# The Dynamics of ESG Investment Under Uncertainty and Externalities

## A Conceptual and Formal Sketch Toward a Systems-Based Model

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## Abstract

This paper develops a conceptual and formal framework for analyzing ESG investment as a dynamic decision problem characterized by delayed payoffs, partial observability, externalities, and strategic interdependence. While modern research increasingly recognizes ESG as economically relevant rather than purely ethical, existing models of managerial behavior often rely on structural assumptions that are poorly matched to the decision environment ESG entails. The framework proposed here distinguishes between latent ESG capital and observable ESG signals, allowing for divergence between substantive impact and perceived performance, and explicitly models noisy feedback, belief-based decision-making, and the role of peer behavior. By combining elements from dynamic optimization, signaling theory, and public goods models, the paper offers a unified structural lens through which common ESG pathologies such as underinvestment, symbolic compliance, herding, and inertia emerge as predictable outcomes of system design rather than individual failure. The contribution is not a fully solved model but a structured sketch intended to clarify mechanisms, motivate future formal analysis, and provide a foundation for subsequent theoretical and empirical extensions.

## Introduction

*"Instead of economy being embedded in social relations, social relations are embedded in the economic system."*
— Karl Polanyi, The Great Transformation

Economic thought has long been shaped by the idea that firms are autonomous agents operating in an abstract market environment, guided primarily by prices, contracts, and profit maximization. In this view, social outcomes emerge indirectly from local optimization, and questions of responsibility are largely external to the firm's objective function. Polanyi's observation challenges this abstraction. It suggests that the organization of economic activity is not merely a matter of efficiency, but a structural force that reshapes social relations.

Whether one agrees with Polanyi's argument in full or not, the broader implication is difficult to dismiss. Large firms do not operate in a social vacuum. They allocate resources, shape labor markets, influence political processes, and transform local environments. Their decisions affect do not only shareholders, but also employees, communities, and future economic conditions. Therefore modern corporations are not just profit-maximizing units, but central parts of our society.

This perspective has increasingly entered economic and managerial discourse. From stakeholder theory to contemporary work on corporate governance and sustainability, firms are now frequently described as systems of relationships rather than isolated optimizers. Environmental, Social, and Governance (ESG) considerations represent one concrete expression of this shift. It is an attempt to formalize the idea that corporate decision-making has consequences that extend beyond short-term financial performance.

Yet acknowledging that firms are socially embedded does not, by itself, explain how such considerations are incorporated into actual managerial decisions. Nor does it clarify why ESG investment remains uneven,

contested, and often superficial despite widespread recognition of long-term environmental and social risks. (citation from a research paper about esg superficiality). Understanding this tension requires moving beyond normative claims about what firms should do, toward a structural analysis of how firms do decide under uncertainty, delayed feedback, and strategic interdependence.

## ESG in Modern Academics: Risk, Strategy, and Institutional Design

Modern academic researcg rarely treats ESG as a purely ethical add-on to business decision-making. Instead, it frames ESG as a structural feature of corporate strategy, governance, and financial markets. A growing body of literature documents that environmental, social, and governance considerations are now embedded in how investors evaluate firms, how boards design governance structures, and how managers respond to external scrutiny.

One of the strongest empirical claims in modern literature concerns the relationship between ESG performance and financial outcomes. Friede, Busch, and Bassen (2015), provide evidence from more than 2,000 empirical studies and conclude that roughly 90% of studies find a non-negative relationship between ESG criteria and corporate financial performance, with the majority reporting a positive association. Importantly, they emphasize that this relationship appears stable across time, regions, and asset classes, suggesting that ESG integration is not merely a transient market trend but reflects deeper economic mechanisms.

This evidence has shaped how ESG is conceptualized in both finance and management research. Rather than being treated as a "constraing", ESG is increasingly framed as a part of long-term risk management, organizational resilience, and strategic positioning. Recent systematic reviews of the investment literature find that ESG factors are widely recognized as influential in sustainable investment decision-making, and that investors increasingly incorporate ESG criteria when assessing firm quality, long-term viability, and ethical legitimacy. Rubab et al. (2025), reviewing 163 academic studies using a structured PRISMA methodology, conclude that ESG considerations now play a central role in how sustainable investment opportunities are evaluated across markets.

Governance literature similarly treats ESG as structurally embedded within organizational design rather than as an external moral overlay. Buchetti et al. (2025), reviewing 91 high-quality academic articles across leading journals, show that corporate governance characteristics systematically influence ESG outcomes. Board composition, director independence, institutional ownership, executive incentives, and the existence of sustainability committees all appear to shape how firms integrate ESG into decision-making and disclosure practices. The authors emphasize that ESG is increasingly understood not as a peripheral metric, but as an indicator of how firms structure responsibility, accountability, and long-term orientation.

At the same time, the literature also highlights fundamental structural tensions within the ESG ecosystem. Perhaps the most striking evidence comes from Berg, Kölbel, and Rigobon (2022), who document substantial divergence across major ESG rating providers. Using data from six prominent agencies, they show that correlations between ESG ratings range only from 0.38 to 0.71, and that this disagreement is driven primarily by differences in measurement and scope rather than by weighting schemes. Importantly, they argue that such divergence weakens incentives for firms to improve ESG performance, as managers receive inconsistent and often contradictory signals about which actions will be rewarded by the market. In their words, ESG rating divergence introduces uncertainty into decision-making and may lead to systematic underinvestment in ESG improvement activities.

## Why ESG Decision-Making Is Structurally Difficult

If contemporary scholarship increasingly recognizes ESG as economically relevant, this does not resolve a more puzzling observation: despite widespread awareness, adoption remains uneven, often superficial, and frequently reactive rather than strategic. From a modeling perspective, this inconsistency is not primarily a failure of motivation, but a consequence of the structural environment in which ESG decisions are made.

Several features distinguish ESG investment from more conventional managerial choices.

Many ESG investments exhibit long, uncertain, and sometimes non-financial payoff structures. Environmental mitigation efforts may reduce tail risk decades into the future. Investments in workforce well-being may affect culture gradually and governance reforms may only matter under rare stress scenarios. Unlike conventional capital investments, where expected returns can be forecast within some precision, ESG actions often generate benefits that are probabilistic, nonlinear, and temporally distant. From a formal perspective, this transforms ESG investment into a problem of intertemporal choice under uncertainty, rather than standard discounted optimization.

Managers do not directly observe the true "state" of their firm's ESG performance. Instead, they receive indirect, noisy signals: ESG ratings, stakeholder reactions, media narratives, regulatory attention, investor sentiment. As documented by Berg, Kölbel, and Rigobon (2022), even professional ESG raters disagree substantially on firm performance, meaning that the feedback environment itself is structurally unreliable. For modeling purposes, this implies that ESG decision-making resembles a partially observed system, where agents must act under uncertainty about both the underlying state and the accuracy of feedback.

Many ESG investments generate benefits that extend beyond the firm undertaking them. Reductions in emissions, improvements in supply chain standards, or investments in community resilience produce positive externalities that competitors, consumers, and society at large may enjoy. From the perspective of any single firm, the private return on investment may therefore be strictly lower than the social return. This difference between private and collective payoff discourages individual, even when all actors agree that the long-term outcome is desirable.

These externalities give rise to classic free-rider problems. If competitors are investing heavily in ESG improvements, a firm may rationally choose to underinvest while still benefiting from industry-wide reputational uplift, regulatory easing, or ecosystem stability. Conversely, if others are not investing, a firm may perceive its own efforts as inconsequential. The resulting incentive structure does not require cynicism or bad faith to generate underinvestment. It is an equilibrium feature of the environment.

Because many ESG outcomes are difficult to observe directly, firms face strong incentives to prioritize actions that are visible rather than those that are effective. This distinction between symbolic and substantive action is well documented in the literature on ESG disclosure and greenwashing, but it also has clear modeling implications. When rewards are tied to noisy proxies, agents rationally optimize for the proxy rather than the underlying construct. From a formal perspective, this introduces a difference between the latent state variable (true ESG impact) and the observed signal (reported or rated ESG), distorting incentives even under rational behavior.

Finally, ESG decisions are rarely made in isolation. Firms observe competitors, benchmark against peers, and react to evolving industry norms. The perceived marginal impact of ESG investment often depends on what others are doing. A single firm acting alone may view its contribution as negligible, while coordinated movement can produce large effects. This creates strategic complementarities and multiple possible equilibria. Industries may become trapped in low-investment regimes not because actors reject ESG in principle, but because no single firm wishes to move first.

Taken together, these features suggest that ESG decision-making is not well described by static cost–benefit frameworks. Instead, it more closely resembles a dynamic, partially observed, strategically coupled system with delayed feedback and distorted incentives. The inconsistencies observed in real-world ESG behavior may therefore be less a puzzle of ethics and more a predictable consequence of structure.

## From Managerial Choice to Formal Models of Behavior

The idea that managerial behavior can be modeled formally is not new. A substantial body of economic theory has sought to describe how decision-makers allocate effort, respond to incentives, and balance competing objectives under uncertainty. Classic agency models frame managers as rational agents operating under imperfect contracts, where observable performance measures imperfectly proxy for true value creation. Holmström and Milgrom's multitasking framework, for example, shows how tying rewards to measurable outputs can systematically distort effort toward what is easily observed rather than what is socially optimal. Career

concerns models extend this logic by emphasizing reputation dynamics: managers optimize not only for firm outcomes, but also for how their actions are interpreted by external audiences over time.

More broadly, modern work in behavioral economics, organizational economics, and dynamic optimization increasingly recognizes that real-world decision-making unfolds in environments characterized by delayed feedback, limited information, and strategic interdependence. Models of learning under uncertainty, signaling, coordination, and dynamic games have all been used to explain why individually rational actors often produce collectively suboptimal outcomes. These frameworks share a common insight. Observed behavior frequently reflects the structure of the environment rather than the moral quality or competence of the decision-maker. The question, then, is not whether such models exist, but whether they adequately capture the structural peculiarities of ESG decision-making.

The existing modeling tradition provides powerful tools for understanding incentives, information, and strategic behavior. However, most applications remain narrowly structured: incentives are often static, payoffs are assumed to be reasonably well-defined, information is simplified, and interactions across agents are either ignored or treated in stylized ways. These assumptions are not unreasonable for many domains. They are, however, increasingly misaligned with the structure of ESG decision-making.

This project departs from the standard framing in three ways. First, it treats ESG investment as a dynamic process rather than a one-shot choice. The relevant object is not whether a firm "does ESG," but how ESG-related states evolve over time under repeated decisions, delayed effects, and accumulated consequences. Second, it explicitly models ESG as a partially observed system. Managers are not assumed to observe the true quality or impact of their actions, but instead update beliefs based on noisy, socially mediated signals such as ratings, stakeholder reactions, and market narratives. Third, it embeds decision-makers in a strategically coupled environment, where the perceived value of ESG action depends on what others do. This introduces coordination problems, free-riding incentives, and the possibility of multiple long-run regimes rather than a single equilibrium outcome.

The shift is therefore not merely thematic but instead structural. Instead of asking how a representative manager optimizes under a given contract, the focus becomes how patterns of behavior emerge from interacting agents operating under delay, uncertainty, and distorted feedback. The goal is not to propose a new normative theory of corporate responsibility, but to offer a formal lens through which common ESG pathologies such as superficial compliance, underinvestment, herding, and inertia arise as predictable outcomes of system structure rather than individual failure.

# A conceptual Model Framework

This section introduces a minimal structural framework for analyzing ESG decision-making. The objective is not to solve the model fully, but to make explicit the mechanisms that distinguish ESG investment from standard managerial control problems.

##€ Latent ESG Capital and Real Investment

Let $x \in \mathbb{R}$ denote the firm's latent ESG capital at time $t$. This variable represents the true long-run quality of the firm's environmental, social, and governance practices. It is not directly observable by external stakeholders and evolves gradually over time.

Managers choose a level of substantive ESG investment $u_t \geq 0$*, which affects the evolution of $x_t$ according to.

$$x_{t+1} = (1 - \delta)x_t + g(u_t) + \eta_{t+1}$$

Where $\delta$ captures depreciation or erosion of ESG capital, $g(\cdot)$ is increasing and concave, reflecting diminishing returns to investment, and $\eta_{t+1}$ is an exogenous shock capturing unforeseen ESG-related events (e.g., unforseen shocks in supply chains, scandals). This formulation emphasizes that ESG performance is best understood as a slowly evolving stock rather than a contemporaneous outcome.

*There is an argument to be made about negative $u_t$, however that is left out of this framework.

### Signaling & the Perception Channel

In addition to substantive investment, managers may engage in symbolic or signaling activity $s_t \geq 0$, such as ESG disclosure, public communication, branding, or compliance-oriented actions designed primarily to influence perceptions. External observers do not observe $x_t$ directly. Instead, they observe a noisy signal:

$$y_t = h(x_t, s_t) + \epsilon_t$$

Where $y_t$ is perceived ESG performance (e.g. ratings, reputation), $h(\cdot)$ is increasing in both arguments ($h_x > 0, h_s > 0$) and $\epsilon_t$ is noise.

This separation between latent substance $x_t$ and the observable signal $y_t$ is central. It formalizes the structural possibility of divergence between real impact and perceived performance, without invoking behavioral assumptions.

### Partial Observability & Belief Dynamics

Because $x_t$ is not directly observable, the manager does not condition decisions on the true state, but on a belief about it.

Let $\mu_t = \mathbb{E}[x_t \mid \mathcal{I}_t]$ denote the manager's belief about ESG capital given information $\mathcal{I}_t$ which includes past signals and actions. In a linear-Gaussian setting, belief updating can be represented as:

$$\mu_{t+1} = (1 - \delta)\mu_t + g(u_t) + K_t \left( y_t - \mathbb{E}[y_t \mid \mathcal{I}_t] \right)$$

where $K_t$ is an updating gain increasing in signal precision. When signals are noisy or inconsistent, learning is weak, and optimal behavior places less weight on long-run state accumulation. Here we try to capture the idea that ESG decision-making operates under epistemic uncertainty rather than full information.

### Preferences and Intertemporal Objectives

Managers receive payoffs that depend on both perception and fundamentals. Let per-period utility be:

$$\pi_t = F_t + \alpha R(y_t) + \beta B(x_t) - C(u_t) - D(s_t)$$

Where:

- $F_t$ represents short-term firm performance,
- $R(y_t)$ represents reputational, market, or career rewards tied to perceived ESG,
- $B(x_t)$ captures long-run fundamental benefits from true ESG capital,
- $C(\cdot)$ and $D(\cdot)$ are convex cost functions,
- $\alpha, \beta \geq 0$ weight of perception vs fundamental benefits.

Then the manager's objective is:

$$\max_{\{u_t, s_t\}} \mathbb{E} \left[ \sum_{t=0}^{\infty} \gamma^t \pi_t \right]$$

With the discount factor $\gamma \in [0, 1]$. This structure proposes that even fully rational agents may allocate effort toward signaling rather than substance when rewards depend more strongly on perception than on latent impact.

**Externalities & Public ESG Stock**

Some ESG outcomes generate benefits that extend beyond the individual firm. Let $z_t$ denote a public ESG stock (e.g. environmental quality, institutional trust), evolving as:

$$z_{t+1} = (1 - \rho)z_t + \frac{1}{N}\sum_{i=1}^{N} \phi g(u_{i,t}) + \xi_{t+1}$$

Where $\rho$ is the decay parameter and $\phi$ scales the contribution of firm-level investment. Now let firm-level long-run benefits depend on both private and public stocks:

$$B = B(x_{i,t}, z_t)$$

Since individual firms internalize only a fraction of the benefits of $z_t$ equilibrium investment is generically inefficiently low even under fully rational behavior. This generates a structural free-rider problem.

**Strategic Interdependence & Coordination**

Finally, ESG payoffs often depend on peer behavior. Let reputational rewards depend on relative performance:

$$R_i = R(y_{i,t} - \bar{y}_t), \bar{y}_t = \frac{1}{N}\sum_j y_{j,t}$$

or more generally exhibit complementarities:

$$R_i = R(y_{i,t}, \bar{y}_t), \frac{\partial^2 R}{\partial y \partial \bar{y}} > 0$$

This introduces coordination effects and allows for multiple equilibria: low-ESG traps, herding, and regime shifts following regulatory or informational shocks.

# Future Directions

This paper represents an early-stage conceptual and formal sketch rather than a completed theoretical model. Its purpose is to clarify structure, define modeling primitives, and motivate a research direction. The framework is therefore intentionally minimal, and several natural extensions remain open. These extensions form the basis for ongoing work and will likely shape the eventual direction of the author's M.Sc thesis.

A first avenue concerns formal analysis of the model dynamics. The current framework is presented at the level of structure rather than solution. Future work will explore equilibrium behavior under specific functional forms, derive comparative statics, and analyze conditions under which phenomena such as underinvestment, signaling dominance, or regime shifts emerge. This may involve dynamic programming, continuous-time formulations, or simulation-based approaches depending on tractability.

A second extension concerns heterogeneity across agents and environments. Firms differ in governance structures, ownership, regulatory exposure, time horizons, and stakeholder pressure. Introducing heterogeneity in parameters such as discounting, signal sensitivity, or reputational incentives would allow the framework to speak more directly to observed variation across industries and institutional contexts.

A third direction involves linking the conceptual model to empirical structure. While the current paper is theoretical, the framework naturally generates testable implications. For example, it predicts systematic divergence between symbolic and substantive ESG actions under noisy evaluation regimes, stronger ESG investment when signals are more standardized, and nonlinear responses to regulatory coordination. Future work may explore whether such implications can be mapped to available data on ESG ratings, disclosure practices, financing costs, or industry-level adoption dynamics.

Finally, the model itself is likely to evolve. The current separation between latent ESG capital, perceived signals, and public ESG stock is one plausible abstraction, not a definitive one. As the project develops, the structure may be refined, simplified, or partially replaced in response to mathematical tractability, conceptual clarity, or empirical relevance.

The ambition is not to defend a specific model architecture, but to develop a rigorous, coherent way of thinking about ESG decision-making as a dynamic system. This paper should therefore be read as a starting point rather than a conclusion.

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