{\kappa_s > \underline{\kappa}_s^D(\tau)\}}, \tag{21}$$

where the first two terms reflect reform in period $t = 0$ and the last term adoption in period $t = \tau$ by the dirty firms remaining in the pooled disclosure category, which occurs in Case 2 only. Throughout, we use $\overline{\kappa}_s^D(\tau) = \overline{\kappa}_s - \beta^\tau \max\{V_a, 0\}$ and $\underline{\kappa}_s^D(\tau) = \max\{0, \overline{\kappa}_s^D(\tau) - \kappa_a\}$ (Step 1 of the proof of Proposition 4), both weakly increasing in τ (Corollary 4), and note that $\kappa_s \leq \underline{\kappa}_s^D(\tau)$ is equivalent to $\kappa_a + \kappa_s \leq \overline{\kappa}_s^D(\tau)$ since $\kappa_s > 0$. We write $W^T := W^{DT}(\infty)$ and $W^B := W^{DB}(\infty)$ for welfare under the static requirements.

The following lemma characterizes the optimal switching period within each lax green disclosure requirement and reduces the regulator's problem to the comparison of strict green disclosure with at most three lax candidates.

Lemma A.1 (Optimal Switching Periods)**.** *Assume $\lambda < \overline{\lambda}$. Conditional on implementing pooling at the top, the regulator sets the switching period to $\tau = 1$. Conditional on implementing pooling at the bottom, the regulator sets the switching period either to $\tau = 1$ or to*

$$\tau = \underline{\tau}^D := \min\{\tau \geq 1 : (\phi_{a,s}^*(\tau), \phi_s^*(\tau)) = (\phi_{a,s}^*, \phi_s^*)\},$$

the earliest switching period that preserves the period-$t = 0$ reform of the static requirement, with $\underline{\tau}^D = \infty$ when no finite switching period does.

Proof of Lemma A.1. **Step 1: Pooling at the top:** In Cases 2 and 3, Corollary 3 implies $\phi_a^*(\tau) = \phi_a^*$ for every τ, so $W^{DT}(\tau) = \phi_a^* G_a$ is constant in τ and $\tau = 1$ is weakly optimal. In Case 1, for any $\tau < \tau'$,

$$W^{DT}(\tau) - W^{DT}(\tau') = \left(\phi_a^*(\tau) - \phi_a^*(\tau')\right) G_a + \left[\beta^\tau(\mu_{g_L} + \phi_a^*(\tau)\mu_d) - \beta^{\tau'}\left(\mu_{g_L} + \phi_a^*(\tau')\mu_d\right)\right]\left(\tfrac{\Delta_s}{1-\beta} - \kappa_s\right).$$

The first term is nonnegative because $\phi_a^*(\tau)$ is weakly decreasing in τ (Corollary 3). The bracket is strictly positive because $\beta^\tau(\mu_{g_L} + \phi_a^*(\tau)\mu_d) \geq \beta^\tau(\mu_{g_L} + \phi_a^*(\tau')\mu_d) > \beta^{\tau'}(\mu_{g_L} + \phi_a^*(\tau')\mu_d)$, where the strict inequality uses $\mu_{g_L} > 0$. Hence W^{DT} is strictly decreasing in τ, and $\tau = 1$ is the unique maximizer. Combining the three cases, $\tau = 1$ maximizes W^{DT}, strictly if and only if Case 1 applies.

Step 2: Pooling at the bottom in Cases 1 and 3: Corollary 4 implies $\underline{\kappa}_s^D(\tau) = \underline{\kappa}_s$ and $\overline{\kappa}_s^D(\tau) = \overline{\kappa}_s$ for every τ, and the last term in (21) vanishes. Hence the period-$t = 0$ reform coincides with its static counterpart for every switching period, $\underline{\tau}^D = 1$, and $W^{DB}(\tau)$ is constant in τ, so $\tau = 1 = \underline{\tau}^D$ is weakly optimal.

Step 3: Pooling at the bottom in Case 2: We distinguish three regions of the scaling cost, which are cases (i) to (iii) of Proposition 2.

First, suppose $\kappa_a + \kappa_s \leq \overline{\kappa}_s$, so the static reform is $(\phi_{a,s}^*, \phi_s^*) = (1, 1)$. A switching period preserves this reform if and only if $\kappa_a + \kappa_s \leq \overline{\kappa}_s^D(\tau)$, that is, if and only if $\tau \geq \underline{\tau}^D$, since $\overline{\kappa}_s^D(\tau)$ is

weakly increasing in τ. For all such τ, $W^{DB}(\tau) = G_{a,s} + G_s$: all firms complete their transitions in period $t = 0$ and welfare attains the first best. Since W^{DB} can never exceed the first best, every preserving switching period, in particular $\tau = \underline{\tau}^D$, maximizes W^{DB}.

Second, suppose $\kappa_s \leq \overline{\kappa}_s < \kappa_a + \kappa_s$, so the static reform is $(\phi^*_{a,s}, \phi^*_s) = (0,1)$. Joint adoption-and-scaling fails for every switching period since $\kappa_a + \kappa_s > \overline{\kappa}_s \geq \overline{\kappa}^D_s(\tau)$, so a switching period preserves the static reform if and only if $\kappa_s \leq \overline{\kappa}^D_s(\tau)$, that is, if and only if $\tau \geq \underline{\tau}^D$, since $\overline{\kappa}^D_s(\tau)$ is weakly increasing in τ. For every τ that preserves the static reform, $W^{DB}(\tau) = G_s + \beta^\tau G_a$ is strictly decreasing in τ, so welfare over preserving switching periods is maximized at $\underline{\tau}^D$. For every τ that does not preserve the static reform, $W^{DB}(\tau) = \beta^\tau G_a$ is strictly decreasing in τ, so welfare over non-preserving switching periods is maximized at $\tau = 1$.

Third, suppose $\kappa_s > \overline{\kappa}_s$, so the static reform is $(\phi^*_{a,s}, \phi^*_s) = (0,0)$. Since $\kappa_s > \overline{\kappa}_s \geq \overline{\kappa}^D_s(\tau)$, no firm reforms in period $t = 0$ under any switching period, so every switching period preserves the static reform and $\underline{\tau}^D = 1$. Then $W^{DB}(\tau) = \beta^\tau G_a$ is strictly decreasing in τ, with unique maximum at $\tau = 1 = \underline{\tau}^D$.

In all configurations, the maximum of W^{DB} is attained at $\underline{\tau}^D$ or at $\tau = 1$. ■

Proof of Proposition 5. **Case 0 ($V_s \geq 0$ and $V_a + V_s \geq 0$):** By Corollary 1, these conditions are equivalent to $\lambda \geq \overline{\lambda}$, and strict green disclosure implements the first best. Since no green disclosure requirement can exceed first-best welfare, the regulator implements strict green disclosure by our convention. The remaining cases exhaust the parameter region $\lambda < \overline{\lambda}$ of Assumption 1.

Static and dynamic pooling at the extremes are weakly dominated by strict green disclosure (Lemma 4 and Proposition C.1), so by our convention the regulator never implements them. It therefore suffices to compare strict green disclosure, pooling at the top, and pooling at the bottom, each with any switching period $\tau \in \{1, 2, \ldots\} \cup \{\infty\}$.

Case 1: Strict green disclosure yields $W^S = G_s$. Under pooling at the bottom, $V_a < 0$ implies $W^{DB}(\tau) = W^B$ for every τ (Step 2 of the proof of Lemma A.1). Under the static requirement, no dirty firm adopts and scales jointly since $V_a + V_s < 0$ makes condition (6) fail for every pool composition, and $V_s \geq 0$ implies $\kappa_s \leq \frac{\lambda \Delta_s}{1-\beta} < \overline{\kappa}_s$, so all low-type green firms scale (Proposition 2). Hence $W^B = G_s = W^S$, and pooling at the bottom is weakly dominated. Under pooling at the top, Lemma A.1 reduces the choice to $\tau = 1$, and

$$W^{DT}(1) - W^S \;=\; \phi^*_a(1)\, G_a \;+\; \beta\, \phi^*_a(1)\, \mu_d\Big(\tfrac{\Delta_s}{1-\beta} - \kappa_s\Big) \;-\; (1-\beta)\, G_s.$$

If $\kappa_a \geq \overline{\kappa}^D_a(1)$, then $\phi^*_a(1) = 0$ and $W^{DT}(1) - W^S = -(1-\beta)G_s < 0$, so strict green disclosure is optimal. If $\kappa_a < \overline{\kappa}^D_a(1)$, then $\phi^*_a(1) > 0$ and dynamic pooling at the top with $\tau = 1$ is optimal if and only if condition (12) holds.

Case 2: Strict green disclosure yields $W^S = G_a$. Under pooling at the top, $V_s < 0$ implies

$W^{DT}(\tau) = \phi_a^* G_a$ for every τ (Step 1 of the proof of Lemma A.1), and $V_a \geq 0$ implies $\kappa_a \leq \frac{\lambda \Delta_a}{1-\beta} < \underline{\kappa}_a$, so $\phi_a^* = 1$ (Proposition 1) and $W^{DT}(\tau) = G_a = W^S$. Pooling at the top is weakly dominated. Under pooling at the bottom, Lemma A.1 reduces the choice to $\underline{\tau}^D$ and $\tau = 1$, and we follow the three regions of Step 3 of its proof. If $\kappa_a + \kappa_s \leq \overline{\kappa}_s$, then $W^{DB}(\underline{\tau}^D) = G_{a,s} + G_s$, which is first-best welfare since all transitions occur in period $t = 0$, and $G_{a,s} + G_s > G_a = W^S$ since $G_{a,s} > G_a$ and $G_s > 0$, while, if $\tau = 1$ does not preserve the static reform, it yields at most $G_s + \beta G_a < G_{a,s} + G_s$. The regulator implements pooling at the bottom with switching period $\underline{\tau}^D$, the earliest of the welfare-maximizing switching periods, attaining the first best. If $\kappa_s \leq \overline{\kappa}_s < \kappa_a + \kappa_s$, then $W^{DB}(\underline{\tau}^D) = G_s + \beta^{\underline{\tau}^D} G_a$, while, if $\tau = 1$ does not preserve the static reform, it yields $\beta G_a < G_a = W^S$ and is never optimal. Hence pooling at the bottom is optimal if and only if $G_s + \beta^{\underline{\tau}^D} G_a > G_a$, which is condition (13), and strict green disclosure is optimal otherwise.

If $\kappa_s > \overline{\kappa}_s$, then $W^{DB}(\tau) = \beta^\tau G_a \leq \beta G_a < G_a = W^S$ for every τ, so strict green disclosure is optimal.

Case 3: Strict green disclosure yields $W^S = 0$. By Steps 1 and 2 of the proof of Lemma A.1, $W^{DT}(\tau) = W^T$ and $W^{DB}(\tau) = W^B$ for every τ, so each dynamic requirement coincides with its static counterpart. Under static pooling at the top, no firm scales, and a fraction ϕ_a^* of dirty firms adopt, so $W^T = \phi_a^* G_a$ (Proposition 1). Under static pooling at the bottom, no dirty firm adopts and scales jointly since $V_a + V_s < 0$, and low-type green firms scale if and only if $\kappa_s \leq \overline{\kappa}_s$, so $W^B = G_s \mathbb{1}_{\{\kappa_s \leq \overline{\kappa}_s\}}$ (Proposition 2). Both lax welfare levels are nonnegative, so strict green disclosure is weakly dominated. If $\kappa_a < \overline{\kappa}_a$ and condition (14) holds, then $W^T = \phi_a^* G_a \geq W^B$, and the regulator implements pooling at the top, breaking the tie toward pooling at the top when (14) holds with equality. Otherwise, if $\kappa_s \leq \overline{\kappa}_s$, then $W^B = G_s > \phi_a^* G_a = W^T$, and the regulator implements pooling at the bottom. If $\kappa_a \geq \overline{\kappa}_a$ and $\kappa_s > \overline{\kappa}_s$, all requirements yield zero welfare, and the regulator implements strict green disclosure by our convention. ■

B Appendix: Timing of Reform

Throughout the paper, we characterize reform in period $t = 0$ and, under dynamic green disclosure requirements, in period $t = \tau$. This appendix shows that this restriction is without loss of generality under pooling at the top and for the welfare-maximizing equilibria we characterize under pooling at the bottom. Under pooling at the extremes, we do not characterize equilibrium. Instead, we show that reform incentives in any period are weakly weaker than under strict green disclosure, which is the basis for the dominance results in Lemma 4 and Proposition C.1.

We first establish a preliminary result that applies to all lax green disclosure requirements, and then analyze static and dynamic requirements in turn. Throughout, we maintain Assumption 1 and refer to the three roadblock configurations of Section 2. Under strict green disclosure, adoption arises only in Case 2 and scaling only in Case 1 (Lemma 1). Since $V_a \geq 0$ arises only in Case 2, where $V_s < 0$, adoption conditions of the form $V_a + \max\{V_s, 0\} \geq 0$ reduce to $V_a \geq 0$. Recall also that the investor has perfect recall, in the sense that a firm's sequence of past disclosure categories is part of the investor's information set in every period. Finally, as in Section 1, whenever managers are indifferent between reforming and waiting in a period, we select the equilibrium in which the largest mass of indifferent firms reforms. This convention is consistent with the weak inequalities in our incentive conditions and is without loss of generality for the welfare-maximizing equilibria we characterize, since delay only discounts the social surplus from reform.

Formally, the regulator chooses the green disclosure requirements, including the switching period, at the beginning of period $t = 0$ and commits to them. Given the requirements, in every period each firm's manager observes the firm's current type and its disclosure history and chooses to adopt, to adopt and scale jointly, to scale, or to wait, so as to maximize the firm's expected end-of-period valuation, taking as given the valuations assigned to disclosure histories. An equilibrium under given green disclosure requirements consists of a strategy profile, a belief system assigning to every disclosure history a distribution over firm types, and a valuation system assigning to every disclosure history an end-of-period valuation, such that (i) each valuation equals the investor's expectation of discounted per-period utilities from the firm with that history, net of reform costs incurred in later periods, under the strategy profile and the belief system, with a firm's own current-period reform cost deducted from its realized profit, (ii) in every period and after every history, each manager's action maximizes the firm's expected end-of-period valuation given the valuation system, and (iii) beliefs satisfy Bayes' rule on histories reached by a positive measure of firms. Off the equilibrium path, the disclosure history does not pin down a firm's type in two situations, and we specify beliefs as follows. Under pooling at the top, a dirty firm that enters the pooled disclosure category after period $t = 0$ is believed to have adopted without scaling, since scaling upon entry is hidden and strictly dominated (Lemma B.1). Under pooling at the bottom, a firm that remains in an otherwise empty pooled disclosure category is believed to be a dirty firm, consistent with the

D1 criterion (see the proof of Lemma 3). The regulator chooses the green disclosure requirements that maximize the expected discounted aggregate social surplus, selecting the welfare-maximizing equilibrium whenever the requirements admit several and implementing strict green disclosure whenever indifferent.

B.1 Preliminary Result

We first show that reform that does not change the investor's information about a firm never occurs.

Lemma B.1 (No Hidden Reform)**.** *Fix any static or dynamic lax green disclosure requirement and any valuations the investor assigns to disclosure categories and histories. No firm pays a reform cost in a period in which the reform does not change the investor's information about the firm. In particular, the following hold in any period before the switch to strict green disclosure. (i) Under pooling at the top, no firm in the pooled disclosure category scales, and no dirty firm scales in the period in which it adopts. (ii) Under pooling at the bottom, no dirty firm adopts without scaling. (iii) Under pooling at the extremes, no dirty firm adopts and scales jointly.*

Proof of Lemma B.1. A firm's expected end-of-period valuation is the sum of its expected end-of-period net profit and the investor's assessment of its current social benefit and the continuation value. The assessment depends only on the investor's information about the firm, namely its current disclosure category and its disclosure history. Consider a reform that changes neither. Although the reform raises the firm's actual social benefit, the investor cannot observe this, so the assessment is identical with and without the reform. The expected end-of-period profit gross of the reform cost is identical as well, since the per-period profit is π independent of type. The reform therefore lowers the firm's expected end-of-period valuation by exactly the reform cost, whatever valuations the investor assigns to disclosure categories and histories, and the manager never undertakes it. Intuitively, the firm pays for a reform the investor cannot see. The argument applies unchanged under dynamic green disclosure requirements, where the hidden reform is revealed in period $t = \tau$. The reform remains unobservable before period $t = \tau$ and therefore cannot affect the expected end-of-period valuation of the social benefit or the continuation value in the reform period. Note that the higher valuations from period $t = \tau$ onward do not enter the manager's objective because they maximize the expected end-of-period valuation which depends on the continuation value based on the investor's, not the manager's, information set.

It remains to verify that the listed reforms do not change the investor's information. Under pooling at the top, a low-type green firm that scales remains in the pooled disclosure category, and a dirty firm that adopts enters the pooled disclosure category whether or not it also scales in the same period. Under pooling at the bottom, a dirty firm that adopts without scaling remains in the pooled disclosure category. Under pooling at the extremes, a dirty firm that adopts and scales

jointly remains in the pooled disclosure category. ■

B.2 Static Lax Green Disclosure Requirements

Parts (i) and (ii) of the following result imply that the period-$t = 0$ reform decisions characterized in Section 3.1 are without loss of generality under static pooling at the top and at the bottom. Under static pooling at the top no reform occurs after period $t = 0$, and under static pooling at the bottom delaying reform beyond period $t = 0$ only reduces welfare and is not the welfare-maximizing equilibrium. Part (iii) concerns static pooling at the extremes, for which we do not characterize equilibrium. Instead, we show that reform incentives in any period are weakly weaker than under strict green disclosure, which is the basis for the dominance result in Lemma 4.

Lemma B.2 (Timing of Reform under Static Lax Green Disclosure)**.** *Fix any static lax green disclosure requirement. (i) Under static pooling at the top, no firm adopts or scales in any period $t \geq 1$. (ii) Under static pooling at the bottom, the welfare-maximizing equilibrium features reform only in period $t = 0$, and any equilibrium in which a positive measure of firms reforms in a period $t \geq 1$ reforms weakly fewer firms, weakly later, and generates weakly lower welfare. (iii) Under static pooling at the extremes, adoption occurs in any period only in Case 2 and scaling only in Case 1, as under strict green disclosure.*

Proof of Lemma B.2. **Step 1: Pooling at the top:** We show part (i): no firm adopts or scales in any period $t \geq 1$ in any equilibrium. By Lemma B.1, no firm in the pooled disclosure category ever scales, and the only remaining reform is adoption by dirty firms. We first show that a dirty firm that adopts in a period $t \geq 1$ is valued at its inferred type rather than at the pooled valuation, so that delay forfeits the mis-valuation subsidy entirely. A dirty firm that does not adopt in period $t = 0$ is disclosed as a dirty firm at the end of period $t = 0$ and remains separately identified for as long as it does not adopt. If it adopts in a period $t \geq 1$, it enters the pooled disclosure category, but because the investor has perfect recall, its disclosure history reveals that it was a dirty firm through period $t - 1$. By the belief specification above, the investor treats it as a low-type green firm and values it at $\frac{\pi+\lambda b_{g_L}}{1-\beta}$, gross of the adoption cost incurred in period t, separately from the pool formed at the end of period $t = 0$. The pool formed at the end of period $t = 0$ is therefore unaffected by later adoption. Indeed, its members never leave and never scale, and later entrants are valued separately, so its composition is constant and the pooled valuation (3) applies to it in every period.

The valuation gain from adopting in period t is then V_a, since the mis-valuation subsidy is forgone entirely. In Cases 1 and 3, delayed adoption strictly lowers the firm's expected end-of-period valuation and never occurs. In Case 2, delayed adoption cannot occur in equilibrium either. In any candidate equilibrium in which a dirty firm adopts in period $t \geq 1$, its expected end-of-period $t = 0$ valuation reflects the dirty flow value until period t and the value of a separately identified

low-type green firm net of the adoption cost thereafter,

$$\frac{1-\beta^t}{1-\beta}(\pi+\lambda b_d)+\beta^t\left(\frac{\pi+\lambda b_{g_L}}{1-\beta}-\kappa_a\right)=\frac{\pi+\lambda b_d}{1-\beta}+\beta^t V_a.$$

Adopting in period $t=0$ instead yields the pooled valuation (3) net of κ_a,

$$\frac{\pi+\theta_{g_L}\lambda b_{g_L}+\theta_{g_H}\lambda b_{g_H}}{1-\beta}-\kappa_a=\frac{\pi+\lambda b_d}{1-\beta}+V_a+\theta_{g_H}\frac{\lambda\Delta_s}{1-\beta},$$

where the equality uses $\theta_{g_L}+\theta_{g_H}=1$, $b_{g_L}=b_d+\Delta_a$, and $b_{g_H}=b_{g_L}+\Delta_s$. The difference between the two valuations is

$$(1-\beta^t)V_a+\theta_{g_H}\frac{\lambda\Delta_s}{1-\beta}>0,$$

where the inequality uses $V_a\geq 0$ and $\theta_{g_H}>0$, which holds because $\mu_{g_H}>0$. The deviation to period-$t=0$ adoption is strictly profitable, so no equilibrium features delayed adoption.

Finally, we verify that the period-$t=0$ equilibria of Proposition 1, whose proof verifies the period-$t=0$ incentive conditions directly and does not rely on this lemma, remain equilibria of the unrestricted game, in which firms can reform in every period. The only additional deviation is adoption by a dirty firm in a period $t\geq 1$, which lowers its valuation if $V_a<0$ and is strictly dominated by adoption in period $t=0$ if $V_a\geq 0$ by the comparison above. This establishes part (i).

Step 2: Valuation bounds: We next derive bounds on equilibrium expected end-of-period valuations under pooling at the bottom and at the extremes, which discipline the exit and entry incentives analyzed in Steps 3 and 4. Fix any equilibrium. First, any firm's expected end-of-period valuation is the investor's expectation of discounted per-period utilities net of reform costs, with per-period utilities between $\pi+\lambda b_d$ and $\pi+\lambda b_{g_H}$ and lifetime reform costs between 0 and $\kappa_a+\kappa_s$. All expected end-of-period valuations are therefore uniformly bounded and, in particular, at most $\frac{\pi+\lambda b_{g_H}}{1-\beta}$. Next, we show that the pooled valuation is at least $\frac{\pi+\lambda b_d}{1-\beta}$, the full-information valuation of a dirty firm, in every period. Two observations discipline the composition of the pooled disclosure category. First, no member reforms within the pooled disclosure category (Lemma B.1), so members' types are constant while they remain in the pool. Second, a firm that enters the pooled disclosure category in a period $t\geq 1$ (a low-type green firm that scales under pooling at the extremes) is recognized from its disclosure history and, as in Step 1, valued separately at its inferred type, so the pool formed at the end of period $t=0$ (which, under pooling at the extremes, includes low-type green firms that scale in period $t=0$) changes composition only through exits.

Let V_t denote the pooled valuation in period t, the valuation of the disclosure history of a firm in the pool formed at the end of period $t=0$, gross of any reform cost the firm incurs in period t. Index the types of pool members by i, where $i\in\{d,g_L\}$ under pooling at the bottom and

$i \in \{d, g_H\}$ under pooling at the extremes, and let θ_i^t denote the share of type-i members in the pooled disclosure category at the end of period t, with $\sum_i \theta_i^t = 1$. Then

$$V_t = \sum_i \theta_i^t \left[(\pi + \lambda b_i) + \beta v_i^{t+1} \right],$$

where v_i^{t+1} denotes the expected end-of-period $t+1$ valuation of a type-i member. The expectation is taken over the member's equilibrium reform decision in period $t+1$. The member's valuation equals V_{t+1} if it remains in the pooled disclosure category, and the exit value net of the reform cost if it exits. Importantly, V_t reflects all reform costs that members incur in later periods, since these reduce the valuations v_i^{t+1}. V_t is gross of any reform cost incurred in period t itself. Such a cost is deducted from the reforming firm's own realized profit and enters its end-of-period valuation at the firm level, as in (3), whether the firm enters or exits the pooled disclosure category. Reform within the pooled disclosure category never occurs (Lemma B.1). The first term satisfies $\sum_i \theta_i^t (\pi + \lambda b_i) \geq \pi + \lambda b_d$, since $b_i \geq b_d$ for every member type i. The second term satisfies $v_i^{t+1} \geq V_{t+1}$ for every member type i: a member that remains in the pooled disclosure category in period $t+1$ is valued at V_{t+1}, and a member that exits is valued at the exit value net of the reform cost, which the manager chooses only if it weakly exceeds the value V_{t+1} of remaining. Hence

$$V_t \geq (\pi + \lambda b_d) + \beta V_{t+1} \quad \text{for every } t.$$

Iterating this inequality forward for T periods yields $V_t \geq \frac{1-\beta^T}{1-\beta}(\pi + \lambda b_d) + \beta^T V_{t+T}$. Since valuations are uniformly bounded, $\beta^T V_{t+T} \to 0$ as $T \to \infty$, and letting $T \to \infty$ yields $V_t \geq \frac{\pi + \lambda b_d}{1-\beta}$ in every period. Intuitively, the pooled disclosure category delivers at least the per-period utility of a dirty firm in every period, and a firm exits it only at a value weakly above the pooled valuation, so its valuation can never fall below the full-information valuation of a dirty firm.[22] Under pooling at the extremes, the same recursive argument bounds the valuation of a separately identified low-type green firm, which is outside the pooled disclosure category but faces the analogous choice between remaining in its own disclosure category and exiting it by scaling into the pooled disclosure category. The investor's expected per-period utility from it is $\pi + \lambda b_{g_L}$, and it scales only if doing so weakly raises its expected end-of-period valuation, so its expected end-of-period valuation is at least $\frac{\pi + \lambda b_{g_L}}{1-\beta}$ in every period.

Step 3: Pooling at the bottom: We establish part (ii) in three parts: we derive necessary cost conditions for reform at any date, show that no equilibrium with delayed reform generates higher welfare than the period-$t = 0$ welfare-maximizing equilibrium, and verify that the period-$t = 0$

[22] If the pooled disclosure category is empty, which can occur only under pooling at the bottom, its valuation is defined by the off-equilibrium belief that a firm in it is a dirty firm, and the same recursion applies with θ_d equal to one.

equilibria of Proposition 2 remain equilibria when firms can reform in every period. By Lemma B.1, every remaining reform moves a firm out of the pooled disclosure category. In particular, low-type green firms can scale, and dirty firms can adopt and scale jointly. A low-type green firm that scales in period t exits the pooled disclosure category and is valued at $\frac{\pi+\lambda b_{g_H}}{1-\beta} - \kappa_s$. By Step 2, a necessary condition for scaling in period t to raise the firm's expected end-of-period valuation is $\frac{\pi+\lambda b_{g_H}}{1-\beta} - \kappa_s \geq \frac{\pi+\lambda b_d}{1-\beta}$, that is, $\kappa_s \leq \overline{\kappa}_s$. By the same argument, a necessary condition for joint adoption-and-scaling in period t is $\kappa_a + \kappa_s \leq \overline{\kappa}_s$.

These are exactly the conditions of cases (i) and (ii) of Proposition 2, whose proof verifies the period-$t = 0$ incentive conditions directly and does not rely on this lemma. In particular, since the value of remaining in the pooled disclosure category can never fall below $\frac{\pi+\lambda b_d}{1-\beta}$, reform incentives at any date are never stronger than those in the period-$t = 0$ welfare-maximizing equilibrium of cases (i) and (ii), in which the value of remaining is evaluated at this bound.

We now compare welfare across equilibria, using that a low-type green firm that scales in period t contributes $\beta^t \left(\frac{\Delta_s}{1-\beta} - \kappa_s \right)$ to social surplus relative to never scaling, and a dirty firm that adopts and scales in period t contributes $\beta^t \left(\frac{\Delta_a+\Delta_s}{1-\beta} - \kappa_a - \kappa_s \right)$. Both contributions are strictly positive by the model primitives and strictly decreasing in the reform date, so each is maximized in period $t = 0$. Consider first case (i), in which $\kappa_s \leq \underline{\kappa}_s$, or equivalently $\kappa_a + \kappa_s \leq \overline{\kappa}_s$. The period-$t = 0$ welfare-maximizing equilibrium implements the first-best transition: every dirty firm adopts and scales and every low-type green firm scales in period $t = 0$. No equilibrium, regardless of the timing of reform, can generate higher welfare. Moreover, any equilibrium in which a positive measure of firms reforms in a period $t \geq 1$ generates strictly lower welfare. Consider next case (ii), in which $\kappa_s \leq \overline{\kappa}_s < \kappa_a + \kappa_s$. Joint adoption-and-scaling then occurs in no period in any equilibrium, since its cost condition fails at every date, so the only remaining reform is scaling by low-type green firms. The period-$t = 0$ welfare-maximizing equilibrium implements this reform in full in period $t = 0$, so any equilibrium in which scaling is delayed reforms weakly fewer firms, weakly later, and any equilibrium in which a positive measure of firms scales in a period $t \geq 1$ generates strictly lower welfare. In case (iii), in which $\kappa_s > \overline{\kappa}_s$, both cost conditions fail and no reform occurs in any period in any equilibrium.

Finally, we verify that the period-$t = 0$ equilibria of Proposition 2 remain equilibria of the unrestricted game, in which firms can reform in every period. Because the manager maximizes the expected end-of-period valuation period by period, it suffices to check that, at every date and given equilibrium valuations, no firm strictly gains from deviating from its equilibrium action at that date. The proposition's proof performs these checks in period $t = 0$. In cases (ii) and (iii) of Proposition 2, the composition of the pooled disclosure category is constant from period $t = 0$ onward, so the value of remaining and the exit values are unchanged over time, and the period-$t = 0$ checks extend to every later period. In case (i), the pooled disclosure category is empty from

the end of period $t = 0$ onward, and a firm that deviates by remaining in it is assessed as a dirty firm under the off-equilibrium belief, whatever its type. If the investor expects a dirty firm with this history to exit in a later period, the deviating firm's expected end-of-period $t = 0$ valuation equals the value of receiving the dirty per-period utility until that period and the dirty firm's exit value thereafter, and if the investor expects it never to exit, its expected end-of-period $t = 0$ valuation equals the perpetual dirty valuation $\frac{\pi+\lambda b_d}{1-\beta}$. Under the case condition ($\kappa_a + \kappa_s \leq \overline{\kappa}_s$ for a dirty firm and $\kappa_s \leq \overline{\kappa}_s$ for a low-type green firm), the immediate exit value weakly exceeds both, so exiting in period $t = 0$ is weakly optimal, and the indifference-breaking convention selects it. This establishes part (ii).

Step 4: Pooling at the extremes: We show part (iii): adoption arises in any period only in Case 2 and scaling only in Case 1. By Lemma B.1, every remaining reform moves a firm out of or into the pooled disclosure category. In particular, dirty firms can adopt, exiting the pooled disclosure category, and low-type green firms can scale, entering it. A dirty firm that adopts in period t becomes separately identified as a low-type green firm. Any subsequent scaling occurs in a later period $T > t$ and moves the firm into the pooled disclosure category, where it is recognized from its disclosure history as a high-type green firm and valued at $\frac{\pi+\lambda b_{g_H}}{1-\beta} - \kappa_s$, so the scaling option adds $\beta^{T-t} V_s \leq \max\{V_s, 0\}$ to the firm's valuation, and the adopting firm's expected end-of-period valuation is at most $\frac{\pi+\lambda b_{g_L}}{1-\beta} + \max\{V_s, 0\} - \kappa_a$. Remaining in the pooled disclosure category is worth at least $\frac{\pi+\lambda b_d}{1-\beta}$ by Step 2, so a necessary condition for adoption in period t is $V_a + \max\{V_s, 0\} \geq 0$. This condition fails in Case 1, where $V_a + V_s < 0$, and in Case 3, where $V_a < 0$ and $V_s < 0$, so adoption arises only in Case 2, where strict green disclosure generates adoption as well.

A low-type green firm that scales in period t enters the pooled disclosure category, where it is valued at the pooled valuation if $t = 0$ and, being recognized from its disclosure history as a high-type green firm, at $\frac{\pi+\lambda b_{g_H}}{1-\beta}$ if $t \geq 1$, in either case at most $\frac{\pi+\lambda b_{g_H}}{1-\beta}$ gross of the scaling cost κ_s. Remaining separately identified is worth at least $\frac{\pi+\lambda b_{g_L}}{1-\beta}$ by Step 2, so a necessary condition for scaling in period t is $V_s \geq 0$, the scaling condition under strict green disclosure, which holds only in Case 1. This establishes part (iii). ■

B.3 Dynamic Lax Green Disclosure Requirements

We now extend Lemma B.2 to dynamic green disclosure requirements with switching period $\tau \in \{1, 2, \ldots\}$. The arguments mirror the static case, with the anticipated switch adding option-value terms that are discounted by $\beta^{\tau-t}$. Parts (i) and (ii) of the following result imply that the reform decisions in periods $t = 0$ and $t = \tau$ characterized in Section 3.2 are without loss of generality under dynamic pooling at the top and at the bottom. Under dynamic pooling at the top no reform occurs in any other period, and under dynamic pooling at the bottom reform in any other period

only reduces welfare and is not a welfare-maximizing equilibrium. Part (iii) concerns dynamic pooling at the extremes, for which we do not characterize equilibrium. Instead, we show that reform incentives in any period are weakly weaker than under strict green disclosure, which is the basis for the dominance result in Proposition C.1.

Lemma B.3 (Timing of Reform under Dynamic Lax Green Disclosure)**.** *Fix any dynamic lax green disclosure requirement with switching period $\tau \in \{1,2,\ldots\}$. (i) Under dynamic pooling at the top, no firm adopts or scales in any period other than $t = 0$ and $t = \tau$. (ii) Under dynamic pooling at the bottom, the welfare-maximizing equilibrium features reform only in period $t = 0$ and in period $t = \tau$, and any equilibrium in which a positive measure of firms reforms in a period $t \geq 1$ other than period $t = \tau$ reforms weakly fewer firms, weakly later, and generates weakly lower welfare. (iii) Under dynamic pooling at the extremes, adoption in any period occurs only in Case 2 and scaling only in Case 1, as under strict green disclosure.*

Proof of Lemma B.3. **Step 1: No reform after the switch in $t \geq \tau + 1$:** We first show that, in any equilibrium, any reform in a period $t \geq \tau$ occurs in period $t = \tau$. From period $t = \tau$ onward, requirements are strict and incentives are stationary. In particular, the valuation gain from a given reform is the same in every period $t \geq \tau$, and delaying it from period $t = \tau$ to a period $T > \tau$ scales its contribution to the expected end-of-period $t = \tau$ valuation by $\beta^{T-\tau}$. Three cases arise. If the valuation gain from a reform is strictly positive, delay strictly reduces its discounted value, so the firm reforms in period $t = \tau$. If the valuation gain is exactly zero, the manager in period $t = \tau$ is indifferent between reforming and waiting, and the firm reforms in period $t = \tau$ by our tie-breaking convention. If the valuation gain is strictly negative, the firm never reforms in any period $t \geq \tau$. By Lemma 1, a revealed dirty firm therefore adopts in period $t = \tau$ in Case 2 only, and a revealed low-type green firm scales in period $t = \tau$ in Case 1 only. In Case 3, no revealed firm reforms. It remains to consider reform in periods $t \in \{1,\ldots,\tau-1\}$.

Step 2: Pooling at the top: We show that no firm adopts or scales in any period $t \in \{1,\ldots,\tau-1\}$ in any equilibrium, which together with Step 1 establishes part (i). The argument mirrors Step 1 of Lemma B.2. By Lemma B.1, no firm in the pooled disclosure category scales before period $t = \tau$, and the only remaining reform before period $t = \tau$ is adoption by dirty firms. We first show that a dirty firm that adopts in a period $t \in \{1,\ldots,\tau-1\}$ is valued at its inferred type rather than at the pooled valuation, so that delay forfeits the mis-valuation subsidy entirely. A dirty firm that does not adopt in period $t = 0$ is disclosed as a dirty firm at the end of period $t = 0$ and remains separately identified for as long as it does not adopt. If it adopts in a period $t \in \{1,\ldots,\tau-1\}$, it enters the pooled disclosure category, but because the investor has perfect recall, its disclosure history reveals that it was a dirty firm through period $t-1$. As in Step 1 of Lemma B.2, in any candidate equilibrium in which entry occurs, Bayes' rule places probability one on the entering firm having adopted only, and for histories off the equilibrium path we specify the same belief,

the only belief that places no probability on the strictly dominated action of scaling before period $t = \tau$. The investor thus treats any entering firm as a low-type green firm and, anticipating its scaling option in period $t = \tau$, values it at $\frac{\pi+\lambda b_{g_L}}{1-\beta} + \beta^{\tau-t}\max\{V_s, 0\}$, gross of the adoption cost incurred in period t, separately from the pool formed at the end of period $t = 0$. The pool formed at the end of period $t = 0$ is therefore unaffected by later adoption. Indeed, its members never leave and never scale before period $t = \tau$, and later entrants are valued separately, so its composition is constant through period $t = \tau - 1$ and the pooled valuation (7) applies to it.

The valuation gain from adopting in period $t \geq 1$ is then $V_a + \beta^{\tau-t}\max\{V_s, 0\}$, since the misvaluation subsidy is forgone entirely. In Cases 1 and 3, Assumption 1 implies $V_a + \max\{V_s, 0\} < 0$, so delayed adoption strictly lowers the firm's valuation and never occurs. In Case 2, delayed adoption cannot occur in equilibrium either. In any candidate equilibrium in which a dirty firm adopts in period t, its expected end-of-period $t = 0$ valuation reflects the dirty flow value until period t and the value of a separately identified low-type green firm, including its scaling option in period $t = \tau$, net of the adoption cost thereafter,

$$\frac{1-\beta^t}{1-\beta}(\pi + \lambda b_d) + \beta^t\left(\frac{\pi + \lambda b_{g_L}}{1-\beta} + \beta^{\tau-t}\max\{V_s, 0\} - \kappa_a\right) = \frac{\pi + \lambda b_d}{1-\beta} + \beta^t\left(V_a + \beta^{\tau-t}\max\{V_s, 0\}\right).$$

Adopting in period $t = 0$ instead yields the pooled valuation (7) net of κ_a,

$$\frac{\pi + \theta_{g_L}\lambda b_{g_L} + \theta_{g_H}\lambda b_{g_H}}{1-\beta} + \beta^\tau \theta_{g_L}\max\{V_s, 0\} - \kappa_a = \frac{\pi + \lambda b_d}{1-\beta} + V_a + \theta_{g_H}\frac{\lambda\Delta_s}{1-\beta} + \beta^\tau\theta_{g_L}\max\{V_s, 0\},$$

where the equality uses $\theta_{g_L} + \theta_{g_H} = 1$, $b_{g_L} = b_d + \Delta_a$, and $b_{g_H} = b_{g_L} + \Delta_s$. The difference between the two valuations is

$$(1-\beta^t)V_a + \theta_{g_H}\left(\frac{\lambda\Delta_s}{1-\beta} - \beta^\tau\max\{V_s, 0\}\right) > 0,$$

where the inequality uses that the first term is nonnegative because $V_a \geq 0$, that $\theta_{g_H} > 0$ because $\mu_{g_H} > 0$, and that the bracket equals $\frac{\lambda\Delta_s}{1-\beta} > 0$ since $V_s < 0$ in Case 2. The deviation to period-$t = 0$ adoption is strictly profitable, so no equilibrium features delayed adoption.

Finally, we verify that the period-$t = 0$ equilibria of Proposition 3, whose proof verifies the incentive conditions in periods $t = 0$ and $t = \tau$ directly and does not rely on this lemma, remain equilibria of the unrestricted game, in which firms can reform in every period. The period-$t = 0$ check in Lemma 5 already incorporates the option to adopt in period $t = \tau$, and Lemma B.1 rules out scaling before period $t = \tau$, so the only additional deviation is adoption by a dirty firm in a period $t \in \{1, \ldots, \tau - 1\}$, which lowers its valuation if $V_a < 0$ and is strictly dominated by adoption in period $t = 0$ if $V_a \geq 0$ by the comparison above. Together with Step 1, this establishes part (i).

Step 3: Valuation bound under pooling at the bottom: Define

$$W_t := \frac{\pi + \lambda b_d}{1-\beta} + \beta^{\tau-t} \max\{V_a, 0\}.$$

We show that, in any equilibrium, the expected end-of-period t valuation of a firm in the pooled disclosure category is at least W_t for every $t \in \{0, \ldots, \tau-1\}$, by backward induction from period $t = \tau$. This bound disciplines exit incentives before the switch in Step 4. The recursion parallels Step 2 of Lemma B.2, with the switch in period $t = \tau$ providing the base case. For the base case, the switch in period $t = \tau$ reveals all remaining firm types. By Step 1, a revealed dirty firm is valued at $\frac{\pi+\lambda b_d}{1-\beta} + \max\{V_a, 0\} = W_\tau$, and a revealed low-type green firm is valued at $\frac{\pi+\lambda b_{g_L}}{1-\beta} + \max\{V_s, 0\} \geq W_\tau$, since $\frac{\lambda \Delta_a}{1-\beta} > \max\{V_a, 0\}$ because $\kappa_a > 0$.

For the inductive step, suppose the bound W_{t+1} holds at the end of period $t+1$. As in Step 2 of Lemma B.2, the end-of-period t pooled valuation is $V_t = \sum_i \theta_i^t \left[(\pi + \lambda b_i) + \beta v_i^{t+1}\right]$, with member types $i \in \{d, g_L\}$, shares θ_i^t, and expected end-of-period $t+1$ member valuations v_i^{t+1}, and V_t is gross of any reform cost incurred in period t itself, as in Step 2 of Lemma B.2. The first term satisfies $\sum_i \theta_i^t (\pi + \lambda b_i) \geq \pi + \lambda b_d$, since $b_i \geq b_d$ for every member type i. The second term satisfies $v_i^{t+1} \geq W_{t+1}$ for every member type i: a member's expected end-of-period $t+1$ valuation is the pooled valuation if the member remains, its exit value net of the reform cost if it exits, which the manager chooses only if it weakly exceeds the pooled valuation, or its revealed value if $t+1 = \tau$, and all three are at least W_{t+1}. Hence $V_t \geq (\pi + \lambda b_d) + \beta W_{t+1} = W_t$.[23]

Step 4: Pooling at the bottom: We establish part (ii) in three parts, mirroring Step 3 of Lemma B.2: we derive necessary cost conditions for reform before the switch, show that no equilibrium with delayed reform generates higher welfare than the period-$t = 0$ welfare-maximizing equilibrium, and verify that the period-$t = 0$ equilibria of Proposition 4 remain equilibria when firms can reform in every period. By Lemma B.1, every remaining reform before period $t = \tau$ moves a firm out of the pooled disclosure category. In particular, low-type green firms can scale, and dirty firms can adopt and scale jointly. A low-type green firm that scales in period $t \in \{1, \ldots, \tau-1\}$ exits the pooled disclosure category and is valued at $\frac{\pi+\lambda b_{g_H}}{1-\beta} - \kappa_s$. By Step 3, a necessary condition for scaling in period t to raise the firm's expected end-of-period valuation is $\frac{\pi+\lambda b_{g_H}}{1-\beta} - \kappa_s \geq W_t$, that is, $\kappa_s \leq \overline{\kappa}_s - \beta^{\tau-t} \max\{V_a, 0\} \leq \overline{\kappa}_s^D(\tau)$. By the same argument, a necessary condition for joint adoption-and-scaling in period t is $\kappa_a + \kappa_s \leq \overline{\kappa}_s - \beta^{\tau-t} \max\{V_a, 0\} \leq \overline{\kappa}_s^D(\tau)$.

These conditions are weakly tighter than the period-$t = 0$ conditions of cases (i) and (ii) of Proposition 4. The proposition's proof verifies the period-$t = 0$ incentive conditions directly and does not rely on this lemma. In particular, since the value of remaining in the pooled disclosure

[23] If the pooled disclosure category is empty, which can occur only under pooling at the bottom, its valuation is defined by the off-equilibrium belief that a firm in it is a dirty firm, and the same recursion applies with θ_d equal to one.

category can never fall below W_t, reform incentives at any date are never stronger than those in the period-$t = 0$ welfare-maximizing equilibrium of cases (i) and (ii), in which the value of remaining is evaluated at this bound.

We now compare welfare across equilibria, using that a low-type green firm that scales in period t contributes $\beta^t \left(\frac{\Delta_s}{1-\beta} - \kappa_s \right)$ to social surplus relative to never scaling, a dirty firm that adopts and scales in period t contributes $\beta^t \left(\frac{\Delta_a+\Delta_s}{1-\beta} - \kappa_a - \kappa_s \right)$, and a dirty firm that instead remains in the pooled disclosure category and adopts in period $t = \tau$ contributes $\beta^\tau \left(\frac{\Delta_a}{1-\beta} - \kappa_a \right) \mathbb{1}_{\{V_a \geq 0\}}$. The first two contributions are strictly positive by the model primitives and strictly decreasing in the reform date, so each is maximized in period $t = 0$, and the period-$t = 0$ joint reform dominates adoption in period $t = \tau$, since the difference equals $(1-\beta^\tau) \left(\frac{\Delta_a}{1-\beta} - \kappa_a \right) + \frac{\Delta_s}{1-\beta} - \kappa_s > 0$ when $V_a \geq 0$, matching the welfare ranking in Step 2 of the proof of Proposition 4. Consider first case (i), in which $\kappa_s \leq \underline{\kappa}_s^D(\tau)$, or equivalently $\kappa_a + \kappa_s \leq \overline{\kappa}_s^D(\tau)$. The period-$t = 0$ welfare-maximizing equilibrium implements the first-best transition: every dirty firm adopts and scales and every low-type green firm scales in period $t = 0$. No equilibrium, regardless of the timing of reform, can generate higher welfare. Moreover, any equilibrium in which a positive measure of firms reforms in a period $t \in \{1, \ldots, \tau - 1\}$ generates strictly lower welfare. Consider next case (ii), in which $\kappa_s \leq \overline{\kappa}_s^D(\tau) < \kappa_a + \kappa_s$. Joint adoption-and-scaling then occurs in no period $t \in \{0, \ldots, \tau - 1\}$ in any equilibrium, since its cost condition fails at every such date, so the remaining reforms are scaling by low-type green firms before the switch and adoption by dirty firms in period $t = \tau$. The period-$t = 0$ welfare-maximizing equilibrium implements full scaling in period $t = 0$ and full adoption in period $t = \tau$ whenever $V_a \geq 0$, so any equilibrium in which scaling is delayed reforms weakly fewer firms, weakly later, and any equilibrium in which a positive measure of firms scales in a period $t \in \{1, \ldots, \tau - 1\}$ generates strictly lower welfare. In case (iii), in which $\kappa_s > \overline{\kappa}_s^D(\tau)$, no firm scales in any period $t \in \{0, \ldots, \tau - 1\}$ in any equilibrium, and reform reduces to adoption in period $t = \tau$ whenever $V_a \geq 0$, as in the period-$t = 0$ welfare-maximizing equilibrium.

Finally, we verify that the period-$t = 0$ equilibria of Proposition 4 remain equilibria of the unrestricted game, in which firms can reform in every period. Because the manager maximizes the expected end-of-period valuation period by period, it suffices to check that, at every date and given equilibrium valuations, no firm strictly gains from deviating from its equilibrium action at that date. The proposition's proof performs these checks in period $t = 0$ and in period $t = \tau$. In cases (ii) and (iii), the composition of the pooled disclosure category is constant in all periods before the switch. In case (ii), the pooled disclosure category contains only dirty firms, so the value of remaining is $V_t = W_t$. In case (iii), it contains dirty and low-type green firms with constant shares θ_d and $\theta_{g_L} = 1 - \theta_d$, and $\kappa_s > \overline{\kappa}_s^D(\tau)$ implies $V_s < 0$, so no low-type green firm scales in period

$t = \tau$ and the value of remaining is

$$V_t = \frac{\pi + \theta_d \lambda b_d + \theta_{g_L} \lambda b_{g_L}}{1-\beta} + \beta^{\tau - t} \theta_d \max\{V_a, 0\}.$$

Both expressions weakly rise as the switch approaches, since the adoption option is discounted by less, while the exit values are constant over time. Exit incentives in periods $t \in \{1, \ldots, \tau - 1\}$ are therefore weakly weaker than in period $t = 0$, and the period-$t = 0$ checks extend to every period before the switch. In case (i) of Proposition 4, the pooled disclosure category is empty from the end of period $t = 0$ onward, and a firm that deviates by remaining in it is assessed as a dirty firm under the off-equilibrium belief, whatever its type. If the investor expects a dirty firm with this history to exit in a later period before the switch, the deviating firm's expected end-of-period $t = 0$ valuation equals the value of receiving the dirty per-period utility until that period and the dirty firm's exit value thereafter, and if the investor expects it to remain until the switch, its expected end-of-period $t = 0$ valuation equals W_0. Under the case condition ($\kappa_a + \kappa_s \leq \overline{\kappa}_s^D(\tau)$ for a dirty firm and $\kappa_s \leq \overline{\kappa}_s^D(\tau)$ for a low-type green firm), the immediate exit value weakly exceeds both, so exiting in period $t = 0$ is weakly optimal, and the indifference-breaking convention selects it. Together with Step 1, this establishes part (ii).

Step 5: Pooling at the extremes: We show that adoption arises in any period $t \in \{0, \ldots, \tau - 1\}$ only in Case 2 and scaling only in Case 1. The argument mirrors Step 4 of Lemma B.2. The upper bound $\frac{\pi + \lambda b_{g_H}}{1-\beta}$ on any firm's valuation holds as in Step 2 of Lemma B.2. Likewise, no member reforms inside the pooled disclosure category (Lemma B.1), and a low-type green firm that scales into it in a period $t \geq 1$ is recognized from its disclosure history and valued separately, so the pool formed at the end of period $t = 0$ changes composition only through exits by dirty firms that adopt, and it is never empty since high-type green firms never leave.

We first show by backward induction that the pooled valuation V_t is at least $\frac{\pi + \lambda b_d}{1-\beta}$ for every $t \in \{0, \ldots, \tau - 1\}$. In period $t = \tau$, types are revealed: a revealed dirty firm is valued at $\frac{\pi + \lambda b_d}{1-\beta} + \max\{V_a, 0\}$ by Step 1 and a revealed high-type green firm at $\frac{\pi + \lambda b_{g_H}}{1-\beta}$, both at least $\frac{\pi + \lambda b_d}{1-\beta}$. For the inductive step, suppose every member's expected end-of-period $t + 1$ valuation is at least $\frac{\pi + \lambda b_d}{1-\beta}$. The end-of-period t pooled valuation is $V_t = \sum_{i \in \{d, g_H\}} \theta_i^t \left[(\pi + \lambda b_i) + \beta v_i^{t+1} \right]$, gross of any reform cost incurred in period t, with $\sum_i \theta_i^t (\pi + \lambda b_i) \geq \pi + \lambda b_d$ since $b_{g_H} > b_d$. A member that remains in period $t + 1$ is valued at V_{t+1}, a member that exits by adopting is valued at its exit value net of the adoption cost, which the manager chooses only if it weakly exceeds V_{t+1}, and a member revealed in period $t + 1 = \tau$ is valued at least $\frac{\pi + \lambda b_d}{1-\beta}$. Hence $v_i^{t+1} \geq \frac{\pi + \lambda b_d}{1-\beta}$ for both member types, and $V_t \geq (\pi + \lambda b_d) + \beta \frac{\pi + \lambda b_d}{1-\beta} = \frac{\pi + \lambda b_d}{1-\beta}$. A separately identified low-type green firm is valued at least at $\frac{\pi + \lambda b_{g_L}}{1-\beta}$ in every period, since the investor knows its type and it scales only when doing so weakly raises its expected end-of-period valuation.

A dirty firm that adopts in period $t \in \{0,\dots,\tau-1\}$ is then valued at most $\frac{\pi+\lambda b_{g_L}}{1-\beta} + \max\{V_s,0\} - \kappa_a$, while remaining in the pooled disclosure category is worth at least $\frac{\pi+\lambda b_d}{1-\beta}$, so a necessary condition for adoption in period t is $V_a + \max\{V_s,0\} \geq 0$. This condition fails in Case 1, where $V_a + V_s < 0$, and in Case 3, where $V_a < 0$ and $V_s < 0$, so adoption arises only in Case 2, where strict green disclosure generates adoption as well.

A low-type green firm that scales in period t enters the pooled disclosure category and is valued at most $\frac{\pi+\lambda b_{g_H}}{1-\beta} - \kappa_s$, while remaining separately identified is worth at least $\frac{\pi+\lambda b_{g_L}}{1-\beta}$, so a necessary condition for scaling in period t is $V_s \geq 0$, the scaling condition under strict green disclosure, which holds only in Case 1. Together with Step 1, this establishes part (iii). ■

C Appendix: Additional Results

Throughout this appendix, we maintain Assumption 1 and refer to the three roadblock configurations of Section 2.

C.1 Dynamic Pooling at the Extremes

This appendix proves the dynamic analog of Lemma 4: dynamic pooling at the extremes is weakly dominated by strict green disclosure for any switching period $\tau \geq 1$.

Proposition C.1 (Dynamic Pooling at the Extremes)**.** *For any switching period $\tau \geq 1$, dynamic pooling at the extremes generates weakly lower social welfare than strict green disclosure in any equilibrium.*

Proof. Under dynamic pooling at the extremes, dirty firms and high-type green firms share a single pooled disclosure category in periods $t \in \{0,\dots,\tau-1\}$, while low-type green firms are separately identified. In period $t = \tau$, the regulator switches to strict green disclosure, after which all three types are separately identified. By Lemma B.1, no dirty firm adopts and scales jointly before the switch, since the joint transition would leave the firm in the pooled disclosure category while paying $\kappa_a + \kappa_s > 0$. By Lemma B.3, adoption can occur in any period only in Case 2, and scaling only in Case 1. Under strict green disclosure, by contrast, all dirty firms adopt in period $t = 0$ in Case 2 and all low-type green firms scale in period $t = 0$ in Case 1 (Lemma 1). Any transition that occurs under dynamic pooling at the extremes in any period therefore also occurs under strict green disclosure, where it occurs in period $t = 0$.

Conversely, a transition that strict green disclosure implements in period $t = 0$ occurs under dynamic pooling at the extremes weakly later, and at the latest in period $t = \tau$ (Lemma B.3), when

types are revealed and, in Case 2, a remaining dirty firm adopts and, in Case 1, a remaining low-type green firm scales. By the model primitives, $\frac{\Delta_a}{1-\beta} > \kappa_a$ and $\frac{\Delta_s}{1-\beta} > \kappa_s$, each such transition carries strictly positive social value, and delaying it from period $t = 0$ to a period $t \geq 1$ reduces its contribution to discounted social surplus by the fraction $1 - \beta^t > 0$. Aggregating across firms, social welfare under dynamic pooling at the extremes is weakly lower than under strict green disclosure in any equilibrium. ■

C.2 Switches from Strict to Lax Green Disclosure

Lemma C.1 in this appendix shows that, under perfect recall, a switch from strict to lax green disclosure is inconsequential. This justifies restricting attention to policies that switch from lax to strict green disclosure. To see the intuition, consider a switch from strict green disclosure to pooling at the top and a low-type green firm. After the switch, the firm is reported in the pooled disclosure category of low-type and high-type green firms, whether or not it scales. Scaling therefore no longer changes the investor's information about the firm, and the firm does not scale. In this respect, the switch prevents reform after period τ, similar to pooling at the top in the main analysis. However, the investor has perfect recall and knows that the firm was low-type green before the switch. Moving to lax green disclosure does not erase this information. Since the firm does not scale within the pooled disclosure category, the investor infers that the firm is still low-type green after the switch and values it accordingly. Using the same logic, the investor also knows a firm that was high-type green before the switch and values it in the same way after the switch. The same reasoning applies to a dirty firm. If it adopts after the switch, it moves into the pooled disclosure category, but the investor knows that it was dirty before the switch and that it does not scale within the pooled disclosure category, so the investor infers that it is now low-type green. The switch thus does not create the mis-valuation subsidy that drives reform under lax green disclosure in the main analysis and adoption and scaling decisions are the same as if strict green disclosure had remained in place. A similar argument for a switch from strict green disclosure to lax green disclosure demonstrates that the switch no longer creates the mis-valuation tax that drives reform under pooling at the bottom.

As in the main text, we maintain Assumption 1 and we restrict attention to equilibria in which reform occurs in period $t = 0$ and upon the switch in period $t = \tau$. We consider switches to pooling at the top and to pooling at the bottom, the two lax green disclosure requirements that can be optimal in the baseline model.

Lemma C.1 (Switches from Strict to Lax Green Disclosure)**.** *Suppose strict green disclosure is in place in periods $t < \tau$ and the regulator switches to pooling at the top or to pooling at the bottom at the beginning of period $\tau \geq 1$. Adoption and scaling decisions and welfare are the same as under strict green disclosure in all periods.*

Proof. By Lemma 1 and Assumption 1, under strict green disclosure in all periods, a low-type green firm scales in period $t = 0$ in Case 1 only, and a dirty firm adopts in period $t = 0$ in Case 2 only, where it does not subsequently scale. In particular, no dirty firm adopts and scales, since the joint transition is ruled out by Assumption 1.

We proceed by backward induction. Step 1 takes the reform decisions in period $t = 0$ as given and characterizes each firm's reform incentives in period τ under the switch. Step 2 derives the reform incentives in period $t = 0$ and shows that the resulting adoption and scaling decisions coincide with those under strict green disclosure in all periods. We describe the investor's information by a firm's disclosure record, the sequence of categories the firm reports. For example, $(d, \ldots, d, \{g_L, g_H\}, \ldots)$ is the record of a firm that reports d before period τ and the pooled disclosure category $\{g_L, g_H\}$ from period τ onward. By the argument of Lemma B.1, no firm undertakes a transition in period τ that does not change its record, since such a transition has a cost and does not change the investor's information about the firm.

Step 1: Reform incentives in period τ: Under strict green disclosure, every firm reports its type before period τ. Consider first the switch to pooling at the top. The record of a high-type green firm is $(g_H, \ldots, g_H, \{g_L, g_H\}, \ldots)$, from which the investor infers that it is high-type green, since the transition is irreversible. The record of a low-type green firm is $(g_L, \ldots, g_L, \{g_L, g_H\}, \ldots)$ whether or not it scales in period τ, so the firm does not scale. The record of a dirty firm is $(d, \ldots, d, d, \ldots)$ if it does not reform and $(d, \ldots, d, \{g_L, g_H\}, \ldots)$ if it adopts, whether or not it also scales, so the firm does not scale. The investor infers from the latter record that the firm has adopted and, since no firm with this record scales, that it is low-type green. A dirty firm that adopts in period τ therefore obtains the valuation gain V_a, so it adopts if and only if $V_a \geq 0$, and it never scales.

Next, consider the switch to pooling at the bottom. The record of a high-type green firm is $(g_H, \ldots, g_H, g_H, \ldots)$, and the investor values it as high-type green. The record of a dirty firm is $(d, \ldots, d, \{d, g_L\}, \ldots)$ whether or not it adopts, so the firm does not adopt without scaling. If it adopts and scales, its record is $(d, \ldots, d, g_H, \ldots)$ and the investor values it as high-type green, so the firm obtains the valuation gain $V_a + V_s$. A dirty firm therefore adopts and scales if and only if $V_a + V_s \geq 0$ and never adopts without scaling. The record of a low-type green firm is $(g_L, \ldots, g_L, \{d, g_L\}, \ldots)$ if it does not scale, and the investor infers that it is low-type green since it cannot have become dirty, and $(g_L, \ldots, g_L, g_H, \ldots)$ if it scales, in which case the investor values it as high-type green. A low-type green firm that scales therefore obtains the valuation gain V_s, so it scales if and only if $V_s \geq 0$.

To summarize, in period τ a low-type green firm obtains no valuation gain from scaling under pooling at the top and V_s under pooling at the bottom, and a dirty firm obtains the valuation gain V_a from adopting under pooling at the top and $V_a + V_s$ from adopting and scaling under pooling at the bottom. The valuation gain from any transition in period τ is thus weakly lower than under strict green disclosure in period τ, under which a low-type green firm obtains V_s from scaling and a dirty

firm obtains V_a from adopting and $V_a + V_s$ from adopting and scaling.

Step 2: Reform incentives in period $t = 0$: Under strict green disclosure in period $t = 0$, every firm is separately identified, so the investor values a firm at its type at the end of period $t = 0$, net of the transition costs it has paid, plus the discounted valuation gain from any reform the investor anticipates the firm to undertake in period τ. By Step 1, the anticipated reform in period τ depends on the firm's type at the end of period $t = 0$ and on the lax green disclosure requirement in place from period τ onward.

Consider a low-type green firm. If it scales in period $t = 0$, its expected end-of-period $t = 0$ valuation is $\frac{\pi+\lambda b_{g_H}}{1-\beta} - \kappa_s$. If it does not scale, its expected end-of-period $t = 0$ valuation is $\frac{\pi+\lambda b_{g_L}}{1-\beta}$ under a switch to pooling at the top, since it does not scale in period τ, and $\frac{\pi+\lambda b_{g_L}}{1-\beta} + \beta^\tau \max\{V_s, 0\}$ under a switch to pooling at the bottom, since it scales in period τ if and only if $V_s \geq 0$. The firm scales in period $t = 0$ if and only if $V_s \geq 0$ under a switch to pooling at the top and if and only if $V_s \geq \beta^\tau \max\{V_s, 0\}$ under a switch to pooling at the bottom, which is equivalent to $V_s \geq 0$. A low-type green firm therefore scales in period $t = 0$ if and only if $V_s \geq 0$, as under strict green disclosure in all periods.

Consider a dirty firm. If it adopts and scales in period $t = 0$, its expected end-of-period $t = 0$ valuation is $\frac{\pi+\lambda b_{g_H}}{1-\beta} - \kappa_a - \kappa_s$. If it adopts without scaling, it is a low-type green firm at the end of period $t = 0$, so its expected end-of-period $t = 0$ valuation is $\frac{\pi+\lambda b_{g_L}}{1-\beta} - \kappa_a$ under a switch to pooling at the top and $\frac{\pi+\lambda b_{g_L}}{1-\beta} - \kappa_a + \beta^\tau \max\{V_s, 0\}$ under a switch to pooling at the bottom. If it does not reform, its expected end-of-period $t = 0$ valuation is $\frac{\pi+\lambda b_d}{1-\beta} + \beta^\tau \max\{V_a, 0\}$ under a switch to pooling at the top, since it adopts in period τ if and only if $V_a \geq 0$, and $\frac{\pi+\lambda b_d}{1-\beta} + \beta^\tau \max\{V_a + V_s, 0\}$ under a switch to pooling at the bottom, since it adopts and scales in period τ if and only if $V_a + V_s \geq 0$. The following table reports the resulting valuation gain in period $t = 0$ from each transition relative to not reforming, where the last term in each entry is the option value of reform in period τ that the firm forgoes by reforming in period $t = 0$.

Switch in period τ to	Pooling at the top	Pooling at the bottom
Adopt without scaling	$V_a - \beta^\tau \max\{V_a, 0\}$	$V_a + \beta^\tau \max\{V_s, 0\} - \beta^\tau \max\{V_a + V_s, 0\}$
Adopt and scale	$V_a + V_s - \beta^\tau \max\{V_a, 0\}$	$V_a + V_s - \beta^\tau \max\{V_a + V_s, 0\}$

We consider the three cases given Assumption 1 in turn.

In Case 1, $V_s \geq 0$ and $V_a + V_s < 0$, which implies $V_a < 0$, so $\max\{V_a, 0\} = \max\{V_a + V_s, 0\} = 0$ and $\max\{V_s, 0\} = V_s$. The valuation gains become

Switch in period τ to	Pooling at the top	Pooling at the bottom
Adopt without scaling	$V_a < 0$	$V_a + \beta^\tau V_s \leq V_a + V_s < 0$
Adopt and scale	$V_a + V_s < 0$	$V_a + V_s < 0$

so a dirty firm does not reform in period $t = 0$ under either switch.

In Case 2, $V_s < 0$ and $V_a \geq 0$, so $\max\{V_a, 0\} = V_a$, $\max\{V_s, 0\} = 0$, and $\max\{V_a + V_s, 0\} \leq V_a$. The valuation gains become

Switch in period τ to	Pooling at the top	Pooling at the bottom
Adopt without scaling	$(1-\beta^\tau)V_a \geq 0$	$V_a - \beta^\tau \max\{V_a + V_s, 0\} \geq (1-\beta^\tau)V_a \geq 0$
Adopt and scale	$(1-\beta^\tau)V_a + V_s$	$V_a + V_s - \beta^\tau \max\{V_a + V_s, 0\}$

Under either switch, adopting without scaling yields a weakly positive gain, and adopting and scaling yields $V_s < 0$ less than adopting without scaling, so a dirty firm adopts without scaling in period $t = 0$.

In Case 3, $V_a < 0$ and $V_s < 0$, so all option values are zero and the valuation gains become

Switch in period τ to	Pooling at the top	Pooling at the bottom
Adopt without scaling	$V_a < 0$	$V_a < 0$
Adopt and scale	$V_a + V_s < 0$	$V_a + V_s < 0$

so a dirty firm does not reform in period $t = 0$ under either switch.

In all three cases, the adoption and scaling decisions of dirty firms in period $t = 0$ coincide with those under strict green disclosure in all periods.

Finally, consider period τ given these reform decisions. In Case 1, every low-type green firm has scaled in period $t = 0$ and no dirty firm has adopted, so the only firms that could reform in period τ are dirty firms, which do not reform under either switch since $V_a < 0$ and $V_a + V_s < 0$. In Case 2, every dirty firm has adopted in period $t = 0$, so in period τ the only remaining reform would be scaling by a low-type green firm, initially low-type green or an adopter, which does not occur under either switch since $V_s < 0$ In Case 3, no firm has reformed in period $t = 0$, and no firm reforms in period τ under either switch since $V_a < 0$, $V_s < 0$, and $V_a + V_s < 0$. No firm reforms in period τ, exactly as under strict green disclosure in all periods. Adoption and scaling decisions in every period, and hence welfare, coincide with those under strict green disclosure in all periods. ■

D Appendix: Extensions and Robustness

Throughout this appendix, we maintain Assumption 1 and refer to the three roadblock configurations of Section 2.

D.1 Voluntary Disclosure and Information Leakage

This appendix extends the baseline model from Section 1 along two dimensions. Appendix D.1.1 allows some firms to disclose their type voluntarily, and Appendix D.1.2 allows information about firm types to leak to the investor independently of green disclosure requirements. Neither extension affects strict green disclosure, under which firm types are already public. We therefore ask how each extension affects lax green disclosure requirements. We follow the structure of the main text by first taking the switching period $\tau \geq 1$ as given, with $\tau = \infty$ denoting the static requirement as in Appendix A, and characterizing firms' incentives and the resulting equilibrium. We show that each extension weakly reduces reform on the margin the requirement targets. We then show that, for every switching period, each extension weakly lowers the welfare the regulator can attain, so both make lax green disclosure less effective.

We analyze pooling at the top when adoption is a roadblock (Cases 1 and 3) and pooling at the bottom when scaling is a roadblock (Cases 2 and 3), since each requirement is weakly dominated by strict green disclosure otherwise (Proposition 5). As in the main text, we characterize reform in period $t = 0$ and in period $t = \tau$. We use the welfare notation of Appendix A: the surplus gains G_a, G_s, and $G_{a,s}$ in (19), welfare W^S under strict green disclosure, and welfare $W^{DT}(\tau)$ and $W^{DB}(\tau)$ under pooling at the top and at the bottom in (20) and (21).

D.1.1 Voluntary Disclosure

A fraction $\psi \in (0,1)$ of the firms of each type has access to a voluntary disclosure technology, for example a third-party certification or an audited sustainability report, which allows the firm to reveal the firm's type to the investor at no cost. A firm learns at the beginning of period $t = 0$ whether it has access to the technology and, if so, decides whether to voluntarily disclose in period $t = 0$ before it makes its reform decisions. The type of a firm that is disclosing voluntarily is public at the end of every period, so its adoption and scaling incentives are those under strict green disclosure (Lemma 1). A firm that does not disclose voluntarily remains subject to the prevailing disclosure requirement, and the investor values the pooled disclosure category according to its composition net of the firms that disclose voluntarily.

Under both pooling at the top and at the bottom, a firm with access to the disclosure technology can leave the pooled disclosure category by disclosing voluntarily. When deciding whether or not to disclose voluntarily, the firm compares the pooled valuation with the value of being priced at its own type, taking into account the reform it would undertake once separately identified. Its decision therefore depends on the composition of the pooled disclosure category, which in turn depends on which firms disclose voluntarily and on the reform decisions of the firms that remain. Thus, voluntary disclosure and reform have to be determined jointly.

Throughout, $\phi_a^{\psi}(\tau)$ denotes the fraction of dirty firms that adopt in period $t=0$ under pooling at the top with voluntary disclosure, and $\phi_s^{\psi}(\tau)$ the fraction of low-type green firms that scale in period $t=0$ under pooling at the bottom with voluntary disclosure, in the welfare-maximizing equilibrium. Welfare is denoted by $W_{\psi}^{DT}(\tau)$ under pooling at the top in any equilibrium, and by $W_{\psi}^{DB}(\tau)$ under pooling at the bottom, where it refers to the welfare-maximizing equilibrium.

Proposition D.1 (Voluntary Disclosure)**.** *Fix the switching period $\tau \geq 1$. In Cases 1 and 3, under pooling at the top, in any equilibrium, the fraction of dirty firms that adopt in period $t=0$ is weakly lower than without voluntary disclosure, $\phi_a^{\psi}(\tau) \leq \phi_a^*(\tau)$, and welfare satisfies*

$$W_{\psi}^{DT}(\tau) \;\leq\; \max\left\{W^{DT}(\tau), W^{S}\right\}. \tag{22}$$

In Cases 2 and 3, under pooling at the bottom, the fraction of low-type green firms that scale in period $t=0$ is weakly lower than without voluntary disclosure, $\phi_s^{\psi}(\tau) = (1-\psi)\phi_s^*(\tau) \leq \phi_s^*(\tau)$, and welfare satisfies

$$W_{\psi}^{DB}(\tau) \;\leq\; (1-\psi)W^{DB}(\tau) + \psi W^{S} \;\leq\; \max\left\{W^{DB}(\tau), W^{S}\right\}. \tag{23}$$

Proof of Proposition D.1. A firm that discloses voluntarily is separately identified in every period, and reforms as under strict green disclosure (Lemma 1). Recall the three configurations under Assumption 1: adoption is the only roadblock in Case 1, scaling is the only roadblock in Case 2, and both margins are roadblocks in Case 3. A low-type green firm that discloses voluntarily therefore scales in Case 1 only and a dirty firm that discloses voluntarily adopts in Case 2 only.

Step 1: All high-type green firms with access disclose voluntarily under pooling at the top: Let $x, y, z \in [0, \psi]$ denote the fractions of dirty, low-type green, and high-type green firms that disclose voluntarily, and let $\phi_a \in [0, 1-x]$ denote the fraction of dirty firms that have not disclosed voluntarily and adopt in period $t=0$. Since a firm that is disclosing voluntarily is separately identified, only non-disclosing dirty firms can enter the pooled disclosure category, and only by adopting. By Lemma B.1, no firm scales inside the pooled disclosure category and no dirty firm that enters it adopts and scales jointly, so the pooled disclosure category contains the non-disclosing green firms and the non-disclosing dirty firms that adopt, with shares

$$\theta_{g_H} = \frac{(1-z)\mu_{g_H}}{(1-z)\mu_{g_H} + (1-y)\mu_{g_L} + \phi_a \mu_d}, \qquad \theta_{g_L} = 1 - \theta_{g_H},$$

both strictly positive because $\mu_{g_H} > 0$, $\mu_{g_L} > 0$, and $y, z \leq \psi < 1$. The fraction x of dirty firms that disclose voluntarily does not enter the composition, so it can be left unspecified. By equation (7),

the expected end-of-period $t = 0$ valuation of a firm in the pooled disclosure category is

$$V_{\text{pool}} = \frac{\pi + \theta_{g_L}\lambda b_{g_L} + \theta_{g_H}\lambda b_{g_H}}{1-\beta} + \beta^{\tau}\theta_{g_L}\max\{V_s, 0\}.$$

A high-type green firm that discloses voluntarily undertakes no reform and is valued at $\frac{\pi+\lambda b_{g_H}}{1-\beta}$, so it has an incentive to disclose voluntarily if and only if $\frac{\pi+\lambda b_{g_H}}{1-\beta} \geq V_{\text{pool}}$, which, using $\theta_{g_L} + \theta_{g_H} = 1$ and $b_{g_H} - b_{g_L} = \Delta_s$, can be rewritten as

$$\theta_{g_L}\left[\frac{\lambda\Delta_s}{1-\beta} - \beta^{\tau}\max\{V_s, 0\}\right] \;\geq\; 0.$$

Since $\theta_{g_L} > 0$ and $\max\{V_s, 0\} < \frac{\lambda\Delta_s}{1-\beta}$ because $\kappa_s > 0$, the inequality is strict, so $z = \psi$.

Step 2: In Cases 1 and 3, adoption by dirty firms and voluntary disclosure by low-type green firms are mutually exclusive under pooling at the top: Recall that we analyze pooling at the top only when adoption is a roadblock, that is, in Cases 1 and 3. Fix any composition of the pooled disclosure category and the associated pooled valuation V_{pool}. A low-type green firm that discloses voluntarily scales in Case 1 and undertakes no reform in Case 3, so it is valued at $\frac{\pi+\lambda b_{g_L}}{1-\beta} + \max\{V_s, 0\}$ and has an incentive to disclose voluntarily if and only if

$$\frac{\pi + \lambda b_{g_L}}{1-\beta} + \max\{V_s, 0\} \;\geq\; V_{\text{pool}}, \tag{24}$$

while, by Lemma 5, a dirty firm has an incentive to adopt if and only if[24]

$$V_{\text{pool}} \;\geq\; \frac{\pi + \lambda b_d}{1-\beta} + \kappa_a. \tag{25}$$

The two conditions bound the pooled valuation from opposite sides and, using $b_{g_L} - b_d = \Delta_a$, together require $V_a + \max\{V_s, 0\} \geq 0$, the adoption condition under strict green disclosure (1), which fails in Cases 1 and 3. In Cases 1 and 3, therefore, the left-hand side of (24) is strictly below the right-hand side of (25), so at any composition at most one of the two conditions holds, and if one holds, the other fails strictly. Intuitively, a pooled disclosure category attractive enough to draw a dirty firm in at the adoption cost is worth more to a low-type green firm than being priced at its own type, so a low-type green firm has no reason to leave it. In any equilibrium, therefore, either $y = 0$ or $\phi_a = 0$.

[24] A dirty firm with access can also disclose voluntarily, but in Cases 1 and 3 a separately identified dirty firm does not adopt, so disclosing voluntarily yields $\frac{\pi+\lambda b_d}{1-\beta}$, the same as not adopting, and leaves the adoption condition unchanged. In particular, a dirty firm with a strict incentive to adopt does not disclose voluntarily, so the constraint $\phi_a \leq 1 - x$ does not restrict the adoption share determined in Step 3.

Step 3: Adoption under pooling at the top: By Step 1, $z = \psi$ in any equilibrium, and by Step 2 either $y = 0$ or $\phi_a = 0$. In an equilibrium with $y = 0$, the share of high-type green firms in the pooled disclosure category is $\theta_{g_H}^{\psi}(\phi_a) = \frac{(1-\psi)\mu_{g_H}}{(1-\psi)\mu_{g_H}+\mu_{g_L}+\phi_a\mu_d}$, and condition (25) reads $f^{\psi}(\phi_a;\tau) \geq \kappa_a$, where

$$f^{\psi}(\phi_a;\tau) \;:=\; \frac{\lambda\Delta_a}{1-\beta} + \theta_{g_H}^{\psi}(\phi_a)\frac{\lambda\Delta_s}{1-\beta} + \beta^{\tau}\left(1-\theta_{g_H}^{\psi}(\phi_a)\right)\max\{V_s,0\}.$$

Since $\theta_{g_H}^{\psi}$ is continuous and strictly decreasing and $\frac{\lambda\Delta_s}{1-\beta} > \beta^{\tau}\max\{V_s,0\}$, the function $f^{\psi}(\cdot;\tau)$ is continuous and strictly decreasing, and the adoption share is determined as in Step 1 of the proof of Proposition 3: it equals one if $\kappa_a \leq f^{\psi}(1;\tau)$, equals zero if $\kappa_a \geq f^{\psi}(0;\tau)$, and is the unique solution of $f^{\psi}(\phi_a;\tau) = \kappa_a$ in $(0,1)$ otherwise. We denote it by $\hat{\phi}_a^{\psi}(\tau)$. In any equilibrium, the fraction of dirty firms that adopt in period $t = 0$ is therefore either $\hat{\phi}_a^{\psi}(\tau)$ or zero.[25]

Let $f(\cdot;\tau)$ denote the function corresponding to $f^{\psi}(\cdot;\tau)$ without voluntary disclosure, defined in the proof of Proposition 3. Since $\theta_{g_H}^{\psi}(\phi_a) < \theta_{g_H}(\phi_a)$ at every ϕ_a, we have $f^{\psi}(\cdot;\tau) < f(\cdot;\tau)$, and because both functions are strictly decreasing, $f^{\psi}(\cdot;\tau)$ falls below κ_a weakly earlier than $f(\cdot;\tau)$, so $\hat{\phi}_a^{\psi}(\tau) \leq \phi_a^*(\tau)$. The adoption share in any equilibrium therefore satisfies $\phi_a^{\psi}(\tau) \leq \phi_a^*(\tau)$.

Step 4: Welfare under pooling at the top: Voluntary disclosure consumes no resources, so welfare is the expected discounted social surplus of the reforms undertaken. Consider any equilibrium. If $\phi_a > 0$, then $y = 0$ by Step 2 and $\phi_a = \hat{\phi}_a^{\psi}(\tau)$ by Step 3, so a fraction $\hat{\phi}_a^{\psi}(\tau)$ of dirty firms adopt in period $t = 0$, no firm scales in period $t = 0$, and all low-type green firms scale in period $t = \tau$ in Case 1. Welfare is then given by (20) with $\phi_a^*(\tau)$ replaced by $\hat{\phi}_a^{\psi}(\tau)$, which is increasing in the adoption share, so welfare is weakly below $W^{DT}(\tau)$. If $\phi_a = 0$, no dirty firm adopts. In Case 1, each low-type green firm scales, in period $t = 0$ if it discloses voluntarily and in period $t = \tau$ otherwise, so welfare is at most G_s, which equals W^S. In Case 3, no firm reforms, so welfare is zero, which also equals W^S. Welfare in any equilibrium is therefore weakly below $\max\{W^{DT}(\tau), W^S\}$, which is (22).

Step 5: Firms with access under pooling at the bottom: We take the three firm types in turn and show that a high-type green firm has no reason to disclose voluntarily, that every low-type green firm with access discloses voluntarily and does not scale, and that no dirty firm with access adopts and scales. In particular, no firm with access scales. In Cases 2 and 3 a separately identified firm does not scale, so a firm that discloses voluntarily does not scale. Let θ_d and $\theta_{g_L} = 1 - \theta_d$ denote the shares of dirty and low-type green firms in the pooled disclosure category, with $\theta_d = 1$

[25] An equilibrium exists for every switching period. If $\hat{\phi}_a^{\psi}(\tau) > 0$, the profile with $y = 0$ and $\phi_a = \hat{\phi}_a^{\psi}(\tau)$ is an equilibrium, since condition (25) holds at its composition and condition (24) therefore fails strictly by Step 2. If $\hat{\phi}_a^{\psi}(\tau) = 0$, no dirty firm adopts in any equilibrium, and the equilibrium fraction y is determined by the disclosure condition at a corner or at the indifference point.

when it is empty, so that by equation (9) its expected end-of-period $t = 0$ valuation is

$$V_{\text{pool}} = \frac{\pi + \theta_d \lambda b_d + \theta_{g_L} \lambda b_{g_L}}{1-\beta} + \beta^\tau \theta_d \max\{V_a, 0\}.$$

A high-type green firm is separately identified under pooling at the bottom, so voluntary disclosure leaves its valuation unchanged.

Consider next the voluntary disclosure decision of a low-type green firm with access. Disclosing voluntarily leaves it valued at $\frac{\pi+\lambda b_{g_L}}{1-\beta}$. Not disclosing yields $\max\left\{V_{\text{pool}}, \frac{\pi+\lambda b_{g_H}}{1-\beta} - \kappa_s\right\}$, the higher of remaining in the pooled disclosure category and scaling out of it as a high-type green firm, since a low-type green firm that remains does not scale in period $t = \tau$ in Cases 2 and 3. We compare disclosing voluntarily with each option in turn. Relative to scaling, disclosing voluntarily yields

$$\frac{\pi + \lambda b_{g_L}}{1-\beta} - \left(\frac{\pi + \lambda b_{g_H}}{1-\beta} - \kappa_s\right) \;=\; -V_s \;>\; 0$$

more. Relative to remaining, using $b_{g_L} - b_d = \Delta_a$, disclosing voluntarily yields

$$\frac{\pi + \lambda b_{g_L}}{1-\beta} - V_{\text{pool}} \;=\; \theta_d \left[\frac{\lambda \Delta_a}{1-\beta} - \beta^\tau \max\{V_a, 0\}\right] \;\geq\; 0$$

more, where the bracket is strictly positive because $\max\{V_a, 0\} < \frac{\lambda \Delta_a}{1-\beta}$ by $\kappa_a > 0$. Disclosing voluntarily therefore weakly dominates not disclosing, strictly so whenever $\theta_d > 0$, and $\theta_d > 0$ in any equilibrium: were the pooled disclosure category to contain no dirty firm, every dirty firm without access would have adopted and scaled, which by condition (11) evaluated at $\theta_{g_L} = 1$ requires $V_a + V_s - \frac{\lambda \Delta_a}{1-\beta} \geq 0$, that is, $V_s \geq \kappa_a > 0$, contradicting $V_s < 0$. Every low-type green firm with access therefore discloses voluntarily and, being separately identified, does not scale.

Consider finally a dirty firm with access. By disclosing voluntarily it obtains $\frac{\pi+\lambda b_d}{1-\beta} + \max\{V_a, 0\}$, since it then adopts in period $t = 0$ in Case 2 and undertakes no reform in Case 3. Adopting and scaling jointly without disclosing voluntarily instead makes it a separately identified high-type green firm valued at $\frac{\pi+\lambda b_{g_H}}{1-\beta} - \kappa_a - \kappa_s$, which, using the definitions of Δ_a and Δ_s, equals $\frac{\pi+\lambda b_d}{1-\beta} + V_a + V_s$ and is therefore lower since $V_s < 0$. No dirty firm with access therefore adopts and scales.

Step 6: Firms without access under pooling at the bottom: We show that the firms without access reform exactly as all firms do in the equilibria of Proposition 4, case by case, without determining whether the dirty firms with access disclose voluntarily or remain in the pooled disclosure category. Let θ_d denote the share of dirty firms among the firms remaining in the pooled disclosure category. By Lemma 6, the scaling incentive of a low-type green firm without access and the joint adoption-and-scaling incentive of a dirty firm without access depend on the composition only

through θ_d, are strictly increasing in θ_d, and, at $\theta_d = 1$, reduce to $\kappa_s \leq \overline{\kappa}_s^D(\tau)$ and $\kappa_a + \kappa_s \leq \overline{\kappa}_s^D(\tau)$, the latter being equivalent to $\kappa_s \leq \underline{\kappa}_s^D(\tau)$, as in Step 1 of the proof of Proposition 4. Since every low-type green firm with access discloses voluntarily by Step 5, the pooled disclosure category contains a low-type green firm only if a low-type green firm without access remains in it. We consider the three cases of Proposition 4 in turn.

In case (i), $\kappa_s \leq \underline{\kappa}_s^D(\tau)$. Consider the profile in which every low-type green firm without access scales and every dirty firm without access adopts and scales in period $t = 0$. No low-type green firm then remains in the pooled disclosure category, so $\theta_d = 1$ whatever the dirty firms with access do, and both conditions hold. The reform profile is therefore an equilibrium, and it is the welfare-maximizing one, since no firm with access scales in any equilibrium by Step 5 and the profile maximizes reform on every remaining margin. The firms without access reform as in case (i) of Proposition 4. Dirty firms with access disclose voluntarily, since at $\theta_d = 1$ disclosing weakly dominates remaining, and adopt in period $t = 0$ in Case 2.

In case (ii), $\kappa_s \in (\underline{\kappa}_s^D(\tau), \overline{\kappa}_s^D(\tau)]$. Consider the profile in which every low-type green firm without access scales in period $t = 0$ and no dirty firm without access adopts and scales. Again $\theta_d = 1$ whatever the dirty firms with access do, at which the scaling condition holds and the joint condition fails, so the profile is an equilibrium. Because scaling decisions are strategic complements through θ_d, equilibria in which fewer low-type green firms without access scale may also exist. Welfare differs across equilibria only through this margin and through the timing of adoption by dirty firms with access, since no firm with access scales in any equilibrium by Step 5, no dirty firm adopts and scales because the joint condition fails at every composition, and dirty firms without access adopt in period $t = \tau$ in Case 2 whatever the scaling decisions of low-type green firms. A dirty firm with access adopts in period $t = 0$ if it discloses voluntarily and in period $t = \tau$ if it remains in the pooled disclosure category. In the profile with full scaling, $\theta_d = 1$, so remaining yields $\frac{\pi+\lambda b_d}{1-\beta} + \beta^\tau \max\{V_a, 0\}$, whereas disclosing voluntarily yields $\frac{\pi+\lambda b_d}{1-\beta} + \max\{V_a, 0\}$. Disclosing voluntarily therefore weakly dominates remaining, strictly so if $V_a > 0$, and dirty firms with access adopt in period $t = 0$ in Case 2, the earliest possible date. In any equilibrium with less scaling, $\theta_d < 1$, and dirty firms with access may instead remain and adopt only in period $t = \tau$, which lowers welfare further. The profile with full scaling maximizes reform on every margin and is therefore the welfare-maximizing equilibrium. The dirty firms without access remain in the pooled disclosure category and adopt in period $t = \tau$ in Case 2. The firms without access reform as in case (ii) of Proposition 4.

In case (iii), $\kappa_s > \overline{\kappa}_s^D(\tau)$. Both conditions fail at $\theta_d = 1$ and hence at every composition, so no firm without access scales in any equilibrium, whatever the dirty firms with access do, and the dirty firms without access remain in the pooled disclosure category and adopt in period $t = \tau$ in Case 2. The firms without access reform as in case (iii) of Proposition 4.

In all three cases, the firms without access reform exactly as all firms do in Proposition 4, so

the fraction of low-type green firms that scale in period $t = 0$ is $(1-\psi)\phi_s^*(\tau)$.

Step 7: Welfare under pooling at the bottom: Expected discounted social surplus is linear in the masses of firms undertaking each reform, so contributions can be summed across groups. We first bound the contribution of the firms with access. The high-type green firms undertake no reform. The low-type green firms with access never scale, by Step 5. The dirty firms with access never scale, by Step 5, and adopt at most once, in period $t = 0$ if they disclose voluntarily and in period $t = \tau$ if they remain in the pooled disclosure category, in Case 2 and never in Case 3, so they contribute at most ψG_a in Case 2 and nothing in Case 3, that is, at most ψW^S. The firms with access therefore contribute at most ψW^S.

The firms without access constitute a fraction $1-\psi$ of each type and, by Step 6, reform exactly as all firms do in the corresponding case of Proposition 4. In case (i), all of them adopt and scale or scale in period $t = 0$, contributing $(1-\psi)(G_{a,s}+G_s)$. In case (ii), the low-type green firms scale in period $t = 0$ and the dirty firms adopt in period $t = \tau$ in Case 2, contributing $(1-\psi)\left(G_s+\beta^\tau G_a \mathbb{1}_{\{V_a\geq 0\}}\right)$. In case (iii), only the dirty firms reform, in period $t = \tau$ in Case 2, contributing $(1-\psi)\beta^\tau G_a \mathbb{1}_{\{V_a\geq 0\}}$. In each case, the contribution equals $(1-\psi)W^{DB}(\tau)$ by (21). Summing the two groups gives $W_\psi^{DB}(\tau) \leq (1-\psi)W^{DB}(\tau)+\psi W^S$, and the right-hand side is a convex combination of $W^{DB}(\tau)$ and W^S and therefore at most $\max\{W^{DB}(\tau), W^S\}$, which is (23). ■

Proposition D.1 shows that voluntary disclosure weakens adoption incentives under pooling at the top and scaling incentives under pooling at the bottom. Intuitively, the firms with the strongest incentive to disclose voluntarily are those that are under-valued in the pooled disclosure category, and in both requirements their exit weakens the green transition. Under pooling at the top, high-type green firms are under-valued. Their voluntary disclosure reduces the share of high-type green firms in the pooled disclosure category and with it the mis-valuation subsidy captured by adoption. Under pooling at the bottom, low-type green firms are under-valued and bear the mis-valuation tax. Voluntary Disclosure allows them to avoid the mis-valuation tax without scaling and therefore substitutes for the reform the requirement is designed to induce.

D.1.2 Information Leakage

We now consider information about firm types that reaches the investor independently of green disclosure requirements, for example through media coverage, analyst research, or reports by non-governmental organizations. With probability $\xi \in (0,1)$, independently across firms and independently of firms' reform decisions, a firm's type is publicly revealed at the end of every period, and a firm learns at the beginning of period $t = 0$ whether it is subject to revelation. A revealed firm's type is public whatever it does, so its adoption and scaling incentives are those under strict green disclosure. An unrevealed firm remains subject to the prevailing disclosure requirement, and

the investor values the pooled disclosure category according to the composition of the unrevealed firms in it. In contrast to voluntary disclosure, leakage is not strategic, and, as such, it exposes a representative slice of every firm type. Let $W_\xi(\tau)$ denote welfare under a lax green disclosure requirement with leakage.

Proposition D.2 (Information Leakage)**.** *Consider pooling at the top in Cases 1 and 3 or pooling at the bottom in Cases 2 and 3 and fix the switching period $\tau \geq 1$. Revealed firms reform as under strict green disclosure and unrevealed firms reform as without leakage, so the fraction of dirty firms that adopt in period $t = 0$ under pooling at the top falls to $(1-\xi)\phi_a^*(\tau)$ and the fraction of low-type green firms that scale in period $t = 0$ under pooling at the bottom falls to $(1-\xi)\phi_s^*(\tau)$. Welfare is*

$$W_\xi(\tau) \;=\; \xi\, W^S + (1-\xi)\, W^{\text{lax}}(\tau) \;\leq\; \max\{W^{\text{lax}}(\tau), W^S\}, \tag{26}$$

where $W^{\text{lax}}(\tau)$ is welfare under the requirement without leakage.

Proof of Proposition D.2. Recall that a separately identified firm scales in Case 1 only and adopts in Case 2 only.

Step 1: Revealed firms: A revealed firm is valued at its type in every period, so its incentives coincide with those under strict green disclosure in Lemma 1. Under pooling at the top, a revealed low-type green firm scales in period $t = 0$ in Case 1 and undertakes no reform in Case 3, and a revealed dirty firm undertakes no reform in either case. Under pooling at the bottom, a revealed dirty firm adopts in period $t = 0$ in Case 2 and undertakes no reform in Case 3, and no revealed firm scales.

Step 2: Unrevealed firms: The pooled disclosure category contains only unrevealed firms. Because revelation is independent of type and of reform decisions, a fraction $1-\xi$ of each type is unrevealed, so for any transition shares among the unrevealed firms, the post-transition measure of each type in the pooled disclosure category equals $1-\xi$ times its counterpart in the economy without leakage. The shares θ_i are ratios of these measures and are therefore unchanged, and so are the pooled valuations (7) and (9) and the incentive conditions of Lemmas 5 and 6. The equilibrium transition shares among unrevealed firms therefore coincide with those of Propositions 3 and 4, the welfare ranking of equilibria under pooling at the bottom is unchanged, and reform in period $t = \tau$ follows as in those propositions.

Step 3: Welfare: Expected discounted social surplus is linear in the masses of firms undertaking each reform, so contributions can be summed across groups. The revealed firms constitute a fraction ξ of each type and reform exactly as all firms do under strict green disclosure, contributing ξW^S, and the unrevealed firms constitute a fraction $1-\xi$ of each type and reform exactly as all firms do under the lax requirement without leakage, contributing $(1-\xi)W^{\text{lax}}(\tau)$. This yields (26), and a convex combination cannot exceed the larger of the two levels it combines. ■

Proposition D.2 shows that leakage moves a fraction ξ of the economy from the lax green disclosure requirement to strict green disclosure. The reason is that a revealed firm behaves as under strict green disclosure, while the composition of the pooled disclosure category, and with it the behavior of the unrevealed firms, is unchanged. Welfare with leakage is therefore a weighted average of welfare under strict green disclosure and welfare under the lax requirement without leakage. Intuitively, leakage removes part of the regulator's choice. A fraction ξ of firms is placed under strict green disclosure whether the regulator wants it or not, so the regulator can no longer apply the better of the two requirements to the whole economy. The maximal attainable welfare therefore cannot rise, and it falls whenever the lax requirement is the better of the two.

D.1.3 Optimal Green Disclosure Requirements

Propositions D.1 and D.2 bound welfare under each lax green disclosure requirement for every switching period. The implications for the regulator's problem follow.

Corollary 6 (Optimal Green Disclosure Requirements under Voluntary Disclosure and Leakage)**.** *Under voluntary disclosure and under information leakage, the maximal welfare the regulator can attain across strict green disclosure, pooling at the top, and pooling at the bottom, and switching periods weakly falls, strictly in some cases.*

Proof of Corollary 6. Welfare under strict green disclosure is unaffected by either extension, since firm types are already public. By Propositions D.1 and D.2, welfare under each lax green disclosure requirement with any switching period is weakly below $\max\{W^{\text{lax}}(\tau), W^S\}$, and both levels in this maximum are attainable without the extensions. The maximum over all green disclosure requirements and switching periods with the extensions is therefore weakly below the maximum without it.

For strictness, consider Case 2 with $\kappa_a + \kappa_s \leq \overline{\kappa}_s^D(\tau)$ for some finite switching period τ. By Proposition 5, pooling at the bottom with switching period $\underline{\tau}^D$ then attains the first best, $W^{DB}(\underline{\tau}^D) = G_{a,s} + G_s$, which strictly exceeds $W^S = G_a$. Under information leakage, welfare under pooling at the bottom with any switching period is $\xi W^S + (1-\xi)W^{DB}(\tau) \leq \xi W^S + (1-\xi)(G_{a,s} + G_s) < G_{a,s} + G_s$ by (26). Under voluntary disclosure, welfare under pooling at the bottom with any switching period is at most $(1-\psi)W^{DB}(\tau) + \psi W^S \leq (1-\psi)(G_{a,s} + G_s) + \psi W^S < G_{a,s} + G_s$ by (23). Welfare under strict green disclosure is $W^S < G_{a,s} + G_s$ in either case. In either extension, the maximal welfare is strictly below the first best attained without it. ■

Corollary 6 shows that neither extension raises the welfare the regulator can attain. The reason is that both extensions reduce the effectiveness of lax green disclosure requirements while leaving strict green disclosure unaffected. Intuitively, the value of lax green disclosure requirements rests on the investor's inability to identify firm types by other means. A regulator who implements them

therefore has reason to limit, rather than encourage, the flow of type-revealing information before the switch to strict green disclosure.

D.2 Initial Distribution of Firm Types

This appendix shows that the initial distribution of firm types in the baseline model arises endogenously from an economy in which all firms are initially dirty. We add a pre-period $t = -1$, in which some firms become green for reasons unrelated to green disclosure. We keep the pre-period deliberately stylized to maintain tractability. At the beginning of period $t = -1$, a unit continuum of dirty firms is born and the investor is endowed with each firm's shares. There are no green disclosure requirements in period $t = -1$, so the investor cannot observe firms' types. Apart from the random transition shocks introduced below, period $t = -1$ is otherwise identical to any other period, and the regulator establishes disclosure requirements at the beginning of period $t = 0$ as in the baseline model.

The transition shocks in period $t = -1$ are firm-specific and random, capturing temporary shocks to technology or managerial preferences for green investment. Each firm's adoption cost is $\kappa_a^L < 0$ with probability η_a and $\kappa_a^H > 0$ otherwise, and each firm's scaling cost is $\kappa_s^L < 0$ with probability η_s and $\kappa_s^H > 0$ otherwise, where $\eta_a, \eta_s \in (0,1)$ and the costs are drawn independently across firms and across the two margins. A negative cost amounts to a transition benefit, such as higher profits from a green investment opportunity or a non-pecuniary managerial benefit.[26] We assume that $\kappa_s^L < -\kappa_a^H$ for brevity, so that a scaling benefit more than offsets a high adoption cost. Four types of firms result. A firm with a scaling benefit, whether it faces an adoption benefit or a high adoption cost, can adopt and scale at a net benefit. A firm with an adoption benefit and a high scaling cost can adopt at a benefit, but scaling adds a positive cost. A firm with high costs on both margins faces positive costs for any transition. The benefits are temporary, and from period $t = 0$ onward all firms face the costs κ_a and κ_s of the baseline model.[27] As in the baseline model, observing $\tilde{\pi} - \kappa$ does not allow the investor to draw inference about κ.

The random transition costs and benefits are a parsimonious way to capture the factors that drive heterogeneity in firms' greenness in practice. First, they can reflect temporary shocks to technology. Some firms can adopt or scale the green technology at low cost, or even at a benefit, for example because the green investment is a by-product of other investments, their existing assets are compatible with the green technology, or they have access to a subsidy. Second, they can reflect

[26] Under the managerial-benefit interpretation, the manager maximizes the firm's valuation plus the private benefit.

[27] We confine the random transition costs and benefits to period $t = -1$ for simplicity. If firms also drew transition benefits in some period $t \geq 0$, some firms would reform irrespective of green disclosure requirements. This would add a reason to reform on top of the incentives created by green disclosure requirements and shift the composition of the pooled disclosure categories, which changes the size of the mis-valuation subsidy and tax. The characterization of equilibrium would become more involved, but the remaining firms would face the same incentives qualitatively as in the baseline model, and the fundamental economics of the paper would be unchanged.

managerial preferences. Some managers may derive a private benefit from adopting or scaling the green technology, as we discuss in Section 5, and a negative cost captures a transition benefit that exceeds the transition cost.

Proposition D.3 (Initial Distribution of Firm Types)**.** *In period $t=-1$, firms with a scaling benefit adopt and scale the green technology, firms with an adoption benefit and a high scaling cost adopt the green technology, and no other firm adopts or scales the green technology, irrespective of the disclosure requirement in periods $t \geq 0$ and of firms' and the investor's expectations about it. The economy enters period $t=0$ with masses $\mu_d = (1-\eta_a)(1-\eta_s)$, $\mu_{g_L} = \eta_a(1-\eta_s)$, and $\mu_{g_H} = \eta_s$, and the analysis of Sections 2 to 4 applies unchanged.*

Proof of Proposition D.3. **Step 1: Valuation in period $t=-1$:** Consider a firm that pays the transition cost κ in period $t=-1$, where $\kappa=0$ if the firm does not reform and $\kappa<0$ if the firm reforms at a net benefit. There are no green disclosure requirements in period $t=-1$, so the investor observes neither the firm's type nor its adoption and scaling decisions, and by assumption the realization of $\tilde{\pi}-\kappa$ is uninformative about κ. The investor's information set at the end of period $t=-1$ is thus identical for all firms. Let C denote the investor's expected discounted utility from the firm's social benefit in period $t=-1$ and from its future profits and social benefits, net of future transition costs, given this information set. C depends on aggregate adoption and scaling in period $t=-1$ and on expectations about future disclosure requirements and firm behavior, but it is identical for all firms. The investor's expected end-of-period valuation of the firm is $\pi-\kappa+C$. Since the manager maximizes this valuation, the manager chooses the adoption and scaling decision that minimizes κ.

Step 2: Adoption and scaling decisions: A firm with adoption cost κ_a^i and scaling cost κ_s^j in period $t=-1$, where $i,j \in \{L,H\}$, can incur 0 (no reform), κ_a^i (adoption), or $\kappa_a^i+\kappa_s^j$ (adoption and scaling). If $j=L$, the firm has a scaling benefit and adoption and scaling minimizes κ: since $\kappa_s^L < -\kappa_a^H < 0$, we have $\kappa_a^i+\kappa_s^L < \kappa_a^i$ and $\kappa_a^i+\kappa_s^L \leq \kappa_a^H+\kappa_s^L < 0$. If $j=H$ and $i=L$, the firm has an adoption benefit and a high scaling cost, and adoption minimizes κ, since $\kappa_a^L<0$ and $\kappa_a^L < \kappa_a^L+\kappa_s^H$. If $j=H$ and $i=H$, the firm faces high costs on both margins and does not reform, since $\kappa_a^H>0$ and $\kappa_a^H+\kappa_s^H>0$. None of these decisions depends on C, and hence on the disclosure requirement in periods $t\geq 0$ or on expectations about it.

Step 3: Distribution of firm types: Since costs and benefits are drawn independently across the continuum of firms and independently of each other, a fraction η_s of firms draws a scaling benefit, a fraction $\eta_a(1-\eta_s)$ draws an adoption benefit and a high scaling cost, and a fraction $(1-\eta_a)(1-\eta_s)$ draws high costs on both margins. By Step 2 and the irreversibility of adoption and scaling, the economy enters period $t=0$ with masses $\mu_{g_H}=\eta_s$, $\mu_{g_L}=\eta_a(1-\eta_s)$, and $\mu_d = (1-\eta_a)(1-\eta_s)$, which are strictly positive and sum to one. From period $t=0$ onward, all firms face the costs κ_a and κ_s, the investor has no information about individual firms' types, and the

regulator maximizes the expected discounted aggregate social surplus from period $t = 0$ onward, in which the transition costs and benefits realized in period $t = -1$ are sunk. The environment from period $t = 0$ onward therefore coincides with the baseline model with these initial masses. ■

Proposition D.3 shows that a single pre-period with random transition costs and benefits maps an economy in which all firms are dirty into the initial distribution of firm types of the baseline model. Without green disclosure requirements, the investor cannot distinguish between firms in period $t = -1$, so valuation differences do not drive adoption and scaling decisions. A firm thus reforms if and only if reform gives it a benefit on its own. The transition benefit can represent a non-pecuniary preference gain for the firm's manager or a profit gain from an advantageous green investment shock. Importantly, we do not need to specify what firms and the investor expect about future disclosure requirements. These expectations affect the investor's valuation of all firms in the same way, since the investor cannot distinguish between them, and therefore do not affect any firm's decision to adopt or scale. The initial distribution of firm types is thus the same under every disclosure requirement.

D.3 Green Disclosure Requirements Without Commitment

This appendix analyzes dynamic green disclosure requirements when the regulator cannot commit to the switching period τ. The regulator sets lax green disclosure requirements in period $t = 0$. At the beginning of every period $t \geq 1$ in which lax green disclosure is in place, the regulator chooses whether to keep lax green disclosure in place or to switch to strict green disclosure, so as to maximize the expected discounted aggregate social surplus from period t onward. Managers and the investor anticipate the regulator's decisions.

As in the main text, we restrict attention to equilibria in which reform occurs in period $t = 0$ and upon the switch, and we focus on the welfare-maximizing equilibrium. We extend the convention of Section 1 to the regulator's sequential decision. That is, whenever the regulator is indifferent between keeping lax green disclosure in place and switching, they switch.[28] Throughout, we maintain Assumption 1 and use the welfare notation of Appendix A, with $W^{DT}(\tau)$ and $W^{DB}(\tau)$ in (20) and (21) denoting welfare under dynamic pooling at the top and at the bottom with commitment to

[28]The regulator is indifferent whenever no firm reforms upon a switch. The convention then matters only through the expectations of a firm that deviates and remains in the pooled disclosure category. Under our convention, it expects a switch in period $t = 1$, whereas under the alternative convention that the regulator keeps lax green disclosure in place when indifferent, it expects no switch and faces the incentives of the static requirement. The two conventions yield different outcomes only if $\overline{\kappa}_s^D(1) < \kappa_a + \kappa_s \leq \overline{\kappa}_s$. In this region, the alternative convention supports an equilibrium in which all firms complete their transitions in period $t = 0$, so that the pooled disclosure category is empty on the equilibrium path and not switching is sequentially rational, whereas under our convention joint adoption and scaling in period $t = 0$ requires $\kappa_a + \kappa_s \leq \overline{\kappa}_s^D(1)$. Under the alternative convention, the lack of commitment therefore lowers welfare only if $\overline{\kappa}_s^D(1) < \kappa_s \leq \overline{\kappa}_s < \kappa_a + \kappa_s$, that is, in the upper part of the scaling-only region of static pooling at the bottom, where an immediate switch undoes scaling in period $t = 0$.

switching period τ.

Proposition D.4 (Green Disclosure Without Commitment)**.** *Suppose the regulator cannot commit to the switching period. Under dynamic pooling at the top and under dynamic pooling at the bottom, the regulator switches to strict green disclosure in period $t = 1$, and the equilibrium coincides with that under the corresponding dynamic requirement with commitment to $\tau = 1$. Welfare under dynamic pooling at the top is the same as under commitment. Welfare under dynamic pooling at the bottom is weakly lower than under commitment, and strictly lower if and only if the regulator with commitment strictly prefers the delayed switch $\underline{\tau}^D$ to an immediate switch, that is, if and only if $W^{DB}(\underline{\tau}^D) > W^{DB}(1)$.*

Proof. Consider the regulator's decision at the beginning of period $t = 1$, after period-$t = 0$ reform has taken place. Keeping lax green disclosure in place generates no reform, whereas switching triggers reform by the firms in the pooled disclosure category as under strict green disclosure (Lemma 1). Each such transition generates strictly positive social surplus by the model primitives, and delaying it from period $t = 1$ to a period $T > 1$ scales its contribution by $\beta^{T-1} < 1$. Switching in period $t = 1$ is therefore strictly optimal whenever a positive mass of firms reforms upon the switch. If no firms reform, the regulator switches by our convention. Managers and the investor anticipate the switch in period $t = 1$, so period-$t = 0$ incentives are those of Lemmas 5 and 6 with $\tau = 1$, and the welfare-maximizing equilibrium is that of Propositions 3 and 4 with $\tau = 1$. Welfare is $W^{DT}(1)$ under pooling at the top and $W^{DB}(1)$ under pooling at the bottom.

Under commitment, the regulator chooses the switching period that maximizes welfare. Under pooling at the top, $\tau = 1$ maximizes $W^{DT}(\tau)$ over switching periods, so welfare without commitment, $W^{DT}(1)$, equals welfare under commitment. Under pooling at the bottom, Lemma A.1 shows that the welfare-maximizing switching period is $\tau = 1$ or $\underline{\tau}^D$, so welfare under commitment equals $\max\{W^{DB}(1), W^{DB}(\underline{\tau}^D)\} \geq W^{DB}(1)$, with equality if and only if $W^{DB}(1) \geq W^{DB}(\underline{\tau}^D)$. Welfare without commitment is therefore strictly lower if and only if $W^{DB}(\underline{\tau}^D) > W^{DB}(1)$. This requires $\underline{\tau}^D > 1$, so that an immediate switch does not preserve the period-$t = 0$ reform of the static requirement, but is not implied by it. By Step 3 of the proof of Lemma A.1, if $\kappa_a + \kappa_s \leq \overline{\kappa}_s$ and $\underline{\tau}^D > 1$, the delayed switch attains the first best while an immediate switch yields at most $G_s + \beta G_a < G_{a,s} + G_s$, so the inequality holds. If $\kappa_s \leq \overline{\kappa}_s < \kappa_a + \kappa_s$ and $\underline{\tau}^D > 1$, the inequality reads $G_s + \beta^{\underline{\tau}^D} G_a > \beta G_a$ and holds if and only if the social value of scaling in period $t = 0$ exceeds the social loss from delaying adoption from period $t = 1$ to period $\underline{\tau}^D$. ■

Proposition D.4 shows that without commitment, the regulator switches to strict green disclosure in period $t = 1$. Under pooling at the top, this is the switching period the regulator would commit to, so commitment is immaterial. Under pooling at the bottom, the option value of future adoption dampens period-$t = 0$ scaling when the switch is immediate, so the regulator may

prefer to commit to the delayed switch $\underline{\tau}^D > 1$, which preserves period-$t = 0$ scaling at the cost of delaying adoption. Whenever the regulator would commit to the delayed switch, the lack of commitment lowers welfare.

D.4 Industry Characteristics

This appendix maps the optimal green disclosure requirements to observable industry characteristics. The mapping proceeds in two steps. We first ask which industries are sensitive to green disclosure requirements, and then which requirement is optimal in these industries.

Any green disclosure requirement operates through the differences in valuations it creates across disclosure categories. In the model, these differences are governed by the valuation gain from adoption, $\frac{\lambda\Delta_a}{1-\beta}$, and the valuation gain from scaling, $\frac{\lambda\Delta_s}{1-\beta}$. Both are large when investors care about firm greenness (λ is high) and when the green technology creates substantial dispersion in externalities across firm types (Δ_a and Δ_s are large). An industry is sensitive to green disclosure requirements when both conditions hold. While λ may differ across countries (e.g., Eskildsen et al., 2024), the larger source of variation across industries is likely to be the technology and its externalities.

Suppose the green technology reduces externalities proportionally. Dirty firms in an industry generate a social benefit $b_d < 0$, adoption shrinks the externality by a fraction $\gamma_a \in (0,1)$ to $(1-\gamma_a)\,b_d$, and scaling shrinks it further to $(1-\gamma_a-\gamma_s)\,b_d$, with $\gamma_a+\gamma_s \leq 1$. Then $\Delta_a = \gamma_a\,|b_d|$ and $\Delta_s = \gamma_s\,|b_d|$, so both valuation gains are proportional to $|b_d|$. Heavier polluters (larger $|b_d|$) therefore exhibit larger valuation gains and are more sensitive to green disclosure requirements. The same logic applies when social benefits are positive, as with carbon capture.

The sensitivity to green disclosure requirements is governed not only by the level of externalities but also by their dispersion across firm types, which is captured by the abatement parameters γ_a and γ_s. These parameters measure how much the green technology can reduce the externality. An industry with large $|b_d|$ but small γ_a and γ_s pollutes heavily, yet the technology barely changes the externality, so valuation gains are negligible and green disclosure requirement has little bite despite the high level of emissions. Conversely, an industry with modest emissions but large dispersion across firm types is highly sensitive.

Among sensitive industries, the optimal requirement depends on transition costs relative to these valuation gains. When the adoption cost κ_a and the scaling cost κ_s are low relative to $\frac{\lambda\Delta_a}{1-\beta}$ and $\frac{\lambda\Delta_s}{1-\beta}$, we have $\lambda \geq \overline{\lambda}$ and strict green disclosure implements the first best (Corollary 1). Neither margin is a roadblock, and the optimal requirement is strict and time-invariant. Industries whose emissions stem mainly from purchased electricity, such as office-based services (e.g., banks and software firms), fit this case well. Adoption amounts to hiring staff with expertise in reducing the

carbon footprint of commercial real estate, and scaling to rolling out their plans across the firm's office portfolio, for example by switching the firm's electricity contracts to renewable power or purchasing carbon offsets. Such expertise is abundant, and the switch to renewable power has become inexpensive as the supply of renewable energy has grown. The costs of solar and wind power have fallen at roughly 10 percent per year for decades while real fossil-fuel prices have stayed flat (Way et al., 2022), so that renewables are now among the cheapest sources of electricity in most of the world (Arkolakis and Walsh, 2024). Both transition costs are therefore low, and strict green disclosure alone induces the transition. Consistent with this, large technology firms have become the dominant corporate buyers of renewable power, accounting for roughly half of global corporate clean-energy procurement (BloombergNEF, 2026).

When $\lambda < \overline{\lambda}$, at least one transition margin is a roadblock under strict green disclosure, and Proposition 5 shows that lax green disclosure can be optimal, with the form of pooling determined by which margin is the roadblock. When the main cost lies in developing the knowledge and capabilities to go green, adoption costs are high, adoption is the roadblock, and the relevant lax requirement is dynamic pooling at the top. When the knowledge is available but deploying it throughout the firm is costly, scaling costs are high, scaling is the roadblock, and the relevant lax requirement is dynamic pooling at the bottom. Two industry examples illustrate this mapping.

Automobile: adoption is the roadblock. For an incumbent automaker, the transition to electric vehicles requires substantial R&D, and the firm must build new expertise in batteries, electric motors, and software, which differs fundamentally from combustion-era engineering. Innovation in the auto industry is highly path-dependent (e.g., Aghion et al., 2016), so incumbents with a long history of combustion-engine innovation may find it especially costly to build this expertise. Several incumbents' programs have stalled at this early stage, as with Volkswagen's software unit Cariad (e.g., Reuters, 2023). Adoption costs are therefore high. Once the first electric platform and software exist, deploying them across product lines is comparatively inexpensive, so scaling costs are low. For example, Volkswagen's electric platform underpins ten models from five brands, and Ford agreed to use the same platform for more than a million vehicles in Europe rather than developing its own (e.g., Electrek, 2022; Volkswagen Group, 2022). Our analysis suggests that dynamic pooling at the top can help overcome the adoption roadblock in such industries.

Consumer-facing industries: scaling is the roadblock. For many firms, the emissions that dominate their footprint tend to lie upstream in its supply chain (Hertwich and Wood, 2018). For example, more than 70 percent of the fashion industry's emissions arise in materials production and processing (McKinsey & Company and Global Fashion Agenda, 2020), and nearly two-thirds of Nestlé's emissions stem from agriculture (Nestlé, 2020). The knowledge required to green the supply chain is largely available, as lower-impact inputs and farming practices already exist (Poore and Nemecek, 2018). As a result, adoption, which may involve hiring sustainability expertise, is comparatively inexpensive. The main cost lies in deployment. Greening the entire supplier base

requires re-sourcing inputs, certifying suppliers' processes, and monitoring compliance (e.g., Villena and Gioia, 2020). Nestlé's plan to halve its emissions by 2030 involves more than 500,000 farmers and is budgeted at CHF 3.2 billion over five years (Nestlé, 2020). Scaling costs can therefore be high. Our analysis suggests that dynamic pooling at the bottom can help overcome the scaling roadblock in such industries.

european corporate governance institute

About ECGI

ECGI is an international non-profit membership organisation that provides a platform for debate and dialogue among academics, policymakers, and business leaders, with a focus on major corporate governance, ESG, and stewardship issues.

The views expressed in this working paper are those of the authors, not those of the ECGI or its members.

www.ecgi.global

european corporate governance institute

ECGI Working Paper Series in Finance

Editorial Board

Editor	**Nadya Malenko,** Professor of Finance, Boston College
Consulting Editors	**Renée Adams,** Professor of Finance, University of Oxford
	Franklin Allen, Professor of Finance and Economics, Imperial College London
	Julian Franks, Professor of Finance, London Business School
	Mireia Giné, Professor of Finance, IESE Business School
	Marco Pagano, Professor of Economics, Facoltà di Economia Università di Napoli Federico II
Series Manager	**Asif Malik,** ECGI Working Paper Series Manager

https://www.ecgi.global/publications/working-papers