
Management Science

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https://pubsonline.informs.org/journal/mnsc

MANAGEMENT SCIENCE
*Articles in Advance*, pp. 1–20
ISSN 0025-1909 (print), ISSN 1526-5501 (online)



# The (Limited) Power of Blockchain Networks for Information Provision

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**Received:** May 29, 2020
**Revised:** July 22, 2021; September 29, 2022; January 26, 2023
**Accepted:** January 31, 2023
**Published Online in Articles in Advance:** March 10, 2023

https://doi.org/10.1287/mnsc.2023.4718



**Abstract.** We investigate the potential and limits of privacy-preserving corporate blockchain applications for information provision. We provide a theoretical model in which heterogeneous firms choose between adopting a blockchain application or relying on traditional third-party intermediaries to inform the capital market. The blockchain's ability to generate information depends on each firm's data profile and all firms' endogenous adoption decisions. We show that blockchain technology can improve the information environment and outperform traditional institutions with firms' adoption decisions serving as a credible value signal and the application uncovering firm values by analyzing all participating firms' data. However, we also characterize an adverse mixed-adoption equilibrium in which neither of the two channels realizes its full potential and information provision declines not only for individual firms, but also in aggregate. The equilibrium is a warning sign that has broad implications for policymakers' regulatory effort and investors' assessment of corporate blockchain applications.

**History:** Accepted by Suraj Srinivasan, accounting.



**Funding:** B. Franke and Q. Gao Fritz gratefully acknowledge financial support from the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) Project-ID 403041268–TRR 266 Accounting for Transparency. A. Stenzel gratefully acknowledges financial support from the DFG through CRC TR 224 (Project C03) during prior employment at the University of Mannheim.

**Supplemental Material:** The online appendix is available at https://doi.org/10.1287/mnsc.2023.4718.

**Keywords:** blockchain • disclosure • information provision • peer-to-peer network

## 1. Introduction

Recent innovations in computer science have fueled the belief that new technologies will improve information provision and eliminate the need for third-party intermediaries. A prime example is blockchain technology that originated as the distributed ledger technology behind the cryptocurrency Bitcoin. Blockchains are peer-to-peer networks designed to keep records of participating parties and can be programmed to analyze or validate data automatically. This functionality offers far-reaching potential, especially in accounting and finance.[1] Policymakers are increasingly active in promoting and creating a regulatory basis for blockchain applications.[2] However, the technology's economic impact is still largely unknown. This paper offers new insights by analyzing the potential and limits of corporate blockchain applications for information provision. We model blockchain technology as a disclosure regime of endogenous strength that leverages participating firms' data to generate information and ensure the necessary data privacy. A central result of our analysis is that such blockchain applications can lead to a deterioration of information provision not only for individual firms, but also for the economy in aggregate.

Firms' data carry valuable information about their behavior, profitability, or economic value that the capital market wants to access for decision making. However, it is usually not optimal for firms to disclose granular data voluntarily, for example, because of proprietary disclosure cost (e.g., D'Souza et al. 2010, Ebert et al. 2017). There are also limits to the amount of information and detail required in mandatory disclosures because it can distort investment incentives or create tensions between managers and shareholders (e.g., Berger and Hann 2007, Arya et al. 2013, Schneider and Scholze 2015, Jayaraman and Wu 2019). Traditionally, this has resulted in firms providing aggregate disclosures and investors relying on third-party intermediaries, such as auditors, analysts, or rating agencies, to generate and verify disclosures.

Corporate blockchain applications are set to rival these intermediaries by offering alternative means of creating and disseminating credible disclosures. Most applications rely on private blockchains utilizing the distributed ledger technology to digitize services as code and deliver them via technical and operational layers.[3] Whereas numerous incarnations exist, all share the core capability of generating information by utilizing participating firms' data (Cong and He 2019). Essentially, the private blockchains keep participating firms' data without exposing individual records—which is crucial in the corporate context—and host applications that analyze the linked data autonomously, for example, by cross-referencing records or predictive analyses (e.g., Yermack 2017, Narang et al. 2019, Bakos et al. 2021).[4] The outcome is usually shared via public-facing services in the form of predefined aggregate metrics, such as scores or ratings. Conceptually, blockchain technology enables a transition from a situation in which informativeness and credibility of disclosures derives from third parties to one in which it derives directly from the network that holds the data.

Whether the transition from a third-party to a blockchain-based system improves information provision critically depends on firms' adoption decisions because blockchain's information capabilities rest on connecting and analyzing previously isolated data sources. Adoption incentives are inherently firm-specific. They ultimately depend on a firm's desire to provide information and the extent to which other firms' data are informative about a given firm. Each firm's adoption decision also imposes an externality on the other firms in the economy, making the overall information provision the result of a complex coordination game.

Consider a blockchain application, such as GumboNet ESG, that uses firms' operational data to generate metrics for environmental, social, and governance (ESG) disclosures. ESG reporting is still largely voluntary but will likely become mandatory soon (see the recently proposed disclosure mandate by the Securities and Exchange Commission (2022)). Such an area is promising for blockchain applications because it relies on access to sensitive data from various parties, such as buyers, suppliers, or logistics, and requires a high level of assurance, and traditional institutions are not yet well-entrenched (see, e.g., Simnett et al. 2009, Pflugrath et al. 2011, Casey and Grenier 2015, Caglio et al. 2020, Christensen et al. 2021). Informational externalities arise because ESG-related data regularly carry information on other firms' ESG performances. For instance, a firm's emission data can inform about other firms' emissions either directly, for example, suppliers contribute to producers' overall emissions under the widely used greenhouse gas (GHG) protocol or, indirectly, by serving as reference points. As such, the more firms contribute data to the blockchain, the more complete the picture of firms' performance becomes.

An environmentally friendly firm striving to signal its type should be more likely to adopt the blockchain application when it expects more firms to contribute data. However, whether the adoption actually improves the firm's ability to signal its type also depends on its fit with the other firms' data, that is, how much their data are predictive of its environmental friendliness. Whereas the data on the blockchain may be more indicative of one firm's environmental friendliness, it may be less indicative of another firm's. For example, other firms' data are arguably more likely to reveal information about the firm when they share similar business models or technologies.[5] Moreover, each firm's adoption decision itself can serve as a signal. Depending on the pool of expected adopters, forgoing traditional third-party services can reveal information about a firm's type.

To study the impact of blockchain technology on information provision, we introduce a model that captures the essential features driving firms' adoption decisions in a disclosure setting. Heterogeneous firms simultaneously decide whether to rely on an exogenous disclosure regime—the traditional institutions—or adopt a disclosure regime with endogenous and firm-specific strength: the blockchain application. Each firm is characterized by a privately known, two-dimensional type that consists of its value, which can be high or low, and its fit for being analyzed by the blockchain, which can be good or bad. Firms select the disclosure regime that maximizes their expected market valuation. Naturally, high-value firms seek information provision to separate from low-value firms, and low-value firms attempt to hide and pool with high-value firms (as in, e.g., Verrecchia 1983, Dye 1985, Jung and Kwon 1988).

Firms trade off between the blockchain application that assesses participating firms' data and traditional intermediaries. The blockchain publicly disseminates an aggregate signal containing either a firm's actual value or no information. The probability that a firm's value is revealed—synonymous with the signal's informativeness—increases both in how many firms adopt the blockchain—its reach into the economy—and the fit with the firm's data profile. Traditional institutions reveal a firm's value with an exogenous probability shared by all firms, representing the average capabilities of all nonblockchain institutions. This approach implicitly incorporates a comparative advantage of traditional institutions in assessing data that are inherently challenging to analyze for the blockchain. Both systems come at a fixed cost, and the blockchain application can be costlier or cheaper than traditional institutions.

We begin our analysis by studying a baseline setting in which the information generation by traditional institutions is muted and blockchain adoption is costly. This setting allows us to cleanly identify two channels through which the technology can provide information. First, firms' adoption decisions may signal their value types. When adoption costs are sufficiently high, only high-value firms join the blockchain in equilibrium, and market participants perfectly learn all firms' values. Second, the blockchain's distributed ledger capabilities may generate information about participating firms. If adoption costs are sufficiently low, some low-value firms join the high-value firms in the blockchain. Whereas the signal from observing firms' adoption decisions becomes less informative, more firms contributing data to the network improves its ability to generate information.

In the generalized setting, we let the relative informativeness of the blockchain and traditional institutions depend on firms' equilibrium actions entirely. Traditional institutions provide information about nonadopting firms and may be costlier or cheaper than the blockchain application. Whereas both information-provision channels from the baseline setting carry over, the key takeaway is the emergence of a novel equilibrium in which a mix of high- and low-value firms is present both inside and outside the blockchain. In this equilibrium, neither the signaling nor the actual information-generation channel work to their full potential. Although blockchain technology can improve the information environment, we provide sharp conditions for when this potential is not realized. Specifically, average mispricing in the economy may increase because of the emergence of blockchain technology and information provision deteriorate not only for individual firms but also in aggregate. Importantly, the adverse outcome results from a blockchain-induced coordination game and not blockchain being an inherently bad technology to generate information. Information provision may deteriorate in equilibrium even when blockchain technology is, in principle, beneficial and would improve the information environment under (mandated) full adoption.

The adverse mixed-adoption equilibrium is a warning sign offering broader implications for policymakers and capital market participants. For instance, economies with intermediate traditional institutions are more likely to suffer from a decrease in information provision unless the institutions are sufficiently strong to rule out the mixed-adoption equilibrium. Moreover, the emergence of blockchain technology results in a complex coordination game in which heterogeneity in firms' fit makes a lack of coordination more likely. The heterogeneity not only impedes the blockchain's capabilities to analyze a given firm's data but also weakens the signaling value of firms' endogenous adoption decisions. Policymakers should, therefore, monitor potential adopters and provide incentives to keep heterogeneity low, for example, in the form of monetary incentives or regulatory relief. However, there is no simple immediate regulatory solution. For example, mandating blockchain adoption for all firms, in the spirit of requiring audited financial statements from public firms, is not unambiguously optimal concerning overall welfare. Although this would eliminate the coordination problem, mandating adoption entails direct costs for all firms and may additionally harm the information environment when there is a sufficient proportion of firms for which the blockchain is an inherently bad technology.

Our study contributes to the literature on emerging technologies in accounting and finance and specifically on the informational aspects of blockchain technology. Most studies concentrate on the technical feasibility (e.g., Vukolić 2015, Christidis and Devetsikiotis 2016, Du et al. 2017) and discuss potential benefits and obstacles associated with specific applications (e.g., Yermack 2017, Wang and Kogan 2018, Cao et al. 2020, Chod et al. 2020, Abadi and Brunnermeier 2022). Dai and Vasarhelyi (2017) emphasize that the blockchain could enable a real-time, verifiable, and transparent accounting ecosystem by enabling timely examinations of potential errors via automatic verification of transactions using data from other participants. The blockchain in our model explicitly features these peer-to-peer capabilities, also ensuring the data privacy necessary in the corporate context (e.g., Narang et al. 2019, Bakos et al. 2021).

A growing list of studies explores the economic implications of blockchain adoption with a focus on cryptocurrencies and smart contracts (e.g., Fanning and Centers 2016, Cong and He 2019, Easley et al. 2019, Cong et al. 2021, Lumineau et al. 2021, Chod and Lyandres 2022). Most closely related to our study is Cao et al. (2019), who focus on auditors integrating blockchain into their audit technology. They examine the effects of auditors' adoption and analyze audit market competition, audit quality, and client misstatements. In their setting, an outside party, such as a regulator, may have to "select" an equilibrium to ensure lower misstatements, audit effort, and regulatory costs. We complement their work by studying firms' adoptions in a disclosure setting and providing policy implications for when blockchain is either a rival or a substitute for traditional institutions.

By considering firms' adoption decisions and the endogenous strength of blockchain, our model relates to positive accounting theory studying the development of accounting-related institutions (Dye and Sridhar 2008; Bertomeu and Magee 2011, 2015a, b; Chen and Yang 2022). The endogenous nature of the blockchain's strength also differentiates us from other blockchain-related studies, such as Chod et al. (2020), that focus on the benefits of blockchain-enabled supply chain transparency. Our model further speaks to the research concerning firms' ex ante commitment to a disclosure regime (e.g., Ferreira et al. 2012, Hermalin and Weisbach 2012, Edmans et al. 2016, Heinle and Verrecchia 2016). For example, Heinle and Verrecchia (2016) consider homogeneous firms that can commit to a disclosure regime but ex post have some discretion about the information being revealed. In contrast, we consider heterogeneous firms that can commit to a disclosure regime—the blockchain—characterized by an endogenous probability of revealing a firm's value.

Finally, our paper relates to the broad literature on multisided markets and network effects going back to Katz and Shapiro (1985) (see Rochet and Tirole 2006, Farrell and Klemperer 2007, for overviews). Specifically, the blockchain in our model operates as a platform, and firms' adoption decisions impose externalities on other participating firms. However, our model differs from existing studies by abstracting from a (product market) game on the platform and instead focusing on complex network effects that are inherent to blockchain applications in a disclosure context. The complexity originates from two sources. First, a heterogeneous fit with the technology implies differences in the extent to which firms benefit from other firms joining the blockchain. Studies with this type of explicit heterogeneity are comparatively scarce with the notable exception of Weyl (2010) and recent work by Jeitschko and Tremblay (2020). Second, other firms' adoption decisions not only affect the informativeness of the blockchain, but also the pooling price of nonidentified firms with the informativeness and pooling price impacting other firms differentially.

The paper proceeds as follows. Section 2 illustrates the common corporate blockchain architecture and the economic setting. Section 3 introduces the model setup and key assumptions. Section 4 contains the analysis of the key mechanisms and the general model. Section 5 discusses additional considerations and the robustness of our model. Section 6 concludes.

## 2. Background

We next introduce the basic architecture of corporate blockchains hosting existing applications, such as GumboNet ESG, IBM Food Trust, GuildOne, or Bloom, and highlight the key factors determining their capabilities to generate information.[6]

Most people associate the word "blockchain" with public blockchains such as Bitcoin and Ethereum. These decentralized networks are permissionless and rely on an associated cryptocurrency, for example, bitcoin or ether, to incentivize participants (miners) to maintain the network. Permissionless networks prosper when numerous mistrusting parties interact and cannot or do not want to rely on a third party to maintain the ledger. However, this feature of public blockchains also induces scalability and privacy issues, making them largely unfit for corporate use (e.g., Fanning and Centers 2016, Yermack 2017, Bakos and Halaburda 2021, Chen et al. 2021).[7]

Corporate blockchains are predominantly private and permissioned blockchains tailored to address corporate-specific needs, such as data privacy, versatility, and governance control. Private blockchains do require a third party to maintain the network but, in return, provide confidentiality of participants and data at scale; data can only be read by explicitly permissioned users. Third parties that host private blockchains rely on trust in a traditional sense, for example, based on reputation and contractual enforcement outside the ecosystem, but may not control the data (e.g., Bakos et al. 2021, Chen et al. 2021).[8] Importantly, the consensus-generating process and data integrity are still ensured by the blockchain's decentralized architecture.[9] Although corporate blockchains lack the maintenance component of their public counterparts, they embrace the advantage of increased data coordination across shared ledgers. Before, each firm stored its ledger separately, and third parties needed to reconcile them largely without having direct access to other firms' data.

Figure 1 illustrates the design behind most corporate blockchain applications to date. Private blockchains host participating firms' data and run protocols to analyze the data autonomously. Data records are put into blocks, added to the chain in chronological order, and stored in a privacy-preserving way. The blockchain layer analyzes the submitted data and establishes a consensus in the form of a predefined state or metric that is later disclosed via public-facing services. For example, Data Gumbo, the provider of the private blockchain-backed network GumboNet, hosts GumboNet ESG that gathers data from firms' operations and transactions to run calculations and generate metrics for ESG reporting. The application integrates with Topl's blockchain-as-a-service platform to publish results on its public blockchain (Data Gumbo 2021).

The distributed ledger architecture allows private blockchains to deliver services traditionally provided by third-party intermediaries via technical layers. Consider a blockchain application that provides income statement information based on firms' reporting data.[10] Figure 2(a) depicts a common sales transaction and an asset impairment.

**Figure 1.** (Color online) Illustration of a Blockchain Disclosure Application

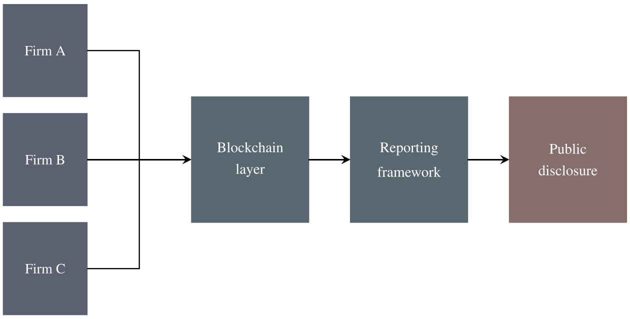
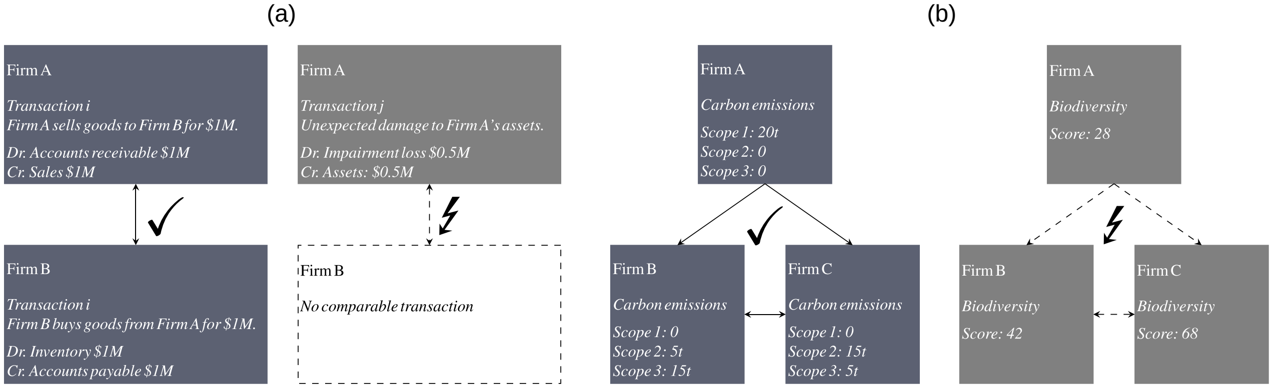


**Figure 2.** (Color online) Illustration of Blockchain Information Generation




*Notes.* (a) Financial data. (b) Nonfinancial data.

The seller claims $1M in its accounts receivable. The blockchain layer can establish a consensus by directly verifying $1M in the buyer's accounts payable.[11] In contrast, an asset impairment is more idiosyncratic in nature, making it inherently more difficult to establish a consensus based on other firms' data. Simply put, a firm recording an asset impairment may not result in another firm recording a similar impairment. The blockchain can revert to historical data to derive an estimate. Nevertheless, the consensus is likely less reliable and informative than the one for the cash transaction. A third party may even be more capable of deriving a reliable estimate as it could physically inspect the asset, use nondigital peer-firm information, or rely on tacit knowledge. These aspects are not unique to mandatory financial reporting but extend to other types of disclosure.

Figure 2(b) depicts data relevant for ESG disclosures. Blockchain applications are promising in such an area because disclosures rely on data from various parties along firms' value chain and require a high level of assurance. Moreover, traditional institutions are not yet as well entrenched, for example, compared with the financial reporting context, meaning that firms likely face a decision to either adopt a new technology or rely on traditional institutions to inform outsiders.[12] Various solutions are available on blockchain networks, such as GumboNet, IBM's Responsible Sourcing Blockchain Network, Kaleido, or Hyperledger Fabric.

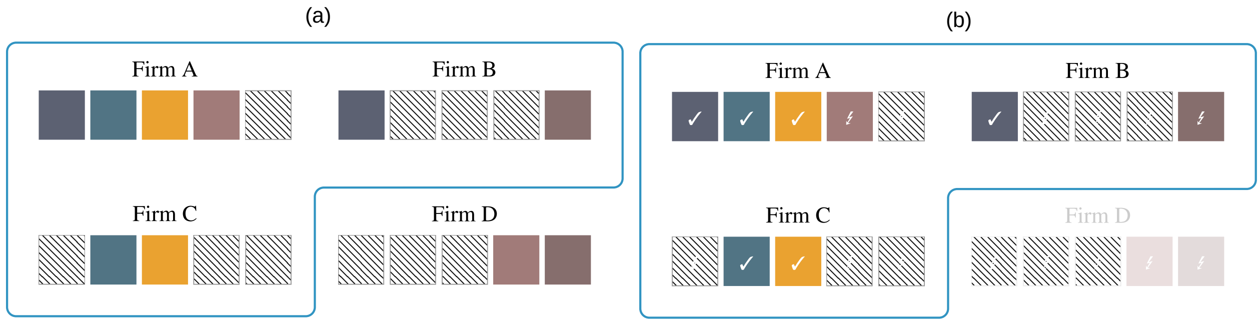
Suppose firm A is an energy producer. It reports its emissions under scope 1 following the GHG protocol.[13] Firms B and C consume the energy and report indirect emissions under scope 2. Both firms also interact and report the other firm's emissions under scope 3. Distributed ledger applications thrive in such a setting. Firm A's direct emissions serve as a reference point for the other firms' indirect emissions, and firm B's indirect emissions serve as a reference point for firm C's emissions and vice versa. However, similar to this, other sustainability metrics, such as a firms' impact on local biodiversity, are more challenging. Because blockchains rely on analyzing firms' data on the shared ledgers, its ability to generate information hinges on the informativeness of other firms' data. As a firm's impact on biodiversity depends on unique features, such as its location or technology, other firms' data may not be as indicative. The higher a firm's proportion of challenging data entries of this kind, the less likely it is that the application can generate reliable information.

The previous examples implicitly assumed that all firms contribute data. However, the blockchain's access to the data depends on firms' adoption decisions. Intuitively, the more firms join the blockchain, the more complete the digital picture of the transaction space becomes. Figure 3 depicts an economy of four firms with all but firm D contributing data. The solid blocks represent data entries that the blockchain can analyze using other firms' data. In contrast, the lined blocks represent data entries for which other firms' data are not informative.

The blockchain is most likely to generate a reliable signal for firm A with four out of five entries being, in principle, analyzable. The other firms have a lower potential with two out of five analyzable entries. Considering that firm D does not contribute data, the blockchain cannot inform about firm D and, in addition, is limited in its ability to inform about the other firms because some relevant data—that of firm D—is inaccessible. The blockchain is still most likely to inform about firm A in this scenario with the signal being based on three out of five entries. However, the other firms exhibit varying degrees of informativeness. Firm C remains at two, whereas firms B and D drop to one and zero out of five analyzable entries, respectively.

This highlights that information provision is inherently firm-specific—depending on each firm's data profile and fit with the distributed ledger technology—and endogenous, driven by firms' adoption decisions. Moreover, each firm's adoption imposes an externality

**Figure 3.** (Color online) Illustration of Blockchain Information Provision Layer




*Notes.* (a) Network data structure. (b) Network data status.

on other firms, making the overall information provision the result of a complex coordination game. We next introduce an analytical model that explicitly captures these inherent features driving information provision and use ESG disclosure applications to illustrate our results when appropriate.

## 3. Model

### 3.1. Firm Types

We consider an economy populated by a mass of firms, which we normalize to one. Each firm $i$ has a privately known type $(v^i, f^i)$ that consists of its value $v^i \in \{l, h\}$ and its fit for being analyzed by the blockchain $f^i \in \{b, g\}$. For notational convenience, the type is denoted by $\theta^i \in \Theta \equiv \{hg, hb, lb, lg\}$; for example, $hg$ is shorthand for $(h, g)$. We use $v_\theta$ as the firm value of type $\theta$, for example, $v_{hg} = v_{hb} = h$, and similarly $f_\theta$ as the fit of type $\theta$, for example, $f_{hb} = f_{lb} = b$. We normalize values to $l = 0$ for low-value firms and $h = 1$ for high-value firms.

Each firm's fit captures blockchain's differential ability to analyze a given set of data entries. In light of environmental disclosure, a firm exhibits a good fit when its environmental friendliness depends on carbon emissions that are, in principle, analyzable by the blockchain. In contrast, a firm exhibits a bad fit when its environmental friendliness to some degree also depends on biodiversity that is more challenging for the blockchain. For firms with a good fit, we set the share of analyzable entries to $g = 1$. For firms with a bad fit, the share of, in principle, analyzable entries is $b = \beta \in (0, 1)$. The proportion of type $\theta \in \Theta$ in the economy is denoted by $\sigma_\theta \in (0, 1)$. We impose no restrictions on $\sigma_\theta$ so that any correlation between the two dimensions of firm types is possible. Figure 4 summarizes the distribution of the firm types.

### 3.2. Firm Incentives

Firms' values are relevant for the capital market, and each firm aims to maximize its market valuation.[14] We denote the price an investor is willing to pay for a share in firm $i$ by $p^i$ and normalize the amount of shares to one. Although a firm cannot credibly inform the market about its value, information can be transmitted via one of two regimes. Firms simultaneously choose to either contribute data to a corporate blockchain application or rely on traditional third-party institutions.[15] We let $D^i \in \{0, 1\}$ indicate the decision of firm $i$ to enter the blockchain ($D^i = 1$) or not ($D^i = 0$). Both regimes are costly with respective costs $C_B \in \mathbb{R}_+$ for the blockchain and $C_T \in \mathbb{R}_+$ for traditional institutions. The cost difference is denoted $C \equiv C_B - C_T \in \mathbb{R}$. Investors observe all firms' adoption decisions and a firm-specific message generated by either the blockchain or the traditional institutions. The adoption decision is synonymous with committing to one of two disclosure regimes, in which one—the blockchain—has an endogenous and firm-specific quality, and the commitment itself may carry information. As such, when deciding about adopting a blockchain application, such as GumboNet ESG, a firm has to trade off the assurance by traditional institutions against disclosure that endogenously depends on the amount and composition of adopting firms.

### 3.3. Information Provision

To capture this trade-off, we formalize information provision via a message $m^i$ that is generated for each firm. The message may either reveal a firm's value, $m^i = v^i$, or be uninformative, $m^i = \emptyset$. The probability of revealing a firm's value represents the informativeness of the respective disclosure regime. As such, information generation resembles disclosure models in which the capital market prices firms according to their disclosed value or a pooling price following no

**Figure 4.** Distribution of Firm Types

| | | Fit: good | Fit: bad | |
|---|---|---|---|---|
| Firm value | high | $\sigma_{hg}$ | $\sigma_{hb}$ | $\sigma_h$ |
| | low | $\sigma_{lg}$ | $\sigma_{lb}$ | $\sigma_l$ |
| | | $\sigma_g$ | $\sigma_b$ | |

disclosure (see, e.g., Dye 1985, Wagenhofer 1990, Bertomeu et al. 2021).[16]

Inside the blockchain, the information generated about each firm depends on its fit and the amount of data accessible to the blockchain. The blockchain reveals a firm's type with a firm-specific probability $\eta^i$, which increases in the fit $f^i$ and the (equilibrium) reach of the blockchain $\rho$. For expositional purposes, we assume that all firms contribute equally to the blockchain's efficacy irrespective of their fit so that the reach is equal to the equilibrium mass of firms adopting the blockchain, $\int \mathbb{1}_{D^i=1} di$.[17] Formally, we consider $Pr\{m^i = v^i \mid D^i = 1\} = \eta^i = \rho \cdot f^i$. For example, if only *hg*- and *hb*-type firms adopt, an *hg*-firm's type is revealed with probability $f_{hg} \cdot \rho = 1 \cdot (\sigma_{hg} + \sigma_{hb}) = \sigma_h$, whereas an *hb*-firm's type is revealed with probability $f_{hb} \cdot \rho = \beta \cdot \sigma_h$.[18] Outside the blockchain, information provision is independent of a firm's data profile. Traditional institutions provide a credible signal about a firm's type with exogenous probability $Pr\{m^i = v^i \mid D^i = 0\} = \gamma \in [0, 1)$. This allows traditional institutions to enjoy a comparative advantage in evaluating data entries that are inherently challenging for blockchain's shared ledger architecture.[19]

### 3.4. Investor Beliefs and Pricing

Investors observe a firm's adoption decision along with the generated message but not firms' fit or value. They update their beliefs about firms' values following Bayes' rule and price them according to their posteriors. We denote the pooling prices inside and outside the blockchain (equal to the posterior beliefs) following an uninformative message by $p^I$ and $p^O$, that is, $p^I = Pr\{v^i = 1 \mid D^i = 1 \wedge m^i = \emptyset\}$ and $p^O = Pr\{v^i = 1 \mid D^i = 0 \wedge m^i = \emptyset\}$. Formally, this gives for the price $p^i$ paid by investors of firm $i$:

$$p^i(D^i, m^i) = \begin{cases} v^i & \text{if} \quad m^i = v^i \\ p^I & \text{if} \quad m^i = \emptyset \wedge D^i = 1 \\ p^O & \text{if} \quad m^i = \emptyset \wedge D^i = 0. \end{cases} \tag{1}$$

### 3.5. Timing of the Game

At the beginning of the game, each firm $i$ privately learns its type $\theta^i \in \{hg, hb, lb, lg\}$; all firms then simultaneously decide whether to join the blockchain ($D^i = 1$) or not ($D^i = 0$). For each firm, a message $m^i$ is generated and made available to the capital market. Subsequently, the market uses all available information, that is, (i) whether firm $i$ entered the blockchain, (ii) the firm-specific message $m^i$, and (iii) the total mass of adopting firms, to price each firm according to the posterior belief that it is of high value. Figure 5 summarizes the timing.

### 3.6. Equilibrium Concept

We look for symmetric perfect Bayesian equilibria, that is, equilibria in which all firms of type $\theta$ play the same strategy. We denote a candidate strategy profile by $\{q_{hg}, q_{hb}, q_{lb}, q_{lg}\}$, where $q_\theta$ refers to the probability that a firm of type $\theta$ joins the blockchain, that is, $q_\theta = Pr\{D_\theta = 1\}$. Throughout the analysis, we focus our discussion on pure strategy equilibria and characterize all mixed-strategy equilibria in the online appendix.[20]

In any equilibrium in which there is a positive mass of firms both inside and outside the blockchain, that is, in which $0 < \sum_\theta q_\theta < 4$, the pooling prices $p^I$ and $p^O$ are determined by Bayes' rule:

$$p^I = \frac{\sum_\theta (1 - \eta_\theta) \cdot \sigma_\theta \cdot q_\theta \cdot v_\theta}{\sum_\theta (1 - \eta_\theta) \cdot \sigma_\theta \cdot q_\theta} = \frac{\sum_\theta (1 - \rho f_\theta) \cdot \sigma_\theta \cdot q_\theta \cdot v_\theta}{\sum_\theta (1 - \rho f_\theta) \cdot \sigma_\theta \cdot q_\theta}, \tag{2}$$

$$p^O = \frac{\sum_\theta (1 - \gamma) \cdot \sigma_\theta \cdot (1 - q_\theta) \cdot v_\theta}{\sum_\theta (1 - \gamma) \cdot \sigma_\theta \cdot (1 - q_\theta)} = \frac{\sum_\theta \sigma_\theta \cdot (1 - D_\theta) \cdot v_\theta}{\sum_\theta \sigma_\theta \cdot (1 - D_\theta)}. \tag{3}$$

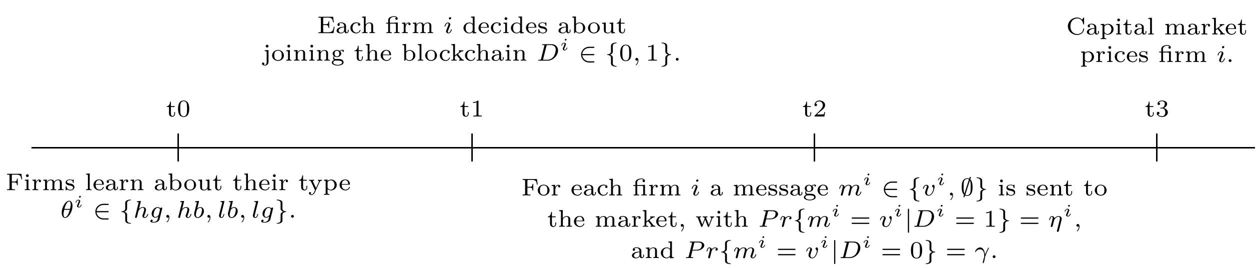
Note that the outside pooling price $p^O$ is independent of $\gamma$ as the probability of being identified is identical across firm types. If all firms join (do not join), the price outside (inside) the blockchain is determined by off-path beliefs.[21]

As each individual firm is atomistic, its decision whether to join the blockchain does not affect these pooling prices. This implies that firms of the same type face the same type-specific expected prices $p^I_\theta$ when joining and $p^O_\theta$ when not joining as

$$p^I_\theta = E[p^i \mid \theta^i = \theta \wedge D^i = 1] = \eta_\theta \cdot v_\theta + (1 - \eta_\theta) \cdot p^I, \tag{4}$$

$$p^O_\theta = E[p^i \mid \theta^i = \theta \wedge D^i = 0] = \gamma \cdot v_\theta + (1 - \gamma) \cdot p^O, \tag{5}$$

**Figure 5.** Timeline of Events



where $\eta_\theta$, $p^I$, and $p^O$ are determined by all other firms' equilibrium decisions.

### 3.7. Adoption Decisions

The expected prices $p^I_\theta$ and $p^O_\theta$ drive firms' adoption decisions; firm *i* joins whenever the benefits $\Delta^i$ exceed the cost *C*. Importantly, $\Delta^i$ is identical for all firms of the same type, $\Delta^i = \Delta_{\theta^i} = p^I_{\theta^i} - p^O_{\theta^i}$. Formally,

$$D^i = D_{\theta^i} = \begin{cases} 1 & \text{if} \quad \Delta_{\theta^i} > C \\ q^i \in [0,1] & \text{if} \quad \Delta_{\theta^i} = C, \\ 0 & \text{if} \quad \Delta_{\theta^i} < C \end{cases} \tag{6}$$

where the $\Delta_\theta$ satisfy

$$\Delta_{hg} = \rho - \gamma + (1-\rho)p^I - (1-\gamma)p^O$$
$$\Delta_{hb} = \rho\beta - \gamma + (1-\rho\beta)p^I - (1-\gamma)p^O$$

$$\begin{aligned} \Delta_{lb} &= (1-\rho\beta)p^I - (1-\gamma)p^O \\ \Delta_{lg} &= (1-\rho)p^I - (1-\gamma)p^O. \end{aligned} \tag{7}$$

The $\Delta_\theta$ exhibit natural comparative statics, that is, weakly increase (decrease) in the inside (outside) pooling price. For high-value firms, $\Delta_\theta$ is increasing in $\rho$ and decreasing in $\gamma$, whereas the reverse is true for low-value firms.

### 3.8. Ordering of Firms' Incentives

Before turning to the analysis of potential equilibria, it is helpful to assess the relative incentives of different types to adopt the blockchain. This implies—under certain conditions—an ordering in types' adoption incentives that restricts the set of potential equilibria. Naturally, high-value firms seek to be identified, whereas low-value firms strive to avoid detection. In addition, *hg*-type firms for which the blockchain provides a better fit have weakly higher incentives to join the blockchain than *hb*-type firms, whereas the reverse is true between *lg*- and *lb*-type firms. These relations follow because the blockchain's ability to generate information about a firm increases in the firm-specific fit. Formally, this is captured by Lemma 1.

**Lemma 1.** *hg-type firms benefit weakly more from joining the blockchain than hb-type firms, whereas lg-type firms benefit weakly less than lb-type firms:*

$$\Delta_{hg} \geq \Delta_{hb} \text{ and } \Delta_{lg} \leq \Delta_{lb}. \tag{8}$$

**Proof of Lemma 1.** See Online Section EC.1.

Pairs of high- and low-value firms of the same fit—for given strategies of all other firms—have the same probability of being identified inside and outside the blockchain, respectively. However, high-value types enjoy a valuation of one when identified, whereas low-value types receive a valuation of zero. The relative attractiveness of the blockchain is, thus, driven by the relative degree of information generation. We obtain

$$\Delta_{hg} - \Delta_{lg} = \rho - \gamma, \tag{9}$$
$$\Delta_{hb} - \Delta_{lb} = \rho\beta - \gamma. \tag{10}$$

The ordering of adoption incentives between the pairs depends on the strength of traditional institutions $\gamma$ and, in particular, the blockchain's equilibrium reach $\rho$. This exemplifies the complementarity in firms' adoption decisions via the endogenous determination of the blockchain's reach.

We also need to consider the relative incentives to join the blockchain between *hg*- and *lb*-types and between *hb*- and *lg*-types, respectively. These incentives depend not only on the primitives $\beta$ and $\gamma$ along with the endogenously determined reach $\rho$, but also on the endogenous pooling price $p^I$:

$$\Delta_{hg} - \Delta_{lb} = \rho - \gamma - (1-\beta)\rho p^I, \tag{11}$$
$$\Delta_{hb} - \Delta_{lg} = \rho\beta - \gamma + (1-\beta)\rho p^I. \tag{12}$$

The pairwise comparisons provide the basis for the subsequent equilibrium analysis in which we exploit the implied ordering regarding firms' adoption incentives.

## 4. Analysis

The complementarity of firms' decisions naturally gives rise to potential equilibrium multiplicity. As the two actions—adopting and not adopting the blockchain—are both taken by a positive mass of firms in all but two potential equilibria (full adoption and full nonadoption), standard equilibrium refinements that restrict off-path beliefs cannot overcome this multiplicity.[22] Throughout the analysis, we, therefore, focus on the likelihood of equilibria obtained by considering comparative statics that affect the size of the parameter space supporting the respective equilibria.

### 4.1. Baseline Setting

We start our analysis by investigating a baseline setting in which information provision by traditional institutions is muted, that is, $\gamma = 0$, and the blockchain is relatively costly, that is, $C > 0$. This allows us to carve out the key mechanisms driving firms' adoption decisions and the resulting information provision to capital market participants.

Because outside information provision is muted, information provision inside the blockchain is strictly stronger whenever a positive mass of firms adopts. As a consequence, high-value firms that seek to signal their type always face stronger adoption incentives than low-value firms of the same fit. Together with Lemma 1, this implies the following ordering of adoption incentives.

**Lemma 2** (Ordering Baseline). *When information provision by traditional institutions is muted, that is, for* $\gamma = 0$, *the benefits for type* $\theta$ *of joining the blockchain,* $\Delta_\theta$*, satisfy*

$$\Delta_{hg} \geq \Delta_{hb} \geq \Delta_{lb} \geq \Delta_{lg}. \tag{13}$$

*If a positive mass of firms joins the blockchain, that is,* $\rho > 0$*, (i)* $\Delta_{hb} > \Delta_{lb}$*, (ii)* $\Delta_{hg} > \Delta_{hb}$ *as long as* $p^I < 1$*, and (iii)* $\Delta_{lb} > \Delta_{lg}$ *as long as* $p^I > 0$.

**Proof of Lemma 2.** The proof follows from the preceding discussion and Lemma 1 with (9) and (10).

Together with the implications for $\rho$ and $p^I$ from considering a given candidate profile, we obtain Lemma 3 that characterizes the reduced set of pure-strategy equilibrium candidates.[23]

**Lemma 3** (Equilibrium Candidates Baseline). *The following pure-strategy profiles are potential equilibria:*

$$\{1,1,1,0\},\ \{1,1,0,0\},\ \{1,0,0,0\},\ \{0,1,0,0\},\ \{0,0,0,0\}. \tag{14}$$

**Proof of Lemma 3.** See Online Section EC.2.

Proposition 1 provides conditions on $C$ such that these candidates are supported in equilibrium.[24]

**Proposition 1** (Equilibria Baseline). *The following pure-strategy profiles can be supported in equilibrium for* $\gamma = 0$ *depending on the cost* $C \geq 0$ *of adopting the blockchain technology:*

i. *For* $C \in [\underline{C}, \overline{C}]$, $\{1,1,1,0\}$ *can be supported.*
ii. *For* $C \in [1-\beta(\sigma_{hb}+\sigma_{hg}), 1]$, $\{1,1,0,0\}$ *can be supported.*
iii. *There exists a unique* $C^{\{1,0,0,0\}} \in (1-(\sigma_{hg}+\sigma_{hb}), 1)$ *such that* $\{1,0,0,0\}$ *can be supported and a unique* $C^{\{0,1,0,0\}} \in (1-(\sigma_{hg}+\sigma_{hb}), 1)$ *such that* $\{0,1,0,0\}$ *can be supported.*
iv. *For* $C > 0$, $\{0,0,0,0\}$ *can be supported.*

$\underline{C}$ *and* $\overline{C}$ *are characterized by*

$$\underline{C} = \sigma_{lg} \frac{\sigma_{lg}\sigma_{hg} + (1-\beta(1-\sigma_{lg}))\sigma_{hb}}{\sigma_{lg}\sigma_{hg} + (1-\beta(1-\sigma_{lg}))(\sigma_{hb}+\sigma_{lb})}, \tag{15}$$

$$\overline{C} = (1-\beta(1-\sigma_{lg})) \frac{\sigma_{lg}\sigma_{hg} + (1-\beta(1-\sigma_{lg}))\sigma_{hb}}{\sigma_{lg}\sigma_{hg} + (1-\beta(1-\sigma_{lg}))(\sigma_{hb}+\sigma_{lb})}. \tag{16}$$

**Proof of Proposition 1.** See Online Section EC.3.

Proposition 1 highlights the two information-provision channels through which the capital market can learn about firms' value types. First, the adoption decisions themselves may reveal information about firms' values; depending on each firm's equilibrium action, the adoption decision may even be perfectly informative. Second, the capital market may learn about participating firms' values via an informative message generated by the blockchain.[25]

Despite firms facing identical adoption costs, joining the blockchain may serve as a credible signal of firm value because benefits—the expected payoffs from joining—differ across firm types. Even perfect separation is possible once adoption costs become sufficiently high. In the context of environmental disclosure, only environmentally friendly firms are willing to bear the costs of adopting a blockchain-based application to inform investors, whereas nonenvironmentally friendly firms would not adopt. The blockchain essentially becomes a "money-burning" signaling device. However, as common in these settings, environmentally friendly firms may be adversely affected by the availability of the blockchain application. In particular, the gains from being correctly perceived as environmentally friendly relative to the situation in which the blockchain application is not available may be more than offset by the costs.[26]

Because environmentally friendly firms have incentives to adopt blockchain applications to separate, nonenvironmentally friendly firms may also want to adopt not to be singled out.[27] However, adopting the application and contributing data to the blockchain not only entails direct costs, but also increases the blockchain's reach, improving its ability to reveal firms' value types. In equilibrium, nonenvironmentally friendly firms balance these considerations. For intermediate costs, only low-value, bad-fit firms—nonenvironmentally friendly firms with biodiversity issues driving their bad environmental performance—join the environmentally friendly firms in the blockchain. The risk of being identified is sufficiently low, and the expected benefits from being pooled with environmentally friendly firms compensate for the direct adoption cost. In contrast, low-value, good-fit firms—nonenvironmentally friendly firms with carbon emissions driving their bad environmental performance—do not expect a sufficient compensation. With more firms contributing data to the blockchain, the application can provide a largely informative message about participating firms' values, especially when their data are easier to analyze.

## 4.2. Generalized Setting

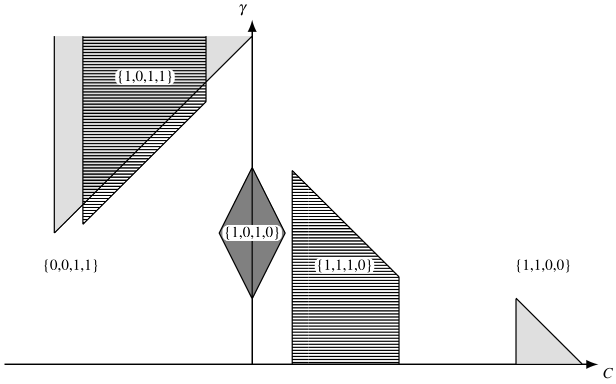
We next lift the restriction muting outside information generation, that is, we allow for $\gamma \in [0,1)$, and consider the blockchain to be cheaper or costlier than traditional institutions, that is, $C \in \mathbb{R}$.

In contrast to the baseline setting, the blockchain may now provide less information than traditional institutions, which affects type-specific adoption incentives and results in novel trade-offs. Consider the baseline setting with intermediate adoption costs such that, in equilibrium, some low-value firms join the high-value firms in the blockchain. The pooling price for unidentified firms using the blockchain application is strictly below one. Firms outside the blockchain are expected to be low-value firms, resulting in an outside pooling price of zero. However, for the same adoption cost, this is no longer an equilibrium in the generalized setting for sufficiently strong traditional institutions. For $\gamma$ close to one, high-value firms have strict incentives to remain with the traditional institutions because they expect them to generate more information than the emerging blockchain. Their expected payoffs approach their true value despite the capital market perceiving them to be of low value following an uninformative message. This highlights that the equilibria in the generalized setting depends on both the adoption cost $C$ and the strength of traditional institutions $\gamma$.

Figure 6 depicts the pure-strategy equilibria for combinations of the relative adoption cost $C$ and the strength of traditional institutions $\gamma$, omitting equilibria in which no firm adopts and all firms adopt and equilibria relying on knife-edge conditions. The full characterization of all equilibria is in Online Section EC.4.[28] Information provision still occurs via the two channels identified in the baseline setting. However, although the adoption decision may carry information, it no longer always serves as a credible signal of high value. Instead, the reliance on traditional institutions can indicate a high value when the blockchain is cheaper. Moreover, firms now have to consider the relative strength of the two information systems with the blockchain's informativeness depending on the mass and composition of adopting firms.

The light gray areas represent separating equilibria in which firms separate according to their value types via the adoption decisions. If traditional institutions are sufficiently weak (sufficiently low $\gamma$), high-value firms seek other means of signaling. For example, for sufficiently high adoption costs ($C \gg 0$), environmentally friendly firms again adopt and incur the high adoption costs to separate from nonenvironmentally friendly firms. In addition, separation can also occur with only low-value firms adopting the blockchain. Nonenvironmentally friendly firms prefer the blockchain if they have sufficient incentives to evade traditional institutions (sufficiently high $\gamma$) and adoption offers cost savings ($C \ll 0$). Environmentally friendly firms remain outside, incur the relative cost disadvantage, and receive a high level of assurance by traditional institutions. In both types of equilibria, there is a degree of substitutability between the strength of traditional institutions and the relative adoption costs; the weaker (stronger) the traditional institutions, the lower the relative cost (relative benefit) cutoff for separation to be sustainable.

**Figure 6.** Illustration of Pure-Strategy Equilibria




*Notes.* This figure illustrates the pure-strategy equilibria in the generalized setting. The lined and dark gray areas depict equilibria in which high- and low-value firms join the blockchain, whereas the light gray areas depict fully separating equilibria. For ease of exposition, we omit equilibria in which no firm adopts, all firms adopt, and equilibria relying on knife-edge conditions.

The lined areas depict partially separating equilibria. For positive adoption costs ($C > 0$), all but the low-value, good-fit firms are willing to contribute data to the blockchain for sufficiently weak traditional institutions. In this case, the blockchain's abilities to generate information become comparably strong, and nonenvironmentally friendly firms with easy-to-analyze carbon emissions data are likely identified by the blockchain. They, therefore, prefer to at least avoid the adoption costs in equilibrium. For negative adoption costs ($C < 0$), it is the high-value, bad-fit firms that have no incentive to join the others in using the blockchain-based disclosure application. These environmentally friendly firms are willing to forego the relative cost savings from adopting the blockchain if the traditional institutions can provide a sufficiently strong service. In contrast, the high-value, good-fit firms—environmentally friendly firms with analyzable carbon emissions data—still adopt because the blockchain is again comparably strong in equilibrium. The combination of higher within-blockchain expected payoffs and cost savings is sufficient to induce adoption. The partially separating equilibria share that the blockchain's distributed ledger capabilities generate comparably informative signals about adopting firms.

A key insight from the generalized setting is the existence of a novel equilibrium in which both high- and low-value firms are present inside and outside the blockchain. Specifically, there are parameter constellations for which only high-value, good-fit firms and low-value, bad-fit firms adopt in equilibrium. This mixed-adoption equilibrium stands out because both information-provision channels do not function to their full potential. The presence of both value types inside and outside the blockchain implies that firms' adoption decisions are not an efficient means of separation. Moreover, the reach and, thus, the blockchain's abilities to identify firms is only intermediate. Although it outperforms traditional institutions for firms with a good fit, it underperforms for firms with an inherently bad fit. As illustrated by the dark gray area in Figure 6, the equilibrium may materialize when the blockchain is both cheaper and costlier than traditional institutions. We next investigate this potentially undesirable situation in more detail.

### 4.3. An Undesirable Situation?

We begin by explicitly deriving the necessary and sufficient condition for the existence of the mixed-adoption equilibrium. Specifically, we establish a condition on the relationship between the proportion of firm types in the economy and the strength of traditional institutions $\gamma$ such that the equilibrium exists for a nonempty range of relative costs $C$.

Note that, for the strategy profile $\{1,0,1,0\}$ to constitute an equilibrium, all firms must weakly prefer their respective adoption choice, that is,

$$\Delta_{hg} \geq C \wedge \Delta_{hb} \leq C \wedge \Delta_{lb} \geq C \wedge \Delta_{lg} \leq C. \tag{17}$$

Given Lemma 1, we know $\Delta_{hg} \geq \Delta_{hb}$ and $\Delta_{lg} \leq \Delta_{lb}$ so that $C$ satisfying (17) exists if and only if

$$\min\{\Delta_{hg}, \Delta_{lb}\} \geq \max\{\Delta_{hb}, \Delta_{lg}\}$$
$$\Longleftrightarrow \rho = \sigma_{hg} + \sigma_{lb} \geq \gamma \geq \beta(\sigma_{hg} + \sigma_{lb}) = \rho\beta, \tag{18}$$

where we use the implied reach of the blockchain in the conjectured equilibrium, $\rho = \sigma_{hg} + \sigma_{lb}$.

The explicit bounds on the relative cost $C$ can be obtained using the implied pooling prices:

$$p^O = \frac{\sigma_{hb}}{\sigma_{hb} + \sigma_{lg}} \quad \text{and} \quad p^I = \frac{(1-\sigma_{hg}-\sigma_{lb})\sigma_{hg}}{(\sigma_{hg}+\sigma_{lb})(1-\sigma_{hg}-\beta\sigma_{lb})}. \tag{19}$$

This also allows us to derive conditions for the equilibrium being supported when the blockchain is cheaper and costlier than traditional institutions, respectively.

**Proposition 2.** *There exist $\underset{\sim}{C}_b(\gamma), \tilde{C}_b(\gamma)$ such that $\{1,0,1,0\}$ can be supported in equilibrium for $C \in [\underset{\sim}{C}_b(\gamma), \tilde{C}_b(\gamma)]$ if and only if $\beta(\sigma_{hg}+\sigma_{lb}) \leq \gamma \leq \sigma_{hg}+\sigma_{lb}$. Moreover,*

i. $\exists \gamma \in [0,1] : \tilde{C}_b(\gamma) > 0 \Longleftrightarrow \frac{\sigma_{hb}\sigma_{lb}}{\sigma_{hg}\sigma_{lg}} < 1$.
ii. $\exists \gamma \in [0,1] : \underset{\sim}{C}_b(\gamma) < 0 \Longleftrightarrow \frac{\sigma_{lb}\sigma_{hb}}{\sigma_{hg}\sigma_{lg}} > \frac{(1-(\sigma_{hg}+\sigma_{lb}))^2}{(1-\beta(\sigma_{hg}+\sigma_{lb}))^2}$.

**Proof of Proposition 2.** Given (18), we can simply define $\underset{\sim}{C}_b \equiv \max\{\Delta_{hb}, \Delta_{lg}\}$ and $\tilde{C}_b \equiv \min\{\Delta_{hg}, \Delta_{lb}\}$ so that the proposition follows. The derivations of the conditions in (i) and (ii) are contained in the general characterization of all equilibria in Online Section EC.4; see (EC.21) and (EC.38).

Proposition 2 offers several insights. First, the heterogeneity in firms' fit is an essential factor inducing the equilibrium. More heterogeneous firms (low $\beta$) increase the parameter space supporting the mixed-adoption equilibrium. In addition, a higher proportion of good-fit firms in the economy increases (decreases) the likelihood that the equilibrium materializes for positive (negative) relative adoption cost. It is, therefore, not sufficient to subsidize an economy-wide blockchain adoption to rule out potentially inefficient information generation.

Second, in the equilibrium, the blockchain has to provide a more informative signal than traditional institutions for good-fit firms such that *hg*-type firms adopt and *lg*-type firms remain outside. The opposite needs to hold for bad-fit firms. As such, the blockchain's equilibrium reach has to be intermediate. Similarly, traditional institutions have to be of intermediate strength too. Whenever they are sufficiently strong—when *hg*-type firms would prefer to rely on traditional institutions—or sufficiently weak—when even *hb*-type firms would prefer to adopt—the scope for the mixed-adoption equilibrium is limited.

Third, blockchain technology induces a coordination game with potentially adverse consequences. Given the equilibrium reach $\rho = \sigma_{hg} + \sigma_{lb}$, traditional institutions provide more information for bad-fit firms, whereas the blockchain performs better for good-fit firms. To maximize information generation about each firm—taking the reach of the blockchain as given—it should be good-fit firms that rely on the blockchain and bad-fit firms that rely on traditional institutions. However, in the equilibrium, low-value firms pick the option that minimizes their likelihood of being detected.[29]

In summary, there are two types of inefficiencies: the blockchain's reach is only intermediate, and conditional on the reach, coordination problems result in low-value firms' adoption decisions being inefficient from an information perspective.

**4.3.1. Average Mispricing in the Economy.** To assess the overall information provision, we next compare the average mispricing in the equilibrium with a scenario in which blockchain technology does not exist.[30] In our model, mispricing occurs whenever firms' values are not revealed by the blockchain or traditional institutions; they are then priced at the respective pooling prices.

Without blockchain, all firms have to rely on traditional institutions. With probability $\gamma$, they are priced correctly, and with probability $(1-\gamma)$, they are mispriced by the absolute difference between their true value and the pooling price $p = \sigma_{hg} + \sigma_{hb}$ of nonidentified firms. The average mispricing without blockchain technology, denoted $AMP_{noBC}$, is, therefore, given by

$$\begin{aligned} AMP_{noBC} &= (1-\gamma) \cdot [(\sigma_{hg}+\sigma_{hb}) \cdot (1-p) \\ &\quad + (1-\sigma_{hg}-\sigma_{hb}) \cdot (p-0)] \\ &= 2(1-\gamma)(\sigma_{hg}+\sigma_{hb})(1-\sigma_{hg}-\sigma_{hb}). \end{aligned} \tag{20}$$

Notably, $AMP_{noBC}$ only depends on the strength of the traditional institutions $\gamma$ and the proportion of high-value firms $\sigma_{hg} + \sigma_{hb}$ because the firm-specific fit does not affect information provision by traditional institutions. Mispricing is decreasing when traditional institutions become stronger as firms are more likely to be priced correctly and increasing in value heterogeneity.[31]

The average mispricing in the mixed-adoption equilibrium strategy profile, $AMP_{\{1,0,1,0\}}$, obtains from summing over the type-specific probabilities that the firms' values are not correctly revealed times the difference between firms' true values and the respective pooling price inside or outside:

$$AMP_{\{1,0,1,0\}} = \sigma_{hg} \cdot (1-\rho) \cdot (1-p^I) + \sigma_{lb} \cdot (1-\rho\beta) \cdot (p^I - 0) + \sigma_{hb} \cdot (1-\gamma) \cdot (1-p^O) + \sigma_{lg} \cdot (1-\gamma) \cdot (p^O - 0). \tag{21}$$

Substituting $p^I$ and $p^O$ from (19) and simplifying yields

$$AMP_{\{1,0,1,0\}} = 2\left[\frac{(1-\gamma)\sigma_{hb}\sigma_{lg}}{\sigma_{hb}+\sigma_{lg}} + \frac{\sigma_{hg}\sigma_{lb} \cdot (1-\sigma_{hg}-\sigma_{lb}) \cdot (1-\beta(\sigma_{hg}+\sigma_{lb}))}{(\sigma_{hg}+\sigma_{lb})(1-\sigma_{hg}-\beta\sigma_{lb})}\right]. \tag{22}$$

Comparing (20) and (22) shows that the mixed-adoption equilibrium may indeed lead to lower information provision. Specifically, we can rewrite $AMP_{\{1,0,1,0\}} > AMP_{noBC}$ as a condition on the strength of the traditional institutions $\gamma$:

$$\gamma > 1 - \frac{\sigma_{hg}\sigma_{lb}(1-\sigma_{hg}-\sigma_{lb})^2(1-\beta(\sigma_{hg}+\sigma_{lb}))}{(\sigma_{hg}+\sigma_{lb})(1-\sigma_{hg}-\beta\sigma_{lb})\left(\sigma_{hg}(1-\sigma_{hb}-\sigma_{hg})^2 - \sigma_{hg}\sigma_{lb} + (\sigma_{hb}+\sigma_{hg})^2\sigma_{lb}\right)} \equiv \hat{\gamma}. \tag{23}$$

The condition $\gamma > \hat{\gamma}$ indicates that, for average mispricing to be higher with blockchain technology, traditional institutions must be sufficiently strong. As such, economies with strong existing institutions are not immune to the undesirable situation. However, (23) only considers the difference in average mispricing conditional on the mixed-adoption equilibrium. We, therefore, also need to account for the implied bounds on the traditional institutions' strength for the equilibrium to materialize (see Proposition 2), that is, assess where $\hat{\gamma}$ lies relative to the lower bound, $\beta(\sigma_{hg}+\sigma_{lb})$, and the upper bound, $(\sigma_{hg}+\sigma_{lb})$. For $\hat{\gamma} < \beta(\sigma_{hg}, \sigma_{lb})$, all mixed-adoption equilibria increase average mispricing, whereas no mixed-adoption equilibria have this effect for $\hat{\gamma} > (\sigma_{hg}+\sigma_{lb})$.

Proposition 3 summarizes the compatibility of $\gamma > \hat{\gamma}$ with both the lower and upper bounds for the mixed-adoption equilibrium from Proposition 2 to be sustainable. For ease of exposition, we consider the case of firms' fit and values being independent with $\lambda$ denoting the probability of a firm's value being high and $\omega$ denoting the probability of a firm's fit being good.[32]

**Proposition 3.** *The availability of blockchain may harm the information environment by leading to an adverse mixed-adoption equilibrium with increased mispricing. This materializes for a nonempty set of $(\gamma, C)$-combinations provided that the heterogeneity in fit is sufficiently large, that is, provided that $\beta$ does not exceed an upper bound $\tilde{\beta}(\lambda, \omega)$. For $\beta > \tilde{\beta}(\lambda, \omega)$, no adverse mixed-adoption equilibrium exists. Formally, (i) $\hat{\gamma} > \beta(\sigma_{hg}+\sigma_{lb})$ and (ii) $\beta \le \tilde{\beta}(\lambda, \omega) \Rightarrow \hat{\gamma} < \sigma_{hg}+\sigma_{lb}$.*

**Proof of Proposition 3.** See Online Section EC.5, which also analytically characterizes $\tilde{\beta}(\lambda, \omega)$.

There are two main takeaways from Proposition 3. First, as $\hat{\gamma} > \beta(\sigma_{hg}+\sigma_{lb})$, information provision does not always deteriorate in the mixed-adoption equilibrium. Specifically, when $\gamma$ is close to the lower bound $\beta(\sigma_{hg}+\sigma_{lb})$ such that the equilibrium can be supported, both information-provision channels remain impeded, but average mispricing still decreases compared with a situation without blockchain. Essentially, traditional institutions are sufficiently weak so that the blockchain can more easily outperform them. Second, average mispricing may nonetheless increase depending on the relationship between the fit $\beta$ and the distribution of firm types.

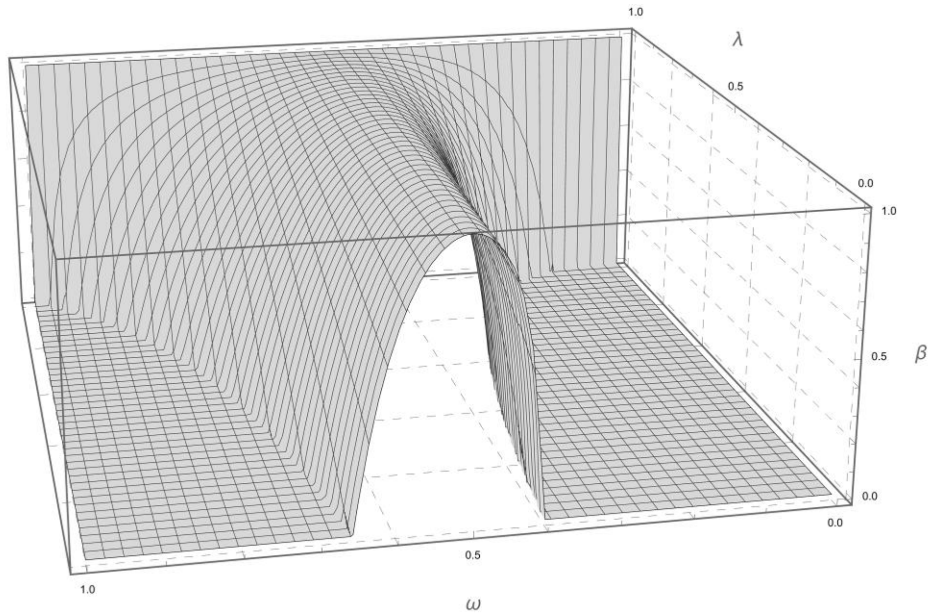
Figure 7 illustrates the threshold level of the fit parameter $\beta$ for which the adverse mixed-adoption equilibrium with increased average mispricing materializes. Information provision only deteriorates if firms' fit heterogeneity is sufficiently high ($\omega$ closer to 0.5 and $\beta$ small), that is, their data profiles are sufficiently different. As such, if all firms' environmental friendliness is driven by carbon emissions alone, the blockchain's emergence is less likely to adversely affect the overall informativeness of environmental disclosures. However, if some firms' environmental friendliness is driven by easy-to-analyze carbon emissions but others' to a sufficient degree by biodiversity, the heterogeneity in firms' fit both increases the scope for the mixed-adoption equilibrium and weakens the overall efficacy of the blockchain. Intuitively, the difficult-to-analyze biodiversity data contributed by bad-fit firms are more likely to lead to mispricing. For the same reason, the bound on the fit parameter $\beta$ and the likelihood that the adverse equilibrium materializes are both higher whenever the probability of a firm having a good fit $\omega$ is intermediate, which implies a comparable fraction of good- and bad-fit firms and, thus, already a large heterogeneity in firm-specific fit.

Moreover, information provision is more likely to decrease under blockchain technology when the share of high-value firms $\lambda$ is higher. As such, an economy with more environmentally friendly firms should be more likely to suffer from less informative environmental disclosures when blockchain technology becomes available even if they are relatively homogeneous with either carbon emissions or biodiversity determining their environmental friendliness. This is due to the coordination game induced by the emergence of the technology, in which even intermediate heterogeneity in fit can result in an overall adverse effect on information provision.[33]

### 4.3.2. Coordination Issue or Inherently Bad Technology?

Proposition 3 highlights that information provision only decreases when the strength of traditional institutions is intermediate. Economies with sufficiently

**Figure 7.** Parameter Constellations for Equilibria with Increased Average Mispricing




*Notes.* This figure illustrates the threshold level of the fit parameter $\beta$ as a function of the likelihood of a firm being of high value, $\lambda$, and the likelihood of a firm being of good fit, $\omega$. Equilibria in which average mispricing increases exist for a positive mass of $(\gamma, C)$-combinations whenever $\beta$ falls below this threshold.



strong traditional institutions are more likely to suffer from a loss in average informativeness unless they are so strong to preclude the mixed-adoption equilibrium. In principle, increased mispricing in the mixed-adoption equilibrium can result from the blockchain-induced coordination game or blockchain being an inherently bad technology to analyze some firms' data so that information provision is on average worse even under (mandated) full adoption.

When we explicitly consider the mispricing induced under full adoption, the pooling price following an uninformative message is $p^I = \sigma hb/(\sigma hb + \sigma lb)$, which implies the following average mispricing:

$$AMP_{\text{full}} = (1-\beta)\sigma_{hb}(1-p^I) + (1-\beta)\sigma_{lb}p^I = 2(1-\beta)\frac{\sigma_{hb}\sigma_{lb}}{\sigma_{hb}+\sigma_{lb}}. \quad (24)$$

Thus, blockchain increases mispricing even under full adoption if and only if

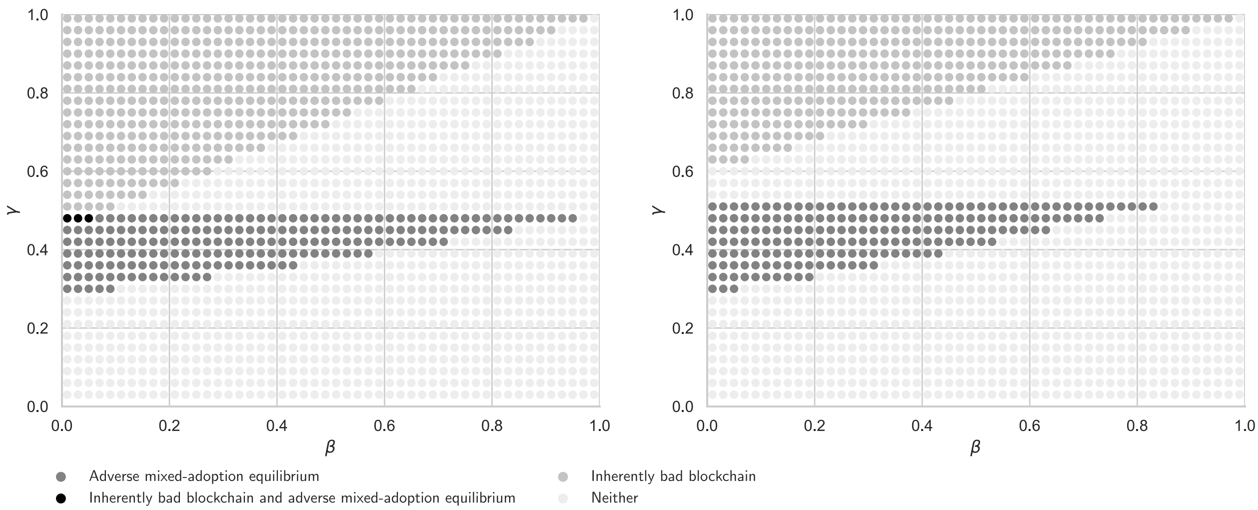
$$AMP_{\text{full}} > AMP_{\text{noBC}} \Longleftrightarrow \beta < \gamma + (1-\gamma)\left[2\sigma_{hg} + \sigma_{hb} - \frac{\sigma_{hg} - \sigma_{hg}^2}{\sigma_{hb}} - \frac{(1-\sigma_{hg}-\sigma_{hb})(\sigma_{hg}+\sigma_{hb})}{\sigma_{lb}}\right]. \quad (25)$$

In the independent fit and value parameterization, (25) further reduces to $\beta < (\gamma - \omega)/(1-\omega)$, highlighting that blockchain is more likely to be an inherently bad technology if traditional institutions are sufficiently strong (high $\gamma$), there is a sufficient fraction of bad-fit firms (low $\omega$), or the technology is sufficiently bad in analyzing bad-fit firms (low $\beta$).

These conditions resemble situations in which large variation between firms renders the adoption of uniform reporting standards undesirable (see, e.g., Ray 2018). As such, mandating the adoption of blockchain-based services is not necessarily desirable from a policy perspective. Although a mandate provides the benefit of avoiding the coordination problem, it carries the risk of harming the information environment in case the blockchain is an inherently bad technology. Furthermore, the direct adoption costs need to be carried by all firms, including smaller ones, which may render mandatory adoption welfare-reducing despite a positive impact on information provision. When there is a low proportion of bad-fit firms, the adoption costs determine whether mandatory adoption is beneficial, whereas a high proportion of bad-fit firms can render mandatory adoption welfare-reducing even absent high adoption costs. In the context of environmental disclosure, such a high proportion of bad-fit firms is more likely in economies closer to achieving carbon neutrality because environmental performance depends more on other aspects, such as a firm's impact on biodiversity, that are inherently challenging for the blockchain to analyze.

Moreover, the blockchain can adversely affect the information environment even when it is not inherently bad. The blockchain-induced coordination game can render the, in principle, viable technology—in the sense that (25) is violated—unfit for information provision by

**Figure 8.** Adverse Mixed-Adoption Equilibrium or Inherently Bad Technology




*Notes.* This figure illustrates combinations of the fit parameter $\beta$ and strength of traditional institutions $\gamma$ for which the blockchain is an inherently bad technology and the mixed-adoption equilibrium features increased average mispricing (black area), the mixed-adoption equilibrium features increased average mispricing (dark gray area), the blockchain is an inherently bad technology (gray area), or neither materializes (light gray area). Both panels are based on the firms' fit and value being independent; the left panel considers $\lambda = 0.65$ and $\omega = 0.45$ and the right panel $\lambda = 0.65$ and $\omega = 0.6$.

limiting its reach and lowering the signaling value of firms' adoption decisions.

Figure 8 illustrates combinations of the fit parameter $\beta$ and the strength of traditional institutions $\gamma$ for which the blockchain is an inherently bad technology and for which the mixed-adoption equilibrium results in increased average mispricing. The adverse mixed-adoption equilibrium generally materializes whenever the blockchain is not an inherently bad technology. The blockchain can both be inherently bad and result in the mixed-adoption equilibrium as illustrated in the left panel. However, the two areas are typically disjoint as in the right panel. Intuitively, for the blockchain to be an inherently bad technology, traditional institutions need to be sufficiently strong. Strong traditional institutions, in turn, create incentives for high-value firms to remain outside the blockchain, making the mixed-adoption equilibrium less likely.

The fact that the adverse mixed-adoption equilibrium occurs when the blockchain is, in principle, a viable technology offers scope for policy interventions. Whereas an ex ante mandate to adopt the technology may adversely affect information provision, encouraging further dissemination of the technology after its emergence can, in fact, be beneficial. An increase in the blockchain's reach can improve information provision if regulators can properly identify the mixed-adoption equilibrium and detect the initial negative impact on the information environment.

## 5. Additional Considerations

In this section, we discuss variations of our model and implications, focusing primarily on the mixed-adoption equilibrium and its impact on information provision.

### 5.1. Scalability of Blockchain Capabilities

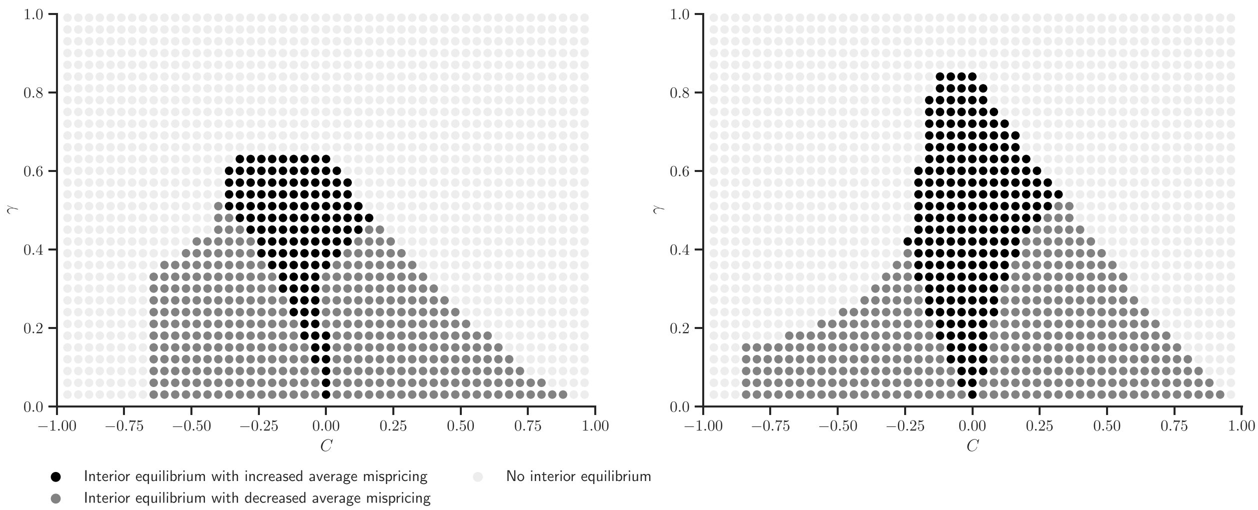
In the model, the blockchain's reach affects firm-specific information provision linearly. However, the blockchain's capabilities to analyze a given set of data may scale differently. Let the firm-specific information provision be $Pr\{m^i = v^i \mid D^i = 1\} = \tilde{\eta}^i = \rho^s \cdot f^i$ with $s$ parameterizing the technology's scalability. As $\rho \in [0, 1]$, a small (large) parameter $s$ implies that even a small (large) mass of firms allows the blockchain to perform well (only exhibit a limited performance).[34]

Firms' incentives to join the blockchain for a given mass of adopting firms may increase (for high-value firms and $s < 1$ or low-value firms and $s > 1$) or decrease (for high-value firms and $s > 1$ or low-value firms and $s < 1$) relative to the main model. However, the ordering of firms' adoption incentives remains with conditions reflecting the change in the blockchain's reach. Interestingly, a more efficient blockchain ($s$ being small) increases the range of traditional institutions $\gamma$ for which the mixed-adoption equilibrium is sustainable. Whereas this effect needs to be traded off against the more informative signal generated by the blockchain for a given mass of adopters, it nonetheless implies that efficiency gains can have adverse consequences.

### 5.2. Continuous Type Spaces

We characterize firms using discrete types along the dimensions of firm value and fit with blockchain technology. To analyze the robustness of our results, we next consider firms' fit to be continuously distributed, retaining the binary value types.[35] Because firms' equilibrium behavior derives from a system of equations

**Figure 9.** Illustration of Equilibria with Continuous Fit-Type Space




*Notes.* This figure illustrates the combinations of the relative adoption cost $C$ and strength of traditional institutions $\gamma$ for which the mixed-adoption equilibrium features increased average mispricing (black area), the mixed-adoption equilibrium features decreased average mispricing (dark gray area), or a corner solution arises in equilibrium (light gray area). Both panels are based on the continuous-fit variant of the model; the left panel considers $\lambda = 0.65$ and the right panel $\lambda = 0.85$.

involving higher order polynomials, we implement a numerical solution.

Figure 9 depicts combinations of the relative adoption cost $C$ and the strength of traditional institutions $\gamma$ for different proportions of high-value firms $\lambda$ and a given fit distribution. In the light gray area, no interior equilibrium exists; that is, all equilibria feature at least one value type adopting or not adopting the blockchain irrespective of the fit. In the dark gray area, the mixed-adoption equilibrium exists, and the information environment improves. Finally, in the black area, the mixed-adoption equilibrium exists, and the information environment deteriorates relative to the scenario without blockchain. As such, the potential adverse impact of the blockchain is robust to departing from the discrete type space. The adverse equilibrium can again materialize when the blockchain is potentially both cheaper or costlier than traditional institutions and is again more likely for intermediate traditional institutions or a larger proportion of high-value firms.

## 5.3. Firms' Contribution to the Blockchain

In the model, all firms contribute equally to the blockchain. Although a firm's fit matters for the firm-specific component of information provision $\eta_i$, only the total mass of adopting firms, and not their types, is relevant for the reach component. We next consider two variants in which firms' contributions to the blockchain's reach vary with their characteristics, in particular, their fit.[36]

First, suppose firms' fit is associated with their reporting quality, meaning that bad-fit firms are—independent of their value—characterized by unintentionally providing false data for a random fraction of $(1-\beta)$ of their transactions. Because false entries inhibit the analysis of correct data entries, bad-fit firms contribute less to the reach of the blockchain than good-fit firms. Although the reach in any equilibrium, given by $\rho' = q_{hg}\sigma_{hg} + \beta q_{hb}\sigma_{hb} + q_{lg}\sigma_{lg} + \beta q_{lb}\sigma_{lb}$, reflects the lower contribution of bad-fit firms compared with the main model, the analysis remains unchanged. The range of outside verification $\gamma$ supporting the mixed-adoption equilibrium shifts downward and shrinks, reflecting the overall lower efficacy of the blockchain relative to the traditional institutions. However, the blockchain's lower efficacy also increases the likelihood that information provision decreases if the mixed-adoption equilibrium materializes.

Second, suppose firms have an inherently different fit—as in the main model—but can strategically submit false data entries. In such a setting, low-value firms in the blockchain naturally have incentives to limit their efficacy to reduce the likelihood of being identified. However, allowing for strategic misreporting has a similar impact as unintentional false entries. Low-value firms' misreporting reduces the blockchain's efficacy, affecting its reach in any equilibrium. The range of outside verification $\gamma$ for which the mixed-adoption equilibrium is supported again shrinks and shifts downward, but the likelihood that information provision decreases in the mixed-adoption equilibrium increases. Notably, strategic misreporting results in an additional tension for low-value firms. Whereas misreporting is desirable conditional on entering the blockchain, low-value firms generally benefit more from sustaining the adverse equilibrium in which overall information provision is lower. As such, it is not clear a priori whether firms would use their ability to falsify data because misreporting decreases the likelihood that the mixed-adoption equilibrium materializes.

### 5.4. The Blockchain Alongside Traditional Institutions

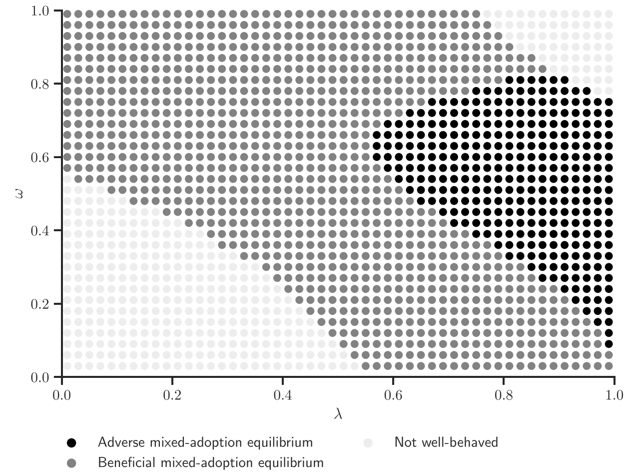
In the main model, we treat blockchain technology and traditional institutions as rivals, and firms that adopt the blockchain forgo the services of the traditional institutions. Whereas this scenario seems appropriate for new disclosure settings, such as ESG reporting, blockchain is less likely to act as a pure rival when traditional institutions are well-established or even entrenched by regulations as in mandatory financial reporting or auditing.

In such scenarios, blockchain is more likely to be adopted alongside traditional institutions, which would most likely strategically respond to the technology. Although a full characterization of the institutions' objectives—including, for example, competition, litigation risk, or compensation—is outside the scope of this paper, we consider a setup in which traditional institutions aim to balance the expected probability of an informative message inside and outside the blockchain.[37] This resembles a setting in which traditional institutions are homogeneous and commit to a certain level of overall information provision, corresponding to $\gamma$ in our model. For example, courts regularly resort to established auditing standards as benchmarks for auditors' due care, and auditors have to commit to an audit quality based on these benchmarks (e.g., Schwartz 1998, Simunic et al. 2017).

Because blockchain is essentially a substitute for information generation by traditional institutions, the latter respond by lowering their efforts for adopting firms.[38] The new effort level, denoted $\gamma^{BC}$, is set such that traditional institutions provide the committed level of information provision $\gamma$ in expectation. However, because traditional institutions cannot condition on firms' unobservable fit and value types, they set a uniform informativeness for all firms in the blockchain. This implies that the mixed-adoption equilibrium generically exists because information provision is still higher for good-fit firms inside the blockchain and lower for bad-fit firms.

Figure 10 illustrates the main takeaways from the setting using fixed values of the traditional institutions' strength and the fit of bad-fit firms. In the light gray area, the conjectured mixed-adoption equilibrium is not well-behaved with the blockchain's detection probabilities exceeding one for good-fit firms. In the dark gray area, relative adoption cost supporting the mixed-adoption equilibrium exist, and information provision improves as a result of the blockchain's emergence. However, in the black area, the adverse mixed-adoption equilibrium exists, resulting in a deterioration of the information environment. Although traditional institutions ensure a constant expected probability of type revelation, the asymmetric impact on good- and bad-fit firms in the blockchain, coupled with the asymmetric impact on the pooling prices, harms capital market participants' ability to extract information. The main forces determining whether the blockchain adversely affects the information environment again carry over from the main model. The information environment is more likely to deteriorate because of blockchain when firms' fit heterogeneity is large, that is, the proportion of good- and bad-fit firms is more comparable, and there are more high-value firms. Overall, treating blockchain as a substitute in the strategic response of traditional institutions does not resolve the potential undesirable impact of the technology on the information environment.

**Figure 10.** Illustration of Equilibria Considering Strategic Response




*Notes.* This figure illustrates combinations of the proportion of high-value firms $\lambda$ and good-fit firms $\omega$ for which the mixed-adoption equilibrium features increased average mispricing (black area), the mixed-adoption equilibrium features decreased average mispricing (dark gray area), or the mixed-adoption equilibrium is not well-behaved (light gray area). The figure is based on the model setup in which the blockchain exists alongside traditional institutions; the panel considers $\beta = 0.45$ and $\gamma = 0.75$.

## 6. Concluding Remarks

Most blockchain applications started as digitization projects, but quickly evolved into larger ecosystems. Consortia, such as Hyperledger and the Ethereum Alliance, or tech companies, such as SAP or Oracle, are promoting private blockchain platforms that leverage the distributed ledger technology to generate information and address firms' privacy needs.[39] Whereas financial reporting–related applications are mostly confined to assurance services, other applications are increasingly engaging in disclosure tasks, such as the publication of sustainability metrics, credit scores, or food safety information. We provide a model that directly speaks to the emergence of blockchain in such contexts, and our results have implications for regulators and investors monitoring the technology.

In the model, heterogeneous firms of privately known types simultaneously decide whether to rely on an exogenous disclosure regime—the traditional institutions—

or adopt a disclosure regime with endogenous and firm-specific strength: the blockchain application. The blockchain leverages its distributed ledger architecture, makes use of all participating firms' data, and ensures the privacy of individual data entries. The application's ability to generate information about a firm's type depends on (i) its fit for analyzing a given firm's data and (ii) its reach into the economy. The setting gives rise to two potential information-provision channels. First, firms' adoption decisions may serve as a credible signal about firms' type. Second, the blockchain may outperform traditional institutions in generating information based on participating firms' data. However, we show that the blockchain's potential to enhance information provision may not materialize and the information environment can even deteriorate because of its emergence. Specifically, we provide sharp conditions for an equilibrium in which both low- and high-value firms are inside and outside the blockchain—harming the efficacy of the two information-provision channels—and for information provision to decline not only for individual firms, but also in aggregate.

Our model demonstrates that firms' fit heterogeneity not only impedes the blockchain's capabilities to analyze data, but also weakens the signaling value of firms' endogenous adoption decisions. The emergence of blockchain technology results in a complex coordination game in which firm heterogeneity makes a lack of coordination more likely. As such, policymakers and investors should pay close attention to the composition of adopting firms and settings implying such heterogeneity; for example, large blockchain ecosystems are more likely to host a variety of differing firms. Policymakers may try to identify potential adopters and provide incentives to keep heterogeneity low by offering monetary incentives or regulatory relief. Theoretically, policymakers could also contemplate addressing the heterogeneity in data profiles directly by adapting reporting requirements. For example, the SEC could ask firms to only report metrics based on easy-to-analyze environmental data in its proposed ESG reporting mandate. However, whereas this may alleviate the blockchain's shortcomings, the underlying data may no longer provide an accurate picture of firms' sustainability. Tailoring reporting requirements to the blockchain may break the link between the underlying economic value and its accounting representation.

We further highlight that blockchain's success in the corporate context heavily depends on existing traditional institutions. Economies with intermediate traditional institutions are more likely to suffer from a decrease in information provision unless the institutions are strong enough to rule out the mixed-adoption equilibrium. The blockchain could, in principle, just be an inherently bad technology that is easily outperformed by sufficiently strong traditional institutions. However, we show that the deterioration of the information environment mainly results from the adverse outcome of a blockchain-induced coordination game. Setting the stage for blockchain by strengthening traditional institutions can prevent the adverse outcome because fit heterogeneity only becomes critical if traditional institutions cannot support full separation via firms' adoption decisions.

Our findings also have broader implications for policymakers and investors because there is no simple immediate regulatory solution. For example, mandating the adoption of a federated blockchain for all firms is not unambiguously optimal concerning overall welfare. Again, this does not require blockchain to be an inherently bad technology for information provision. Although network effects are strongest when all users coordinate on a given platform, such as a federated blockchain, some firms may simply be unable to bear the adoption cost. Thus, even if information provision improves, it may come at the expense of some firms being driven out of business.

Our study is naturally subject to limitations. Our analysis suggests that blockchain technology may lead to a deterioration of the information environment even when traditional institutions respond to the emergence of the blockchain as a substitute. However, these strategic responses and the blockchain's endogenous strength offer a wide range of interesting considerations, especially concerning potential structural changes in different markets and the need for regulatory interventions. Governments are trying to attract the blockchain industry by offering favorable regulatory conditions, which may not only lead to regulatory arbitrage, but affect the competitive landscape. Future work may focus on traditional institutions' response, accounting for the impact of third-party actions, for example, consortia offering blockchain-based applications and the effect on the market structure when third parties compete for clients via their pricing. In a similar vein, even if the main drivers of our model remain in play because the composition of all adopting firms at a given moment impacts the pooling prices, analyzing the fully dynamic interplay between current blockchain adoption and firms' incentives to adopt in the future may yield additional insights. Finally, we take the blockchain's mechanism design as a given with firms choosing between two disclosure regimes to inform the capital market. The optimal mechanism design choices that reflect the fundamental premises of the blockchain's reach and firm-specific fit, and potential ecosystem-level challenges, seem to offer interesting research opportunities.

## Acknowledgments

The authors thank Christian Laux (discussant at the 2021 European Accounting Association Virtual Annual Congress), Dirk Simons, and Anton Sobolev as well as seminar participants at the University of Bonn, Skema Business School, the University of Graz, and the University of Mannheim for their helpful comments and suggestions. We further appreciate participants' comments at the 2019 American Accounting Association Annual Meeting in San Francisco, the 2020 Annual Meeting of the German Academic Association for Business Research (VHB) in Frankfurt, and the 2021 EAA Virtual Annual Congress. The views in this paper are solely those of the authors. No responsibility for them should be attributed to the Bank of Canada.

## Endnotes

[1] See, for example, Dai and Vasarhelyi (2017), Yermack (2017), Cao et al. (2019), Cong and He (2019), Pimentel and Boulianne (2020), and Cong et al. (2021).

[2] In the United States, the 117th Congress has seen 35 bills in 2021 that focus on cryptocurrencies, blockchain technology, or central bank digital currencies (Brett 2021).

[3] For a more detailed discussion of the corporate setting and the use of the distributed ledger technology, see Section 2.

[4] Public blockchains, such as Bitcoin and Ethereum, offer limited privacy that may result in deanonymization of users. Cryptographic means, such as zero-knowledge proofs, offer a privacy-increasing analysis even on public blockchains.

[5] Applications, such as Maple Finance, Bloom, or LedgerScore, allow investors to retrieve credit scores based on firms' background information without exposing financial data. Similarly, the scores' informativeness weakly increases in coverage and depends on whether the other firms' records are actually predictive for a firm's future creditworthiness.

[6] GumboNet ESG automates ESG reporting following a predefined standard. IBM Food Trust creates food safety and freshness data according to the latest FDA regulations. GuildOne provides information about exploration, extraction, and production in the oil and gas industry. Bloom is a privacy-preserving credit-scoring system.

[7] For instance, Ethereum switched to a proof-of-stake architecture in 2022 to increase security and energy efficiency and to introduce better scaling solutions compared with its previous proof-of-work architecture.

[8] For example, Hyperledger, R3, or the Enterprise Ethereum Alliance with their solutions Fabric, Corda, and Enterprise Ethereum have earned considerable recognition as hosts. These consortia have numerous members spanning across industries using their solutions. For instance, Hyperledger lists around 150 members as of 2022 including Accenture, Bosch, FedEx, IBM, Oracle, Visa, and Walmart.

[9] Bakos and Halaburda (2021) also show that blockchain operators with a minimal level of trust and well-designed permissioned blockchains can offer both high operational efficiency and high transaction security.

[10] Accounting academics and professionals propose to refine double-entry bookkeeping into a triple-entry system to incorporate blockchain technology (e.g., Grigg 2005, Kiviat 2015, Dai and Vasarhelyi 2017, Carlin 2019, Cai 2021). The third entry is a digital representation of firms' own accounting records on the blockchain.

[11] Note that the buyer has little incentive to collude in such a transaction because it implies that the buyer overstates the purchase and the seller shows a lower net income to stretch sales. Such collusion costs also imply that information provided by the counterparty can even be more reliable than the seller provides alone (Cao et al. 2019).

[12] The most prominent players representing traditional third-party institutions in this context are ESG data providers, such as Bloomberg, Refinitiv, Sustainalytics, or MSCI ESG Research, the big-three rating agencies, the big-four auditors, or assurance providers.

[13] Scope 1 emissions are direct emissions from firm-controlled resources. Scope 2 emissions are indirect emissions from purchased energy. Scope 3 emissions are the remaining indirect emissions along the value chain (GHG Protocol 2015).

[14] We take this objective as given. It is easy to provide a microfoundation, for example, by having firms require additional capital that is raised via an equity issuance.

[15] Absent type-specific coordination opportunities, both simultaneous and sequential decision making require each atomistic firm to form beliefs about all firms' equilibrium actions irrespective of the sequence in which they would act in the sequential game. We, therefore, restrict attention to simultaneous play to facilitate the formal exposition.

[16] The reduced-form characterization of signal informativeness is similar to prior literature on disclosure regime or information system commitment; see, for example, Bertomeu and Magee (2011), Gao and Liang (2013), and Edmans et al. (2016).

[17] We discuss heterogeneity in the contribution to the blockchain in Section 5. Results are robust to bad-fit firms exerting an externality on good-fit firms by contributing less to the blockchain's reach, and to firms strategically falsifying data entries to lower the blockchain's efficacy.

[18] We abstract from explicitly collusive behavior. It is unlikely to occur if incentives are misaligned, for example, because a high sales price in a purchase of goods benefits the seller but harms the buyer. If incentives are aligned, for example, because one firm pockets cash payments in exchange, the blockchain can use all participating firms' data, including that of firms not taking part in a given transaction, to identify fraudulent transactions and raise red flags.

[19] Consider the extreme case with $\beta = 0$. Irrespective of the equilibrium reach, traditional institutions always outperform the blockchain for bad-fit firms.

[20] Mixed strategy equilibria predominantly "fill in the gap" between pure-strategy equilibria, adding little economic meaning to our main message.

[21] To characterize the full set of sustainable equilibria, it is, hence, natural to adopt the most pessimistic off-path beliefs, that is, $p^I = 0$ ($p^O = 0$), to provide the strongest incentives against possible deviations.

[22] We discuss the application of the intuitive criterion in detail in Online Section EC.11.

[23] For example, whenever a positive fraction of $lb$-types joins, that is, $q_{lb} \in (0,1)$, it must be the case that $\Delta_{lb} = C$ so that $lb$-types are indifferent. If this holds in equilibrium, we also have $\rho > 0$, and hence, $\Delta_{hg} \geq \Delta_{hb} > \Delta_{lb} = C$, that is, all high-value types strictly prefer to join the blockchain.

[24] Note that the equilibria in which only $hg$- or $hb$-types join, respectively, are only sustainable when $C$ satisfies a knife-edge condition. In contrast, the other pure-strategy equilibria $\{1,1,1,0\}$ and $\{1,1,0,0\}$ are sustainable for a range of costs $C$ with $\{1,1,1,0\}$ being sustainable for a disjoint and lower cost range than $\{1,1,0,0\}$. We also characterize the emerging mixed-strategy equilibria in Online Section EC.3.

[25] Because of the one-period nature of our model, both information-provision channels have equal weight. Allowing for multiple periods with potentially changing firm values renders the adoption signal weaker than the blockchain's ongoing information provision. Nonetheless, both channels remain relevant in such a setting.

[26] For $C \to 1$, the $\{1,1,0,0\}$-equilibrium exists and features $p^I_\theta - C \to 0$ for $\theta \in \{hg, hb\}$. If the blockchain were unavailable, these two types would enjoy a strictly positive $p^O_\theta$. Nonetheless, high-value firms strictly prefer to adopt the blockchain in this equilibrium as they earn $1 - C$ instead of zero, which is the pooling price outside the blockchain.

[27] The only exceptions are the equilibrium in which all firms rely on traditional institutions, $\{0,0,0,0\}$, and the knife-edge equilibria in which one of the high-value types joins and the other relies on traditional institutions.

[28] We first exploit the implied ordering of incentives to join the blockchain to restrict the set of equilibrium candidates; see Online Section EC.4.1. We then characterize the parameter ranges supporting a given equilibrium candidate separately for the case in which the blockchain is more expensive than traditional institutions ($C \geq 0$, Online Section EC.4.2) and it is cheaper ($C < 0$, Online Section EC.4.3). Online Section EC.4.3 characterizes the mixed-strategy equilibria.

[29] Note that this is distinct from the general incentive to avoid detection for low-value firms. In other equilibria, some low-value firms choose the more informative disclosure channel in equilibrium because they are compensated with a high pooling price following an uninformative message.

[30] A complete welfare analysis requires a microfoundation for investors' behavior to properly determine the cost of mispricing. As any such specification would be inherently arbitrary, we focus on mispricing itself.

[31] The distribution of firm values in the economy is fully described by the share of high-value firms, so (20) is, thus, maximized for $\sigma_{hg} + \sigma_{hb} = \frac{1}{2}$, that is, when the value heterogeneity is at its maximum, and equal to zero for $\sigma_{hg} + \sigma_{hb} = 0$ or $\sigma_{hg} + \sigma_{hb} = 1$ when the pooling price is correct because all firms share the same value and valuation.

[32] The distribution of firm types becomes $\sigma_{hg} = \lambda\omega$, $\sigma_{hb} = \lambda(1-\omega)$, $\sigma_{lg} = (1-\lambda)\omega$, $\sigma_{lb} = (1-\lambda)(1-\omega)$.

[33] Whereas the overall impact of blockchain technology is more likely to be negative, the absolute amount of mispricing is lower when firms are more homogeneous in the value dimension.

[34] For a detailed analysis, see Online Section EC.7.

[35] For a detailed analysis, see Online Section EC.8. The case in which the fit is binary and value-type continuous follows an analogous setup and yields similar results.

[36] For a detailed analysis, see Online Section EC.9.

[37] The case in which the blockchain is purely on top of traditional institutions leads to the same implications as the baseline setting with muted outside verification. Denoting $\Delta'_\theta$ as the incentives to adopt the blockchain for a firm of type $\theta$, we obtain

$$\Delta'_{hg} - \Delta'_{hb} = \rho(1-\beta)(1-\gamma)(1-p^I) \geq 0$$
$$\Delta'_{hb} - \Delta'_{lb} = \rho\beta(1-\gamma) \geq 0$$
$$\Delta'_{lb} - \Delta'_{lg} = \rho(1-\beta)(1-\gamma)p^I \geq 0.$$

This is for the relative adoption incentives so that the ordering from the baseline carries over. Because information provision under blockchain technology is strictly better compared to without the technology, each firm's adoption decision again becomes a costly signal, and the information environment improves.

[38] For a detailed analysis, see Online Section EC.10.

[39] For example, SAP secured a U.S. patent for a side-chain to verify data from two or more independent blockchains (SAP 2020). The side chain hosts an engine that verifies data stored on firms' accounting systems and creates a verification token. In the application, firms' accounting systems are considered private blockchains for compatibility reasons, but the data could also be stored on existing server-based networks.

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