Accounting Uniformity, Comparability, and Resource Allocation Efficiency

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Abstract

Uniformity, the use of a common accounting measurement, is an essential feature of financial reporting, yet its desirability has long been debated. We study a model in which firms decide whether to adopt either their local accounting methods or a common method, followed by an investor allocating capital across firms. We model comparability as a possible but not necessarily ensuing outcome of uniformity that renders accounting reports more informative about productivity differences among firms. Firms' choices of a common method are strategic complements on attaining more comparable reports. As a result, multiple equilibria may exist in the economy, and firms may fail to coordinate on adopting a Pareto-optimal accounting method. Specifically, a Pareto-optimal equilibrium in which all firms use a common accounting method (the common equilibrium) may be risk-dominated by an equilibrium in which each firm uses its optimal local method (the local equilibrium). Moreover, if investments exhibit substitutability, the universal use of a Pareto-optimal common accounting method may not even be an equilibrium. In contrast, a universal use of a Pareto-suboptimal common accounting method can be an equilibrium, especially if investments exhibit complementarity. These coordination problems provide accounting regulation an opportunity to facilitate the efficient allocation of capital in the economy. Thus, our results provide a micro-foundation for accounting measurement regulation and elucidate the impact of accounting uniformity on resource allocation efficiency.

Keywords: Accounting standards, uniformity, comparability, disclosure regulation, resource allocation.

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1 Introduction

Accounting uniformity, the homogeneity of accounting practices across firms, has been a central matter of concern that goes far back in accounting history. On December 7, 1887, twelve accounting officers of the major railways in the U.S. gathered. In that meeting, "the subject uppermost in the minds of the gentlemen there assembled was the matter of uniformity in handling interline freight accounts" (Nay, 1913). Almost half a century later, the Security Exchange Act of 1934 established the first federal securities regulator, the Securities and Exchange Commission (SEC), with the power to oversee accounting and auditing methods. The push for uniformity intensified when the SEC created the Accounting Principles Board (APB) in 1953, intending to provide guidelines and stipulate rules on accounting principles. Uniformity is still persistently present in fundamental accounting debates regarding a broad range of issues, including the discretion among optional accounting methods[1] (e.g., LIFO vs. FIFO, full cost vs. successful efforts, alternative depreciation methods), the economic effects of mandating specific accounting methods (e.g., R&D expensing), and the international convergence of accounting standards (e.g., Ball, 2006; Dye and Sunder, 2001).

In many accounting policy deliberations, uniformity is advocated as a means to increase comparability in financial reports. While some practitioners believe that comparability cannot be achieved without uniformity in accounting methods, others argue that uniformity reduces comparability by overlooking each firm's idiosyncrasies (Zeff, 2007). As stated by the FASB (2010) itself, "financial information is not enhanced by making unlike things look alike any more than it is enhanced by making like things look different." These opposing views were already present even before the creation of accounting institutions (Coe and Merino, 1978) and have instigated intense debates since then. We see such conflicting positions as manifestations of two fundamental measurement effects of uniformity in accounting methods. Using the same accounting method for different entities inevitably entails introduc-

[1] The extant literature on accounting reporting discretion is extensive, and includes a large variety of accounting procedures (e.g., Beatty and Weber, 2006; Bushman and Williams, 2012).

ing correlation among measurement errors (henceforth, *common-method effect*). Uniformity, therefore, may improve comparability because common errors offset each other in the comparison between entities. However, since a uniform accounting method cannot be tailored to each of the entities, it must also increase each firm's measurement error. This *one-size-fits-all problem* potentially reduces comparability because it simply makes the comparison noisier. How do these two measurement effects influence resource allocation efficiency? Would firms coordinate into voluntarily adopting a common accounting method? Can a regulatory intervention improve allocation efficiency? Answers to these questions can help us to better understand the need for regulation of accounting methods.

We examine whether firms would coordinate on their own in adopting a Pareto-dominant common accounting method in a resource-allocation setting. In particular, we assume that all firms in the economy can choose between their locally optimal accounting methods and a common accounting method. After choosing an accounting method, each firm uses it to generate an accounting report about the firm's productivity. Then, using all public information, a representative investor allocates capital among firms. Finally, each firm uses its capital to generate a terminal cash flow, and all parties consume. The literature in economic growth has shown that the efficient allocation of resources is important in determining productivity growth (Restuccia and Rogerson, 2017) and that information quality is an important determinant of allocation efficiency (e.g., David et al., 2016). Such empirical findings are consistent with the FASB's claim that "the objective of financial reporting acknowledges that users make resource allocation decisions." Accordingly, a resource-allocation setting serves us best to parsimoniously illustrate the real consequences of accounting method choices among firms.

We first examine the game with only two firms to emphasize the economic tradeoffs in a simple setting. We show that two possible equilibria emerge: an equilibrium in which both firms choose their own locally optimal accounting methods (the local equilibrium) and another equilibrium in which both firms choose the common accounting method (the common equilibrium). We find that, while the local equilibrium always exists, the common equilibrium exists only for a range of parameters. The multiplicity of equilibria originates directly from the interaction between the common-method effect and the one-size-fits-all problem. A firm's choice of the common measurement system is a unilateral attempt to increase uniformity. Taking such a step always aggravates the one-size-fits-all problem, thereby increasing the firm's measurement error. However, such a unilateral choice does not guarantee uniformity. Indeed, uniformity and the ensuing correlation between the firms' measurement errors increase only if both firms choose the common accounting method. This complementarity between the firms' accounting method choices results in a multiplicity of equilibria.

We further show that there exists a range of parameters under which the common equilibrium Pareto-dominates the local equilibrium. Even though accounting reports are less precise in the common equilibrium, the common-method effect may introduce enough positive correlation among the measurement errors of different firms' reports to increase their comparability, thereby improving capital allocation efficiency. Therefore, a regulatory intervention to coordinate firms on the common equilibrium may be justified. To support this claim, we also show that it is often the case that even though the common equilibrium is Pareto-dominant, the local equilibrium is risk-dominant. This is the case because the one-size-fits-all problem harshly punishes a firm's attempt to coordinate on the common equilibrium if the attempt is not reciprocated by the other firm. Since we know that, experimentally, players often coordinate on the risk-dominant equilibrium (Anctil et al., 2004; Cabrales et al., 2007), this result reinforces the need for a regulator to guide the coordination.

We extend our analysis to an economy with a continuum of firms to examine the effect of investment externalities in a tractable way. Introducing externalities allows us to examine two kinds of coordination failures in accounting measurement choices. First, if investments exhibit a strong enough substitutability, allocation efficiency is maximized with a common accounting method. Indeed, investment substitutability mitigates the intensity with which the common productivity shock affects investment efficiency, making it critical for the investor to learn about productivity differences across firms. However, since individual firms do not internalize such externalities and focus more on investment efficiency at the firm level, the common equilibrium may not even exist. That is, firms may fail to adopt the common method despite it being Pareto-optimal. Such inefficiency further justifies the need for a regulator to impose a common accounting method. Second, investment complementarity magnifies the effect of the common productivity shock on each firm's investment productivity, thereby diminishing the value of comparability. Indeed, if the one-size-fits-all effect is not too strong, firms may be stuck in the common-equilibrium. Once the common accounting method is established as a norm, no firm wants to deviate because its accounting report would become less comparable to other reports, decreasing the firm's value. In this situation, the regulator can potentially improve capital allocation efficiency by explicitly offering several accounting methods to encourage each firm to use its optimal local method.

We analyze an extension in which investment decisions are decentralized. That is, we allow firms to decide how much capital to invest in their investment opportunity. We show that a decentralized investment setting makes the adoption of a common method more desirable in increasing investment efficiency. Intuitively, a centralized investor makes use of information about the common productivity shock to increase the allocation efficiency in the economy. In contrast, with decentralized investment decisions, firms make investment decisions to increase their firm value, but not necessarily to increase the allocation efficiency in the economy. Thus, they make better use of information about their idiosyncratic shocks. As a result, the increase in comparability brought by the adoption of the common method makes a larger impact under decentralization.

Overall, our results show that firms may be vulnerable to a coordination failure in their collective accounting decisions. They may fail to adopt a uniform accounting method when it is in their own best interest to do so. Thus, our paper suggests that a centralized regulator can increase the economy's capital allocation efficiency by coordinating accounting choices across firms.

As a central concern of accounting research, the literature on real effects of accounting examines how accounting measurement and disclosure ultimately affects real efficiency (see Kanodia and Sapra, 2016, for a review). Although most work in this literature focuses on single-firm settings, a few papers have examined the benefits and shortcomings of accounting standards in multi-firm settings. For instance, Dye (1990) studies a one-period model with multiple firms with financial and real externalities and compares the disclosure policies that firms would adopt voluntarily with the "optimal" mandated disclosure policy. The study shows that whether the two coincide depends on certain factors, including the nature of the externalities and the risk preferences of existing and potential investors. In a similar setting, Admati and Pfleiderer (2000) assume risk neutrality and focus on the adverse selection problem between investors and firms. Externalities arise because each firm's disclosure is informative about other firms' fundamentals. This creates a free-riding problem, resulting in an undersupply of disclosure. In contrast, in our paper, externalities arise due to firms' choices of accounting method. Specifically, measurement errors become correlated for those firms that jointly choose the common accounting method, making their reports more comparable and, thereby, their investment potentially more efficient. Perhaps closer to our analysis, Zhang (2013) examines how the information structure of accounting standards affects real investment efficiency and welfare in a multi-firm asset pricing setting. In contrast to these papers, our analysis focuses on the measurement effects of uniformity on comparability and the need for a regulatory mandate on the uniformity of accounting methods.

In this literature, some view uniformity as an antagonist to reporting flexibility and the associated opportunistic behavior. For instance, Dye and Sridhar (2008) model a rigid standard that prevents reporting manipulation but eliminates firm reporting discretion. Relatedly, Laux and Stocken (2018) model rigidity in accounting standards as the intensity with which accounting rules are enforced, and examine the implications for entrepreneurial innovation. We complement this view of uniformity by focusing instead on the measurement effects that arise when multiple firms adopt the same accounting method and how such effects may justify mandating uniformity. Allowing for opportunistic behavior in our analysis would further justify such a mandate. Therefore, our results are more robust when regulation is deemed optimal without such considerations.

Uniformity has also been examined in other contexts. For instance, Barth et al. (1999) and Gao et al. (2019) examine the economic effects of harmonizing domestic GAAP with foreign GAAP focusing on the information processing benefits of harmonization. Chen et al. (2017) examines the desirability of uniformity in a setting where the precision of reported information is unverifiable and varies across firms. They find that uniformity can prevent firms from costly signaling their precision, which can be socially beneficial when information serves a coordination role among investors within each firm. Friedman and Heinle (2016) investigates uniform accounting regulation in the context of political economics, showing that uniformity can be welfare increasing because it discourages welfare-decreasing lobbying by firms. We complement this literature by focusing on the need for accounting regulation through another channel: the coordination of accounting choices on a common measurement method that improves resource allocation efficiency by increasing comparability.

Our paper is also related to the literature that evaluates the effects of information in economies in which agents take ex-post decisions with externalities. This literature includes the vast literature on higher-order beliefs (Morris and Shin, 2002; Angeletos and Pavan, 2004; Angeletos and Pavan, 2007). Typically, in this literature, externalities arise through assumed complementarities on ex-post real decisions. In our paper, however, externalities arise even without investment complementarity or substitutability. Externalities are mainly informational and affect firms' accounting choices. In fact, we find that, if investment complementarity is present, it goes against informational complementarity. In particular, investment complementarity reduces the need for a common accounting method.

Our paper is closely related to the literature on the role of information comparability. A pioneering paper, Stein (1997), shows that comparability is valuable in a firm operated by an empire-building manager because the projects' right ranking becomes more important than the absolute profitability of each project. A more recent paper, Wu and Xue (2019), studies how accounting comparability affects firms' ex-ante investment. In this study, comparability alleviates the under-investment problem, but it also increases the undiversifiable risk and thus increases the risk premium. Our paper adopts a complementary approach and focuses on how comparability affects the investor's subsequent resource allocation decisions based on accounting reports. We believe both approaches capture certain aspects of reality and provide valuable new insights. Another recent paper, Fang et al. (2020), examines accounting consistency both theoretically and empirically. Although the analytical side of this study shares some assumptions with our analysis, its purpose is different and limited to generating hypotheses empirically tested in the same paper. Our contribution to this nascent literature is three-pronged. First, in our study, we distinguish between the accounting choice (uniformity) and its informational effects (e.g., comparability). Second, we consider accounting choices as both a firm choice and a regulatory choice. This allows us to analyze the coordination on a common standard among firms and the need for regulatory intervention. Third, we see uniformity as a coordination outcome. The correlation of measurement errors between two firms only arises if both firms choose the same accounting method. Therefore, none of them can unilaterally affect the correlation.

Our paper is also closely related to the literature in economics on productivity and resource (mis)allocation. Restuccia and Rogerson (2008) and Restuccia and Rogerson (2017) show that the misallocation of resources across firms can substantially negatively impact aggregate total factor productivity. For example, Hsieh and Klenow (2009) show that in manufacturing industries, if misallocation were eliminated, total factor productivity would increase by 86 -110 percent in China, 100-128 percent in India, and 30-43 percent in the United States. Such misallocation can be attributable to policies that favor less efficient industries or firms, distorting tariffs, lack of protection of property rights, or informational frictions. Our paper contributes to this literature by showing how a common set of accounting standards can improve or hinder resource allocation efficiency.

The rest of the paper is organized as follows. Section 2 studies a two-firm model in which firms voluntarily choose accounting methods, and show that firms may not coordinate on the common equilibrium and a regulator can be needed to facilitate the efficient allocation of capital in the economy. Section 3 studies coordination problems in a continuum-of-firm setting in which investments exhibit either complementarity or substitutability. Section 4 extends the main model by allowing firms to decide how much capital they invest. Section 5 concludes.

2 Accounting Method Choice: Two-Firm Analysis

We start with a two-firm model in which both firms simultaneously decide which accounting method to adopt. Each firm can choose between two accounting methods: a local accounting method tailored to the firm's idiosyncrasies (henceforth, *local method*) and a shared method that inevitably needs to compromise between its fit with the idiosyncrasies of the two firms (henceforth, *common method*.) We show that there are multiple equilibria and that the two firms may fail to coordinate on adopting an accounting method that better facilitates the efficient allocation of capital. Thus, the analysis provides insights into the role a centralized regulator can play in coordinating firms' choices of accounting methods and sheds light on the origins of financial-reporting regulation.

2.1 The Model

Consider an economy with two firms, indexed by $i \in \{1, 2\}$, and one representative investor. Firm i is operated by a manager (he) who chooses an accounting method to maximize his firm's value. We may often simply say that the firm itself chooses an accounting method. The investor (she) is risk-neutral and has unlimited access to capital. She decides how much capital to invest in each firm.[2] Broadly, the timeline of the game is as follows. First, firm $i \in \{1, 2\}$ chooses its accounting method to maximize its firm value, which we denote as W_i. Second, each firm generates an accounting report conforming to the previously chosen accounting method. Third, the representative investor invests capital in each firm. Finally, cash flows from the investment are realized, and all parties consume. We now describe in more detail the information structure and the decisions in the game.

Investment. Each firm $i \in \{1, 2\}$ has an investment opportunity with diminishing-returns-to-scale in capital k_i, which generates an uncertain net cash flow:

$$2\theta_i \sqrt{k_i} - k_i, \tag{1}$$

where θ_i is the realization of a random variable $\tilde{\theta}_i$ that represents the uncertain investment productivity of firm i, unknown to all parties in the economy. We assume that firms are heterogeneous in their productivity. In particular, the productivity of each firm i, $\tilde{\theta}_i$, consists of two components:

$$\tilde{\theta}_i \equiv \tilde{m} + \tilde{n}_i.$$

The first component, $\tilde{m} \sim N(\mu, v_m)$, captures a productivity shock that is common to both firms. The second component, $\tilde{n}_i \sim N(0, v_n)$, captures a productivity shock that is specific to each firm i. While θ_i is not directly observable, the accounting system of each firm i generates a report s_i which is informative about the firm's productivity θ_i. The information content of the reports, s_1 and s_2, is determined by the accounting methods that govern their preparation. Once the reports have been released, the representative investor chooses the optimal amounts of capital k_1^* and k_2^* to maximize the expected net cash flows from both

[2] We assume a centralized investment decision for two main reasons. First, in our main model we want to focus on the coordination problem of firms' choices of accounting methods.Therefore, we keep other elements in the setup parsimonious. In Section 3.5, we study an extension in which investment is decentralized. Second, our setup does not require any private information, and a representative investor is a good approximation to a capital market that allocates capital efficiently given the publicly available information.

firms:[3]

$$(k_1^*, k_2^*) \in \arg\max_{k_1,k_2} E\left[2\tilde{\theta}_1\sqrt{k_1} - k_1 + 2\tilde{\theta}_2\sqrt{k_2} - k_2 | s_1, s_2\right] \tag{2}$$

Accounting Methods. Firm $i \in \{1,2\}$ chooses its accounting method $\omega_i \in \{\Omega_i, \Omega_c\}$ at date 1. Here, Ω_c denotes the *common method*, and Ω_i denotes firm i's *local method.* If firm i chooses its local method, $\omega_i = \Omega_i$, an accounting report, $s_i(\Omega_i) \equiv \theta_i + \delta_i$, is generated at date 2. Here, δ_i is the realization of a random variable, $\tilde{\delta}_i \sim N(0, v_\delta)$, that captures the measurement error of the local method. If firm i chooses the common method, $\omega_i = \Omega_c$, a report, $s_i(\Omega_c) \equiv \theta_i + \tau_{i,c}$, is generated, where $\tau_{i,c}$ is a realization of a random variable, $\tilde{\tau}_{i,c} \sim N(0, v_\tau)$, that captures the measurement error of the common method. We assume that $\tilde{m}$, $\tilde{n}_i$, and $\tilde{\delta}_i$ are independent from each other. Then, for a given pair of accounting method choices (i.e., ω_1 and ω_2), the value of firm $i \in \{1,2\}$ can be expressed as follows:

$$W_i(\omega_i, \omega_j) = E\left[E\left[2\tilde{\theta}_i\sqrt{k_i^*} - k_i^* | s_i(\omega_i), s_j(\omega_j)\right] | \omega_i, \omega_j\right]. \tag{3}$$

We make two fundamental assumptions regarding the measurement errors of the two accounting methods. First, we assume that the measurement errors of both reports, s_1 and s_2, become correlated if and only if both firms choose the common method. This assumption reflects the fact that, if both firms use the same method, at least part of that error is associated with the method and, therefore, correlated across firms. We call this the *common-method effect.* We operationalize this assumption by decomposing the error of the common method into two components: $\tilde{\tau}_{i,c} = \tilde{\eta} + \tilde{\epsilon}_i$, with $\tilde{\eta} \sim N(0, v_\eta)$ and $\tilde{\epsilon}_i \sim N(0, v_\epsilon)$, and they are independent from each other and from other random variables in the model. The first error term, $\tilde{\eta}$, becomes a common measurement error across the two reports if both firms choose the common method. However, if firm i chooses the common method, and firm j chooses its local method, then $\tilde{\eta}$ is an error term of firm i, but not an error term of firm

[3]Note that, in this two-firm setting without investment externalities, firms and investor would make the same investment decisions, since they all have the same information and capital is unlimited. In Section 3, this ceases to be the case, because investment decisions generate externalities.

Date 1	Date 2	Date 3
Accounting methods are chosen for $i \in \{1, 2\}$.	The investor observes s_1 and s_2, chooses k_i for $i \in \{1, 2\}$.	Firms generate cash flows.

Figure 1: Timeline

j; thus, $\tilde{\eta}$ is specific to firm i. The second error term, $\tilde{\epsilon}_i$, is always firm-specific. That is, $\tilde{\epsilon}_1$ and $\tilde{\epsilon}_2$ are always independent. Second, we assume that the local methods are more precise than the common method. This reflects the fact that a local method can be tailored to the idiosyncrasies of a firm, whereas a common method has to make a compromise between the idiosyncrasies of both firms. We call this the *one-size-fits-all problem.* This assumption translates to the following inequality:

$$v_\delta < v_\eta + v_\epsilon. \tag{4}$$

To briefly summarize, if both firms use the common method, each firm's report exhibits a higher degree of total measurement error, but both reports share a common measurement error $\tilde{\eta}$. If each firm uses its respective local method, each firm has a lower total measurement error, and the reports of both firms do not share a common measurement error. Finally, if firm i uses its local method and firm j uses the common method, their reports do not share a common measurement error. In other words, the correlation in measurement error exists only when the two firms use the same accounting method.

Timeline. The model consists of three dates, which we summarize as follows. At date 1, each firm chooses an accounting method $\omega_i \in \{\Omega_c, \Omega_i\}$, and this choice becomes common knowledge. At date 2, reports $s_1(\omega_1)$ and $s_2(\omega_2)$ are issued according to the accounting method $\omega_i \in \{\Omega_i, \Omega_c\}$ chosen at date 1. Based on reports s_1 and s_2, the representative investor chooses the optimal amounts of capital k_1^* and k_2^* to maximize the expected net cash flows of both firms. At date 3, each project generates a cash flow that is distributed back to the investor.

Tractability Assumption. We follow Dye and Sridhar (2008) and make an additional assumption for algebraic tractability:[4] For any productivity factor $\tilde{\theta}$ with mean μ and density $f(\theta|\mu)$, μ is large enough such that

$$\int_{\theta>0} \theta^2 f(\theta|\mu)\, d\theta \approx \int_{-\infty}^{+\infty} \theta^2 f(\theta|\mu)\, d\theta.$$

This assumption implies that the mean μ of productivity $\tilde{\theta}_i$ is sufficiently large so that the probability of a negative productivity $\tilde{\theta}_i$ is almost zero. We assume that this approximation assumption holds for every proposition.

Equilibrium Definition. The equilibrium definition is based on the notion of Sub-game Perfect Bayesian Equilibrium:

1. Conjecturing the other firm's choice of accounting method, $\hat{\omega}_j$, and anticipating the representative investor's investment strategy $k_i^*(s_i(\omega_i), s_j(\hat{\omega}_j))$, each firm i's choice of accounting method $\omega_i \in \{\Omega_c, \Omega_i\}$ maximizes its firm value

$$W_i(\omega_i, \hat{\omega}_j) = E\left[E\left[2\tilde{\theta}_i\sqrt{k_i^*} - k_i^* | s_i(\omega_i), s_j(\hat{\omega}_j)\right] | \omega_i, \hat{\omega}_j\right].$$

2. In equilibrium, conjectures are true. That is, for $j \in \{1, 2\}$, $\hat{\omega}_j = \omega_j$.

3. Observing the firms' choices of accounting methods, (ω_i, ω_j), and the realized reports, (s_i, s_j), the investor's investment strategy $k_i^*(s_i(\omega_i), s_j(\omega_j))$ maximizes the expected net cash flows of both firms, that is,

$$(k_1^*, k_2^*) \in \arg\max_{k_1,k_2} E\left[2\tilde{\theta}_1\sqrt{k_1} - k_1 + 2\tilde{\theta}_2\sqrt{k_2} - k_2 | s_i(\omega_i), s_j(\omega_j)\right].$$

[4] We make this assumption because we assume a non-negative investment. Alternatively, we can assume that the investment return is linear and its cost is quadratic, and the results remain qualitatively.

2.2 Comparability vs. Uniformity

The Conceptual Framework of the FASB (2010) states that comparability is "the qualitative characteristic that enables users to identify and understand similarities in, and differences among, items." Conceptually, we think of comparability as the extent to which differences in accounting reports are informative about the differences of firms' underlying fundamentals. We operationalize this by defining comparability ρ_c as the correlation between $\theta_i - \theta_j$ and $s_i - s_j$:

$$\rho_c \equiv Corr\left(\theta_i - \theta_j, s_i - s_j\right) = \frac{Cov\left(\theta_i - \theta_j, s_i - s_j\right)}{\sqrt{Var\left(\theta_i - \theta_j\right)}\sqrt{Var\left(s_i - s_j\right)}}. \tag{5}$$

This definition of comparability emphasizes the investor's use of accounting reports to compare productivity across firms. It reflects the extent to which, by comparing accounting reports, the investor can estimate the difference between the firms' fundamentals. This can be formally seen with the expression,

$$\frac{E[\theta_i - \theta_j | s_i - s_j]}{\sqrt{Var[\theta_i - \theta_j]}} = \rho_c \frac{s_i - s_j}{\sqrt{Var[s_i - s_j]}}.$$

Uniformity refers to the practice that the same set of measurement rules is applied to all firms. For instance, in our model, uniformity is obtained if both firms adopt the common method. Uniformity is often promoted as a means to make accounting reports more comparable. The FASB asserts in its Statement of Financial Accounting Concepts (FASB, 1980) that "the difficulty in making financial comparisons among enterprises because of the use of different accounting methods has been accepted for many years as the principal reason for the development of accounting standards." In our paper, however, uniformity and comparability are distinct in the sense that more uniformity does not necessarily render accounting reports more comparable.

In our two-firm setting, there are three possible combinations of accounting method choices that yield different degrees of comparability. Let $\rho_c\left(\Omega_1, \Omega_2\right)$, $\rho_c\left(\Omega_c, \Omega_c\right)$, and $\rho_c\left(\Omega_i, \Omega_c\right)$ denote the comparability between the reports if each firm uses its local method (i.e., $\omega_i = \Omega_i$

for $i \in \{1,2\}$), if both firms use the common method (i.e., $\omega_1 = \omega_2 = \Omega_c$), and if one firm uses its local method and the other firm uses the common method (i.e., $\omega_1 \neq \omega_2$), respectively. They can be expressed as follows:

$$\rho_c(\Omega_1, \Omega_2) = \sqrt{\frac{v_n}{v_n + v_\delta}}, \quad \rho_c(\Omega_c, \Omega_c) = \sqrt{\frac{v_n}{v_n + v_\epsilon}}, \quad \rho_c(\Omega_i, \Omega_c) = \sqrt{\frac{2v_n}{2v_n + v_\delta + v_\eta + v_\epsilon}}. \tag{6}$$

Notice that with $v_\epsilon < v_\delta$, the reports are more comparable if both firms adopt the common method than if both firms adopt their local method. This is the case even though a firm choosing the common method exhibits a higher degree of total measurement error than choosing its local method (i.e., $v_\delta < v_\eta + v_\epsilon$). This observation captures the measurement trade-off that arises from the homogenization of accounting methods. Applying the same accounting method may improve comparability between the reports but may also increase the total measurement error. However, the adoption of a common method by both firms does not guarantee higher comparability. Indeed, if local methods exhibit smaller idiosyncratic measurement errors than the common method (i.e., $v_\epsilon > v_\delta$), reports are more comparable with the local methods (i.e., $\omega_i = \Omega_i$ for $i \in \{1,2\}$). Therefore, for a common method (i.e., uniformity) to increase comparability, it must be the case that i) the idiosyncratic measurement error under the common method is smaller than that under the local methods (i.e., $v_\epsilon < v_\delta$), and ii) both firms adopt the common method (i.e., $\omega_i = \Omega_c$ for $i \in \{1,2\}$).

2.3 Equilibrium Analysis

We solve the model using backward induction: we first characterize the investor's optimal investment decision upon observing the accounting reports. Then, we step back to date 1 to examine the firm's optimal choice of accounting method.

Date 2 - Investment Decisions. At date 2, the investor observes the reports $s_1(\omega_1)$ and $s_2(\omega_2)$ and chooses the optimal amount of capital investment in firm 1 and firm 2. The first-order condition regarding the investment decision k_i implies that the optimal level of capital investment in firm $i \in \{1,2\}$ is given by,

$$k_i^* = \left(E\left[\theta_i | s_i\left(\omega_i\right), s_j\left(\omega_j\right)\right]\right)^2.$$

Considering the accounting methods chosen at date 1, the investor uses both firms' accounting reports to update her beliefs about the productivity of each firm i, θ_i. Indeed, the accounting methods chosen by the firms affect the variance-covariance structure of the measurement errors. In particular, if $\omega_i = \Omega_i$ for $i \in \{1,2\}$, the joint distribution of the reports and the fundamental is,

$$\begin{pmatrix} \theta_i \\ s_i \\ s_j \end{pmatrix} \sim N\left(\begin{pmatrix} \bar{\mu} \\ \bar{\mu} \\ \bar{\mu} \end{pmatrix}, \begin{pmatrix} v_m + v_n & v_m + v_n & v_m \\ v_m + v_n & v_m + v_n + v_\delta & v_m \\ v_m & v_m & v_m + v_n + v_\delta \end{pmatrix}\right).$$

If instead $\omega_i = \omega_j = \Omega_c$, then the joint distribution is,

$$\begin{pmatrix} \theta_i \\ s_i \\ s_j \end{pmatrix} \sim N\left(\begin{pmatrix} \bar{\mu} \\ \bar{\mu} \\ \bar{\mu} \end{pmatrix}, \begin{pmatrix} v_m + v_n & v_m + v_n & v_m \\ v_m + v_n & v_m + v_n + v_\eta + v_\epsilon & v_m + v_\eta \\ v_m & v_m + v_\eta & v_m + v_n + v_\eta + v_\epsilon \end{pmatrix}\right).$$

Finally, if $\omega_i = \Omega_i$ and $\omega_j = \Omega_c$, the joint distribution is,

$$\begin{pmatrix} \theta_i \\ s_i \\ s_j \end{pmatrix} \sim N\left(\begin{pmatrix} \bar{\mu} \\ \bar{\mu} \\ \bar{\mu} \end{pmatrix}, \begin{pmatrix} v_m + v_n & v_m + v_n & v_m \\ v_m + v_n & v_m + v_n + v_\delta & v_m \\ v_m & v_m & v_m + v_n + v_\eta + v_\epsilon \end{pmatrix}\right).$$

Date 1 - Accounting Method Choice. We plug in k_i^* into the expected net cash flow of firm i. We then take another expectation to obtain the ex-ante value of firm i as a function of the accounting method choices:

$$W_i(\omega_i,\omega_j) = E\left[E\left[2\tilde{\theta}_i\sqrt{k_i^*} - k_i^*|s_i(\omega_i), s_j(\omega_j)\right]|\omega_i,\omega_j\right] = E\left[(E[\theta_i|s_i(\omega_i), s_j(\omega_j)])^2\right]$$

Firms play a simultaneous game in which each firm $i \in \{1,2\}$ has two accounting methods to choose from, $\omega_i \in \{\Omega_i, \Omega_c\}$. The payoff matrix of such a game is expressed in Figure 2.

	$\omega_2 = \Omega_2$	$\omega_2 = \Omega_c$
$\omega_1 = \Omega_1$	$W_1(\Omega_1,\Omega_2), W_2(\Omega_1,\Omega_2)$	$W_1(\Omega_1,\Omega_c), W_2(\Omega_1,\Omega_c)$
$\omega_1 = \Omega_c$	$W_1(\Omega_c,\Omega_2), W_2(\Omega_c,\Omega_2)$	$W_1(\Omega_c,\Omega_c), W_2(\Omega_c,\Omega_c)$

Figure 2: Payoff matrix for Firm 1 and Firm 2

The analysis of this game yields the following proposition summarizing the pure-strategy equilibria in the two-firm setting.

Proposition 1. *In the two-firm game,*

(a) there always exists an equilibrium in which both firms choose their local methods, i.e.,$\{\omega_1 = \Omega_1, \omega_2 = \Omega_2\}$, and at date 2, the investor chooses the investment,

$$k_i^* = \left(\frac{s_i v_n(2v_m + v_n) + \{(s_i + s_j)v_m + (\mu + s_i)v_n\}v_\delta + \mu v_\delta^2}{(v_n + v_\delta)(2v_m + v_n + v_\delta)}\right)^2.$$

(b) There exists another equilibrium in which both firms choose the common method, i.e., $\{\omega_1 = \Omega_c, \omega_2 = \Omega_c\}$, when v_m is sufficiently small and $v_\delta \in [v_\delta^*, v_\eta + v_\epsilon]$, where $v_\delta^* > 0$ and is defined in the Appendix. At date 2, the investor chooses the investment,

$$k_i^* = \left(\frac{\mu(v_n + v_\epsilon)(v_\epsilon + 2v_\eta) + s_j(v_m v_\epsilon - v_n v_\eta) + s_i(v_m(2v_n + v_\epsilon) + v_n(v_n + v_\epsilon + v_\eta))}{(v_n + v_\epsilon)(2v_m + v_n + v_\epsilon + 2v_\eta)}\right)^2.$$

Proposition 1 shows that there are two possible equilibria: one in which both firms adopt the common method, the *common equilibrium*, and another one in which both firms adopt their own local methods, the *local equilibrium*. The local equilibrium always exists because no firm wants to deviate into being the only firm choosing the common method. If a firm attempts to coordinate on the common method but the other firm does not reciprocate, the correlation in measurement error does not take place. Thus, the measurement error becomes entirely idiosyncratic, which renders the accounting reports, s_1 and s_2, less comparable. In addition, the firm suffers from the larger measurement error under the common method. [5] Thus, if firm j chooses its local method (i.e., $\omega_j = \Omega_j$), it is always optimal for firm i to choose its local method as well (i.e., $\omega_i = \Omega_i$).

The common equilibrium does not always exist. For the common equilibrium to exist, the improvement in comparability resulting from both firms adopting the common method must be large enough to compensate for the larger total error accompanying the common method. Such a larger error is not as much of a problem if the local method is not that precise. Thus, for the common equilibrium to exist, v_δ needs to be large enough. In other words, the local method cannot be too precise. Also, for the common equilibrium to exist, comparability must be a valuable informational property. This is the case if v_m is small enough. If v_m is large, firms cannot afford to have a correlated measurement error because it obfuscates the investor's learning about the common productivity component, m. When v_m is small, then v_n is relatively large. That is, when firms are more heterogeneous in their productivity, learning about their differences becomes more important, making the adoption of the common method, which improves comparability, more valuable. In other words, the common equilibrium exists if the productivity is sufficiently heterogeneous across firms.

2.4 Pareto-dominant vs Risk-dominant Accounting Methods

The results so far show that there can be multiple equilibria, which can pose a coordination problem for firms in adopting a Pareto-dominant accounting method. This section illustrates conditions under which a common equilibrium yields higher allocation efficiency

[5] $v_\eta + v_\epsilon > v_\delta$ implies $\rho_c(\Omega_c, \Omega_j) = \sqrt{2v_n/(2v_n + v_\delta + v_\eta + v_\epsilon)} < \sqrt{v_n/(v_n + v_\delta)} = \rho_c(\Omega_1, \Omega_2)$.

but may not be an equilibrium on which firms coordinate. In particular, we use the notion of risk dominance in the sense of Harsanyi and Selten (1988).

Research has shown that in repeated games, players often reach a risk-dominant equilibrium, instead of a Pareto-dominant equilibrium. Intuitively, in a two-player game with two actions for each player, H and G, the equilibrium (H, H) risk-dominates the equilibrium (G, G) if, while both (H, H) and (G, G) are equilibria, players think that playing G is riskier and should play H. That is, it is costlier for a player to mistakenly think that the other player chooses G than to mistakenly think that the other player chooses H. Specifically, (H, H) risk-dominates (G, G) if the product of the two players' deviation losses is higher under (H, H) than under (G, G). In our setting, the common equilibrium risk-dominates the local equilibrium if and only if $W_i(\Omega_c; \Omega_c) - W_i(\Omega_i; \Omega_c) > W_i(\Omega_i; \Omega_j) - W_i(\Omega_c; \Omega_j)$.

Proposition 2. *Assume that v_m is sufficiently small such that there exists a unique $v_\delta^* < v_\eta + v_\epsilon$ for any $v_\delta \in [v_\delta^*, v_\eta + v_\epsilon]$ and both the common equilibrium and the local equilibrium exist. Then there exist $\bar{v}_p$* and *$\bar{v}_r$ with $v_\delta^* < \bar{v}_p < \bar{v}_r < v_\eta + v_\epsilon$, such that the followings hold:*

(a) The common equilibrium, $\omega_i = \Omega_c$ for $i \in \{1, 2\}$ is Pareto-dominant if $v_\delta > \bar{v}_p$; and it is Pareto-dominated if $v_\delta < \bar{v}_p$.

(b) The common equilibrium, $\omega_i = \Omega_c$ for $i \in \{1, 2\}$ is risk-dominant if $v_\delta > \bar{v}_r$; and it is risk-dominated if $v_\delta < \bar{v}_r$.

The results in Proposition 2 show that there are conditions under which the common equilibrium Pareto-dominates but is risk-dominated by the local equilibrium. Holding v_η and v_ϵ constant, Proposition 2 divides the range of values of v_δ for which the common equilibrium exists into three regions. If v_δ is relatively small such that $v_\delta \in (v_\delta^*, \bar{v}_p)$, then the local equilibrium is Pareto-dominant and also risk-dominant. In contrast, if v_δ is relatively large such that $v_\delta \in (\bar{v}_r, v_\eta + v_\epsilon)$, then the common equilibrium is both Pareto-dominant and risk-dominant. However, if v_δ is at an intermediate level such that $v_\delta \in (\bar{v}_p, \bar{v}_r)$, then the common equilibrium is Pareto-dominant, but it is risk-dominated. At $v_\delta = \bar{v}_p$, the common and local equilibria generate the same aggregate firm value. However, it is riskier to play the common equilibrium. A firm loses a lot by choosing the common method if the other firm switches to the local method. Such move eliminates the correlation in measurement error, making the measurement error entirely idiosyncratic and resulting in less comparability across the reports. In addition, the common method exhibits a larger total measurement error. Thus, it is safer to play the local equilibrium, as the loss is smaller if the other firm switches to the common method. The local equilibrium exhibits a lower comparability but also a lower total error. In short, the common equilibrium is a risky one to coordinate on as a firm suffers more if the other firm deviates. Therefore, there is a sizable intermediate range for v_δ in which the common equilibrium Pareto dominates but is risk dominated by the local equilibrium.

The results in Proposition 2 shed light on the role a regulator can play in coordinating firms' choices of accounting methods. The multiplicity of equilibria whenever a common equilibrium exists poses a coordination problem. In other words, the multiplicity of equilibria itself is already a reason to have a central authority imposing an accounting method that facilitates the efficient allocation of capital. The central authority can improve the allocation efficiency by coordinating the adoption of a common method when the common equilibrium is Pareto-dominant but firms are stuck playing a local equilibrium, or by encouraging firms to adopt their local methods when the local equilibrium is Pareto-dominant but not chosen. Moreover, the result that the local equilibrium risk-dominates the Pareto-dominant common equilibrium makes the case for regulation even more compelling. Indeed, it has been experimentally shown that players of a game in which a Pareto-dominant equilibrium is risk dominated by another equilibrium usually coordinate on the risk-dominant equilibrium (Anctil et al., 2004; Cabrales et al., 2007). Thus, if firms were allowed to choose accounting rules on their own, they would most likely choose their locally optimal accounting methods, even if they all could be better off coordinating on a common accounting set of standards.

3 Accounting Method Choice: Continuum-of-Firm Analysis

We now examine a setting with a continuum of firms with mass one, indexed by $i \in [0, 1]$. We further assume that investments exhibit externalities, behaving as either complements or substitutes. Such investment externalities are widely recognized in macroeconomics literature. For example, investment complementarity can arise as a result of technology spillovers. Each firm's investment may generate technological knowledge that improves other firms' marginal productivity (e.g., Arrow, 1962). Conversely, investment substitutability is common within industries where, for example, products are less differentiated and competition is fierce. In such industries, higher aggregate investment leads to lower marginal profitability for each firm.

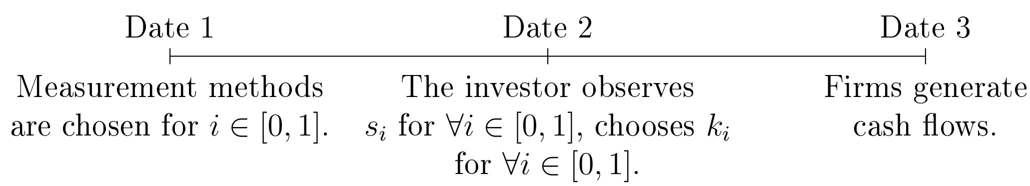

Figure 3: Timeline

3.1 Model

The timeline of the model is essentially the same as in Section 2. At date 1, firm $i \in [0, 1]$ chooses between its local method, $\omega_i = \Omega_i$, and a common method, $\omega_i = \Omega_c$, to maximize its firm value. At date 2, the representative investor observes all reports s_i for $i \in [0, 1]$ and allocates capital across firms to maximize the expected net cash flows from her investment, that is, aggregate firm value. At date 3, cash flows are realized, and all parties consume.

We assume that each firm's productivity is affected by the investment decisions of all other firms in the economy. In particular, the terminal cash flow of firm i is of the form:

$$2 (\theta_i - \lambda \Gamma) \sqrt{k_i} - k_i,$$

where, $\Gamma \equiv \int_0^1 \sqrt{k_i} di$ governs how the investments of all firms in the economy affect the productivity of each firm. Also, the coefficient $\lambda > -1/2$ captures the intensity and sign of the investment externalities. If λ is positive, investments exhibit substitutability and decrease each other firm's investment return. If λ is negative, investments exhibit complementarity and thus increase the investment returns of other firms. If $\lambda = 0$, there are no investment externalities, as in Section 2.[6]

We assume that a representative investor allocates capital across firms to abstract away from the coordination problem at the investment stage. Thus, the allocation of capital is assumed to be efficient at the market level, given the available public information. We instead focus on the coordination problem that firms face in choosing their accounting methods. Our results show that even without an investment coordination problem and without private information at the investment stage, the choice of each firm's accounting method can affect the efficiency of capital allocation.

Comparability. We now apply the comparability measure, $\rho_c = Corr\left(\theta_i - \theta_j, s_i - s_j\right)$, to the setting with a continuum of firms. Let $\rho_c\left(\Omega_c\right)$ and $\rho_c\left(\Omega_i\right)$ denote the measure of comparability if every firm adopts the common method and if every firm adopts its local method, respectively. Then, we have

$$\rho_c\left(\Omega_c\right) = \sqrt{\frac{v_n}{v_n + v_\epsilon}}, \quad \rho_c\left(\Omega_i\right) = \sqrt{\frac{v_n}{v_n + v_\delta}}. \tag{7}$$

Notice that the expressions are the same as the ones in the two-firm setting. In addition, in both cases, the comparability measures decrease with idiosyncratic measurement error variances, that is, v_ϵ and v_δ.

Aggregate Informativeness. Let S denote the set of all reports s_i for $i \in [0, 1]$. Then, the investor can utilize all the available reports to update her belief about the aggregate productivity shock in the economy. Let $\bar{\theta} \equiv \int_0^1 \theta_i di$ denote the aggregate productivity shock

[6]We assume that λ is not too large, so that the probability of a negative marginal productivity, $\tilde{\theta}_i - \lambda\Gamma$, is negligible, as in Dye and Sridhar (2008).

in the economy, and let $\bar{s} = \int_0^1 s_i di$ denote the aggregate report in the economy. We define *aggregate informativeness*, ρ_a, as the correlation between the aggregate productivity shock and the aggregate report in the economy. That is,

$$\rho_a \equiv Corr\left(\bar{\theta}, \bar{s}\right).$$

We can now apply this definition to our model. Let $\rho_a\left(\Omega_c\right)$ denote the measure of aggregate informativeness if every firm adopts the common method. Then, since $\bar{s} = m + \eta$ and $\bar{\theta} = m$, we have,

$$\rho_a\left(\Omega_c\right) = Corr\left(m, m + \eta\right) = \sqrt{\frac{v_m}{v_m + v_\eta}}. \tag{8}$$

Let $\rho_a\left(\Omega_i\right)$ denote the measure of aggregate informativeness if every firm adopts its local method. Then, we have $\bar{s} = m$, and

$$\rho_a\left(\Omega_i\right) = Corr\left(m, m\right) = 1. \tag{9}$$

3.2 Equilibrium Analysis

As in the previous section, we solve the model using backward induction.

Date 2 - Investment. At date 2, the representative investor observes reports s_i for $i \in [0,1]$. Given set of all the available reports S and $\Gamma = \int_0^1 \sqrt{k_i} di$, the investor chooses k_i^* for each firm $i \in [0,1]$ to maximize the aggregate firm value:

$$E\left[\int_0^1 \left[2\left(\theta_i - \lambda \int_0^1 \sqrt{k_j} dj\right)\sqrt{k_i} - k_i\right] di|S\right].$$

With the first-order condition, we obtain the optimal investment k_i^* for each firm i:

$$k_i^* = \left(E\left[\theta_i - 2\lambda \int_0^1 \sqrt{k_j} dj|S\right]\right)^2. \tag{10}$$

Then, by aggregating $\sqrt{k_i^*}$ over $i \in [0,1]$, we obtain Γ:

$$\Gamma = \int_0^1 E\left[\theta_i|S\right] di - 2\lambda\Gamma \Rightarrow \Gamma = \frac{1}{1+2\lambda}\int_0^1 E\left[\theta_i|S\right] di = \frac{1}{1+2\lambda} E\left[m|S\right].$$

The investor calculates the conditional expected value of θ_i, $E\left[\theta_i|S\right]$, considering the prevailing accounting methods. For example, if all firms, $i \in [0,1]$, choose their local method, $\omega_i = \Omega_i$, or all firms choose the common method, $\omega_i = \Omega_c$,we have,

$$E\left[\tilde{\theta}_i|S\right] = \mu + \rho_a^2\left(\omega_i\right)\left(\bar{s} - \mu\right) + \rho_c^2\left(\omega_i\right)\left(s_i - \bar{s}\right). \tag{11}$$

Expression 11 shows that the investor's belief about a firm i's productivity is contingent on two signals. First, the investor utilizes all available reports in the economy and obtains the aggregate report, $\bar{s} \equiv \int_0^1 s_j dj$, which is the most informative signal about the common productivity shock, m. With the aggregate report $\bar{s}$, the investor obtains the second signal for each firm i, $s_i - \bar{s}$, which reflects all the available information about the firm's idiosyncratic productivity shock, n_i. Notice also that the expected productivity of firm i is contingent on two coefficients that capture the informational effects of the accounting method choices of all firms in the economy: aggregate informativeness, ρ_a, and comparability, ρ_c. That is, all firms' collective accounting choices determine the sensitivity of the investor's belief to common productivity shock information, ρ_a, and to idiosyncratic shock information, ρ_c.

Date 1 - Accounting Method Choice. At date 1, each firm $i \in [0,1]$ chooses its accounting method $\omega_i \in \{\Omega_c, \Omega_i\}$ to maximize its firm value. With investment externalities, the expression for firm i's value is given by:

$$W_i = E\left[E\left[2\left(\theta_i - \lambda\Gamma\right)\sqrt{k_i^*} - k_i^*|S\right]\right]$$

This expression can be rewritten in a way that better reflects the economic tradeoffs:

$$W_i = \mu^2 + \underbrace{Var\left[E\left[\theta_i|S\right]\right]}_{Informativeness} - \underbrace{2\lambda E\left[E\left[\theta_i|S\right]E\left[\Gamma|S\right]\right]}_{investment\, externalities} \tag{12}$$

The firm value expression in 12 is quite general, as it does not make any distributional assumptions. The first term in 12, μ^2, is the square of the unconditional expected productivity. The second term captures the informativeness of all the accounting reports regarding the productivity of firm i. This term embodies the investment efficiency as affected by all firms' accounting choices, absent investment externalities. The third term reflects the effect of investment externalities on the firm's value. Such an effect is generated by the expected product between the conditional expected productivity of firm i and the aggregate investment, which is essentially their covariance. Thus, externalities are mediated by their intensity, λ, and by the commonality among the productivity of all firms in the economy. Embedding the information structure assumptions made thus far in expressions 10 and 12, we can express the optimal investment and the ensuing firm value as follows:

Lemma 1. *Suppose that firms choose $\omega_i = \Omega_c$ for all $i \in [0,1]$, or they choose $\omega_i = \Omega_i$ for all $i \in [0,1]$. Then, the optimal amount of capital investment in firm i, k_i^*, is given by the expression,*

$$k_i^* = \left(\frac{1}{1+2\lambda}\left[\mu + \rho_a^2\left(\omega_i\right)\left(\bar{s}-\mu\right)\right] + \rho_c^2\left(\omega_i\right)\left(s_i - \bar{s}\right)\right)^2, \tag{13}$$

and the value of firm i is given by the expression,

$$W_i = \frac{1}{1+2\lambda}\left(\mu^2 + \rho_a^2\left(\omega_i\right)v_m\right) + \rho_c^2\left(\omega_i\right)v_n \tag{14}$$

Conveying firm value as in 14 reveals that firms' collective choices of accounting methods affect the firm value through the measurement properties we previously defined: aggregate informativeness, ρ_a, and comparability, ρ_c. Notice that comparability, ρ_c, is multiplied by the idiosyncratic productivity shock variance, v_n. Thus, comparability increases the firm value to the extent that firms are heterogeneous in their productivity. Likewise, aggregate informativeness, ρ_a, is multiplied by the common productivity shock variance, v_m. Thus, aggregate informativeness increases the firm value to the extent that firms share the common productivity shock. Lastly, notice that the externality intensity, λ, interacts with the common shock variance v_m, the unconditional expected productivity μ, but not the idiosyncratic shock variance v_n. This confirms the insight we obtained previously with expression 12 that externalities affect the firm value through the common productivity shock across firms.

With the firm value expressed as a function of the firms' accounting choices as in 14, we now analyze the equilibrium. The following proposition summarizes the pure-strategy equilibria in this setting.

Proposition 3. *Let $v_\delta < v_\eta + v_\epsilon$. In this game, there are two possible pure-strategy equilibria:*

(a) Local Equilibrium: there always exists an equilibrium in which every firm chooses its local method, i.e., $\omega_i = \Omega_i$ for $i \in [0,1]$.

(b) Common Equilibrium: there exist an equilibrium in which every firm chooses the common method, i.e., $\omega_i = \Omega_c$ for $\forall i \in [0,1]$, if v_ϵ and v_η satisfy either one of the following two conditions (where v_η^N and $v_\epsilon^N(v_\eta)$ are defined in the Appendix):

1. *If $\frac{v_\delta}{v_n} \leq \frac{\lambda}{1+\lambda}$: $v_\epsilon \in \left[v_\delta - v_\eta, v_\epsilon^N(v_\eta)\right]$ and $v_\eta \geq 0$,*
2. *If $\frac{v_\delta}{v_n} > \frac{\lambda}{1+\lambda}$ and $v_m \geq 0$ is sufficiently small: $v_\epsilon \in \left[v_\delta - v_\eta, v_\epsilon^N(v_\eta)\right]$ and $v_\eta \geq v_\eta^N$.*

As in the two-firm analysis, there exist conditions under which there are multiple equilibria. Part (a) in Proposition 3 shows that there always exists an equilibrium in which every firm i adopts its local method - the local equilibrium. Intuitively, if other firms $j \neq i$ adopt their local method and firm i deviates by choosing the common method, the report of firm i does not become more comparable to other firms' reports. In addition, it suffers from a larger measurement error than the one it would obtain with its local method. Then, the informativeness of all the accounting reports about firm i decreases, and so does the firm value. Thus, firm i has no reason to deviate from the local equilibrium.

Part (b) in Proposition 3 shows that if v_ϵ is sufficiently small (i.e., $v_\epsilon \leq v_\epsilon^N$), there is another equilibrium in which every firm adopts the common method - the common equilibrium. Because of the one-size-fits-all problem, the common method introduces a larger total measurement error than the local method (i.e., $v_\delta < v_\eta + v_\epsilon$). Therefore, there is the lower bound for idiosyncratic error variance: $v_\epsilon \geq v_\delta - v_\eta$. Thus, a common method characterized by a low v_η is constrained to exhibit a larger $v_\epsilon \geq v_\delta - v_\eta$, thereby producing less comparable reports. That is, $\rho_c(\Omega_c) = \sqrt{v_n / (v_n + v_\epsilon)}$ decreases in the common equilibrium. Part (b.1) shows that a common method with a low $v_\eta \geq 0$ can nevertheless be chosen as an equilibrium if investments exhibit strong substitutability, that is, a large $\lambda > 0$. Investment substitutability emphasizes the differences among firms, reducing the investor's need to learn about the common productivity shock. Thus, a common method with a small $v_\eta \geq 0$ (and a large $v_\epsilon \geq 0$) can also be chosen in an equilibrium, even though the reports under the common equilibrium may exhibit lower comparability. Conversely, Part (b.2) shows that if investment substitutability is weak, then the existence of a common equilibrium requires the common productivity shock to be small (i.e., low v_m) and the adoption of the common method to result in high comparability $\rho_c(\Omega_c)$ (i.e., a small $v_\epsilon \geq v_\delta - v_\eta$ for a large $v_\eta \geq v_\eta^N$). With a low v_m, productivity differences among firms become more relevant for the investor. Thus, firm value increases by adopting the common method, producing more comparable reports.

One can think of the pair of measurement error variances, (v_η, v_ϵ), as the characterization of a possible common accounting method. Figure 4 graphically illustrates a numerical case in the space of possible common methods. In that space, fixing the local-method idiosyncratic error variance, $v_\delta > 0$, $v_\epsilon^N(v_\eta)$ is the set of common methods that make each firm i indifferent between choosing its own local method, $\omega_i = \Omega_i$, and choosing the common method, $\omega_i = \Omega_c$, when other firms adopt the common method. That is, fixing v_δ and v_η, v_ϵ^N is the threshold level of idiosyncratic error variance below which the common equilibrium can subsist. In the same figure, v_η^N satisfies $v_\epsilon^N\left(v_\eta^N\right) = v_\delta - v_\eta^N$. In other words, v_η^N is the lowest possible level of the common measurement error that places $v_{\epsilon}^{N}(v_{\eta})$ above the constraint $v_{\delta} - v_{\eta}$. Thus, in figure 4, the shaded area below the threshold $v_{\epsilon}^{N}(v_{\eta})$ and above the constraint $v_{\delta} - v_{\eta}$ delimits the set of common method pairs (v_{η}, v_{ϵ}) for which the common equilibrium exists.

It is important to note that there is no pure-strategy equilibrium in which some firms adopt the common method and other firms adopt their local methods whenever $v_{\delta} \neq v_{\epsilon}$. This can be shown by contradiction. Assume that a positive measure, strictly less than 1, of firms adopt the common method while the rest of the firms adopt their local method. By the law of large numbers, the aggregation of reports elaborated with the local method would reveal the common productivity shock, m. Similarly, the aggregation of the reports elaborated with the common method would reveal $m + \eta$. With this information, the investor would be able to observe $n_i + \delta_i$ from all firms using the local method, and $n_i + \epsilon_i$ from all firms using the common method. This is not an equilibrium because, with all this information, only one of the two methods can survive. If $v_{\epsilon} < v_{\delta}$, the common method is more comparable and more precise. Conversely, if $v_{\epsilon} > v_{\delta}$, then the local method dominates in both aspects. Thus, in both cases, firms always deviate, and we reach a contradiction. Such an equilibrium is sustainable only in the knife-edge case with $v_{\epsilon} = v_{\delta}$.

3.3 Pareto-Dominant Accounting Method

Having characterized an equilibrium choice of accounting methods, we now characterize the conditions under which the economy is better off with firms adopting the common method (i.e., $\omega_i = \Omega_c$ for $i \in [0,1]$), relative to firms adopting their local methods (i.e., $\omega_i = \Omega_i$ for $i \in [0,1]$). Let $W(\Omega_c) \equiv \int W_i(\Omega_c)\,di$ denote the aggregate firm value if all firms adopt the common method, and let $W(\Omega_i) \equiv \int W_i(\Omega_i)\,di$ denote the aggregate firm value if all firms adopt their local methods. Then, using the expression of aggregate firm value from 14 and

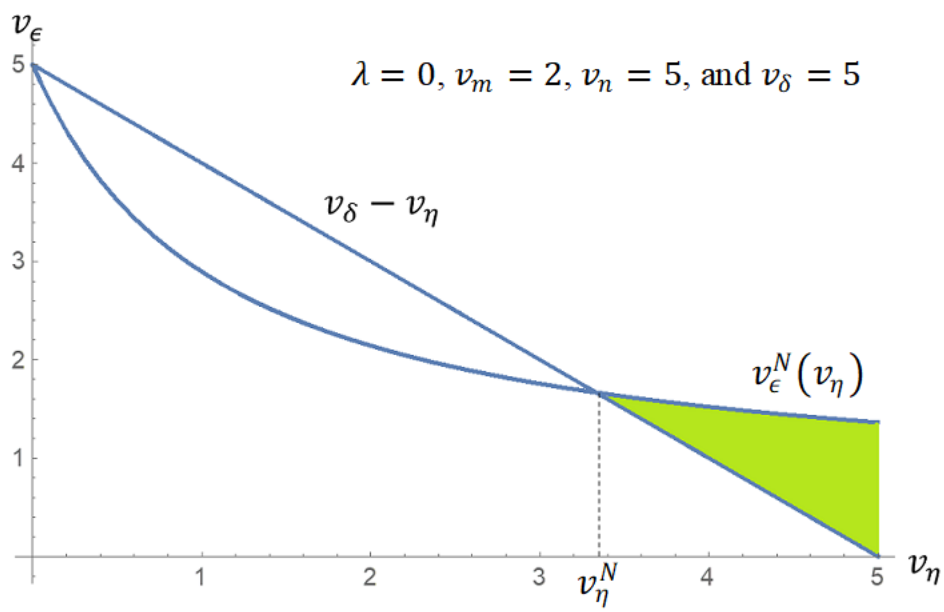

Figure 4: The set of common accounting methods that are sustainable as a common equilibrium (shaded region).

the measures of comparability and aggregate informativeness from 7, 8, and 9, we obtain

$$W(\Omega_c) = \frac{1}{1+2\lambda}\left(\mu^2 + \frac{v_m^2}{v_m + v_\eta}\right) + \frac{v_n^2}{v_n + v_\epsilon} \tag{15}$$

$$W(\Omega_i) = \frac{1}{1+2\lambda}\left(\mu^2 + v_m\right) + \frac{v_n^2}{v_n + v_\delta} \tag{16}$$

The following proposition characterizes the conditions under which a common method, if used by all firms in the economy, generates a higher aggregate firm value than the local methods, i.e., $W(\Omega_c) > W(\Omega_i)$. Notice that we do not require the universal use of a common method to be an equilibrium outcome. We identify the conditions under which the universal use of a common method is not an equilibrium but still can facilitate a more efficient capital allocation in the economy than the use of local methods.

Proposition 4. *Consider a local method and a common method such that $v_\delta < v_\eta + v_\epsilon$, and $v_\epsilon^P(v_\eta)$ and v_η^P are as defined in the Appendix.*

(a) The common method, if used by every firm, Pareto-dominates the local equilibrium if

v_ϵ and v_η satisfy either one of the following two set of conditions:

1. *$\lambda \geq \frac{v_\delta(2v_n+v_\delta)}{2v_n^2}$, $v_\epsilon \in \left[v_\delta - v_\eta, v_\epsilon^P(v_\eta)\right]$, and $v_\eta \geq 0$,*
2. *$\lambda < \frac{v_\delta(2v_n+v_\delta)}{2v_n^2}$, $v_m \geq 0$ is sufficiently small, $v_\epsilon \in \left[v_\delta - v_\eta, v_\epsilon^P(v_\eta)\right]$, and $v_\eta \geq v_\eta^P$.*

(b) If the use of the common method by all firms Pareto-dominates the local equilibrium, then we have $\rho_c(\Omega_c) > \rho_c(\Omega_i)$.

(c)$\frac{\partial v_\epsilon^P}{\partial v_m} \leq 0$, $\frac{\partial v_\eta^P}{\partial v_m} \geq 0$.

Part (a) of Proposition 4 identifies the conditions for the Pareto optimality of a common method. Given the variance of the local method's idiosyncratic measurement error, v_δ, $v_\epsilon^P(v_\eta)$ captures the pairs of common and idiosyncratic measurement errors (v_η, v_ϵ) that make aggregate firm value under the common method the same as the one under the local methods. That is, for any v_δ and v_η, v_ϵ^P is the threshold level of idiosyncratic measurement error below (above) which the common method is Pareto-dominant (dominated). v_η^P satisfies $v_\epsilon^P\left(v_\eta^P\right) = v_\delta - v_\eta^P$. That is, v_η^P is the lowest possible level of the common measurement error that satisfies the constraint $v_\epsilon^P(v_\eta) + v_\eta \geq v_\delta$. As in Proposition 3, a strong degree of investment substitutability (i.e., large λ) makes learning about productivity differences more important. Thus, a common method that, if universally adopted, leads to lower comparability (i.e., relatively a high v_ϵ and a low $v_\eta \geq 0$) can still be Pareto-dominant with a large enough λ. Conversely, weak investment substitutability makes the learning of the common productivity shock more useful. Thus, for the common method to be Pareto-dominant, the variance of the common productivity shock, v_m, must be low so that comparability is a valuable property. In addition, the universal adoption of the common method must lead to a sufficiently high degree of comparability.

Part (b) of Proposition 4 shows that for a common method to be Pareto-dominant, the comparability under the common method needs to be larger than the one attained with the local method. Finally, Part (c) in Proposition 4 shows that reducing the variance of the common productivity shock, v_m, enlarges the set of parameters under which the common method is Pareto-dominant. Intuitively, with a lower v_m, it becomes more important to learn about productivity differences across firms than to learn about the common productivity shock in the economy. Thus, the investor benefits more from the common method, as it enhances the comparability among firms.

Pareto-dominant vs Equilibrium Accounting Methods. Having characterized the set of common methods that are Pareto-dominant, we now investigate whether they can be attained as an equilibrium outcome. This analysis helps us understand whether firms can coordinate on the Pareto-dominant method voluntarily without a centralized regulator. The results are summarized in Proposition 5.

Proposition 5. *Consider a local method and a common method such that* $v_\delta < v_\eta + v_\epsilon$.

a) $\frac{\partial v_\epsilon^P}{\partial \lambda} > 0$, $\frac{\partial v_\epsilon^P}{\partial \lambda} > 0$.

b) $v_\epsilon^N > v_\epsilon^P$ *if and only if* $\lambda < \frac{v_\delta}{2v_n}$. *Therefore,*

b.1) suppose $\lambda < \frac{v_\delta}{2v_n}$, *if the common method is Pareto-optimal, then the common equilibrium exists,*

b.2) suppose $\lambda \geq \frac{v_\delta}{2v_n}$, *if the common equilibrium exists, then it Pareto-dominates the local equilibrium.*

Part (a) in Proposition 5 summarizes the effects of investment externalities on the parameter range under which the common equilibrium exists and the range under which the common method is Pareto-optimal. The Pareto-dominance region expands with a higher λ because a stronger investment substitutability makes it more valuable for the investor to allocate capital to highly productive firms. The common-equilibrium region also expands with a higher λ because a stronger investment substitutability implies that individual firms can better reduce the residual uncertainty about their productivity with more comparable accounting reports.

Part (b.1) in Proposition 5 shows that there exists a set of parameters under which the common equilibrium is Pareto-dominated by the local equilibrium if the condition $\lambda < \frac{v_\delta}{2v_n}$ is satisfied. Investment complementarity (i.e., lower λ) magnifies the common productivity

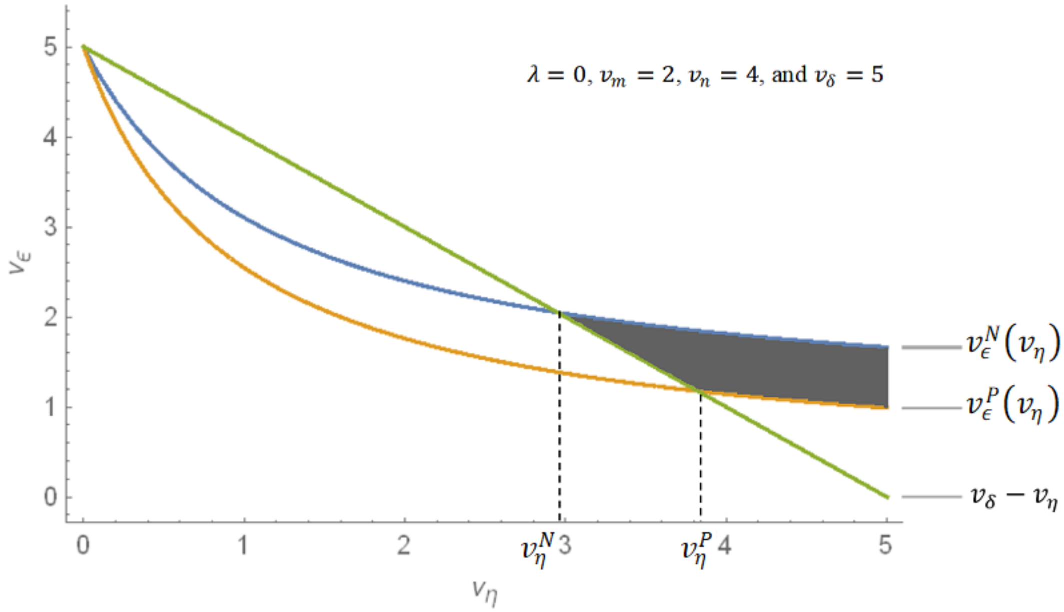

Figure 5: Equilibrium common methods Pareto-dominated by the local equilibrium.

shock in the economy, making learning about the common productivity shock more critical. This is also the case with a smaller idiosyncratic productivity shock variability (i.e., lower v_n). These conditions make the adoption of local methods more desirable since they facilitate learning about the common productivity shock. However, once the common method becomes a norm, firms cannot deviate from it unilaterally for two reasons. First, the common method's disadvantage of one-size-fits-all effect is not too severe with a high v_δ. Second, upon deviating, the loss of comparability obfuscates the investor's learning about the firm's idiosyncratic productivity shock, thereby lowering the firm's value. The shaded region in Figure 5 describes a parameter space in which the common method, $\omega_i = \Omega_c$ for $i \in [0,1]$, is not Pareto-dominant but it is still an equilibrium.

Part (b.2) shows that if $\lambda > \frac{v_\delta}{2v_n}$, then the common method can Pareto-dominate the local equilibrium, even if the common equilibrium does not exist. A strong substitutability (i.e., higher λ) or more idiosyncratic productivity shocks variability (i.e., higher v_n) mitigate the importance of learning about the common productivity shock and stress the differences among firms, making comparable reports more valuable. Thus, the common method facili-

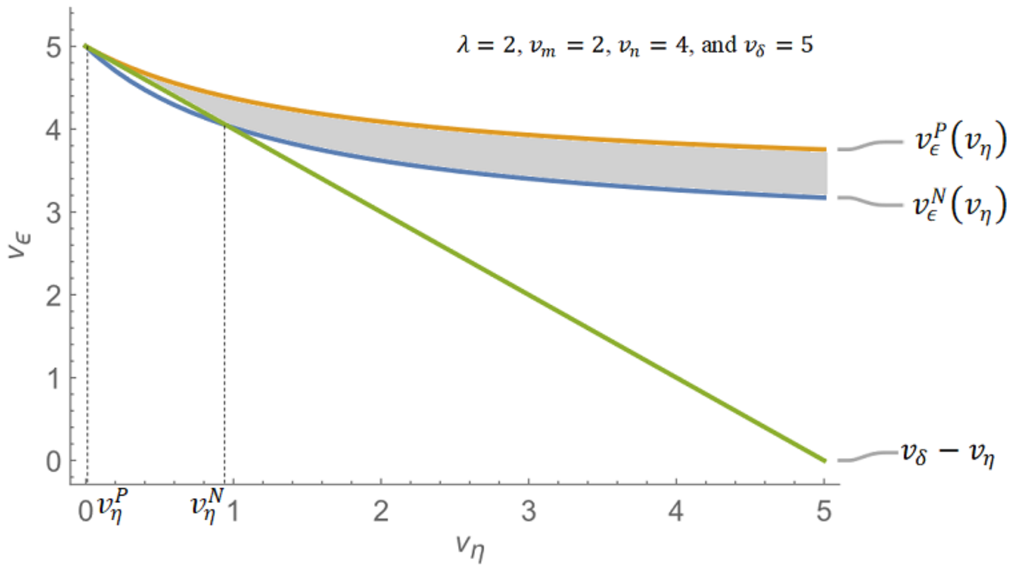

Figure 6: Non-equilibrium common methods that Pareto-dominate the local equilibrium.

tates the efficient allocation of capital across firms, even if the common method suffers from a large one-size-fits-all effect relative to the local method (i.e., low v_δ). However, each firm is more concerned with increasing its own firm value than with improving capital allocation efficiency in the economy (i.e., the aggregate firm value). Thus, in the presence of a relatively strong one-size-fits-all effect, each firm prefers its local method to increase its own firm value. The shaded region in Figure 6 describes a parameter space in which the common method is not an equilibrium, but still Pareto-dominates the local equilibrium.

The results in Proposition 5, illustrated in Figures 5 and 6, shed light on the role a regulator can play in coordinating firms' accounting choices. There are two potential scenarios under which a regulator can facilitate an efficient capital allocation by coordinating firms' choices of accounting methods. First, firms may not adopt a common method in equilibrium, despite it generating a higher aggregate firm value. This can be more problematic when investment substitutability is high. In this case, a regulator can mandate the adoption of a common method to render reports more comparable, thereby facilitating capital allocation across firms in the economy. Second, firms may adopt a common method, even if it is Pareto-dominated. This is more likely the case with a strong investment complementarity because then local methods allow firms to learn better about the common productivity shock. In this case, the regulator can encourage each firm to adopt its own local method. Overall, a regulator can guide firms to coordinate on a Pareto-optimal equilibrium when multiple equilibria exist or mandate a common method when it is socially optimal but non-existing as an equilibrium.

3.4 Decentralized Investment

So far, our main analysis has assumed that a representative investor allocates investment across firms to maximize aggregate firm value, given the prevailing accounting methods and information. This assumption implies that the representative investor internalizes investment externalities, and the aggregate investment is efficient, given all publicly available information. In this section, we consider a decentralized investment setting in which each firm i chooses the amount of investment k_i to maximize its firm value. Thus, the aggregate investment may not necessarily be efficient. We investigate how a decentralized investment decision affects firms' choices of accounting methods.

We modify the model with a continuum of firms analyzed so far in Section 3 by assuming that k_i is chosen by each firm $i \in [0, 1]$ to maximize its firm value W_i, and we conduct the analysis using backward induction.

At date 2, each firm observes all the reports in the economy, s_i for all $i \in [0, 1]$, and makes its investment decision. An important difference from a centralized investment setting is that the firm takes as given the effect of its investment on other firms' productivity. That is, Γ is treated as a constant, entailing that the firm fails to internalize the investment externalities on other firms. The firm solves the following maximization problem with respect to k_i:

$$\max_{k_i} E\left[2\left(\theta_i - \lambda\Gamma dj\right)\sqrt{k_i} - k_i|S\right].$$

With the first-order condition, we obtain firm i's optimal investment k_i^D:

$$k_i^D = \left(E\left[\theta_i - \lambda \int_0^1 \sqrt{k_j} dj | S \right] \right)^2 .$$

Then, by aggregating $\sqrt{k_i^D}$ over $i \in [0,1]$, we obtain $\Gamma^D = \int_0^1 E\left[\theta_i | S\right] di - \lambda \Gamma^D$, or

$$\Gamma^D = \frac{1}{1+\lambda} \int_0^1 E\left[\theta_i | S\right] di.$$

The following lemma derives the aggregate firm values in the decentralized investment setting.

Lemma 2. *Let $W^D(\Omega_c)$ and $W^D(\Omega_i)$ denote the aggregate firm value under a common and local methods in a decentralized investment setting, respectively. Then, we have*

$$W^D(\Omega_c) = \frac{1}{(1+\lambda)^2} \left(\mu^2 + \frac{v_m^2}{v_m + v_\eta} \right) + \frac{v_n^2}{v_n + v_\epsilon} \tag{17}$$

$$W^D(\Omega_i) = \frac{1}{(1+\lambda)^2} \left(\mu^2 + v_m \right) + \frac{v_n^2}{v_n + v_\delta} \tag{18}$$

In addition, we have $W(\Omega_c) \geq W^D(\Omega_c)$ and $W(\Omega_i) \geq W^D(\Omega_i)$.

Lemma 2 shows that the aggregate firm value with decentralized investments is smaller than the aggregate firm value with centralized investments. Comparing the aggregate values in both settings, it is clear that the differences are caused by the first terms, which are related to the common productivity shock:

$$\frac{1}{(1+\lambda)^2} \left(\mu^2 + \frac{v_m^2}{v_m + v_\eta} \right) < \frac{1}{1+2\lambda} \left(\mu^2 + \frac{v_m^2}{v_m + v_\eta} \right),$$

$$\frac{1}{(1+\lambda)^2} \left(\mu^2 + v_m \right) < \frac{1}{1+2\lambda} \left(\mu^2 + v_m \right).$$

Because firms do not internalize the effects of their investment decisions on the aggregate firm value in the decentralized investment setting, their decisions are not fully adjusted to reflect the common productivity shock in the economy, leading to a lower aggregate firm value. Conversely, the second terms about firm-specific shocks are not affected by whether investments are decentralized because firms always internalize the effects of their investment decisions on their firm values. This insight leads to the following proposition.

Proposition 6. *For* $\lambda \neq 0$*, if* $W(\Omega_c) \geq W(\Omega_i)$*, then* $W^D(\Omega_c) > W^D(\Omega_i)$*. For* $\lambda = 0$*,*$W(\Omega_c) = W(\Omega_i)$ *if and only if* $W^D(\Omega_c) = W^D(\Omega_i)$*.*

Proposition 6 shows that the set of parameters under which the common method Pareto-dominates the local equilibrium in a centralized economy is a subset of the set of parameters under which the common method Pareto-dominates the local equilibrium in a decentralized economy. In short, when investment decisions do not internalize investment externalities, the common method becomes more desirable, regardless of whether the investment externalities exhibit either substitutability or complementarity. Intuitively, as expressions 12 and 14 convey, externalities affect firm values through common productivity shock information. In a centralized setting, the representative investor adjusts capital allocation to reflect externalities making the best use of the publicly available information regarding the common productivity shock. In a decentralized investment setting, however, firms do not make such a good use of that information because they do not take externalities under consideration. Instead, it is better to provide them with information they want to use, information regarding their idiosyncrasies. The common accounting method does precisely that by increasing the comparability of accounting reports.

4 Conclusion

Uniformity has been a central topic of controversy among accountants since the very first accounting standardization attempts. In this paper, we strive to reflect the traditional opposing views about the consequences of uniformity in an analytical model that allows us to examine its effects on capital allocation efficiency.

We show that a necessary condition for accounting uniformity to improve capital allocation efficiency is that it increases comparability, i.e., it reduces idiosyncratic measurement errors and tells differences more clearly across firms. Such benefit is larger when firms' productivity shocks are more heterogeneous or when the prior uncertainty regarding the common productivity shock is smaller. Extant research has shown that "both macro and micro uncertainty appear to rise sharply in recessions and fall in booms." (Bloom, 2014, p. 153). Our result suggests that, the benefit of accounting uniformity can vary with macroeconomic conditions: it can be more valuable in good times when firms are more heterogenous, and less so when macroeconomic uncertainty is high. Learning regarding the common economic factor has recently received attention in the accounting literature (e.g., Roychowdhury et al., 2019), and our analysis provides further empirical implications.

We also show that accounting regulation can improve capital allocation efficiency by coordinating firms on adopting the Pareto dominant accounting method. Without regulation, there can be cases where firms face multiple equilibria and have difficulty coordinating on the Pareto dominant one. More importantly, when investment shows strong substitutability, it can be Pareto dominant for all firms to adopt the common method, but this cannot be self-enforceable as a Nash equilibrium. Thus, the benefits of comparability and the existence of a coordination problem can justify the regulatory imposition of a common accounting method.

We further study cases where accounting uniformity is more desirable. We first show that it is desirable when aggregate investment shows more substitutability (or less complementarity). In mature industries, for instance, over-capacity can make one firm's investment pose a severe negative externality on others. (e.g., Spence, 1977). Such substitutability makes the efficient allocation of capital across heterogeneous firms more important, thereby stressing the need for uniformity to better learn about the differences across firms. This can potentially explain why uniform accounting methods were proposed in the highly competitive railway industry in the early 20th century (Nay, 1913). On the other hand, in new industries, investments may be complements because they generate knowledge spillover, or expand the customer base, that also benefit other firms. This "learning-by-doing" effect has been widely recognized in the economics literature (e.g., Arrow, 1962). Indeed, in these cases it is more important to learn about the common factor, and uniformity can be potentially harmful. Finally, we also show that uniformity is more desirable when the investment is decentralized and firms fail to internalize the externality of their investment on other peers.

5 Appendix

Proof of Proposition 1.

With $k_i^* = (E[\theta_i|s_i(\omega_i), s_j(\omega_j)])^2$, we derive the expected value for firm i:

$$W_i(\omega_i, \omega_j) = E\left[(E[\theta_i|s_i(\omega_i), s_j(\omega_j)])^2\right] = \mu^2 + Var\left(E[\theta_i|s_i(\omega_i), s_j(\omega_j)]\right).$$

Then, we have

$$W_i(\Omega_i, \Omega_j) = \mu^2 + \frac{1}{2}\left(\frac{v_n^2}{v_n + v_\delta} + \frac{(2v_m + v_n)^2}{2v_m + v_n + v_\delta}\right),$$

$$W_i(\Omega_c, \Omega_c) = \mu^2 + \frac{1}{2}\left(\frac{v_n^2}{v_n + v_\epsilon} + \frac{(2v_m + v_n)^2}{2v_m + v_n + v_\epsilon + 2v_\eta}\right),$$

$$W_i(\Omega_c, \Omega_j) = \mu^2 + \frac{v_n^2(v_n + v_\delta) + v_m v_n(3v_n + 2v_\delta) + v_m^2(2v_n + v_\delta + v_\eta + v_\epsilon)}{(v_n + v_\delta)(v_n + v_\eta + v_\epsilon) + v_m(2v_n + v_\delta + v_\eta + v_\epsilon)},$$

$$W_i(\Omega_i, \Omega_c) = \mu^2 + \frac{v_n^2(v_n + v_\eta + v_\epsilon) + v_m^2(2v_n + v_\eta + v_\epsilon + v_\delta) + v_m v_n(3v_n + 2(v_\eta + v_\epsilon))}{(v_n + v_\delta)(v_n + v_\eta + v_\epsilon) + v_m(2v_n + v_\eta + v_\epsilon + v_\delta)}.$$

(a) We first check whether both firms choosing the local method is an equilibrium. Given the symmetry, we only need to check whether firm i's best response is $\omega_i = \Omega_i$, when firm j chooses $\omega_j = \Omega_j$ and $j \neq i$. Let $A(x)$ be defined for $x \geq 0$ such that

$$A(x) \equiv \mu^2 + \frac{v_n^2(v_n + v_\delta) + v_m v_n(3v_n + 2v_\delta) + v_m^2(2v_n + v_\delta + x)}{(v_n + v_\delta)(v_n + x) + v_m(2v_n + v_\delta + x)}.$$

Notice that $\frac{\partial}{\partial x}A\left(x\right)=-\left(\frac{v_n(v_n+v_\delta)+v_m(2v_n+v_\delta)}{(v_n+v_\delta)(v_n+x)+v_m(2v_n+v_\delta+x)}\right)^2<0$, $A\left(v_\delta\right)=W_i\left(\Omega_i,\Omega_j\right)$, and $A\left(v_\eta+v_\epsilon\right)=W_i\left(\Omega_c,\Omega_j\right)$. Since $v_\delta<v_\eta+v_\epsilon$, we have $W_i\left(\Omega_i,\Omega_j\right)>W_i\left(\Omega_c,\Omega_j\right)$. This implies that by symmetry, both firms choosing their respective local method is an equilibrium. By plugging in the optimal investment amount, we have

$$k_i^*=\left(E\left[\theta_i|s_i\left(\Omega_i\right),s_j\left(\Omega_j\right)\right]\right)^2=\left(\frac{s_iv_n\left(2v_m+v_n\right)+\left\{\left(s_1+s_2\right)v_m+\left(\mu+s_i\right)v_n\right\}v_\delta+\mu v_\delta^2}{\left(v_n+v_\delta\right)\left(2v_m+v_n+v_\delta\right)}\right)^2.$$

(b) Suppose that firm j chooses $\omega_j=\Omega_c$. Let $\Omega_i\left(v_\delta\right)$ denote a local method with the idiosyncratic measurement error variance $v_\delta\geq 0$. Then, $W_i\left(\Omega_i\left(v_\delta\right),\Omega_c\right)$ is a function of $v_\delta\geq 0$, and it is decreasing in v_δ:

$$\frac{\partial}{\partial v_\delta}W_i\left(\Omega_i\left(v_\delta\right),\Omega_c\right)=-\left(\frac{v_n\left(v_n+v_\epsilon+v_\eta\right)+v_m\left(2v_n+v_\epsilon+v_\eta\right)}{\left(x+v_n\right)\left(v_n+v_\epsilon+v_\eta\right)+v_m\left(v_\delta+2v_n+v_\epsilon+v_\eta\right)}\right)^2<0.$$

Furthermore, [7]

$$W_i\left(\Omega_i\left(0\right),\Omega_c\right)-W_i\left(\Omega_c,\Omega_c\right)=v_m+v_n+\mu^2-\left(\frac{1}{2}\left(\frac{v_n^2}{v_n+v_\epsilon}+\frac{\left(2v_m+v_n\right)^2}{2v_m+v_n+v_\epsilon+2v_\eta}\right)+\mu^2\right)>0;$$

$$\lim_{v_m\to 0}\left\{W_i\left(\Omega_i\left(v_\eta+v_\epsilon\right),\Omega_c\right)-W_i\left(\Omega_c,\Omega_c\right)\right\}=-\frac{2v_n^2v_\eta^2}{\left(v_n+v_\epsilon\right)\left(v_n+v_\epsilon+v_\eta\right)\left(v_n+v_\epsilon+2v_\eta\right)}<0.$$

Putting it together, when v_m is sufficiently small, we have $W_i\left(\Omega_i\left(v_\eta+v_\epsilon\right),\Omega_c\right)<W_i\left(\Omega_c,\Omega_c\right)$. Then, since $W_i\left(\Omega_i\left(v_\delta\right),\Omega_c\right)$ is continuous in v_δ, there must exist a unique $v_\delta^*<v_\eta+v_\epsilon$ such that $W_i\left(\Omega_i\left(v_\delta^*\right),\Omega_c\right)=W_i\left(\Omega_c,\Omega_c\right)$, and the common equilibrium exists whenever $v_\delta\geq v_\delta^*$. When this is the case, the optimal investment is:

$$k_i^*=\left(\frac{\mu\left(v_n+v_\epsilon\right)\left(v_\epsilon+2v_\eta\right)+s_j\left(v_mv_\epsilon-v_nv_\eta\right)+s_i\left(v_m\left(2v_n+v_\epsilon\right)+v_n\left(v_n+v_\epsilon+v_\eta\right)\right)}{\left(v_n+v_\epsilon\right)\left(2v_m+v_n+v_\epsilon+2v_\eta\right)}\right)^2.$$

Q.E.D.

[7] $\frac{1}{2}\left(\frac{v_n^2}{v_n+v_\epsilon}+\frac{(2v_m+v_n)^2}{2v_m+v_n+v_\epsilon+2v_\eta}\right)=\frac{1}{2}\underbrace{\left(\frac{v_n}{v_n+v_\epsilon}+\frac{2v_m+v_n}{2v_m+v_n+v_\epsilon+2v_\eta}\right)}_{less\,than\,2}v_n+\frac{2v_m+v_n}{2v_m+v_n+v_\epsilon+2v_\eta}v_m<v_n+v_m.$

Proof of Proposition 2.

(a) We first consider the region of Pareto dominance for the common equilibrium. Let $Q(v_\delta)$ denote the difference in firm value between the common equilibrium and the local equilibrium: $Q(v_\delta) \equiv W_i(\Omega_c, \Omega_c) - W_i(\Omega_i(v_\delta), \Omega_j(v_\delta))$Then, we have

$$W_i(\Omega_c, \Omega_c) - W_i(\Omega_i(v_\delta), \Omega_j) = \frac{1}{2}\left(\frac{v_n^2}{v_n + v_\epsilon} + \frac{(2v_m + v_n)^2}{2v_m + v_n + v_\epsilon + 2v_\eta}\right) - \frac{1}{2}\left(\frac{v_n^2}{v_n + v_\delta} + \frac{(2v_m + v_n)^2}{2v_m + v_n + v_\delta}\right),$$

which is increasing in v_δ. In addition, at $v_\delta = v_\eta + v_\epsilon$, we have $W_i(\Omega_i, \Omega_j) = \mu^2 + \frac{1}{2}\left(\frac{v_n^2}{v_n + v_\eta + v_\epsilon} + \frac{(2v_m + v_n)^2}{2v_m + v_n + v_\eta + v_\epsilon}\right)$, which is equal to $W_i(\Omega_i(v_\eta + v_\epsilon), \Omega_c)$. From Part (b) of Proposition 1, we also have $W_i(\Omega_i(v_\eta + v_\epsilon), \Omega_c) < W_i(\Omega_c, \Omega_c)$. Thus, we have $Q(v_\eta + v_\epsilon) = W_i(\Omega_c, \Omega_c) - W_i(\Omega_i, \Omega_j) > 0$ in equilibrium. Furthermore, we have $Q(v_\delta^*) < 0$, because, $W_i(\Omega_c, \Omega_c) = W_i(\Omega_i(v_\delta^*), \Omega_c)$, and $W_i(\Omega_i, \Omega_c) < W_i(\Omega_i, \Omega_j)$ for $v_\delta < v_\eta + v_\epsilon$.[8] Thus, there exists a $\bar{v}_p \in (v_\delta^*, v_\eta + v_\epsilon)$ such that $Q(\bar{v}_p) = 0$, and when $v_\delta > \bar{v}_p$, the common equilibrium is Pareto-dominant, and vice versa.

(b) We next consider the region of risk dominance for the common equilibrium. Let $Y(v_\delta) \equiv \{W(\Omega_c; \Omega_c) - W_i(\Omega_i(v_\delta); \Omega_c)\} - \{W_i(\Omega_i(v_\delta); \Omega_j(v_\delta)) - W_i(\Omega_c; \Omega_j(v_\delta))\}$, i.e., the difference in the deviation loss between the common equilibrium with (v_η, v_ϵ) and the local equilibrium (v_δ). We have $\frac{\partial Y(v_\delta)}{\partial v_\delta} > 0$.[9] In addition, we have $Y(v_\eta + v_\epsilon) > 0$ with sufficiently small v_m, because $\lim_{v_m \to 0} Y(v_\eta + v_\epsilon) = \frac{(v_n v_\eta)^2}{(v_n + v_\epsilon)(v_n + v_\epsilon + v_\eta)(v_n + v_\epsilon + 2v_\eta)} > 0$; we have $Y(v_\delta^*) < 0$, because at $v_\delta = v_\delta^*$, $W_i(\Omega_c, \Omega_c) - W_i(\Omega_i, \Omega_c) = 0$ and $W_i(\Omega_i, \Omega_j) - W_i(\Omega_c, \Omega_j) > 0$ from part (a) of Proposition 1. Thus, there exists a $\bar{v}_r \in (v_\delta^*, v_\eta + v_\epsilon)$ such that $Y(\bar{v}_r) = 0$, and when $v_\delta > \bar{v}_r$, the common equilibrium is risk-dominant, and vice versa.

Furthermore, at $v_\delta = \bar{v}_p$, we have

$$Y(\bar{v}_p) = W_i(\Omega_c; \Omega_j(\bar{v}_p)) - W_i(\Omega_i(\bar{v}_p); \Omega_c) = \frac{v_n(2v_m + v_n)(v_\delta - v_\eta - v_\epsilon)}{(v_n + v_\delta)(v_n + v_\epsilon + v_\eta) + v_m(2v_n + v_\delta + v_\eta + v_\epsilon)} < 0$$

[8] $W_i(\Omega_i, \Omega_c) - W_i(\Omega_i, \Omega_j) = \frac{v_m^2 v_\delta^2 (v_\delta - v_\eta - v_\epsilon)}{(v_n + v_\delta)(2v_m + v_n + v_\delta)((v_n + v_\delta)(v_n + v_\epsilon + v_\eta) + v_m(2v_n + v_\delta + v_\epsilon + v_\eta))} < 0$ for $v_\delta < v_\eta + v_\epsilon$.

[9] The proof is omitted for brevity but can be provided upon request.

for $v_\delta < v_\eta + v_\epsilon$. Thus, we have $v_\delta^* < \bar{v}_p < \bar{v}_r < v_\eta + v_\epsilon$. Then, the common equilibrium is risk-dominated at $\bar{v}_p < \bar{v}_r$. By continuity, for $v_\delta \in (\bar{v}_p, \bar{v}_r)$, the common equilibrium is Pareto-dominant but risk-dominated.

Q.E.D.

Proof of Lemma 1.

Suppose that all firm $i \in [0,1]$ choose either $\omega_i = \Omega_c$ or $\omega_i = \Omega_i$. Then, $\bar{s}$ is a sufficient statistic for m, and $s_i - \bar{s}$ is a sufficient statistic for n_i. Then, given that $\Gamma = \frac{1}{1+2\lambda} E\left[m|S\right]$ and $k_i^* = \left(E\left[\underbrace{m + n_i}_{=\theta_i} - 2\lambda\Gamma|S\right]\right)^2$, the optimal investment is expressed by $k_i^* = \left(\frac{1}{1+2\lambda} E\left(m|s_i, \bar{s}\right) + E\left(n_i|s_i, \bar{s}\right)\right)^2$. With $E\left(m|s_i, \bar{s}\right) = \mu + \rho_a^2\left(\omega_i\right)\left(\bar{s} - \mu\right)$, and $E\left(n_i|s_i, \bar{s}\right) = \rho_c^2\left(\omega_i\right)\left(s_i - \bar{s}\right)$, we have

$$k_i^* = \left(\frac{1}{1+2\lambda}\left[\mu + \rho_a^2\left(\omega_i\right)\left(\bar{s} - \mu\right)\right] + \rho_c^2\left(\omega_i\right)\left(s_i - \bar{s}\right)\right)^2.$$

We also obtain

$$\begin{aligned} E\left(\sqrt{k_i^*}|S\right) &= E\left[\left(\frac{1}{1+2\lambda} m + n_i\right)|S\right] \\ &= \frac{1}{1+2\lambda} E\left(m|S\right) + E\left(n_i|S\right). \end{aligned}$$

Then we have:

$$
\begin{aligned}
W &= E\left[E\left[\left(2\left(\theta_i-\lambda\Gamma\right)-\sqrt{k_i^*}\right)\sqrt{k_i^*}|S\right]\right] \\
&= E\left[E\left[\left(\frac{1}{1+2\lambda}m+n_i\right)|S\right]E\left(m+n_i|S\right)\right] \\
&= E\left[\frac{1}{1+2\lambda}E\left[m|S\right]^2+\left[E\left(n_i|S\right)\right]^2\right] \\
&= \frac{1}{1+2\lambda}\left(\left\{E\left[E\left(m|S\right)\right]\right\}^2+Var\left[E\left(m|S\right)\right]\right)+\left\{E\left[E\left(n_i|S\right)\right]\right\}^2+Var\left[E\left(n_i|S\right)\right] \\
&= \frac{1}{1+2\lambda}\left(\mu^2+Var\left[E\left(m|S\right)\right]\right)+Var\left[E\left(n_i|S\right)\right] \\
&= \frac{1}{1+2\lambda}\left(\mu^2+\rho_a^2 v_m\right)+\rho_c^2 v_n \\
&= \begin{cases} \frac{1}{(1+2\lambda)}\left(\mu^2+v_m\right)+\frac{v_n^2}{v_n+v_\delta}, & if\ local\ equilibrium \\ \frac{1}{(1+2\lambda)}\left(\mu^2+\frac{v_m^2}{v_m+v_\eta}\right)+\frac{v_n^2}{v_n+v_\epsilon}, & if\ common\ \ equilibrium \end{cases}
\end{aligned}
$$

Q.E.D.

Proof of Proposition 3.

(a) Suppose that every firm $j \neq i$ has chosen $\omega_j = \Omega_j$. If $\omega_i = \Omega_i$ is chosen, Lemma 1 implies $W_i\left(\Omega_i\right) = \frac{1}{1+2\lambda}\left(\mu^2+v_m\right)+\frac{v_n^2}{v_n+v_\delta}$.If $\omega_i = \Omega_c$ is chosen given $\omega_j = \Omega_j$ for all $j \neq i$, we have $E\left[E\left(\theta_i|S\right)E\left(\Gamma|S\right)\right] = \frac{1}{1+2\lambda}v_m$. Then, the value of firm i becomes

$$
W_i\left(\Omega_c;\Omega_j\right) = \frac{1}{1+2\lambda}\left(\mu^2+v_m\right)+\frac{v_n^2}{v_n+v_\eta+v_\epsilon}.
$$

Since $v_\eta+v_\epsilon > v_\delta$, we have $W_i\left(\Omega_i;\Omega_j\right) > W_i\left(\Omega_c;\Omega_j\right)$. Thus, given $\omega_j = \Omega_j$ for all $j \neq i$, firm i also chooses $\omega_i = \Omega_i$, and $k_i^* = \left(\frac{1}{1+2\lambda}m+\frac{v_n}{v_n+v_\delta}\left(s_i-m\right)\right)^2$.

(b) Suppose every firm $j \neq i$ has chosen $\omega_j = \Omega_c$. If firm i chooses $\omega_i = \Omega_c$, Lemma 1 implies $W_i\left(\Omega_c\right) = \frac{1}{1+2\lambda}\left(\mu^2+\frac{v_m^2}{v_m+v_\eta}\right)+\frac{v_n^2}{v_n+v_\epsilon}$. If firm i chooses $\omega_i = \Omega_i$, $E\left[E\left(\theta_i|S\right)E\left(\Gamma|S\right)\right] = \mu^2+\frac{v_m\left\{v_n v_\eta+v_m\left(v_n+v_\delta+v_\eta\right)\right\}}{\left(v_n+v_\delta\right)v_\eta+v_m\left(v_n+v_\delta+v_\eta\right)}$. Then, the value of firm i is

$$
W_i\left(\Omega_i;\Omega_c\right) = \mu^2+\frac{v_m\left\{v_n^2+v_m\left(v_n+v_\delta\right)\right\}+\left(v_m+v_n\right)^2 v_\eta}{\left(v_n+v_\delta\right)v_\eta+v_m\left(v_n+v_\delta+v_\eta\right)}-\frac{2\lambda}{1+2\lambda}\left[\mu^2+\frac{v_m\left\{v_n v_\eta+v_m\left(v_n+v_\delta+v_\eta\right)\right\}}{\left(v_n+v_\delta\right)v_\eta+v_m\left(v_n+v_\delta+v_\eta\right)}\right].
$$

Then, there is a unique solution v_ϵ^N to the equation $W(\Omega_i;\Omega_c) = W(\Omega_c)$:

$$v_\epsilon^N(v_\eta) = \frac{v_n\left(v_m v_n\{(2+4\lambda)v_\delta - v_\eta\} + (1+2\lambda)v_n v_\delta v_\eta^2 + v_m^2\left(v_n(v_\delta + 2\lambda v_\delta - v_\eta) - v_\eta^2\right)\right)}{(v_n v_\eta + v_m(v_n + v_\eta))((1+2\lambda)v_n v_\eta + v_m((1+2\lambda)v_n + v_\eta))}.$$

There are three solutions to $v_\epsilon^*\left(v_\eta^*\right) = v_\delta - v_\eta^*$, which is a cubic equation in v_η, and one of the solutions is $v_\eta^N = 0$.

First, it can be shown that $\frac{\partial^2 v_\epsilon^N(v_\eta)}{\partial v_\eta^2} > 0$, so if $\frac{\partial v_\epsilon^N(v_\eta)}{\partial v_\eta}|_{v_\eta=0} > -1$, then $v_\eta^N = 0$; i.e., for any $v_\eta > 0$, there is an non-empty set of $v_\epsilon \in \left(v_\delta - v_\eta, v_\epsilon^N(v_\eta)\right)$ such that the pair (v_η, v_ϵ) can be a common equilibrium. A sufficient and necessary condition for $\frac{\partial v_\epsilon^N(v_\eta)}{\partial v_\eta}|_{v_\eta=0} \geq -1$ is that $\lambda v_n \geq (1+\lambda)v_\delta$.

Suppose that $\lambda v_n < (1+\lambda)v_\delta$. This implies

$$\frac{\partial v_\epsilon^N(v_\eta)}{\partial v_\eta}|_{v_\eta=0} = -\frac{v_n + 2v_\delta(1+\lambda)}{v_n(1+2\lambda)} < -1.$$

Then, if we have $v_\epsilon^N(v_\eta) > 0$ at $v_\eta = v_\delta$, by continuity there is a unique positive solution $v_\eta^N < v_\delta$ that satisfies the equation $v_\epsilon^N\left(v_\eta^N\right) = v_\delta - v_\eta^N$. At $v_\eta = v_\delta$, we have

$$v_\epsilon^N(v_\delta) = \frac{v_n v_\delta\{v_m^2(2\lambda v_n - v_\delta) + (1+4\lambda)v_m v_n v_\delta + (1+2\lambda)v_n v_\delta^2\}}{\{v_n v_\delta + v_m(v_n + v_\delta)\}[(1+2\lambda)v_n v_\delta + v_m\{(1+2\lambda)v_n + v_\delta\}]} > 0$$

if $\lambda > \frac{v_\delta\left(v_m^2 - v_m v_n - v_n v_\delta\right)}{2v_n(v_m+v_\delta)^2}$. Notice that $\lim_{v_m\to 0}\frac{v_\delta\left(v_m^2 - v_m v_n - v_n v_\delta\right)}{2v_n(v_m+v_\delta)^2} = -\frac{1}{2}$. Since λ is bounded below by $-\frac{1}{2}$, we have $\lambda > \frac{v_\delta\left(v_m^2 - v_m v_n - v_n v_\delta\right)}{2v_n(v_m+v_\delta)^2}$ with v_m sufficiently close to zero. Thus, if v_m is sufficiently small, there exists $v_\eta^N \in (0, v_\delta)$ such that $v_\epsilon^N\left(v_\eta^N\right) = v_\delta - v_\eta^N$. Then, $v_\epsilon^N(v_\eta)$ lies below $v_\delta - v_\eta$ for $v_\eta < v_\eta^N$ and above $v_\delta - v_\eta$ for $v_\eta > v_\eta^N$. Since $W(\Omega_c) = \frac{1}{1+2\lambda}\left(\mu^2 + \frac{v_m^2}{v_m+v_\eta}\right) + \frac{v_n^2}{v_n+v_\epsilon}$ is decreasing in v_ϵ, we have $W(\Omega_c) > W(\Omega_i;\Omega_c)$ if $v_\delta - v_\eta < v_\epsilon < v_\epsilon^N$, subject to $v_\eta > v_\eta^N$.

Lastly, we show that in an equilibrium, every firm chooses the same standard. Suppose by contradiction that firms of mass $N \in (0,1)$ have chosen $\omega_i = \Omega_i$, and firms of mass $1-N$ have chosen $\omega_j = \Omega_c$. Then, $\int_N^1(\theta_i + \eta + \epsilon_i)\,di = (1-N)(m+\eta)$ and $\int_0^N(\theta_i + \delta_i) = Nm$.

Thus, m and η are revealed to the investor, and $\Gamma = \frac{1}{1+2\lambda}\int_0^1 E\left[\theta_i|S\right] = \frac{1}{1+2\lambda}m$. Then, the ex-ante firm value with $\omega_i = \Omega_i$ is $\frac{1}{1+2\lambda}\left(\mu^2 + v_m\right) + \frac{v_n^2}{v_n+v_\delta}$; the ex-ante firm value with $\omega_j = \Omega_c$ is $\frac{1}{1+2\lambda}\left(\mu^2 + v_m\right) + \frac{v_n^2}{v_n+v_\epsilon}$. Thus, if $v_\delta > v_\epsilon$, we have $\frac{v_n^2}{v_n+v_\epsilon} > \frac{v_n^2}{v_n+v_\delta}$, and, firm i with $\omega_i = \Omega_i$ has an incentive to deviate to $\omega_i = \Omega_c$, a contradiction. If $v_\delta < v_\epsilon$, we have $\frac{v_n^2}{v_n+v_\epsilon} < \frac{v_n^2}{v_n+v_\delta}$, and firm j with $\omega_j = \Omega_c$ has an incentive to deviate to $\omega_j = \Omega_j$, a contradiction. If $v_\delta = v_\epsilon$ firms are indifferent between their own standards and the common standard. Thus to sum up, unless $v_\delta = v_\epsilon$, in equilibrium either firms all adopt the local method, or all adopt the common method.

Q.E.D.

Proof of Proposition 4.

(a) Let $v_\eta + v_\epsilon > v_\delta$ be given. There is a unique solution to equation $W\left(\Omega_c\right) = W\left(\Omega_i\right)$ in v_ϵ:

$$v_\epsilon^P = \frac{v_n\left(\left(1+2\lambda\right)v_n v_\delta v_\eta + v_m\left(\left(1+2\lambda\right)v_n v_\delta - \left(v_n+v_\delta\right)v_\eta\right)\right)}{\left(1+2\lambda\right)v_n^2 v_\eta + v_m\left(\left(1+2\lambda\right)v_n^2 + \left(v_n+v_\delta\right)v_\eta\right)}.$$

Then, if $v_\epsilon < v_\epsilon^P$, the common method Pareto-dominates the local equilibrium; we need to check $v_\eta + v_\epsilon > v_\delta \Rightarrow v_\epsilon > v_\delta - v_\eta$. Notice that $v_\epsilon^P\left(v_\eta\right) = v_\delta$ at $v_\eta = 0$ and $v_\epsilon^P\left(v_\eta\right) = \frac{v_n v_\delta\{v_m(2\lambda v_n - v_\delta) + (1+2\lambda)v_n v_\delta\}}{(1+2\lambda)v_n^2 v_\delta + v_m\left\{(1+2\lambda)v_n^2 + v_n v_\delta + v_\delta^2\right\}}$ at $v_\eta = v_\delta$. In addition, $v_\epsilon^P\left(v_\eta\right)$ is decreasing and convex in v_η.

$$\frac{\partial v_\epsilon^P}{\partial v_\eta} = -\frac{\left(1+2\lambda\right)\left(\left(v_n+v_\delta\right)v_m v_n\right)^2}{\left(\left(1+2\lambda\right)v_n^2 v_\eta + v_m\left(\left(1+2\lambda\right)v_n^2 + \left(v_n+v_\delta\right)v_\eta\right)\right)^2} < 0,$$
$$\frac{\partial^2 v_\epsilon^P}{\partial v_\eta^2} = \frac{2\left(1+2\lambda\right)v_m^2 v_n^2\left(v_n+v_\delta\right)^2\left(\left(1+2\lambda\right)v_n^2 + v_m\left(v_n+v_\delta\right)\right)}{\left(\left(1+2\lambda\right)v_n^2 v_\eta + v_m\left(\left(1+2\lambda\right)v_n^2 + \left(v_n+v_\delta\right)v_\eta\right)\right)^3} > 0.$$

Thus, if $v_\epsilon^P\left(v_\eta\right) > 0$ and $\frac{\partial v_\epsilon^P}{\partial v_\eta} < -1$ at $v_\eta = v_\delta$, there exists a unique solution $v_\eta^P \in \left(0, v_\delta\right)$ such that $v_\epsilon^P\left(v_\eta^P\right) = v_\delta - v_\eta^P$. If v_m is sufficiently small, we have $v_\epsilon^P\left(v_\eta\right) > 0$ at $v_\eta = v_\delta$, because $\lim_{v_m\to 0} v_\epsilon^P\left(v_\delta\right) = v_\delta > 0$. Thus, if v_m is sufficiently small, there exists a Pareto-dominant common method $\left(v_\eta, v_\epsilon\right)$ such that $v_\delta - v_\eta < v_\epsilon < v_\epsilon^P$ for $v_\eta > v_\eta^P$. Notice that

$\frac{\partial v_\epsilon^P}{\partial v_\eta} = -\frac{(v_n+v_\delta)^2}{(1+2\lambda)v_n^2} < -1$ at $v_\eta = 0$ for $\lambda < \frac{v_\delta(2v_n+v_\delta)}{2v_n^2}$. Thus, we have $v_\eta^P = 0$ if $\lambda \geq \frac{v_\delta(2v_n+v_\delta)}{2v_n^2}$ and $v_\eta^P = \frac{v_m\left(2v_nv_\delta+v_\delta^2-2\lambda v_n^2\right)}{(1+2\lambda)v_n^2+v_m(v_n+v_\delta)}$ if $-\frac{1}{2} < \lambda < \frac{v_\delta(2v_n+v_\delta)}{2v_n^2}$.

(b) Suppose by contradiction $\rho\left(\Omega_c\right) \leq \rho\left(\Omega_i\right)$. This implies $v_\epsilon \geq v_\delta$. Then, we have

$$W\left(\Omega_i\right) = \frac{1}{1+2\lambda}\left(\mu^2+v_m\right) + \frac{v_n^2}{v_n+v_\delta} \geq \frac{1}{1+2\lambda}\left(\mu^2+\frac{v_m^2}{v_m+v_\eta}\right) + \frac{v_n^2}{v_n+v_\epsilon} = W\left(\Omega_c\right).$$

This contradicts $W\left(\Omega_c\right) > W\left(\Omega_i\right)$. Thus, we have $\rho\left(\Omega_c\right) \leq \rho\left(\Omega_i\right)$.

(c) Notice that, we have

$$\frac{\partial v_\epsilon^P}{\partial v_m} = -\frac{\left((1+2\lambda)\left(v_n+v_\delta\right)v_\eta v_n\right)^2}{\left((1+2\lambda)\,v_n^2v_\eta + v_m\left((1+2\lambda)\,v_n^2+\left(v_n+v_\delta\right)v_\eta\right)\right)^2} < 0,$$

and $\frac{\partial v_\eta^P}{\partial v_m} = 0$ if $\lambda \geq \frac{v_\delta(2v_n+v_\delta)}{2v_n^2}$. If $-\frac{1}{2} < \lambda < \frac{v_\delta(2v_n+v_\delta)}{2v_n^2}$, we have

$$\frac{\partial v_\eta^P}{\partial v_m} = -\frac{(1+2\lambda)\,v_n^2\left(2\lambda v_n^2-2v_nv_\delta-v_\delta^2\right)}{\left((1+2\lambda)\,v_n^2+v_m\left(v_n+v_\delta\right)\right)^2} > 0,$$

and $\frac{\partial v_\eta^P}{\partial v_m} = 0$ if $\lambda \geq \frac{v_\delta(2v_n+v_\delta)}{2v_n^2}$.

Q.E.D.

Proof of Proposition 5.

(a) We have

$$\frac{\partial v_\epsilon^P}{\partial \lambda} = \frac{2v_mv_n^2\left(v_n+v_\delta\right)^2v_\eta\left(v_m+v_\eta\right)}{\left((1+2\lambda)\,v_n^2v_\eta+v_m\left((1+2\lambda)\,v_n^2+\left(v_n+v_\delta\right)v_\eta\right)\right)^2} > 0,$$
$$\frac{\partial v_\epsilon^N}{\partial \lambda} = \frac{2v_mv_n^2v_\eta\left(v_m+v_\eta\right)\left\{\left(v_n+v_\delta\right)v_\eta+v_m\left(v_n+v_\delta+v_\eta\right)\right\}}{\left\{v_nv_\eta+v_m\left(v_n+v_\eta\right)\right\}\left[(1+2\lambda)\,v_nv_\eta+v_m\left\{(1+2\lambda)\,v_n+v_\eta\right\}\right]^2} > 0.$$

(b) We have

$$v_\epsilon^P - v_\epsilon^N = \frac{1}{\{v_n v_\eta + v_m (v_n + v_\eta)\}[(1+2\lambda) v_n v_\eta + v_m \{(1+2\lambda) v_n + v_\eta\}]} \times \frac{(1+2\lambda) v_m v_n^2 (2\lambda v_n - v_\delta) v_\delta v_\eta (v_m + v_\eta)^2}{[(1+2\lambda) v_n^2 v_\eta + v_m \{(1+2\lambda) v_n^2 + (v_n + v_\delta) v_\eta\}]}$$

so it is greater than 0 if and only if $\lambda \geq \frac{v_\delta}{2v_n}$.

Suppose $\lambda < \frac{v_\delta}{2v_n}$ so that $v_\epsilon^P < v_\epsilon^N$ and the condition in part (b) of Proposition 3 is satisfied so that the set of the common equilibrium is nonempty. Then, any Pareto-dominant common method with $v_\epsilon < v_\epsilon^P$ for $v_\epsilon > v_\delta - v_\eta$ constitutes a common equilibrium, because $v_\epsilon < v_\epsilon^P < v_\epsilon^N$ is satisfied for $v_\epsilon > v_\delta - v_\eta$. Conversely, we can find a common equilibrium that is not Pareto-optimal. Specifically, for $v_\eta > v_\eta^N$, we have $v_\epsilon^N > v_\delta - v_\eta$. Thus, we can always find $\hat{v}_\epsilon \in (v_\epsilon^P, v_\epsilon^N)$ such that $\hat{v}_\epsilon > v_\delta - v_\eta$. We can verify that this pair of $(v_\eta, \hat{v}_\epsilon)$ gives a common method that is a Pareto-dominated Nash equilibrium: Since $\hat{v}_\epsilon < v_\epsilon^N$, it is sustainable as a Nash equilibrium; since $\hat{v}_\epsilon > v_\epsilon^P$, the common equilibrium is Pareto-dominated by the local equilibrium.

(b) Suppose $\lambda \geq \frac{v_\delta}{2v_n} \Rightarrow v_\epsilon^P \geq v_\epsilon^N$ and the condition in part (a) of Proposition 4 is satisfied so that the set of Pareto-dominant common method is nonempty. Then, any common equilibrium with $v_\epsilon \leq v_\epsilon^N$ for $v_\epsilon > v_\delta - v_\eta$ is Pareto-dominant, since $v_\epsilon \leq v_\epsilon^N < v_\epsilon^P$ is satisfied for $v_\epsilon > v_\delta - v_\eta$. Conversely, we can find a Pareto-dominant common method that cannot be reached in an equilibrium. Pareto-dominant common method from the set satisfies $v_\epsilon^P > v_\delta - v_\eta$ for $v_\eta > v_\eta^P$; we can also find $\tilde{v}_\epsilon \in (v_\epsilon^N, v_\epsilon^P)$ for $\tilde{v}_\epsilon > v_\delta - v_\eta$. Since $\tilde{v}_\epsilon < v_\epsilon^P$, the common method is Pareto-dominant; since $\tilde{v}_\epsilon > v_\epsilon^N$, the common method cannot be chosen in an equilibrium.

Q.E.D.

Proof of Lemma 2.

We first calculate the aggregate firm value in a decentralized economy as follows:

$$\begin{aligned} W^D &= E\left[E\left[2\left(\theta_i - \lambda\Gamma\right)\sqrt{k_i^*} - k_i^*|S\right]\right] \\ &= E\left[E\left[\left(\theta_i - \lambda\Gamma_D\right)^2|S\right]\right] \\ &= E\left[\left(\theta_i - \lambda\Gamma_D\right)^2\right] \\ &= \begin{cases} \frac{1}{(1+\lambda)^2}\left(\mu^2 + v_m\right) + \frac{v_n^2}{v_n+v_\delta}, & if\ local\ equilibrium \\ \frac{1}{(1+\lambda)^2}\left(\mu^2 + \frac{v_m^2}{v_m+v_\eta}\right) + \frac{v_n^2}{v_n+v_\epsilon}, & if\ common\ \ equilibrium \end{cases} \end{aligned}$$

Comparing with Equations (15) and (16), it is easy to see that for each equilibrium, the aggregate firm value is larger under centralized investment as long as $\lambda \neq 0$, since $\frac{1}{1+2\lambda} > \frac{1}{(1+\lambda)^2}$.

Proof of Proposition 6.

It is easy to see that as long as $\lambda \neq 0$, we have $W^D\left(\Omega_c\right) - W^D\left(\Omega_i\right) > W\left(\Omega_c\right) - W\left(\Omega_i\right)$:

$$\begin{aligned} W^D\left(\Omega_c\right) - W^D\left(\Omega_i\right) &= -\frac{1}{1+2\lambda+\lambda^2}\frac{v_m v_\eta}{v_m+v_\eta} + \left(\frac{v_n^2}{v_n+v_\epsilon} - \frac{v_n^2}{v_n+v_\delta}\right) \\ W\left(\Omega_c\right) - W\left(\Omega_i\right) &= -\frac{1}{1+2\lambda}\frac{v_m v_\eta}{v_m+v_\eta} + \left(\frac{v_n^2}{v_n+v_\epsilon} - \frac{v_n^2}{v_n+v_\delta}\right) \end{aligned}$$

Then, if $\lambda \neq 0$, $W^D\left(\Omega_c\right) - W^D\left(\Omega_i\right) > W\left(\Omega_c\right) - W\left(\Omega_i\right)$; and if $\lambda = 0$, $W^D\left(\Omega_c\right) - W^D\left(\Omega_i\right) = W\left(\Omega_c\right) - W\left(\Omega_i\right)$. Thus, if $\lambda \neq 0$, $W\left(\Omega_c\right) > W\left(\Omega_i\right)$ implies $W^D\left(\Omega_c\right) - W^D\left(\Omega_i\right) > W\left(\Omega_c\right) - W\left(\Omega_i\right) > 0$, which then implies $W^D\left(\Omega_c\right) > W^D\left(\Omega_i\right)$. If $\lambda = 0$, $W\left(\Omega_c\right) = W\left(\Omega_i\right)$ implies $W^D\left(\Omega_c\right) = W^D\left(\Omega_i\right)$.

Q.E.D.

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