Regulatory Standards, Auditor Industry Specialization, and Audit Quality*

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Abstract

We study how audit regulation affects auditor industry specialization and audit quality. In an industry where firm fundamental values are correlated, auditor specialization yields synergies derived from information spillovers. In the presence of regulation, the value of the specialist auditor's information spillovers is non-monotonic in the stringency of a regulatory standard. Consequently, standards affect the likelihood of auditor specialization in a non-monotonic way. To encourage auditor specialization and thereby increase firm value, net of audit fees, the regulator should optimally decrease standards in industries where the cost of audit is low and the prior uncertainty is high; whereas the regulator should optimally increase standards in industries where the cost of auditing is high and prior uncertainty is low. We relate our results to the extant empirical evidence documenting the association between audit specialization and audit quality.

Keywords: auditor specialization, PCAOB regulation, audit fees, audit market structure

JEL Codes: C72, D80, D83, L22, M42, M48

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1 Introduction

We examine how audit regulation affects auditor efficiency. Following the accounting debacles around the turn of the century, such as those involving Adelphia, Enron, and WorldCom, there was wide-spread public concern that public accountants were not adequately protecting the interests of investors and the broader public interest—auditors were viewed as being insufficiently regulated and not providing rigorous, impartial audits. As a consequence, the U.S. Congress enacted the Sarbanes-Oxley Act of 2002, which among other things, led to the creation of the Public Company Accounting Oversight Board (PCAOB). The PCAOB was charged with overseeing the auditors of public companies and also the setting and enforcement of standards.

The PCAOB has had an important impact on the audit profession and the audits of public companies (see DeFond and Lennox, 2011; Lamoreaux, 2016). Recently, however, the PCAOB has begun to consider potential changes in its direction as it has experienced increasing resistance to its practices from the large audit firms as well as the Securities and Exchange Commission (SEC), which oversees the PCAOB. In May 2018, PCAOB Chairman William Duhnke declared that "substantial opportunities exist for us to improve our policy-making and our external engagement" (Rapoport, 2018). He noted that the PCAOB was considering changes to its process for inspecting auditors to gauge the quality of their audits: specifically, it was debating tailoring its inspections more to the circumstances of individual audit firms and on broad issues across audit firms (Rapoport, 2018).

Audit risk is a function of the information that an auditor gathers from the portfolio of firms in an industry that it audits and not only the evidence it obtains from auditing a single firm. Accordingly, it seems that the PCAOB's consideration of an auditor's specific circumstances when setting standards of fieldwork ought to recognize the auditor's entire information set gathered auditing a portfolio of firms. This study addresses the question of optimal audit standard regulation when a regulator recognizes that possible auditor specialization across an industry affects the auditor information set and the quality of audit reports that investors use for capital allocation decisions.

To address this question, we study a model with an endogenous probability of observing a specialist in the audit market. We consider an economy containing two firms with correlated fundamental values, two incumbent auditors, and two prospective auditors. Each firm conducts a first-price, sealed-bid auction to determine which auditor to engage to audit its financial statements. Each firm's incumbent auditor only participates in the auction of the firm that it is currently auditing, whereas each of the two prospective auditors bids for the right to audit each of the firms. A firm chooses the auditor with the lowest proposed audit fee. If one of the prospective auditors wins both auctions, she is referred to as a *specialist*. Otherwise, we call the auditor a *generalist*. Once hired, each auditor exerts costly effort to collect information about the client firm, and it authorizes the firm to issue its financial statements. Each auditor faces business risk, the cost of which is proportional to the quadratic difference between the issued financial statement and the firm's fundamental value. We consider an unregulated setting in which an audit is not constrained to comply with a regulatory standard of fieldwork and a regulated setting in which an audit is constrained to comply. In both settings, however, a specialist enjoys the reduction in the expected audit cost that arises from information spillovers between the specialist's audit clients, which we label as *synergy*. Finally, once the financial statements are issued and observed, the investors choose how much additional capital to invest in the firm to maximize its value.

We obtain several key results that crucially depend on the synergy of being a specialist. First, we show that in the absence of regulation, the specialist may choose either a higher or a lower level of audit effort than a generalist. On one hand, the marginal benefit of performing more fieldwork to collect evidence is lower for the specialist as she can apply her extant industry knowledge associated with information spillovers gained from another firm. This effect discourages the specialist from exerting audit effort. On the other hand, there is an additional benefit of collecting more evidence as it allows the specialist to build industry knowledge that she can apply when auditing another firm. This effect encourages the specialist to exert more audit effort. The effect of being able to apply extant industry knowledge, which discourages effort, prevails in environments featuring a low cost of audit and high prior uncertainty about the firms' fundamental values. In contrast, the effect of building industry knowledge, which encourages effort, dominates in environments with a high cost of audit and low prior uncertainties.

Second, we explore how audit quality differs between the firms audited by specialists and generalists when auditors are unregulated and regulated. We show that the presence of a specialist's synergy allows the specialist to issue more precise audit reports resulting in higher audit reporting quality independently of regulation. In contrast, the effect of specialization on the investor perception of audit quality is more subtle. On one hand, in an unregulated audit environment where audit costs are low and prior uncertainty is high, a specialist exerts less audit effort than a generalist. This lower audit effort decreases overall investor information quality, thereby reducing investment efficiency and investor perception of audit quality. On the other hand, in unregulated industries where the cost of audit is high and prior uncertainty is low, the specialist exerts more effort than the generalist, thereby enhancing investment efficiency and the investors' perception of audit quality. Conversely, in a regulated environment, specialization has no effect on the investor perception of audit quality.

Third, we derive a set of empirical predictions about the determinants of auditor industry specialization. We find that the specialist's synergy, and hence the probability of audit specialization, is increasing in the absolute value of correlation of firms' fundamental values and is unimodal in the degree of prior precision. The effect of the marginal cost of exerting audit effort is more subtle: the probability of audit specialization is unimodal in the marginal cost of audit effort in the unregulated audit environment, whereas it is unaffected by changes in the marginal cost of audit effort in the regulated environment. In the unregulated environment, the specialist auditor can react to the changes in the marginal cost by adjusting her audit effort. Conversely, in the regulated environment, the specialist must comply with the audit standards and exert the same effort as a generalist, so that the specialist's synergy is unaffected by the marginal cost of effort.

Fourth, we study how standards affect the probability of specialization in the audit market. We find that audit standards have a non-monotonic impact on specialization. Initially, as standards increase, a generalist's costs increase disproportionately more than those of a specialist because of the growing industry knowledge of the specialist who can beneficially use the increasing information spillovers. As the regulatory standard increases further and becomes extremely stringent, the regulation requires any auditor to collect almost perfect firm-specific information, thereby making information spillovers to a specialist irrelevant. Hence, extremely high standards eliminate the benefit of being a specialist and decrease the probability of observing industry specialization.

Finally, we characterize how a regulator optimally chooses audit standards to maximize firm value when recognizing the effect of these standards on the structure of the audit industry. In the absence of potential specialization, the regulator chooses an optimal standard trading off the positive effect of a more stringent standard on the firm's investment efficiency and the negative effect of an increase in the audit fees. The regulator encourages auditor specialization as the informational benefits of specialization decrease the fees that auditors charge. Since a regulatory standard can either increase or decrease the extent of auditor specialization, the regulator needs to adjust the standard depending on the industry to encourage auditor specialization. In industries where the cost of audit is low and the prior uncertainty is high, counter-intuitively, the regulator optimally decreases the audit standard to encourage specialization; whereas in industries where the cost of auditing is high and prior uncertainty is low, counter-intuitively, the regulator optimally increases the standard. Thus, we argue that audit standards should recognize the information that an auditor gathers from the portfolio of firms that it audits and not only the evidence it obtains from auditing a single firm; in short, regulators should consider the ecosystem within which an audit occurs.

This paper connects to several strands of the audit literature. It is related to work examining the influence of auditor regulation on audit quality. DeFond and Lennox (2011) and Lamoreaux (2016) empirically find that PCAOB inspections are positively associated with audit quality. Consistent with this work, we find that more stringent standards lead to higher investment efficiency. More interestingly, however, we find that even though more stringent standards are positively associated with investment efficiency, this association comes at the expense of higher audit fees. We find that an increase in the fees is driven, not only by the increased amount of prescribed fieldwork, but also by the change in the structure of the audit industry. As a consequence, we find that more stringent audit standards can crowd out specialists from the audit market, which drives audit fees up.[1]

In a related vein, analytical research also suggests other negative consequences of heightened regulation, apart from its impact on specialization. For instance, Patterson and Smith (2007) argue that the Sarbanes-Oxley Act has reduced tests of internal controls thereby increasing audit risk. Gao and Zhang (2019) and Ewert and Wagenhofer (2019) demonstrate that tighter audit regulation may lower audit quality. Chen, et al. (2019) show that audit disclosure regulation may have negative consequences for investment efficiency.

[1] Iliev (2010) shows that small capitalization firms experienced a negative market reaction following implementation of Section 404 of the Sarbanes-Oxley Act of 2002 because of higher audit fees. Section 404, which has been costly for firms to implement and is probably the most vigorously criticized provision of the Act, requires a firm's registered accounting firm to attest to and report on their assessment of the effectiveness of the internal control structure and procedures for financial reporting.

Our paper is also connected to the literature examining the relation between audit quality and the extent of auditor specialization. We show that specialization may increase, decrease, or have no effect on different measure of audit quality, depending on the parameters of the environment and the nature of the audit quality metric. This ambiguity aligns with the empirical literature documenting mixed relations between audit quality and the extent that the auditor specializes in the client's industry (see, for instance, Reichelt and Wang, 2010; Bell, et al., 2015; Brown and Knechel, 2016; Bills, et al., 2015).

Our research also connects to the literature studying the relation between industry specialization and audit fees. We find that the prospective auditors bid more competitively in anticipation of benefiting from becoming an auditor specialist. The empirical evidence on the relation between industry specialization and audit fees is mixed. For instance, Carson (2009) finds that global industry audit specialists charge higher audit fees than other firms, regardless of their national industry specialization. In contrast to Carson (2009), Bills, et al. (2015) find that industry specialists charge lower audit fees in industries with homogenous operations and complex accounting practices. Moreover, they find that industry specialists do not provide audits of lower quality. Rather they attribute the lower fees to the auditors passing on their audit efficiencies to clients in the form of lower audit fees. On a related note, DeFond, et al. (2000) document specialization among smaller audit firms that leads to production economies and the capture of market share through lower fees for a clientele seeking low-priced audits. These findings are consistent with the predictions of our analysis.

Our paper is also related to theoretical work that examines the pricing of audits in a competitive market. Kanodia and Mukherji (1994), Morgan and Stocken (1998), and Schatzberg and Sevcik (1994) examine equilibrium audit pricing when an incumbent auditor has an informational advantage over its rivals for the cost of performing the audit of a single firm in an industry. In our model, in contrast, there are two simultaneous auctions for the audit of two firms in the industry in which prospective auditors bid against the firms' incumbent auditors. This interconnectedness of the payoffs of the prospective auditors in the auctions considerably complicates the analysis of the pricing game, but yields novel characterization of the forces yielding auditor industry specialization.

The paper proceeds as follows: Section 2 offers a model of the audit environment featuring multiple firms, multiple auditors, and a role for an auditor regulator. Section 3 characterizes the equilibrium and performs comparative static exercises within an unregulated and regulated audit environment. Section 4 examines the relation between auditor specialization and measures of audit quality. Section 5 studies how the presence of synergies shapes the determination of audit fees in a competitive audit environment and the probability of auditor specialization. It also highlights the effect of competing in a market with restricted competition. Section 6 considers a regulator's choice of an audit standard to maximize investor value when the regulator explicitly recognizes the cost of audit standard compliance. Section 7 extends the analysis to a minimum audit standard setting where the auditor may exert more effort than prescribed by the standard as opposed to the benchmark setting in which the auditor must exactly comply with an audit standard. This robustness check confirms the earlier findings. Section 8 concludes. The proofs of the lemmas and propositions have been relegated to the Appendix.

2 Model

We analyze an economy that has two firms.[2] Each firm i, where $i \in \{1, 2\}$, has a fundamental value μ_i that is normally distributed with mean zero and common prior precision τ^0 (i.e., inverse of prior uncertainty).[3] The firms' fundamental values are correlated with correlation coefficient $\rho \neq 0$. There are three dates. After describing the three dates, we will motivate the key ingredients in the model.

Date 1: Hiring of auditor

Each of the firms is mandatorily required to appoint a registered public accountant — or auditor — to conduct an audit of its financial statements. Each firm i has an incumbent auditor, which it had previously appointed; this incumbent auditor offers a fee of $\phi_{o,i}$. The incumbent auditor of firm i, who is assumed to only participate in the auction of firm i, offers a fee that equals its expected cost of the audit, thereby earning zero profits on average. Firm i privately observes the incumbent auditor's proposed fee $\phi_{o,i}$.

Each firm i also receives simultaneous bids to audit its financial statements from two prospective auditors. A prospective auditor n, where $n \in \{1, 2\}$, bids to audit firm i's financial statements for a fee $\phi_{n,i}$; if appointed, the auditor (with pronoun

[2] While we consider an industry containing only two firms, the analysis should, in principle, apply to an industry with an arbitrary number of firms. Such an analysis, however, is not expected to offer any substantial insight but will clutter the exposition.

[3] Assuming a zero mean is without loss of generality.

"she") is committed to charge this fee. A prospective auditor proposes an audit fee so as to maximize her expected payoff, which depends on the audit fee less her expected cost of performing the audit at Date 2.

Firm i appoints the auditor with the lowest proposed fee. If the same auditor is appointed to audit the financial statements of both of the firms, we call this auditor a *specialist*. Otherwise, the auditors are called *generalists.* Observe that an auditor's type is not exogenously fixed as we wish to explore how industry specialization arises in equilibrium.

Date 2: Performing fieldwork and issuing audited financial statements

The audit is performed in an unregulated or a regulated audit environment. In an unregulated environment, we ignore the possibility of a regulator who imposes standards of audit fieldwork that constrain the precision of evidence the auditors are required to collect. In a regulated audit environment, auditor's choice of fieldwork is constrained. Here a regulator, such as the PCAOB, imposes audit standards with which the auditor must comply.

Conditional on the regulatory environment, an appointed auditor plans the fieldwork to evaluate the fairness of the firm's financial statements. The auditor of firm i chooses the level of effort τ_i that determines the precision of her signal s_i about the firm's value μ_i. Exerting more effort leads to a more precise signal, but it is also more costly. The cost of exerting effort τ_i to audit firm i is given by $c\tau_i$, where $c > 0$ is the marginal cost of effort. The generalist's effort yields a signal s_i^g with precision τ_i^g, and the specialist's effort yields a signal s_i^s with precision τ_i^s. In this light, the auditor's choice of effort coincides with the precision of her signal.[4]

After observing the signals about firm value, firm i's auditor chooses the report that the firm will issue. We denote the report of a generalist as $R_i^g \in \mathbb{R}$ and that of a specialist as $R_i^s \in \mathbb{R}$. Reports that differ from the firm's fundamental value expose the auditor to business risk, which includes litigation risk, reputation risk, and regulation risk associated with an engagement (Defond and Zhang, 2014). The cost of business risk is a function of the quadratic difference between the issued financial statements and the fundamental value of the firm i, that is, this cost is $(R_i^g - \mu_i)^2$ for a generalist and $(R_i^s - \mu_i)^2$ for a specialist.

The auditor of firm i incurs *firm-specific costs* that include the cost of performing fieldwork and the cost of business risk. These costs depend on the actions of auditors,

[4]While we assume a linear cost function, the results that follow are qualitatively unchanged if we instead assume a non-linear cost function of the form $c\tau^m$, where $m > 1$.

and consequently, these costs can differ for specialists and generalists. These firm-specific costs are denoted as

$$C_i^g = c\tau_i^g + (R_i^g - \mu_i)^2$$

and

$$C_i^s = c\tau_i^s + (R_i^s - \mu_i)^2 .$$

In addition, an auditor incurs *auditor-specific costs* of fieldwork that depend on the characteristics of the auditor, such as its geographic location, engagement staffing, and employee training and supervision. Specifically, the auditor n who is hired by a firm i incurs the auditor n specific cost u_n, which is privately observed by the auditor n, and is distributed uniformly on the interval $[-\delta, \delta]$. The variance of the auditor-specific costs equals $\delta^2/3$.

Coupling the firm-specific cost and the auditor-specific costs, the generalist auditor n auditing firm i incurs a total realized cost of $C_i^g + u_n$, whereas a specialist auditor n auditing firm i incurs a total realized cost of $C_i^s + u_n$. An auditor's objective is to perform fieldwork and issue an audit report to minimize the total realized costs.

Date 3: Firm investment

After the audited financial statements are issued, investors choose the level of additional capital k_i to inject into the firm i to maximize the firm i's value V_i, which is given by

$$V_i = \mu_i + \left(k_i \mu_i - \frac{L_i k_i^2}{2} \right) , \qquad (1)$$

where $L_i > 0$ denotes the cost of capital parameter for firm i. Observe that V_i is the sum of firm's fundamental value from its existing assets in place and the value from the incremental investment; further, V_i reflects the firm's value before the audit fees are paid.

Given that we study publicly traded companies, all investors have access to the audited statements of *both* firms when they make their capital investment decisions.

We summarize the extensive form of the game in the following time line.

Date 1	Date 2	Date 3
Auditors privately observe their auditor-specific costs. Each firm i receives bids $\phi_{1,i}$ and $\phi_{2,i}$ from the prospective auditors and a bid $\phi_{o,i}$ from the incumbent auditor. The auditor with the lowest fee is appointed.	The specialist (generalist) auditor of firm i exerts effort τ_i^s (τ_i^g), receives a signal s_i^s (s_i^g), and releases a report R_i^s (R_i^g).	Investors observe both reports R_1 and R_2 and choose how much additional capital k_i to invest in the firm i.

Figure 1: Timeline of events.

All aspects of the game are common knowledge except for the auditors' idiosyncratic auditor-specific costs, their choice of effort, and their signal realizations. We characterize the Symmetric Perfect Bayesian Equilibrium, which requires that players' beliefs are formed using Bayes' rule whenever possible, and given their beliefs, the players' actions maximize their payoffs. Further, we consider pure bidding strategies of prospective auditors that are symmetric.

At this point, we motivate key features of the model: First, we model the incumbent auditor and the prospective auditors as simultaneously submitting fee offers in the first-price sealed bid auction for the engagement and the firm then selecting the auditor that submits the lowest fee. It is most common for a client to make the appointment decision after soliciting proposals from competing auditors (Glezen and Elser, 1996). Recently, to heighten auditor independence, the European Commission published EU Regulation 537/2014 in 2014 requiring public-interest entities to implement a policy of mandatory auditor rotation and to implement an audit tender process to select a successor auditor. Fifteen of the member states adopted this regulation, significantly increasing the importance of audit tenders (Baumann, et al., 2019). Furthermore, auditors effectively compete in audit fees (rather than quantities or other strategic variables); for instance, Eichenseher and Shields (1983) find that the audit fee is the most important choice variable in a firm's choice of auditor.

Second, each auction has the feature that the incumbent auditor of each firm only participates in the auction for that firm's audit, unlike the prospective auditors who participate in the auctions of both firms. This assumption about the auction participation of the incumbent auditor comports with an institutional setting in which a growing firm needs to raise additional capital and may have to change it auditor as a consequence. This injection of capital, which we denote as k, will increase the size of the firm. Typically, smaller auditors are less capable and often unwilling to audit several large firms as they do not have the scale to do so or believe that servicing several large audit clients will reduce their ability to satisfactorily service their existing clients (see Carson, 2009). In our model, we think of the prospective auditors as being large auditors capable of servicing several public firms in the same industry, as is the case for the Big Four professional service firms. Accordingly, we model the prospective auditor as bidding strategically to audit other large firms in the same industry, and we model the incumbent auditor as seeking to retain the audit of its client but not add another large firms to its client list.[5]

On the technical front, modeling the incumbent auditor as only participating in the auction of its client and not bidding strategically to engage the other firms in the industry offers richer insights into industry specialization. When all bidders can participate in two simultaneously held, first-price auctions with synergies, the bidding strategies are symmetric (Krishna and Rosenthal, 1996). Consequently, in the absence of an incumbent auditor, one of the prospective auditors always wins both auctions and becomes a specialist. Therefore, to better understand auditor specialization, we require that each firm has the default option of appointing an incumbent auditor that is non-strategic. We model the incumbent as offering a fee that equals its expected cost of the audit. We expect our results to remain qualitatively unaltered if we instead assume that the incumbent auditor offers a fee equal to its expected cost plus a fixed profit margin.

Third, we model the specialist as conditioning her audit opinion on the correlated signals about both of the firms being audited, and a generalist as conditioning her audit opinion only on the signal about the firm being audited. Auditors aim to reduce the audit risk of expressing an inappropriate opinion on financial statements to an acceptable level. PCAOB AS 1101 defines *audit risk* as a function of the risk of material misstatement and detection risk. The risk of material misstatement is a function of the inherent susceptibility of an assertion to a misstatement and the failure

[5] Audits of large firms are concentrated among the largest four professional service firms—Deloitte, EY, KPMG, and PwC. In the United Kingdom, for instance, the Big Four audited 99 percent of the companies in the FTSE 100 index and 96 percent of the next-biggest, mid-cap listed companies included in FTSE 250 index in 2011 (Christodoulou, 2011).

of the system of internal controls to prevent the misstatement. Detection risk arises when an auditor's substantive procedures will not detect a material misstatement that exists in an assertion in the financial statements. Thus, the risk of material misstatement within a firm is independent of the auditor, whereas detection risk relates to an auditor's procedures.

When an auditor performs an audit of more than one firm in an industry, the auditor can use the evidence learned about the characteristics of an industry, the industry specific accounting practices, and the effectiveness of its internal control procedures when evaluating the risk of material misstatement of another firm in the same industry (see Bills, et al., 2015). PCAOB AS 1101 notes that as the risk of material misstatement increases, the level of detection risk needs to be reduced to preserve audit risk at an appropriately low level. Thus, an auditor's understanding of the risk of material misstatement yields the possibility of information spillover that affects the detection risk.

Fourth, we assume the report R that an auditor issues is continuous—specifically $R \in \mathbb{R}$. Under PCAOB AS 3101, an auditor may express an qualified opinion, unqualified opinion, adverse opinion, or disclaimer of opinion on the financial statements. An auditor can express an unqualified opinion only if the financial statements are fairly presented in all material respects. In practice, auditors discuss proposed adjustments with their client's management before issuing an audit opinion. An auditor will only issue an unqualified audit opinion if the client makes the proposed material adjustments. In effect, therefore, expressing an unqualified audit opinion is economically equivalent to consenting to the release of the firm's financial statements R, as modeled in this paper.

Fifth, we model the cost of business risk as a function of the quadratic difference between the audited financial report and the fundamental value of the firm. Business risk includes audit risk and other engagement-related risks. AU Section 312—*Audit Risk and Materiality in Conducting an Audit*—notes that audit risk is the risk that the "auditor may unknowingly fail to appropriately modify his or her opinion on financial statements that are materially misstated." AU section 312 further notes that, in addition to audit risk, an auditor is also "exposed to loss of or injury to his or her professional practice from litigation, adverse publicity, or other events arising in connection with financial statements audited and reported on. This exposure is present even though the auditor has performed the audit in accordance with generally accepted auditing standards and has reported appropriately on those financial statements" (para. 02). Thus, we interpret business risk as the risk to the auditor of a lawsuit that remains after complying with the audit standards. Recognizing that it is often impossible for the auditor to avoid being sued regardless of due diligence efforts, O'Malley (1993,89,93), former chairman and senior partner of Price Waterhouse, claimed that "unwarranted litigation and forced settlements constitute the vast majority of claims against accountants" and that shareholders demand compensation from auditors even if "auditors need not have done anything to cause the loss." Dye (1995) also emphasizes that auditors have been sued irrespective of whether the audit complied with the generally accepted auditing standards. In this light, we model the auditor expected cost arising from the business risk associated with opining on firm i's financial statements as $E\left[(R_i - \mu_i)^2\right]$.

3 Analysis

In this section, we characterize the auditor's effort, the auditor's reporting strategy, and the level of capital that investors inject into the firm. These choices are made at Date 2 and Date 3 after the audit fees have been established in Date 1. Accordingly, at Date 2 and 3, audit fees are sunk and have no bearing on the analysis. Before turning to characterize the auditor's choice of effort, we begin by considering an auditor's reporting strategy and the reports the auditors will choose to issue in Date 2 after they have performed their fieldwork. When an auditor chooses her report, the auditor only considers the expected cost of business risk because at this point the cost of fieldwork is sunk. Formally, given the signal s_i^g that the generalist auditor of firm i has observed, she chooses R_i^g to minimize $E\left[\left(R_i^g - \mu_i\right)^2 | s_i^g\right]$. Thus, the optimal audited report that the generalist issues for the firm i is

$$R_i^g = E[\mu_i | s_i^g]. \tag{2}$$

In contrast to the generalist, the specialist auditor observes two signals s_1^s and s_2^s about the firms. For each firm i that she audits, the specialist chooses R_i^s to minimize $E\left[(R_i^s - \mu_i)^2 | s_1^s, s_2^s\right]$. Accordingly, the optimal report that the specialist issues for firm i is given by

$$R_i^s = E[\mu_i | s_1^s, s_2^s]. \tag{3}$$

Stepping backwards, before choosing her report at Date 2, we now consider an auditor's choice of fieldwork. The extent of the auditor's fieldwork τ_i^a depends on whether the environment is unregulated or regulated and whether an auditor a is either a generalist $a = g$ or a specialist $a = s$. The total firm-specific costs of auditing a firm equals the sum of the cost of performing the fieldwork and the cost of business risk associated with issuing the report. Formally, auditor a's expected firm-specific cost of auditing firm i given her effort τ_i^a is

$$E[C_i^a] = c\tau_i^a + E\left[(R_i^a - \mu_i)^2\right].$$

Now turning to Date 3, we characterize how much capital investors will choose to inject into firm i after observing the reports from both firms. The investor in firm i chooses the capital contribution k_i^a, where $a \in \{g, s\}$, to maximize firm value V_i^a, given in (1). Specifically,

$$k_i^a = \frac{1}{L_i} E\left[\mu_i | R_1^a, R_2^a\right]. \tag{4}$$

Note that both reports are either issued by the same specialist or each report is issued by different generalists.

We proceed by first considering the unregulated audit environment before considering the regulated audit environment.

3.1 Unregulated audit

Having characterized the investors' strategy at Date 3 and the reporting strategy at Date 2, we turn to study the optimal choice of audit effort in a setting without a regulator. The next lemma characterizes a generalist auditor's choice of effort and compares it with that of the specialist. To avoid trivial outcomes, we assume henceforth that the cost of effort c is sufficiently low that the generalists would always choose to exert non-zero effort; that is, $c < 1/\left(\tau^0\right)^2$.

Lemma 1 *A generalist i chooses the level of effort to obtain a signal with positive precision*

$$\tau^g = 1/\sqrt{c} - \tau^0.$$

- *If the firms' fundamental values are uncorrelated, i.e., $\rho = 0$, then a specialist chooses the same precision as a generalist $\tau^g = \tau^s$.*

- *If the firms' fundamental values are correlated, i.e., $\rho \neq 0$, then there exists a unique threshold $t(\rho) \in (0, 1)$ such that a specialist chooses a lower level of precision than a generalist $\tau^s < \tau^g$ if and only if $\sqrt{c}\tau^0 < t(\rho)$.*

When the firms' fundamental values are uncorrelated, the specialist and generalist choose to exert the same level of effort. Intuitively, in the absence of information externalities, the specialist is unable to use information gained from auditing one firm to opine on the financial statements of another firm. To allow a specialist to enjoy synergies from auditing multiple firms in an industry, we henceforth assume $\rho \neq 0$.

When the firms' fundamental values are correlated, the specialist's choice of effort is subtle. The specialist enjoys positive externalities from gathering audit evidence when the firms' fundamental values are correlated. Thus, one might conjecture that for each firm the specialist would choose to gather less precise evidence than a generalist given that the specialist can use the knowledge gathered from auditing other firms in the industry. Strikingly, a specialist performs an audit that is *more or less* thorough than that which a generalist performs depending on the prior uncertainty and cost.

When the prior uncertainty about the firm's value is high (i.e., τ^0 is low), a generalist needs to perform a thorough audit to reduce the expected cost of business risk. When the cost of exerting effort c is low, the generalist is willing to gather a lot of information to be able to express an informed opinion. Accordingly, the industry knowledge obtained by a specialist that exerts the same effort as a generalist is substantial. Since the specialist can apply this substantial industry knowledge, the marginal benefit of exerting more effort to reduce the expected cost of business risk is lower for the specialist than the generalist. In contrast, the marginal cost of effort c auditing each of the firms is the same for both the specialist and a generalist. Thus, the specialist reduces her effort auditing each of her clients in the industry. On balance, therefore, when the prior uncertainty about the firm's value is high and the cost of gathering evidence is low, the specialist gathers less precise information than the generalist.

Conversely, when the prior uncertainty about the firm's value is low (i.e., τ^0 is high), a generalist does not need to gather much evidence to reduce the expected cost of business risk; further, when the cost of gathering evidence c is high, the generalist is less willing to exert audit effort. Hence, a generalist chooses a low level of effort. If the specialist exerts the same low level of effort as the generalist, then the specialist will not have much industry knowledge. Since the industry knowledge is low, the specialist enjoys a marginal benefit from exerting more effort to build her industry knowledge and thereby reduce the expected cost of business risk from expressing an opinion relative to a generalist. Since the marginal cost of effort is the same for a specialist and a generalist, on balance, the specialist chooses to exert greater effort auditing each of the firms than a generalist.

Having characterized the auditors' optimal choice of effort, we examine the impact of these effort choices on the expected cost of auditing a firm. While, in the absence of regulation, a specialist may choose to exert more or less effort than a generalist, it does not imply that the specialist incurs greater audit costs than a generalist. In fact, the specialist is always better off as she enjoys synergies associated with the information spillovers between her clients. The *firm-specific synergy* of the specialist who audits firm i is defined as the difference in a generalist's expected costs relative to a specialist's; formally,

$$Syn_i \equiv E[C_i^g] - E[C_i^s].$$

The specialist audits both firms in the industry. Thus, the *synergy* of being a specialist is denoted as

$$Syn = Syn_1 + Syn_2.$$

The following lemma establishes the properties of the synergy of a specialist arising from her industry knowledge.

Lemma 2 *In the absence of audit regulation, the synergy of being a specialist auditor equals*

$$Syn = \frac{2}{\tau^g + \tau^0} + 2c\tau^g - \left(\frac{2}{\tau^s + \tau^0 G} + 2c\tau^s\right),$$

where $G = \frac{1}{1-\rho^2\tau^s/(\tau^0+\tau^s)}$.

Syn is positive, increasing in the absolute value of correlation $|\rho|$, *and hump-shaped in both the prior precision* τ^0 *and marginal cost of audit effort* c.

Higher $|\rho|$ implies higher information spillovers within the industry, allowing the specialist to benefit from gaining industry knowledge. While the effect of the correlation of the firms' fundamentals on the synergy of being a specialist is intuitive, the impact of the prior precision τ^0 and the marginal cost of audit effort c is more subtle. When the prior precision is low, an auditor barely relies on her priors when opining on her client. As a consequence, covariance in the firms' fundamental values is low, as is the specialist's synergy. As the prior precision rises and the covariance increases, however, the industry knowledge of a specialist auditor grows, thereby raising the specialist's synergy. As the prior precision increases yet further and prior uncertainty about the firms' fundamentals vanishes, the information spillovers from one client to another disappear, implying that the specialist's synergy also vanishes. In short, synergy is unimodal, which we refer to as *hump-shaped*, in prior precision τ^0.[6]

Turning to the marginal cost of audit effort c, we observe that the synergy is also hump-shaped in c. As Lemma 1 shows, the specialist exerts less effort than a generalist, $\tau^s < \tau^g$, when the marginal cost of effort c is small. As c increases, the cost of an audit increases faster for a generalist than for a specialist, increasing the specialist's synergy. As c becomes sufficiently large, however, the specialist starts choosing more effort than a generalist, $\tau^s > \tau^g$. Thus, as c continues to grow, the cost of an audit increases faster for a specialist than for a generalist, reducing the specialist's synergy.

3.2 Regulated audit

Concerns about the quality if audit evidence raised as a consequence of the accounting debacles at WorldCom, Enron, HealthSouth, among others, led to the establishment of regulatory bodies with the function of "watching the watchmen". The examples of such authorities include the PCAOB in the USA, the Financial Reporting Council (FRC) in the UK and Ireland, and the National Financial Reporting Authority (NFRA) in India. One of the functions of such a regulator is to choose the standards of audit engagements and ensure auditors comply with the standards that it has promulgated.

We model regulation of audit fieldwork as imposing the precision τ^* of information that the auditor is required to gather for each client. When the regulator is present, we suppose that the regulator specifies the precision of the auditor's signal τ^*. An auditor is said to comply with the audit standard when the auditor's choice of precision $\tau_i = \tau^*$. We shall consider an extension in Section 7 in which the regulator specifies a minimum audit standard with which auditors must comply. This extension largely confirms the key findings in the regulated audit setting when $\tau_i = \tau^*$.

Recall that the auditor faces business risk that is modeled as a function of the difference between the audited report and fundamental value of the firm. Business risk is present even though the auditor has performed the audit in accordance with generally accepted auditing standards and has reported appropriately on those finan-

[6] A function $f(\tau)$ is a *unimodal* function if for some value m, it is monotonically increasing for $\tau \leq m$ and monotonically decreasing for $\tau \geq m$.

cial statements (AU Section 312). Formally, even though an auditor chooses a level of precision $\tau_i = \tau^*$, the auditor expected cost of $E\left[(R_i - \mu_i)^2\right]$ associated with opining on firm i's financial statements remains.

Lemma 3 establishes that the synergy of being a specialist remains positive and increases in the absolute value of correlation $|\rho|$, as in Lemma 2. It further shows how the specialist's synergy depends on the standard and the prior uncertainty.

Lemma 3 *In the regulatory setting with an audit standard τ^*:*

- *the synergy of being a specialist Syn is positive and increasing in the absolute value of correlation $|\rho|$, and,*
- *the synergy Syn is hump-shaped with respect to the audit standard τ^* and the initial precision τ^0, but independent of the marginal cost of audit effort c.*

The informational advantage of a specialist auditor associated with the information spillovers between audited firms with correlated fundamental values are still present when the actions of the auditors are regulated. However, the synergy of being a specialist auditor is non-monotonic with respect to the audit standard and the prior uncertainty of firm fundamentals.

To understand why the synergy of a specialist auditor is hump-shaped with respect to the audit standard, consider first a lenient standard $\tau^* \to 0$. Under such a standard, an auditor exerts almost no effort doing fieldwork, and the information she obtains about each firm that she audits becomes almost useless. Consequently, the overall industry knowledge of a specialist also becomes useless, and the synergy of being a specialist shrinks to zero. As the standard becomes stricter, however, the auditor starts to exert more effort to comply with it. Hence, the industry knowledge of a specialist auditor also grows, as does the synergy associated with information spillovers. But as the audit standard becomes even tougher, the specialist is required to collect almost perfect information about each client. Thus, there is not much incremental value in her industry knowledge from auditing another firm in the industry. The specialist's synergy, therefore, again shrinks to zero as $\tau^* \to \infty$ and the standard becomes increasingly stringent.

The intuition behind the non-monotonicity of the value of synergy with respect to the prior precision τ^0 is analogous. When the prior precision in beliefs about firm fundamental values is low, the covariance in the firm fundamentals is low. Therefore, the specialist's synergy is low. As the prior precision increases and the covariance in the signals increases, the specialist's industry knowledge grows, as does the specialist's synergy. Ultimately, however, as the prior precision becomes high, information spillovers between clients vanish, and the specialist's synergy drops to zero.

To see why the synergy is independent of the marginal cost of audit effort c, observe that an audit standard requires that both a specialist and a generalist exert the same level of audit effort. As a consequence, an increase in the marginal cost of audit effort increases the costs of performing fieldwork equally for both a generalist and a specialist, but it does not affect their expected costs of business risk. The specialist's synergy, defined as the difference between a generalist's and a specialist's expected audit costs, therefore remains unaffected.

Our analysis highlights that specialist's information spillovers are a primary economic force in the audit environment. Accordingly, in the next three sections, we discuss the effect of information spillovers on audit quality, audit fees, and optimal audit standards.

4 Audit Quality

Audit quality is typically viewed as how faithfully the audited financial statements represent the fundamental value of the firm. Much empirical work has examined the relation between measures of audit quality and auditor specialization; Defond and Zhang (2014) offer a comprehensive survey of the extant literature. They note that a variety of empirical proxies are used to measure audit quality. Some of these proxies measure the direct effect of the audit function on the properties of the financial report, such as restatements, SEC issued Accounting and Auditing Enforcement Releases (AAER), and going concern modified audit opinions. Other proxies use investor perception-based measures, such as earnings response coefficients, the stock market reaction to the financial report, and the cost of capital. While these latter proxies do not directly capture the effect of the auditor effort, Defond and Zhang (2014) note that they more comprehensively capture the various dimensions of audit quality by focusing on the effect of the audit function on the firm's market value.

The extant literature examining the relation between audit quality and auditor specialization is mixed; the relation depends on the proxy for audit quality. To theoretically reconcile these mixed empirical results, we define two measures of audit quality—an audit reporting measure and an investor-perception measure—and explore the properties of these two measures.

Audit reporting measure: The audit reporting measure captures how faithfully the audited financial statements represent the fundamental value of the firm. More formally, the *audit reporting* quality of auditor $a \in \{g, s\}$ of firm i, Q_i^a, is defined as the negative expected variance of the fundamental value of the firm μ_i conditional on the auditor a's report,

$$Q_i^a \equiv -E\left[(R_i^a - \mu_i)^2\right] = -E[Var[\mu_i|\Omega_i^a]],$$

where Ω_i^a denotes the auditor a's information set for firm i: the specialist s's information set is $\Omega_i^s = \{s_1^s, s_2^s\}$ and the generalist g's information set is $\Omega_i^g = \{s_i^g\}$.

The next lemma compares an audit reporting measure of audit quality of specialists and generalists in the presence or absence of regulation.

Lemma 4 *The audit reporting measure is* higher *when the firm is audited by a specialist rather than a generalist regardless of the presence of regulation. Further, in the presence of regulation, the audit reporting measure is increasing in the standard τ^* irrespective of whether the firm is audited by a specialist or a generalist.*

When there is a regulatory audit standard in place, any auditor is required to exert a specified level of audit effort. When $\rho \neq 0$, a specialist auditor enjoys an information advantage associated with information spillovers. Thus, she can deliver a report of higher precision despite exerting the same level of effort on each audit as a generalist. On the other hand, when the audit market is unregulated, the specialist can choose a lower level of effort on each audit than the generalist even though she still enjoys an information advantage. Given that the auditor effort choice could be lower, it is unclear whether the specialist would still provide an audit of higher quality. We show, however, that the effect of the specialist's information advantage always prevails. Consequently, as in the regulated setting, the audit quality measure also is higher in the unregulated setting for firms that are audited by specialists. Lemma 4 also offers the intuitive result that as the audit standard is raised, any auditor regardless of specialization exerts greater effort and thereby increases audit reporting quality.

Investor-perception measure: The investor-perception measure reflects the expected effect of the audit function on the investors' valuation of the firm. Formally, the *investor perception* of the audit quality of auditor $a \in \{g, s\}$ of firm i, I_i^a, is defined as ex ante expected value of the firm i (before it pays the audit fees), and given by

$$\begin{aligned} I_i^a &\equiv E\left[V_i^a\right] \\ &= E\left[\mu_i + \frac{1}{L_i} E\left[\mu_i | R_1^a, R_2^a\right] \mu_i - \frac{1}{2L_i} \left(E\left[\mu_i | R_1^a, R_2^a\right]\right)^2\right] \\ &= E[\mu_i] + \frac{1}{2L_i} \left(Var\left[\mu_i\right] - Var\left[\mu_i | R_1^a, R_2^a\right]\right), \end{aligned}$$

where: the first equality follows from substituting the expression for the capital investment k_i^a from (4) into the ex ante value of the firm given in (1), and the second equality follows from substituting in the auditor reports R_i^a in (2) or (3), applying the law of iterated expectations, and the properties of normal random variables.

The investor-perception measure of audit quality depends on audit effort. Higher audit effort results in more precise reports. This effort lowers the ex-post variance of fundamentals, thereby allowing investors to make more efficient investment decisions. Thus, high audit effort ultimately increases the ex ante value of the firm.

The next lemma compares an investor-perception measure of audit quality of specialists and generalists in the presence or absence of regulation.

Lemma 5 *(i) The investor-perception measure is* higher *(*lower*) when the firm is audited by a specialist rather than a generalist if the specialist chooses a higher (respectively, lower) level of precision than a generalist in the absence of regulation.*

(ii) The investor-perception measure is independent *of whether the firm is audited by a specialist or a generalist in the presence of regulation, and it is increasing in the standard* τ^*.

The investor-perception measure captures how much information the reports of the firms collectively contain. As a consequence, the investor-perception measure is higher for a firm audited by a specialist only when the specialist exerts more audit effort than a generalist auditor. When the audit market is not regulated, the effort of the specialist is chosen endogenously, it can be higher or lower for a specialist than for a generalist. This results in a higher or lower investor-perception measure of the audit quality. In contrast, when a regulatory audit standard is in place, any auditor is required to exert a specified level of effort. Accordingly, specialization does not induce a different level of audit effort for specialists and generalists and does not improve the overall quality of investor information. Thus, compared to the unregulated audit market, specialization does not affect investor information quality. Lemma 5 also establishes that increasing the audit standard induces greater audit effort, regardless of the audit specialization, and thereby raises the investors' perception of audit quality.

Comparing Lemmas 4 and 5, we find that while the auditing reporting quality measure is always higher for a specialist than a generalist, the difference in level of the investor-perception quality measure between specialists and generalists depends on the prior uncertainty in the environment and the marginal cost of gathering audit evidence and the regulatory environment.

The empirical literature documenting the relation between audit quality and the extent that the auditor specializes in the client's industry is also somewhat mixed. On one hand, several studies find that audit quality is positively associated with industry specialization. For example, Reichelt and Wang (2010) find that audit quality (measured using discretionary accruals) is higher when the auditor is both a national and city-specific industry specialist. Similarly, Bell, et al. (2015) find that audit partner specialization in the clients industry is associated with higher audit quality. He, et al. (2019) explore mergers of audit firms in China and find that specialization creates knowledge transfers that lead to a reduction in misstatements and modified audit opinions. On the other hand, heightened industry specialization and hence stronger compatibility between auditors and their clients may cause audit quality to decline. For instance, Brown and Knechel (2016) find that audit quality (measured using accounting restatements) is lower when a firm is similar to its auditor's other audit clients. More consistent with the thesis of our paper, Bills, et al. (2015) document that audit quality (measured using either discretionary accruals, going concern opinions, or accounting restatements) is not significantly different when auditors specialize in homogenous industries (i.e., analogous to $|\rho|$ being large in our model). We also find an ambiguous relation between audit quality and specialization. Consistent with our analysis, they claim that a specialist auditor generates audit evidence production efficiencies without sacrificing audit quality.

In light of the ambiguous empirical relation between audit quality and industry specialization that the extant literature documents, a contribution of our paper is to offer guidance as to how the empirical data might be analyzed to identify the relation between audit quality and auditor specialization. Even though the audit-reporting measures of audit quality are always positively associated with audit specialization, it is not true for the investor-perception measures of audit quality. Specifically, in settings in which the auditor has discretion over the level of fieldwork, the investor-perception measures of audit quality and audit specialization are positively associated when the cost of gathering audit evidence is high (as in the case of a complex business) and prior certainty is high (as might arise when the firm operates in a stable business environment); conversely, the investor-perception measures of audit quality and audit specialization are negatively associated when the cost of gathering audit evidence and prior certainty is low.

5 Audit fees

We have analyzed the auditors' effort choices and reporting decisions and the investors' capital investment decision at Date 2 and 3. These decisions were made after the audit fees were established in Date 1, and therefore, did not depend on the audit fees. The empirical literature, however, finds that tougher accounting standards increase audit fees and may decrease investor value. Indeed, Iliev (2010) documents that small capitalization firms suffered a negative market reaction following implementation of the Sarbanes-Oxley Act of 2002 because of higher audit fees incurred assessing the internal control structure and procedures for financial reporting to comply with Section 404. Recognizing the cost of compliance, in May 2019 the SEC proposed to exempt public companies with revenues of less than $100 million from a mandatory external audit of their internal control structure (Rubin, 2019). Accordingly, to recognize how regulation affects audit fees and in turn firm value, in this section we step back to Date 1 and consider the bidding strategies of the prospective auditors when they participate in the auction in which they propose their fees to potential future clients.

The next lemma characterizes the equilibrium biding strategies of the prospective auditors.

Lemma 6 *Let $\delta > 3Syn/4$. The equilibrium fee $\phi_{n,i}$ that the prospective auditor n with an auditor-specific cost u_n proposes for the audit of firm i is*

$$\phi_{n,i} = E[C_i^g] + \delta - A\left(\delta - u_n\right),$$

where A, which reflects the prospective auditor's aggressiveness cutting the proposed fees, is given by

$$A \equiv \frac{2}{3 - \frac{3Syn}{4\delta}} \in [2/3, 1)\,. \tag{5}$$

The fee $\phi_{n,i}$ decreases in the aggressiveness A. The aggressiveness A increases in the future synergy of being a specialist, Syn, and decreases in the variation in the auditor-specific costs, parameterized by δ.

Recall that the incumbent auditor of firm i, who only participates in the auction of firm i, offers a fee that equals its expected cost of the audit. Formally, the incumbent auditor offers an audit fee of $\phi_{o,i} = E\left[C_i^g\right] + u_i^o$, where: $E\left[C_i^g\right]$ is the expected cost of a generalist when auditing firm i, and u_i^o is incumbent-specific cost for auditor i that, like the prospective auditor-specific costs, is distributed uniformly on the interval $[-\delta, \delta]$. Given this pricing function $\phi_{o,i}$, the incumbent auditor earns zero profits on average.

Lemma 6 establishes that the equilibrium bidding strategies of the prospective auditors are more subtle. While their proposed audit fees also include the firm specific-component $E\left[C_i^g\right]$ and the auditor-specific part u_n, the strategic entrants bid in a fashion that yields a positive payoff if they win the auction. Consequently, they always propose a higher fee than an incumbent auditor with the same auditor-specific cost because $\delta - A\left(\delta - u_n\right) > u_n$.

However, as specialists internalize the benefits associated with winning both auctions, they bid more aggressively and lower their bid when the synergy of being a specialist is higher. A prospective auditor's aggressiveness A is endogenous: it is increasing in the synergy of being a specialist and decreasing in δ, which captures the uncertainty about the auditor-specific costs of other bidders. Indeed, higher synergy motivates the entrant auditor to bid more aggressively to win both auctions, and higher uncertainty about the bids of other players decreases the probability of winning twice. The condition on δ specified in Lemma 6 ensures that the bidding strategy of the prospective auditors is never more aggressive than the bidding of the incumbent auditors.

Extant work has examined the motivation for prospective auditors to low-ball their audit fee and thereby increases their market share. Low-balling is traditionally defined as setting the audit fee below the first period expected cost of the audit (e.g., DeAngelo, 1981a, b; Kanodia and Mukherji, 1994). In our model, the fact that the expected audit fees decline in the specialist synergies does not yield low-balling. In contrast, the prospective auditor prices the audit above her expected cost. The synergy from being a specialist, however, decreases a prospective auditor's expected audit costs when winning both auctions, which raises its payoff. These synergies motivate prospective auditors to decrease their fees to raise the probability of winning the engagement from the incumbent auditors. The next lemma derives the probability of observing audit market specialization.

Lemma 7 *The probability that one prospective auditor wins both auctions and becomes a specialist, denoted as* $\Pr(sp)$*, is*

$$\Pr(sp) = A^2/2.$$

The probability of becoming a specialist increases in the aggressiveness of an entrant's strategy, and consequently, in the specialist's synergy Syn. Intuitively as the benefit of being an audit specialist increases, prospective auditors lower their bid, thereby increasing the likelihood that specialists will populate the audit market. This lemma also suggests that the probability of observing industry audit specialists decreases in heterogeneity of the auditor-specific costs, captured by the parameter δ.

In a model in which auditors strategically propose fees, the probability of becoming a specialist arises endogenously as a consequence of audit market competition. Importantly, auditor specialization is not an exogenous type characteristics of an auditor. The extent of an auditor's industry specialization will evolve over time as a function of the strategic interaction between the competing auditors and the regulatory characteristics of the environment. In this light, we combine the results of Lemma 7 with Lemma 2 to develop testable predictions of how the underlying parameters affect the probability of observing a specialist in an unregulated environment.

Corollary 1 *If the firms' auditors operate in the* unregulated *environment, then the probability of observing a specialist in the audit market* $\Pr(sp)$ *increases in the absolute value of correlation between firms* $|\rho|$*, is hump-shaped in the prior precision* τ^0*, decreases in heterogeneity of the auditor-specific costs captured by the parameter* δ*, and is hump-shaped in the marginal cost of audit effort* c*.*

We proceed further by combining the results of Lemma 7 with Lemma 3 to develop testable predictions on how the underlying parameters in the regulated audit environment affect the probability of observing a specialist.

Corollary 2 *If the firms' auditors are* regulated *by audit standard* τ^**, then the probability of observing a specialist* $\Pr(sp)$ *increases in the absolute value of correlation between firms* $|\rho|$*, is hump-shaped in the prior precision* τ^0*, is hump-shaped in the standard* τ^**, decreases in heterogeneity of the auditor-specific costs captured by the parameter* δ*, and is independent of the marginal cost of audit effort* c*.*

Interestingly, one of the key differences between the unregulated and regulated audit markets is the comparative static of the probability of specialization $\Pr(sp)$ with respect to the marginal cost of audit effort c. The cost is irrelevant for specialization in the regulated environment. As we explained above, regulation ensures the auditors choose the same level of effort, and consequently, the marginal cost of exerting effort c affects both a generalist and a specialist in the same way, thus having no impact on the specialist's synergy. In contrast, in the unregulated environment, the specialist may choose a different level of effort relatively to the generalist. Consequently, the cost c of exerting audit effort differently affects the specialist's and generalist's effort choice. Thus, changes in the cost c also affect the specialist's synergy.

The synergy of being a specialist has direct implications for the average audit fees that a firm pays, as the next lemma shows.

Lemma 8 *The expected audit fee that the firm i pays is*

$$E[\phi_i] = E[C_i^g] - \delta A^2/2.$$

The expected audit fee decreases in the synergy of being a specialist Syn and in the parameter δ that captures the variance in the auditor-specific costs.

This lemma shows that more aggressive bidding driven by the perceived future benefits of becoming a specialist decreases the expected audit fees that a firm pays. In other words, firms also benefit from the positive information spillovers that reduce a specialist's expected cost of business risk. Further, since Lemma 7 established that $\Pr(sp) = A^2/2$, Lemma 8 implies $E[\phi_i] = E[C_i^g] - \delta \Pr(sp)$, and thus, the expected audit fees are negatively associated with the probability that a specialist performs the audit.

Many empirical studies have examined the relation between audit fees and industry specialization. The results are generally mixed. For instance, Carson (2009) documents that specialization leads to lower competition and higher audit fees, while Minutti-Meza (2013) finds no substantial evidence of a specialist fee premium. In contrast, Defond, et al. (2000) report that specialization leads to production economies allowing auditors to offer lower fees. In a related vein, Bills, et al. (2015) show that industry specialists charge lower audit fees in industries with homogenous operations and complex accounting practices. Moreover, they report that industry specialists do not provide audits of lower quality, which might explain the lower audit fee; rather they attribute the lower fees to the auditors passing on their audit efficiencies to clients. These findings are consistent with our predictions.

In light of this mixed evidence, we note that several studies finding a specialist fee premium use high market concentration as a proxy for the audit firm being a specialist (e.g., Carson, 2009). This proxy confounds the effect of specialization with the degree of competition in the audit market. To explore the interplay between these two effects and to sharpen the empirical analysis, we turn to an alternative to our benchmark setting. We consider a *restricted competition* setting in which only one prospective auditor competes against the incumbent auditors. We compare these results with those when there are rival prospective auditors.[7]

In this restricted competition setting, the following lemma characterizes the bidding strategy of the prospective auditor, the probability that the auditor becomes a specialist, and the expected audit fee that the firm incurs.

Lemma 9 *Let $\delta > 3Syn/4$ and suppose there is a single prospective auditor in the market. The equilibrium fee $\overline{\phi_i}$ that the prospective auditor with an auditor-specific cost u offers to firm i is*

$$\overline{\phi_i} = E[C_i^g] + \delta - \bar{A}\,(\delta - u)\,,$$

where $\bar{A} = 3A/4$ reflects the prospective auditor's aggressiveness cutting the proposed fees. Accordingly, the probability that the prospective auditor wins both auctions and becomes a specialist is $\overline{\Pr(sp)} = 3\Pr(sp)/8$, and the expected audit fee that the firm i pays is $E\left[\overline{\phi_i}\right] = E[\phi_i] + 5\delta A^2/16$.

Lemma 9 establishes that having only one prospective auditor decreases competition in the audit market, and hence, decreases the aggressiveness of the bidding strategy. The prospective auditor's aggressiveness $\bar{A}$ in this restricted competition setting is smaller than a prospective auditor's aggressiveness A in the benchmark setting, as established in Lemma 6. Consequently, the prospective auditor with the same auditor-specific cost u proposes a higher fee than in the benchmark setting.

The probability of becoming a specialist, $\overline{\Pr(sp)}$, is also lower than in the benchmark setting. It is lower for two reasons: first, an auditor's bidding strategy is less

[7] An alternative explanation for the specialist fee premium is that firms requiring specialists may be more expensive to audit. To the extant that an empirical specification does not adequately identify the cost of performing an audit, it may inadvertently attribute higher audit fees to specialist auditors.

aggressive than when there are two prospective auditors, and second, there is one less auditor who could potentially have a low auditor-specific cost realization and become a specialist.

Lemma 9 also intuitively shows that less competition in the audit market results in higher average audit fees. The premium in the average audit fees attributable to restricted competition is $5\delta A^2/16$, and it increases in the amount of specialist's synergy through its effect on auditor aggressiveness A. While the audit fees decline in the specialist's audit synergies, this decline is more pronounced in a setting in which there is greater competition between the prospective auditors. Explicitly, the future synergy of informational spillover enjoyed by a specialist results in a proposed audit fee of $E\left[\phi_i\right] = E[C_i^g] - \delta A^2/2$ in the benchmark model with two prospective auditors (see Lemma 8) and in a proposed audit fee of $E\left[\overline{\phi_i}\right] = E[C_i^g] - 3\delta A^2/16$ in the restricted competition setting (see Lemma 9). Thus, as the specialist's synergy increases, the audit fees decrease when the competition in the audit market is restricted, but *at a lower rate.*

Our finding suggests that to identify the relation between auditor specialization and audit fees, it is important to separate the effects of competition and specialization when examining the relation between audit fees and specialization. Failure to control for the intensity of competition may explain the empirical finding of audit fees premiums associated with specialization. Our analysis suggest that when competition is restricted—that is, market concentration is high—the audit fee discount associated with larger specialization is small. Using market concentration as an empirical proxy for audit specialization, therefore, can cause the effects of audit market competition to confound the relation between specialization and audit fees. Accordingly, other environmental factors, such as the self-selection of clients with more costly audits may easily contaminate the relation between auditor specialization and audit fees.

6 Optimal audit standard

The PCAOB's mission is to "protect the interests of investors and further the public interest in the preparation of informative, accurate and independent audit reports".[8] Until this point, we assumed that audit standards were imposed exogenously. Given the PCAOB's mission, in this section we turn to focus on the optimal audit standards that the regulator chooses to maximize the ex ante value of the firm. Further, we study

[8] See https://pcaobus.org/Careers/Pages/our-mission.aspx.

how auditor industry specialization, which arises endogenously, affects the optimal standards.

To recognize the costs borne by investors, we define the ex ante expected value of firm i *after* audit fees as

$$F_i \equiv E[V_i] - E[\phi_i] = \Pr(sp) I_i^s + (1 - \Pr(sp))\, I_i^g - E[\phi_i],$$

where $I_i^s = E\left[V_i^s\right]$ and $I_i^g = E\left[V_i^g\right]$ are the expected values *before* audit fees of the firm i audited by a generalist and a specialist auditor respectively, which we labeled as an investor-perception measure of audit quality above. In the regulated environment, the investor-perception measure of audit quality does not depend on the specialization of the auditor (see Lemma 5), thus $I_i^s = I_i^g$, and the expected firm i's value after incurring audit fees simplifies to

$$F_i = E[V_i^g] - E[\phi_i] = I_i^g - \left(E[C_i^g] - A^2\delta/2\right). \tag{6}$$

In practice, audit standards are not customized for a particular firm. Accordingly, we establish the optimal standard that maximizes the ex ante value F_i of the firm before the choice of auditor. We also assume that the of cost of capital parameter is common across firms, $L_1 = L_2 = L$, so that the ex ante expected value is the same for both firms, $F_1 = F_2$. This assumption ensures that an optimal audit standard that maximizes ex ante firm value is common across the firms.

The next lemma compares the optimal standard in the benchmark case when there are no synergies of being a specialist (i.e., $\rho = 0$), denoted as τ_{opt}^B, to the optimal standard when there are audit synergies, denoted as τ_{opt}. Most importantly, this lemma shows that the presence of synergies can make the optimal standard higher or lower, depending on the parameters of the model.

Lemma 10 *There exists an optimal audit standard τ_{opt}^B that maximizes the expected value of the firm after audit fees in the absence of the specialist's synergy. Relative to τ_{opt}^B, the optimal audit standard in the presence of synergies τ_{opt} has the following properties:*

- *If $\sqrt{c}\tau^0 > h(L)$, then $\tau_{opt} > \tau_{opt}^B$;*
- *If $h(L) \geq \sqrt{c}\tau^0 \geq \frac{3}{2+\sqrt{2}} h(L)$, then there exists a threshold on the absolute value of correlation $|\rho|^*$ such that $\tau_{opt} > \tau_{opt}^B$ when $|\rho| > |\rho|^*$, and $\tau_{opt} < \tau_{opt}^B$ when $|\rho| < |\rho|^*$; and,*

- *If* $\sqrt{c}\tau^0 < \frac{3}{2+\sqrt{2}} h(L)$, *then* $\tau_{opt} < \tau_{opt}^B$.

  Here $h(L) = \frac{2}{3}\sqrt{1 + 1/(2L)}$, *which is a decreasing function in* L.

First, consider the case without specialist synergy, $Syn = 0$. The expected value of firm i after audit fees simplifies to

$$F_i = I_i^g - E[C_i^g] + 2\delta/9.$$

Here the effect of a stricter audit standard τ^* on the firm value is two-fold: On one hand, it increases firm's value as it raises the investor-perception quality of the firm I_i^g by making capital investment more efficient. On the other hand, it decreases the firm's value because it increases the expected audit fees $E[C_i^g]$. The optimal standard τ_{opt}^B aimed at maximizing the firm value trades off these two effects.

In the presence of synergies from auditor specialization, however, a change in the audit standard has an additional effect on firm value that operates through the aggressiveness of bidding A—see expression (6). As established in Lemma 3, the synergy of being a specialist Syn is hump-shaped in the audit standard τ^*. Accordingly, the aggressiveness of bidding A is also hump-shaped in the standard, and therefore, there is an additional impact of the standard on the expected audit fees. Thus, relative to when synergy is absent, a regulator may choose a lower or a higher standard τ_{opt} depending on whether the synergy locally decreases or increases in the standard.

When the marginal cost of audit effort c is high and the prior uncertainty is low, a more stringent standard substantially increases the expected audit fees but only marginally improves investment efficiency. The regulator therefore chooses a low standard to maximize expected firm value in the benchmark case without synergies. When a standard is low, the synergy is increasing in the standard. Thus, the regulator chooses a higher standard when there are specialist synergies compared to the benchmark case in which there are no synergies, $\tau_{opt} > \tau_{opt}^B$. Conversely, when the marginal cost of audit c is low and the prior uncertainty is high, the regulator chooses a lower standard relative to the benchmark case, $\tau_{opt} < \tau_{opt}^B$.

7 Robustness: Minimum audit standard

In a regulated environment, an auditor was required to gather the exact level of evidence that the audit standard required, $\tau_i = \tau^*$. Institutionally, however, auditors are not precluded from performing more expansive procedures than required by the audit standards of fieldwork. Accordingly, in this section, we modify the model and assume that the regulator merely imposes a minimum audit standard while allowing auditors to exert a level of effort above the lower bound that the standard prescribes. This extension, which serves to assess the robustness of our earlier analysis, builds on the intuition developed above and largely confirms the key findings documented in the benchmark setting.

Formally, we define a *minimum audit standard* that the regulator imposes as a threshold τ^* for the precision of the auditor's signal. An auditor is said to comply with the standard when the auditor's choice of precision is such that $\tau_i \geq \tau^*$. With this weakened notion of compliance in hand, Lemma 11 characterizes how the synergy of a specialist changes with the imposed minimum standard τ^*.

Lemma 11 *Suppose auditors are regulated according to a minimum audit standard* τ^**.*

- *If a specialist chooses a* lower *precision than a generalist in the absence of a regulator,* $\tau^s < \tau^g$*, then the synergy Syn is constant in the standard* τ^* *for* $\tau^* < \tau^s$*, and is monotonically decreasing in the standard* τ^* *for* $\tau^* > \tau^s$*.*
- *If a specialist chooses a* higher *precision than a generalist in the absence of a regulator,* $\tau^s > \tau^g$*, then the synergy Syn is constant in the standard* τ^* *for* $\tau^* < \tau^g$*, and is hump-shaped in the standard* τ^* *for* $\tau^* > \tau^g$*.*

A minimum audit standard imposes a lower bound on the precision of collected evidence. It allows the auditors to exert more effort and collect information of better quality. The lemma establishes that the impact of the minimum standard τ^* on the specialist auditor's synergy depends on whether a specialist chooses a higher or lower level of precision than a generalist when there is no audit regulation.

Consider first the environment with a specialist choosing a lower precision than a generalist in the absence of regulation — $\tau^s < \tau^g$. According to Lemma 1, in the absence of a regulator, $\tau^s < \tau^g$ when the marginal cost of effort is low and the prior uncertainty is high. For low standards $\tau^* < \tau^s$, both a specialist and a generalist choose to exert more effort than needed to comply with the standard. As long as the audit standard τ^* is sufficiently low, increasing it does not change the auditors' fieldwork, and consequently, the specialist's synergy. However, as the standard become more stringent and exceeds τ^s, it starts affecting the fieldwork of the specialist. Indeed, she would exert lower audit effort in the absence of regulation than that which the regulation demands, but, in the presence of regulation, she has to achieve the audit precision of at least τ^* to comply. Since this choice of precision τ^* is suboptimal, the cost of the audit starts increasing in τ^* for the specialist but not yet for a generalist (as $\tau^s < \tau^g$). Thus, the synergy of being a specialist falls. As the standard is raised further and exceeds τ^g, it starts affecting the choice of audit effort of the generalist as well. Despite this impact on the generalist, the synergy of being a specialist continues to fall. Intuitively, this occurs because the specialist's optimal choice of effort is lower than that of a generalist, $\tau^s < \tau^g$, so a high audit standard τ^* still affects the specialist relatively more intensively than the generalist. Overall, the synergy Syn is weakly decreasing in the minimum standard τ^* when the specialist chooses a lower precision than a generalist in the absence of regulation.

Alternatively, consider an environment in which a specialist chooses a higher precision than a generalist would choose in the absence of regulation — $\tau^s > \tau^g$. One can similarly develop the intuition for why the synergy of being a specialist Syn is hump-shaped in the standard τ^* in such scenario. In contrast to the previous case, making the standard τ^* more stringent starts affecting the generalist earlier than the specialist. It follows that the synergy increases in the standard τ^* before eventually shrinking to zero as the standard becomes increasingly stringent.

Before proceeding, we highlight the differences where auditors may exert more effort than prescribed by the regulator with the setting where an auditor has to choose the exact level of effort, as established in Lemma 3. This lemma showed that the synergy of being a specialist was hump shaped in the standard τ^*. Allowing the auditors to exert more effort than prescribed by the regulator preserves the hump shape when the the specialist voluntarily chooses a *higher* precision than a generalist in the absence of a regulator (when the cost of auditing is high and prior uncertainty is low). However, the synergy becomes *weakly decreasing* in the standard when the specialist voluntarily chooses a *lower* precision than a generalist in the absence of a regulator (when the cost of auditing is low and prior uncertainty is high). In this case, any regulation adversely affects a specialist more than a generalist.

Audit Quality: We show how specialization in the audit market with a minimum standard τ^* affects the audit reporting measure and the investor-perception measure of audit quality.

Lemma 12 *Suppose auditors are regulated according to a minimum audit standard* τ^**.*

- *The audit reporting measure is always higher when the firm is audited by a specialist rather than a generalist.*
- *The ranking of the investor-perception measure when the firm is audited by a specialist rather than a generalist is ambiguous. Specifically:*
  - *If a specialist chooses a* lower *precision than a generalist in the absence of a regulator, $\tau^s < \tau^g$, then investor-perception measure is higher for a firm audited by a generalist for $\tau^* < \tau^g$ and is the same for firms audited by specialists and generalists for $\tau^* \geq \tau^g$.*
  - *If a specialist chooses a* higher *precision than a generalist in the absence of a regulator, $\tau^s > \tau^g$, then investor-perception measure is higher for a firm audited by a specialist for $\tau^* < \tau^s$ and is the same for firms audited by specialists and generalists for $\tau^* \geq \tau^s$.*

When there is a minimum audit standard in place, a specialist auditor still enjoys the information advantage associated with the information spillovers, and hence, can deliver a report of better precision, resulting in a higher audit reporting measure. This is the same result as in Lemma 4.

Turning to the investor-perception measure, the results combine the findings of the unregulated and regulated scenarios in Lemma 5. Consider first the environment with a specialist choosing a lower precision than a generalist in the absence of regulation — $\tau^s < \tau^g$. For a high standard $\tau^* > \tau^g$, both the specialist and the generalist exert the same level τ^* to comply with the standard. Therefore, their reports lead to the same investment efficiency and result in the same investor-perception measure. In contrast, when the standard τ^* is lower than the optimal effort τ^g that a generalist would choose, the generalist voluntarily performs more fieldwork than the specialist. This choice leads to a higher investor-perception measure for the firms that the generalist audits. Similar intuition applies in the environment with a specialist choosing a higher precision than a generalist in the absence of regulation — $\tau^s > \tau^g$.

Audit Fees: We next turn to examine the impact of having a minimum audit standard on auditor's fees and auditor's specialization. As we established in Lemma 11, the specialist's synergy can be weakly decreasing or non-monotonic in the minimum standard. Combining these results with the result of Lemma 7, the probability of having an audit market specialist also can be weakly decreasing or non-monotonic in the standard. We formalize this finding in the next corollary.

Corollary 3 *Suppose the auditors are regulated according to a minimum audit standard* τ^*.

- *If a specialist chooses a* lower *precision than a generalist in the absence of a regulator,* $\tau^s < \tau^g$*, then the probability of observing a specialist in the audit market* $\Pr(sp)$ *is weakly monotonically decreasing in the minimum audit standard* τ^*.
- *If a specialist chooses a* higher *precision than a generalist in the absence of a regulator,* $\tau^s > \tau^g$*, then the probability of observing a specialist in the audit market* $\Pr(sp)$ *is hump-shaped in the minimum audit standard* τ^*.

Recall that when an auditor must choose the exact level of effort prescribed by the regulator the probability of observing a specialist is hump-shaped in the standard—see Corollary 2. This relation still holds true when auditors may exert more effort than the minimum standard τ^*, provided a specialist chooses a higher precision than a generalist in the absence of a regulator. Thus, in those industries in which prior uncertainty about the firm's value in an industry is low, such as in mature industries with little earnings volatility, the impact of the PCAOB's heightened regulation on auditor industry specialization is ambiguous.

In contrast, if a specialist chooses a lower precision than a generalists in the absence of a regulator, then any minimum standard will crowd out specialists from the audit market. Thus, when the prior uncertainty about the firm's value in an industry is high, the probability of industry specialization is decreasing in the stringency of audit standards. Given that the PCAOB has promulgated and enforced stricter standards than the AICPA, this corollary yields the following prediction: in those industries in which prior uncertainty about the firm's value is high, such as in the biotechnology industry in which there is much uncertainty about a firm's prospects, we expect a decline in auditor industry specialization following the creation of the PCAOB.

A similar prediction applies to industries where the cost of exerting audit effort is low. We expected these costs to be low in industries where the business model, internal control systems, and reporting issues are straight-forward, and thus, auditors can assign junior staff accountants to perform the field work and provide relatively low levels of supervision. For more complex audits, the auditor would need to rely on its more skilled staff and heightened partner supervision to perform the audit.

Optimal Minimum Standard: Lastly, we examine the optimal minimum standards τ_{opt} and τ_{opt}^B that maximize the expected value of the firm after audit fees in the presence and absence of a specialist's synergies.

Lemma 13 *Let the absolute value of correlation $|\rho|$ be small. Then the optimal minimum standard in the presence of a specialist's synergies, τ_{opt}, is larger than the optimal minimum standard in the absence of synergies, τ_{opt}^{B}, if and only if $\sqrt{c}\tau^{0} \geq h(L)$, where $h(L) = \frac{2}{3}\sqrt{1 + 1/(2L)}$ is a decreasing function in L.*

The optimal minimum audit standards have similar characteristics to the optimal standards observed when auditors must choose the exact level of effort that the regulator prescribes—see Lemma 10. Specifically, when the correlation ρ is small, the results of Lemma 10 and Lemma 13 are essentially the same. This holds because the optimal minimum standard in the absence of synergies always binds, and the optimal minimum standard in the presence of synergies binds when the correlation ρ between the firms' fundamental values converges to zero.

To understand why the optimal minimum standard in the absence of synergies always binds, observe that a generalist voluntarily chooses an amount of fieldwork that equalizes the marginal cost of additional effort with the marginal benefit of decreasing the expected cost of business risk. Doing so minimizes the audit cost. The expected audit cost, however, is ex ante borne by the firm in the form of audit fees. Hence, when the regulator ex-ante chooses the standard to maximize firm value, the regulator trades off the marginal cost and benefit of a specialist doing extra fieldwork, and, *additionally*, the marginal benefit of inducing higher quality audited reports that increase the efficiency of investment. Since there is an additional marginal benefit, it follows that the optimal standard chosen by a regulator is always larger than that chosen by a generalist.

When the absolute value of correlation $|\rho|$ is small, the effect of specialization is small, and it has a negligible effect on the optimal standard the regulator chooses. Thus, like the optimal minimum standard in the benchmark without the specialist's synergy, the optimal minimum standard when the synergy is present also binds.

These two observations ensure that the results of Lemma 10 are essentially unchanged when the correlation ρ is small. Numerical calculations establish the key qualitative observation that the optimal standard in the presence of synergies, τ_{opt}, can be higher or lower than the optimal standard τ_{opt}^{B} in the absence of synergies.

8 Conclusion

We examine the determinants of specialization in the audit market. Being a specialist gives an auditor an advantage stemming from information spillovers between its clients. This advantage decreases the specialist's expected cost of audit, increases the probability of having an audit market specialist, and decreases the expected audit fees paid by the clients. Thus, while the empirical findings on the effect of audit specialization on audit fees are mixed, possibly because this relation might be confounded by the effect of audit market concentration on audit fees, we find that firms also enjoy the specialist's information advantage by paying lower fees.

A regulator maximizing the ex ante firm's value optimally adjusts the standard to support specialization. We find that the specialist's synergy is non-monotonic in the audit standard. Accordingly, the presence of the audit synergies increases the audit standard that maximizes investor value when the marginal cost of audit is high and the inherent risk of audit is low, and it decreases the standard when the marginal cost of audit is low and the inherent risk of audit is high.

Recently, in light of the increasing resistance to its practices from the large audit firms as well as the SEC, the PCAOB has begun to consider ways of improving its policy-making and external engagement (Rapoport, 2018). We establish that to advance the PCAOB's mission to further the public interest in the preparation of informative audit reports, the regulator ought to optimally adjust audit standards to recognize the audit synergies that are present when audit firms evaluate multiple firms in an industry and that these synergies critically affect audit quality and audit fees.

9 APPENDIX

This appendix contains the proofs of the lemmas and propositions.

Proof of Lemma 1:

- A generalist i chooses the effort τ_i^g to minimize the expected business risk cost and the cost of effort:
$$E[C_i^g] = Var[\mu_i|s_i] + c\tau_i^g = \frac{1}{\tau^0 + \tau_i^g} + c\tau_i^g. \qquad (7)$$
Taking derivative with respect to τ_i^g and solving the first order condition gives
$$\tau_g^i = \frac{1}{\sqrt{c}} - \tau^0.$$
Since the optimization program is convex, this is the optimal effort as long as it is non-negative (indeed the restriction is $\frac{1}{\sqrt{c}} - \tau^0 \geq 0$).

- A specialist chooses the levels of effort τ_1^s and τ_2^s to minimize the expected business risk costs and the costs of effort:
$$E[C^s] = E[C_1^s] + E[C_2^s] = Var[\mu_1|s_1, s_2] + c\tau_1^s + Var[\mu_2|s_1, s_2] + c\tau_2^s.$$
To compute the posterior variances upon observation of two signals s_1 and s_2, define the prior variance-covariance matrix of the distribution of fundamental firm values as
$$\Sigma^0 = \frac{1}{\tau^0}\begin{pmatrix} 1 & \rho \\ \rho & 1 \end{pmatrix}$$
and the matrix of precision of the signals s_1 and s_2 as
$$\Sigma^s = \begin{pmatrix} \frac{1}{\tau_1^s} & 0 \\ 0 & \frac{1}{\tau_2^s} \end{pmatrix}.$$
Now, the posterior variance-covariance matrix is computed as
$$\Sigma \;=\; \left(\left(\Sigma^0\right)^{-1} + \left(\Sigma^s\right)^{-1}\right)^{-1},$$
so that
$$\begin{aligned} Var[\mu_1|s_1, s_2] &= \Sigma|_{1,1} = \frac{1}{\tau_1^s + \tau^0 \frac{1}{1-\rho^2 \frac{\tau_2^s}{\tau^0+\tau_2^s}}} \\ Var[\mu_2|s_1, s_2] &= \Sigma|_{2,2} = \frac{1}{\tau_2^s + \tau^0 \frac{1}{1-\rho^2 \frac{\tau_1^s}{\tau^0+\tau_1^s}}}. \end{aligned}$$

The specialist's cost simplifies to

$$E[C^s] \;=\; \frac{2\tau^0 + (1-\rho^2)\left(\tau_1^s + \tau_2^s\right)}{\left(\tau^0\right)^2 + \tau^0\left(\tau_1^s + \tau_2^s\right) + (1-\rho^2)\,\tau_1^s\tau_2^s} + c\left(\tau_1^s + \tau_2^s\right).$$

The minimum of the specialist's cost is attained at equal levels of effort $\tau_1^s = \tau_2^s$. We prove this by contradiction. Assume that the minimum is attained at $\tau_1^s > \tau_2^s$. Then, at a small ϵ-perturbation $\tilde{\tau}_1^s = \tau_1^s - \epsilon$ and $\tilde{\tau}_2^s = \tau_2^s + \epsilon$, we have that $\tau_1^s + \tau_2^s = \tilde{\tau}_1^s + \tilde{\tau}_2^s$ but $\tau_1^s\tau_2^s < \tilde{\tau}_1^s\tilde{\tau}_2^s$. Consequently, the cost $E[\tilde{C}^s]$ should decrease following such perturbation in the levels of effort. Consequently, it has to be that $\tau_1^s = \tau_2^s$.

Denote such an optimal level of effort by $\tau_1^s = \tau_2^s = \tau^s$. Rewriting the specialist's cost gives

$$E[C^s] \;=\; \frac{2}{\tau^s + \tau^0 \frac{1}{1-\rho^2\frac{\tau^s}{\tau^0+\tau^s}}} + 2c\tau^s \tag{8}$$

One can show that the second order condition is always positive, so the optimal effort τ^s solves the first order condition:

$$\frac{dE[C^s]}{d\tau^s} = 0\,.$$

To compare such a level of effort to the optimal efforts of generalists $\tau_1^g = \tau_2^g = \tau^g = \frac{1}{\sqrt{c}} - \tau^0$, one can compute $\frac{dE[C^s]}{d\tau^s}$ and substitute $\tau^g = \frac{1}{\sqrt{c}} - \tau^0$. Given that the program is convex, we have that $\tau^s < \tau^g$ if and only if

$$\left.\frac{dE[C^s]}{d\tau^s}\right|_{\tau^g} > 0.$$

This holds true if and only if

$$\rho^2\left(2 - 3\sqrt{c}\tau^0 - \rho^2\left(2-\sqrt{c}\tau^0\right)\left(1-\sqrt{c}\tau^0\right)^2\right) > 0. \tag{9}$$

Obviously, if $\rho = 0$, then the specialist and the generalist both choose the same levels of effort as there are no differences between them. Henceforth, we assume $\rho \neq 0$. Define $l = \sqrt{c}\tau^0$, where $l > 0$ but $l < 1$ as assumed in the lemma. Consider the expression

$$L(l) = 2 - 3l - \rho^2(2-l)(1-l)^2,$$

and take its derivatives with respect to l. Since

$$L'' < 0,\; L(0) = 2(1-\rho^2) > 0,\; L(1) = -1 < 0,$$

$L(l)$ has a unique root $t(\rho) \in (0,1)$ that solves $L(t(\rho)) = 0$. Therefore, for all $\sqrt{c}\tau^0 < t(\rho)$, we have that

$$\left(2 - 3\sqrt{c}\tau^0 - \rho^2\left(2 - \sqrt{c}\tau^0\right)\left(1 - \sqrt{c}\tau^0\right)^2\right) > 0 \rightarrow \tau^s < \tau^g,$$

and for all $\sqrt{c}\tau^0 > t(\rho)$, we have that

$$\left(2 - 3\sqrt{c}\tau^0 - \rho^2\left(2 - \sqrt{c}\tau^0\right)\left(1 - \sqrt{c}\tau^0\right)^2\right) < 0 \rightarrow \tau^s > \tau^g. \blacksquare$$

Proof of Lemma 2:

The total synergy is given by

$$Syn = Syn_1 + Syn_2 = E[C_1^g] - E[C_1^s] + E[C_2^g] - E[C_2^s] = 2E[C^g] - E[C^s].$$

Substituting the expected costs from (7) and (8), we have

$$Syn = \frac{2}{\tau^0 + \tau^g} + 2c\tau^g - \left(\frac{2}{\tau^s + \tau^0 \frac{1}{1-\rho^2 \frac{\tau^s}{\tau^0+\tau^s}}} + 2c\tau^s\right).$$

One can see that even if the specialist chooses the same precision as a generalist, i.e. $\tau_s = \tau_g$, the expected costs $E[C^s]$ of the specialist are lower as

$$G = \frac{1}{1 - \rho^2 \frac{\tau^s}{\tau^0+\tau^s}} > 1,$$

and consequently, the synergy is positive. The specialist may optimally choose a level of precision that differs fromτ_g. This choice further lowers the expected cost of the audit and makes the synergy even more positive.

To show that the synergy is decreasing in $|\rho|$, observe that

$$\begin{aligned} \frac{dSyn}{d|\rho|} &= \frac{\partial Syn}{\partial|\rho|} + \frac{\partial Syn}{\partial\tau^s}\frac{\partial\tau^s}{\partial|\rho|} + \frac{\partial Syn}{\partial\tau^g}\frac{\partial\tau^g}{\partial|\rho|} \\ &= \frac{\partial Syn}{\partial|\rho|} - \frac{\partial E[C^s]}{\partial\tau^s}\frac{\partial\tau^s}{\partial|\rho|} + 2\frac{\partial E[C^g]}{\partial\tau^g}\frac{\partial\tau^g}{\partial|\rho|} \\ &= \frac{\partial Syn}{\partial|\rho|}, \end{aligned}$$

where the last equality holds because the optimal τ^s and τ^g minimize the expected costs of a specialist and a generalist, respectively, and consequently, solve the corresponding first order conditions (the envelope theorem). The last thing to notice is that $\partial Syn/\partial|\rho| > 0$.

Similarly, the envelope theorem allows to compute that

$$\frac{dSyn}{dc} = \frac{\partial Syn}{\partial c} = 2\left(\tau^g - \tau^s\right) .$$

It follows from Lemma 1 that $\tau^g > \tau^s$ for low costs c and $\tau^g < \tau^s$ for high costs c. Hence, $dSyn/dc$ switches its sign from plus to minus once and only once as c increases. Consequently the synergy is hump-shaped in c.

Finally, we have that

$$\frac{dSyn}{d\tau^0} = \frac{\partial Syn}{\partial \tau^0} .$$

We take the partial derivative, substitute $\tau^g = 1/\sqrt{c} - \tau^0$, and use the first order condition that implicitly defines the specialist's effort τ^s so that the simplified expression becomes

$$\frac{dSyn}{d\tau^0} \propto (1-\rho^2)(\tau^s)^2 - (\tau^0)^2 .$$

We can show using the implicit function theorem derivative that τ^s in decreasing in τ^0. Moreover, $\tau^s \to +\infty$ as $\tau^0 \to 0$, and $\tau^s \to 0$ as $\tau^0 \to +\infty$. Hence, $dSyn/d\tau^0$ switches its sign from plus to minus once and only once as τ^0 increases. Consequently the synergy is hump-shaped in τ^0. ■

Proof of Lemma 3:

- We derived in Lemma 2 the synergy of a specialist with an effort level τ^s as compared to a generalist with an effort level τ^g to be

$$Syn = \frac{2}{\tau^0 + \tau^g} + 2c\tau^g - \left(\frac{2}{\tau^s + \tau^0 \frac{1}{1-\rho^2 \frac{\tau^s}{\tau^0 + \tau^s}}} + 2c\tau^s \right)$$

Let τ^* be the regulatory audit standard, so that $\tau^g = \tau^s = \tau^*$. Then

$$Syn = \frac{2\tau^0 \tau^* \rho^2}{\left(\tau^* + \tau^0\right)\left(\left(\tau^* + \tau^0\right)^2 - \rho^2\left(\tau^*\right)^2\right)}$$

It is positive as long as $\rho \neq 0$ and we have

$$\frac{dSyn}{d\left|\rho\right|} = \frac{4\left|\rho\right| \tau^0 \tau^* \left(\tau^0 + \tau^*\right)}{\left(\left(\tau^* + \tau^0\right)^2 - \rho^2\left(\tau^*\right)^2\right)^2} > 0 ,$$

so the synergy increases in the absolute value of the correlation between two firms' fundamental values as long as $\rho \neq 0$. Additionally,

$$\frac{dSyn}{dc} = 0 ,$$

so the synergy is unaffected by the marginal cost of audit effort.

To find how the synergy is affected by the standard τ^*, we compute

$$\frac{dSyn}{d\tau^*} = \frac{2\tau^0\rho^2\left(\left(\tau^0\right)^3 - (3-\rho^2)\tau^0\left(\tau^*\right)^2 - 2(1-\rho^2)\left(\tau^*\right)^3\right)}{\left(\tau^*+\tau^0\right)^2\left(\left(\tau^*+\tau^0\right)^2 - \rho^2\left(\tau^*\right)^2\right)^2},$$

so the synergy decreases in the standard τ^* if and only if

$$\rho^2\left(\left(\tau^0\right)^3 - (3-\rho^2)\tau^0\left(\tau^*\right)^2 - 2(1-\rho^2)\left(\tau^*\right)^3\right) < 0\,.$$

We have that

$$\begin{aligned}
\frac{d\left(\left(\tau^0\right)^3 - (3-\rho^2)\tau^0\left(\tau^*\right)^2 - 2(1-\rho^2)\left(\tau^*\right)^3\right)}{d\tau^*} &< 0\,,\\
\lim_{\tau^*\to 0}\left(\left(\tau^0\right)^3 - (3-\rho^2)\tau^0\left(\tau^*\right)^2 - 2(1-\rho^2)\left(\tau^*\right)^3\right) &> 0\,,\\
\lim_{\tau^*\to \infty}\left(\left(\tau^0\right)^3 - (3-\rho^2)\tau^0\left(\tau^*\right)^2 - 2(1-\rho^2)\left(\tau^*\right)^3\right) &< 0\,.
\end{aligned}$$

It follows, that if $\rho \neq 0$, then the synergy has an inverse U-shape with respect to the audit standard τ^*.

Similarly, the synergy has an inverse U-shape with respect to the prior precision τ^0:

$$\frac{dSyn}{d\tau^0} = \frac{2\tau^*\rho^2\left((1-\rho^2)\left(\tau^*\right)^3 - 3\left(\tau^0\right)^2\tau^* - 2\left(\tau^0\right)^3\right)}{\left(\tau^*+\tau^0\right)^2\left(\left(\tau^*+\tau^0\right)^2 - \rho^2\left(\tau^*\right)^2\right)^2},$$

where

$$\begin{aligned}
\frac{d\left((1-\rho^2)\left(\tau^*\right)^3 - 3\left(\tau^0\right)^2\tau^* - 2\left(\tau^0\right)^3\right)}{d\tau^0} &< 0,\\
\lim_{\tau^0\to 0}\left((1-\rho^2)\left(\tau^*\right)^3 - 3\left(\tau^0\right)^2\tau^* - 2\left(\tau^0\right)^3\right) &> 0,\\
\lim_{\tau^0\to \infty}\left((1-\rho^2)\left(\tau^*\right)^3 - 3\left(\tau^0\right)^2\tau^* - 2\left(\tau^0\right)^3\right) &< 0.\blacksquare
\end{aligned}$$

Proof of Lemma 4:

- First, we consider an environment without regulation. The reporting quality of the firm i audited by a generalist is

$$Q_i^g = -E\left[Var\left[\mu_i | s_i^g\right]\right] = -\frac{1}{\tau^0+\tau^g}\,.$$

The reporting quality of the firm i audited by a specialist is

$$Q_i^s = -E\left[Var\left[\mu_i | s_1^s, s_2^s\right]\right] = -\frac{1}{\tau^0 f(\tau^s) + \tau^s},$$

where

$$f(\tau^s) = \frac{1}{1 - \rho^2 \frac{\tau^s}{\tau^0 + \tau^s}}.$$

Now recall from Lemma 1 that the generalist's effort τ^g maximizes

$$Q_i^g - c\tau^g$$

and the specialist's effort τ^s maximizes

$$2Q_i^s - 2c\tau^s.$$

The first order conditions are, respectively,

$$\left(Q_i^g\right)^2 - c = 0,$$

and

$$2\left(Q_i^s\right)^2 \left(1 + \tau^0 f'(\tau^s)\right) - 2c = 0,$$

It follows that

$$\left(Q_i^g\right)^2 = \left(Q_i^s\right)^2 \left(1 + \tau^0 f'(\tau^s)\right),$$

where $f'(\tau^s) > 0$. Consequently, $\left(Q_i^g\right)^2 > \left(Q_i^s\right)^2$ and $Q_i^g < Q_i^s$.

- Now consider the regulated environment with a standard τ^*. The reporting quality of the firm i audited by a generalist is

$$Q_i^g = -E\left[Var\left[\mu_i | s_i^g\right]\right] = -\frac{1}{\tau^0 + \tau^*}.$$

The reporting quality of the firm i audited by a specialist is

$$Q_i^s = -E\left[Var\left[\mu_i | s_1^s, s_2^s\right]\right] = -\frac{1}{\tau^0 f(\tau^*) + \tau^*},$$

where

$$f(\tau^*) = \frac{1}{1 - \rho^2 \frac{\tau^*}{\tau^0 + \tau^*}}.$$

One can immediately see that $Q_i^s > Q_i^g$ because $f(\tau^*) > 1$. Moreover, Q_i^g is increasing in τ^* and Q_i^s in increasing in τ^* because $f'(\tau^*) > 0$.■

Proof of Lemma 5:

- First, we consider an environment without regulation. The investor-perception measure of audit quality of a firm i audited by a generalist is
$$I_i^g = E[V_i^g] = \frac{1}{2L_i}\left(Var\left[\mu_i\right] - Var\left[\mu_i|R_1^g, R_2^g\right]\right)$$
and the investor-perception measure of audit quality of a firm i audited by a specialist is
$$I_i^s = E[V_i^s] = \frac{1}{2L_i}\left(Var\left[\mu_i\right] - Var\left[\mu_i|R_1^s, R_2^s\right]\right).$$
The first one is higher if and only if
$$Var\left[\mu_i|R_1^g, R_2^g\right] < Var\left[\mu_i|R_1^s, R_2^s\right].$$
Since the market observes the audited reports of both firms, it can filter out what the signals that the auditors received were in both cases. Consequently, the later condition can be rewritten as
$$Var\left[\mu_i|s_1^g, s_2^g\right] < Var\left[\mu_i|s_1^s, s_2^s\right].$$
The expected variance of the fundamental value μ_i given two signals of generalists is lower if and only if the precision of the signals is higher, i.e. if $\tau^g > \tau^s$.

- In the environment with regulated audit, the regulator imposes the same standard and the auditors have to choose the same precision independently of their preferences. Consequently, in the regulated audit environment, two signals of two generalists have the same informational value as two signals of one specialist:
$$Var\left[\mu_i|s_1^g, s_2^g\right] = Var\left[\mu_i|s_1^s, s_2^s\right].$$
Hence, $I_i^g = I_i^s$.

  Moreover, the investor-perception measure of audit quality is increasing in the audit standard:
$$\begin{aligned}\frac{dI_i^g}{d\tau^*} &= -\frac{1}{2L_i}\frac{dVar\left[\mu_i|R_1^g, R_2^g\right]}{d\tau^*} \\ &= -\frac{1}{2L_i}\frac{dVar\left[\mu_i|s_1^g, s_2^g\right]}{d\tau^*} \\ &= -\frac{1}{2L_i}\frac{d}{d\tau^*}\left(\frac{1}{\tau^* + \tau^0\frac{1}{1-\rho^2\frac{\tau^*}{\tau^0+\tau^*}}}\right) > 0\,.\blacksquare\end{aligned}$$

Proof of Lemma 6:

The bids of the incumbent auditor of a firm $i = 1, 2$ are given by

$$\phi_{o,i} = E\left[C_i^g\right] + u_i^o$$

We assume that the new entrant 2 bids with a linear strategy

$$\phi_{2,i} = E[C_i^g] + Au_2 + (1 - A)\delta \, ,$$

where

$$A = \frac{1}{\frac{3}{2} - \frac{3Syn}{8\delta}} \, .$$

and prove that the optimal strategy of the incumbent auditor 1 is also linear with

$$\phi_{1,i} = E[C_i^g] + Au_1 + (1 - A)\delta \, .$$

In the interest of simplifying the derivations, we will be using the "normalized" bids $b_{1,i}$, $b_{2,i}$, $b_{o,i}$ instead of the bids $\phi_{1,i}$, $\phi_{2,i}$, $\phi_{o,i}$, where

$$\begin{aligned} b_{1,i} &= \phi_{1,i} - E[C_i^g] \, , \\ b_{2,i} &= \phi_{2,i} - E[C_i^g] = Au_2 + (1 - A)\delta \, , \\ b_{o,i} &= \phi_{o,i} - E[C_i^g] = u_i^o . \end{aligned}$$

Given that u_i^o and u_i are distributed uniformly at $[-\delta, \delta]$, we have that $b_{o,i}$ is distributed uniformly at $[-\delta, \delta]$ and $b_{2,i}$ is distributed uniformly at $[(1 - 2A)\,\delta, \delta]$. Observe that for $\delta > 3Syn/4$, we have $(1 - 2A)\,\delta > -\delta$.

The expected utility of the prospective auditor 1 is given by

$$\begin{aligned} & \sum_{i=1,2} \left(\phi_{1,i} - E[C_i^g] - u_1\right) \Pr\left(\text{auditor 1 wins only auction } i\right) \\ & + \sum_{i=1,2} \left(\phi_{1,i} - E[C_i^s] - u_1\right) \Pr\left(\text{auditor 1 wins both auctions}\right) \\ = \; & \sum_{i=1,2} \left(\phi_{1,i} - E[C_i^g] - u_1\right) \Pr\left(\text{auditor 1 wins auction } i\right) \\ & + \sum_{i=1,2} \left(E[C_i^g] - E[C_i^s]\right) \Pr\left(\text{auditor 1 wins both auctions}\right) \\ = \; & \sum_{i=1,2} \left(b_{1,i} - u_1\right) \Pr\left(\text{auditor 1 wins auction } i\right) \\ & + Syn \; \Pr\left(\text{auditor 1 wins both auctions}\right) \\ = \; & \sum_{i=1,2} \left(b_{1,i} - u_1\right) \Pr\left(b_{1,i} < b_{2,i}, b_{1,i} < b_{o,i}\right) \\ & + Syn \; \Pr\left(b_{1,1} < b_{2,1}, b_{1,1} < b_{o,1}, b_{1,2} < b_{2,2}, b_{1,2} < b_{o,2}\right) \, . \end{aligned}$$

We proceed with the proof as follows. First, we find an optimal strategy where the auditor 1 bids the same $b_{1,i}$ for both firms $i = 1, 2$. This strategy turns out to coincide with the conjectured strategy of the prospective auditor 2. Second, we prove by contradiction that a strategy $b_{1,1} \neq b_{1,2}$ can never be optimal.

1. We start by finding an optimal bid of the auditor 1 assuming she bids the same $b_{1,i}$ for both firms $i = 1, 2$. We denote $b_1 = b_{1,1} = b_{1,2}$.

   The auditor 1 will not bid anything higher than δ because that makes her lose in both auctions. Indeed, $b_{2,i} \leq \delta$ and $b_{0,i} \leq \delta$. She will also not bid anything lower than $-\delta$ because this is suboptimal to betting $-\delta$. Indeed, in both cases the auditor 1 almost surely wins both bets, so she is better off bidding a higher fee $-\delta$.

   Consequently, we need to look at two cases: when $b_1 \in [-\delta, (1 - 2A)\delta]$ and when $b_1 \in [(1 - 2A)\delta, \delta]$. In the former case, the auditor 1 bids lower than the other prospective auditor 2, but may lose each auction to each firm's incumbent auditor. In the later case, she may lose both to the prospective auditor 2 and to the incumbents.

   Let us first consider a case when $b_1 \in [-\delta, (1 - 2A)\delta]$ and find an optimal b_1 in this range. The auditor 1 chooses b_1 to maximize

$$\begin{aligned} & \sum_{i=1,2} (b_{1,i} - u_1) \Pr(b_{1,i} < b_{2,i}, b_{1,i} < b_{o,i}) \\ & + Syn \Pr(b_{1,1} < b_{2,1}, b_{1,1} < b_{o,1}, b_{1,2} < b_{2,2}, b_{1,2} < b_{o,2}) \\ = & \sum_{i=1,2} (b_1 - u_1) \Pr(b_1 < b_{o,i}) + Syn \Pr(b_1 < b_{o,1}, b_1 < b_{o,2}) \\ = & \; 2(b_1 - u_1) \frac{\delta - b_1}{2\delta} + Syn \frac{(\delta - b_1)^2}{4\delta^2} \end{aligned}$$

   Taking the derivative with respect to b_1 and solving the first order condition gives

$$b_1 = \delta \left(1 - \frac{1 - u_1/\delta}{2 - Syn/(2\delta)}\right) \geq \delta \left(1 - \frac{1 + \delta/\delta}{2 - Syn/(2\delta)}\right) = \delta(1 - 3A/2)$$

   Given that A is positive, we have $b_1 > \delta(1 - 2A)$ which is not in the initially assumed range. Consequently, the optimal b_1 should be on the border of the range, i.e. $b_1 = \delta(1 - 2A)$.

Let us now consider a case when $b_1 \in [(1-2A)\delta, \delta]$ and find an optimal b_1 in this range. The auditor chooses b_1 to maximize

$$\begin{aligned} & \sum_{i=1,2} (b_{1,i} - u_1) \Pr(b_{1,i} < b_{2,i}, b_{1,i} < b_{o,i}) \\ & + Syn \Pr(b_{1,1} < b_{2,1}, b_{1,1} < b_{o,1}, b_{1,2} < b_{2,2}, b_{1,2} < b_{o,2}) \\ = & \sum_{i=1,2} (b_1 - u_1) \Pr(b_1 < b_{o,i}) \Pr(b_1 < b_{2,i}) \\ & + Syn \Pr(b_1 < b_{o,1}) \Pr(b_1 < b_{o,2}) \Pr(b_1 < \min\{b_{2,1}, b_{2,2}\}) \\ = & \; 2(b_1 - u_1) \frac{\delta - b_1}{2\delta} \frac{\delta - b_1}{2A\delta} + Syn \frac{(\delta - b_1)^2}{4\delta^2} \frac{\delta - b_1}{2A\delta} \end{aligned}$$

Taking the derivative with respect to b_1 and solving the first order condition gives

$$b_1 = \frac{1}{\frac{3}{2} - \frac{3Syn}{8\delta}} u_1 + \left(1 - \frac{1}{\frac{3}{2} - \frac{3Syn}{8\delta}}\right)\delta$$

Observe that this is the same as

$$b_1 = Au_1 + (1-A)\delta \,,$$

which finishes the proof. Interestingly, we didn't need to specify A to derive the expression for b_1. This guarantees that the equilibrium we derived is a unique symmetric linear equilibrium.

2. Let us now prove that for any strategy $b_{1,1} \neq b_{1,2}$ there is an optimal ϵ-deviation which increases the utility of the entrant auditor 1 so that $b_{1,1} \neq b_{1,2}$ cannot be an equilibrium. Assume without loss of generality that $b_{1,1} < b_{1,2}$. There are three possible cases: (a) $b_{1,1}, b_{1,2} \geq (1-2A)\delta$, (b) $b_{1,1}, b_{1,2} \leq (1-2A)\delta$, and (c) $b_{1,1} \leq (1-2A)\delta$, $b_{1,2} \geq (1-2A)\delta$.

   We only provide the proof for the case (a) but the deviations in other cases are similar. In this case the ex-ante utility of the auditor 1 is given by

$$\begin{aligned} U = & \sum_{i=1,2} (b_{1,i} - u_1) \Pr(b_{1,i} < b_{2,i}, b_{1,i} < b_{o,i}) \\ & + Syn \Pr(b_{1,1} < b_{2,1}, b_{1,1} < b_{o,1}, b_{1,2} < b_{2,2}, b_{1,2} < b_{o,2}) \\ = & \sum_{i=1,2} (b_1 - u_1) \Pr(b_{1,i} < b_{o,i}) \Pr(b_{1,i} < b_{2,i}) \\ & + Syn \Pr(b_1 < b_{o,1}) \Pr(b_1 < b_{o,2}) \Pr(b_{1,2} < \min\{b_{2,1}, b_{2,2}\}) \\ = & \sum_{i=1,2} (b_{1,i} - u_1) \frac{\delta - b_{1,i}}{2\delta} \frac{\delta - b_{1,i}}{2A\delta} + Syn \frac{(\delta - b_{1,1})(\delta - b_{1,2})}{4\delta^2} \frac{\delta - b_{1,2}}{2A\delta} \end{aligned}$$

Consider a small deviation to $\tilde{b}_{1,1} = b_{1,1} + \epsilon$ and $\tilde{b}_{1,2} = b_{1,2} + e$. The new utility is given by

$$\tilde{U} = \sum_{i=1,2} \left(\tilde{b}_{1,i} - u_1\right) \frac{\delta - \tilde{b}_{1,i}}{2\delta} \frac{\delta - \tilde{b}_{1,i}}{2A\delta} + Syn \frac{(\delta - \tilde{b}_{1,1})(\delta - \tilde{b}_{1,2})}{4\delta^2} \frac{\delta - \tilde{b}_{1,2}}{2A\delta}$$

After simplifying the difference (and taking into account that the deviation is small), we have that the change in the utility is given by

$$\begin{aligned}\tilde{U} - U \quad &= \quad \frac{1}{4\delta^2 A} \left[\epsilon \left(\delta - 3b_{1,1} + 2u_1\right) + e \left(\delta - 3b_{1,2} + 2u_1\right)\right. \\ &\quad \left. - \frac{Syn}{2\delta} \left(2\left(\delta - b_{1,2}\right)\left(\delta - b_{1,1}\right) e + \left(\delta - b_{1,2}\right)^2 \epsilon\right)\right]\end{aligned}$$

Consider two cases: (a) when $\delta - 3b_{1,1} + 2u_1 \leq 0$ and (b) when $\delta - 3b_{1,1} + 2u_1 > 0$.

In the case (a) we have that $\delta - 3b_{1,2} + 2u_1 < \delta - 3b_{1,1} + 2u_1 < 0$. Since $b_{1,i} < \delta$ and $b_{1,2} \leq \delta$, we have that any negative deviation with $\epsilon < 0$, $e < 0$ is profitable so that $\tilde{U} - U > 0$.

In the case (b) consider a deviation $e < 0$ and $\epsilon = -2e\frac{\delta - b_{1,1}}{\delta - b_{1,2}}$. At this deviation we have

$$\tilde{U} - U = \frac{-e\left[2\left(\delta - b_{1,1}\right)\left(\delta - 3b_{1,1} + 2u_1\right) - \left(\delta - 3b_{1,2} + 2u_1\right)\left(\delta - b_{1,2}\right)\right]}{4\delta^2 A\left(\delta - b_{1,2}\right)}$$

The expression in the numerator is always positive because $\delta - 3b_{1,1} + 2u_1 > 0$ and $\delta - 3b_{1,2} + 2u_1$ is either negative or positive but smaller than $\delta - 3b_{1,1} + 2u_1$.■

Proof of Lemma 7:

To find the ex-ante probability of having a specialist observe that this only happens if either of two prospective auditors wins both auctions. Since their bidding strategies are symmetric, a probability is twice bigger than a probability that a particular new prospective auditor (e.g. auditor 1) wins in both auctions. We have

$$\begin{aligned}
\Pr(sp) &= \Pr(\text{auditor 1 wins both auctions}) \\
&\quad + \Pr(\text{auditor 2 wins both auctions}) \\
&= 2\Pr(\text{auditor 1 wins both auctions}) \\
&= 2\Pr\left(\phi_{2,1} > \phi_{1,1}, \phi_{2,2} > \phi_{1,2}, \phi_{o,1} > \phi_{1,1}, \phi_{o,2} > \phi_{1,2}\right) \\
&= 2\Pr\left(u_2 > u_1, u_{o,1} > Au_1 + (1-A)\delta, u_{o,2} > Au_1 + (1-A)\delta\right) \\
&= 2\int_{-\delta}^{\delta} \frac{1}{2\delta}\left(\int_{u_1}^{\delta}\frac{du_2}{2\delta}\int_{Au_1+(1-A)\delta}^{\delta}\frac{du_{o,1}}{2\delta}\int_{Au_1+(1-A)\delta}^{\delta}\frac{du_{o,2}}{2\delta}\right)du_1 \\
&= 2\int_{-\delta}^{\delta}\frac{1}{2\delta}\frac{\delta-u_1}{2\delta}\frac{A(\delta-u_1)}{2\delta}\frac{A(\delta-u_1)}{2\delta}du_1 \\
&= \frac{2A^2}{(2\delta)^4}\int_{-\delta}^{\delta}(\delta-u_1)^3 du_1 = \frac{A^2}{2}. \blacksquare
\end{aligned}$$

Proof of Corollary 1: The result follows directly from combining the result of Lemma 2 and Lemma 7. ■

Proof of Corollary 2: The result follows directly from combining the result of Lemma 3 and Lemma 7. ■

Proof of Lemma 8: The auction for audit of firm i is won by the participant who offers the lowest fee. The fee that the firm i pays is

$$\begin{aligned}
\phi_i &= \min\left\{\phi_{o,1},\ \phi_{1,i},\ \phi_{2,i}\right\} \\
&= \min\left\{E\left[C_i^g\right] + u_i^o,\ E[C_i^g] + Au_1 + (1-A)\delta,\ E[C_i^g] + Au_2 + (1-A)\delta\right\} \\
&= E\left[C_i^g\right] + \min\left\{u_i^o,\ Au_1 + (1-A)\delta,\ Au_2 + (1-A)\delta\right\} \\
&= E\left[C_i^g\right] + \min\left\{u_i^o,\ Au_1 + (1-A)\delta,\ Au_2 + (1-A)\delta\right\}\ .
\end{aligned}$$

Denote $Z = \min\{u_i^o,\ Au_1 + (1-A)\delta,\ Au_2 + (1-A)\delta\}$. Observe that $Z = u_i^o$ conditional on $u_i^o \leq (1-2A)\delta$. Moreover, conditional on $u_i^o > (1-2A)\delta$, u_i^o is distributed uniformly on $[(1-2A)\delta,\ \delta]$. We use this to compute the expected fee ϕ_i as

$$\begin{aligned}
E[\phi_i] &= E\left[C_i^g\right] + E[Z] \\
&= E\left[C_i^g\right] + \Pr\left(u_i^o \leq (1-2A)\delta\right) E\left[Z|u_i^o \leq (1-2A)\delta\right] \\
&\quad + \Pr\left(u_i^o > (1-2A)\delta\right) E\left[Z|u_i^o > (1-2A)\delta\right] \\
&= E\left[C_i^g\right] + \Pr\left(u_i^o \leq (1-2A)\delta\right) E\left[u_i^o|u_i^o \leq (1-2A)\delta\right] \\
&\quad + \Pr\left(u_i^o > (1-2A)\delta\right) E\left[\min\left\{z_1,\ z_2,\ z_3\right\}\right]\ ,
\end{aligned}$$

where $z_1,\ z_2$ and z_3 are independent random variables uniformly distributed on $[(1-2A)\delta,\ \delta]$. We further simplify the expression for expected audit fees and obtain

$$\begin{aligned} E[\phi_i] &= E\left[C_i^g\right] + \frac{((1-2A)\delta-(-\delta))}{2\delta}\frac{((1-2A)\delta+(-\delta))}{2} \\ &\quad + \frac{\delta-(1-2A)\delta}{2\delta}E\left[\min\left\{z_1,\ z_2,\ z_3\right\}\right] \\ &= E\left[C_i^g\right] + (1-A)(-A\delta) + AE\left[\min\left\{z_1,\ z_2,\ z_3\right\}\right] \end{aligned}$$

Now, we compute $E\left[\min\left\{z_1,\ z_2,\ z_3\right\}\right]$. Define a random variable $y = \min\left\{z_1,\ z_2,\ z_3\right\}$. We have

$$\begin{aligned} \Pr(y<Y) &= 1-\Pr(y\geq Y) = 1-\Pr\left(\min\left\{z_1,\ z_2,\ z_3\right\}\geq Y\right) \\ &= 1-\Pr\left(z_1\geq Y, z_2\geq Y, z_3\geq Y\right) \\ &= 1-\Pr\left(z_1\geq Y\right)\Pr\left(z_2\geq Y\right)\Pr\left(z_3\geq Y\right) \\ &= 1-\left(\frac{\delta-Y}{2A\delta}\right)^3, \end{aligned}$$

so the distribution density of y is

$$f_y(Y) = \frac{\partial\Pr(y<Y)}{\partial Y} = 3\frac{(\delta-Y)^2}{(2A\delta)^3}$$

and

$$E\left[\min\left\{z_1,\ z_2,\ z_3\right\}\right] = E[y] = \int_{(1-2A)\delta}^{\delta} Y f_y(Y)dY = \delta\left(1-\frac{3A}{2}\right).$$

Substituting the result into $E[\phi_i]$, we have

$$\begin{aligned} E[\phi_i] &= E\left[C_i^g\right] + (1-A)(-A\delta) + A\delta\left(1-\frac{3A}{2}\right) \\ &= E\left[C_i^g\right] - \frac{A^2\delta}{2}. \blacksquare \end{aligned}$$

Proof of Lemma 9: The proof is similar to the proof of Lemma 6, Lemma 7 and Lemma 8, the difference being that there is only one prospective auditor in the market.■

Proof of Lemma 10: Observe that the firms are by assumption identical ex ante ($L_i = L$), so the optimal standard is the same for both firms. In the benchmark case there are no specialist's synergies $Syn = 0$, and $\tau^* = \tau_{opt}^B$ maximizes the ex-ante firm's value F_i:

$$\begin{aligned} F_i &= \frac{1}{2L_i}\left(Var\left[\mu_i\right] - Var\left[\mu_i | R_1^g, R_2^g\right]\right) - E[C_i^g] + A^2\delta/2 \\ &= \frac{1}{2L_i}\left(Var\left[\mu_i\right] - Var\left[\mu_i | R_1^g, R_2^g\right]\right) - E[C_i^g] + 2\delta/9 \\ &= \frac{1}{2L_i}\left(\frac{1}{\tau^0} - \frac{1}{\tau^* + \tau^0 \frac{1}{1-\rho^2\frac{\tau^*}{\tau^0+\tau^*}}}\right) - \left(\frac{1}{\tau^*+\tau^0} + c\tau^*\right) + 2\delta/9 \end{aligned}$$

This is a concave problem (the second order condition with respect to τ^* is negative). Moreover, F_i increases in τ^* at $\tau^* = 0$, and $F_i \to -\infty$ when $\tau^* \to +\infty$, so there exists a single finite $\tau^* = \tau_{opt}^B$ which maximizes the F_i; $\tau^* = \tau_{opt}^B$ solves

$$\left(-\frac{1}{2L_i}\frac{\partial Var\left[\mu_i | R_1^g, R_2^g\right]}{\partial \tau^*} - \frac{\partial E[C_i^g]}{\partial \tau^*}\right)\Bigg|_{\tau^*=\tau_{opt}^B} = 0\,. \tag{10}$$

Now, let us consider a setup where there are synergies of being a specialist. Similarly, there exists a finite $\tau^* = \tau_{opt}$ that solves

$$\left(-\frac{1}{2L_i}\frac{\partial Var\left[\mu_i | R_1^g, R_2^g\right]}{\partial \tau^*} - \frac{\partial E[C_i^g]}{\partial \tau^*} + A\delta\frac{\partial A}{\partial Syn}\frac{\partial Syn}{\partial \tau^*}\right)\Bigg|_{\tau^*=\tau_{opt}} = 0\,.$$

Given the local concavity of the program, we have

$$\begin{aligned} \tau_{opt} < \tau_{opt}^B \quad &\Longleftrightarrow \quad \left(-\frac{1}{2L_i}\frac{\partial Var\left[\mu_i | R_1^g, R_2^g\right]}{\partial \tau^*} - \frac{\partial E[C_i^g]}{\partial \tau^*} + A\delta\frac{\partial A}{\partial Syn}\frac{\partial Syn}{\partial \tau^*}\right)\Bigg|_{\tau^*=\tau_{opt}^B} < 0 \\ &\Longleftrightarrow \quad \left(A\delta\frac{\partial A}{\partial Syn}\frac{\partial Syn}{\partial \tau^*}\right)\Bigg|_{\tau^*=\tau_{opt}^B} < 0 \\ &\Longleftrightarrow \quad \frac{\partial Syn}{\partial \tau^*}\Bigg|_{\tau^*=\tau_{opt}^B} < 0\,, \end{aligned}$$

where the last equality holds because $\frac{\partial A}{\partial Syn} > 0$. Indeed, the optimal standard τ_{opt} is lower as compared to the benchmark τ_{opt}^B when the synergies are locally decreasing in the standard, so it is worth decreasing it to stimulate specialization. We substitute the definition of synergy and the definition of τ^B_{opt} from (10) to have

$$\begin{aligned}
\tau_{opt} < \tau^B_{opt} \quad &\Longleftrightarrow \quad \left.\frac{\partial Syn}{\partial \tau^*}\right|_{\tau^*=\tau^B_{opt}} < 0 \\
&\Longleftrightarrow \quad \left.\left(2\frac{\partial E[C^g_i]}{\partial \tau^*} - 2\frac{\partial Var\left[\mu_i|R^g_1, R^g_2\right]}{\partial \tau^*} - 2c\right)\right|_{\tau^*=\tau^B_{opt}} < 0 \\
&\Longleftrightarrow \quad (1+2L)\left.\frac{\partial E[C^g_i]}{\partial \tau^*}\right|_{\tau^*=\tau^B_{opt}} - c < 0 \\
&\Longleftrightarrow \quad (1+2L)\left.\frac{\partial\left(1/(\tau^0+\tau^*)+c\tau^*\right)}{\partial \tau^*}\right|_{\tau^*=\tau^B_{opt}} - c < 0 \\
&\Longleftrightarrow \quad (1+2L)\left.\frac{\partial\left(1/(\tau^0+\tau^*)+c\tau^*\right)}{\partial \tau^*}\right|_{\tau^*=\tau^B_{opt}} - c < 0 \\
&\Longleftrightarrow \quad \tau^B_{opt} < \sqrt{\frac{1/(2L)+1}{c}} - \tau^0 \; .
\end{aligned}$$

Let us denote $W = \sqrt{\frac{1/(2L)+1}{c}}$. We have that

$$\tau_{opt} < \tau^B_{opt} \quad \Longleftrightarrow \quad \tau^B_{opt} < W - \tau^0 \; ,$$

if $W < \tau^0$, then this does not hold and, consequently, $\tau_{opt} > \tau^B_{opt}$.

Let us now consider $W \geq \tau^0$. Given the convexity of the program (10) defining τ^B_{opt}, we have that

$$\begin{aligned}
\tau^B_{opt} < W - \tau^0 \quad &\Longleftrightarrow \quad \left.\left(-\frac{1}{2L}\frac{\partial Var\left[\mu_i|R^g_1, R^g_2\right]}{\partial \tau^*} - \frac{\partial E[C^g_i]}{\partial \tau^*}\right)\right|_{\tau^*=W-\tau^0} < 0 \\
&\Longleftrightarrow \quad -\left.\frac{\partial Var\left[\mu_i|R^g_1, R^g_2\right]}{\partial \tau^*}\right|_{\tau^*=W-\tau^0} - 1/W^2 < 0 \\
&\Longleftrightarrow \quad -\rho^2(\tau^0-2W)(\tau^0-W)^2 + (3\tau^0-2W)W^2 < 0 \, .
\end{aligned}$$

For small W such that $\tau^0 \leq W < 3/2\tau^0$, both parts of the last expression are positive, so $\tau_{opt} > \tau^B_{opt}$. For large W such that $W > \tau^0(1+\sqrt{2}/2)$, the second part becomes negative and so large that the sum is negative for all $\rho \in [-1, 1]$, so $\tau_{opt} < \tau^B_{opt}$. For intermediate W such that $3/2\tau^0 \leq W \leq \tau^0(1+\sqrt{2}/2)$, the first part is positive and the second one is negative. The overall sum is positive (and, consequently, $\tau_{opt} > \tau^B_{opt}$) as long as the first part is bigger, i.e. $|\rho| > |\rho|^*$, where

$$|\rho|^* = \frac{W}{\tau^0 - W}\sqrt{\frac{3\tau^0-2W}{\tau^0-2W}} \, .$$

It is left to see that given $W = \sqrt{\frac{1/(2L)+1}{c}}$, the conditions are rewritten as follows:

$$
\begin{aligned}
W < 3/2\tau^0 &\iff \sqrt{c}\tau^0 > \frac{2}{3}\sqrt{1+1/(2L)}\,, \\
3/2\tau^0 \leq W \leq \tau^0(1+\sqrt{2}/2) &\iff \frac{2}{3}\sqrt{1+1/(2L)} \geq \sqrt{c}\tau^0 \geq \frac{\sqrt{2}}{1+\sqrt{2}}\sqrt{1+1/(2L)}\,, \\
W > \tau^0(1+\sqrt{2}/2) &\iff \sqrt{c}\tau^0 < \frac{\sqrt{2}}{1+\sqrt{2}}\sqrt{1+1/(2L)}\,.
\end{aligned}
$$

In the first case, $\tau_{opt} > \tau_{opt}^B$; in the second case, $\tau_{opt} > \tau_{opt}^B$ if and only if $|\rho| > |\rho|^*$; in the third case $\tau_{opt} < \tau_{opt}^B$. ■

Proof of Lemma 11:

- Let us first consider the case when a specialist chooses a higher precision than a generalist without regulation, i.e. $\tau^s > \tau^g$.

  For low standards $\tau^* < \tau^g$, both a specialist and a generalist choose higher effort on their own, so their expected costs of audit do not change in τ^* and neither does the synergy of being a specialist.

  For intermediate standards $\tau^g < \tau^* < \tau^s$, a specialist still chooses a higher effort τ^s on her own, but a generalist has to increase the effort to τ^* to comply with the standard. Since the effort is suboptimal from the point of view of the generalist, her expected cost increases, while the expected cost of the specialist remains the same. Consequently, the synergy of being a specialist increases.

  For high standards, $\tau^* > \tau^s$, both a specialist and a generalist have to increase their effort to τ^* to comply with the standard. This is equivalent to the case of a rigid standard described in Lemma 3. We showed there that the synergy either decreases or has an inverse U-shape with respect to τ^*.

  Summarizing the findings, the synergy is constant for $\tau^* < \tau^g$ and is hump-shaped for $\tau^* > \tau^g$.

- Let us now consider the case when a generalist chooses a higher precision than a specialist without regulation, i.e. $\tau^g > \tau^s$.

  For low standards $\tau^* < \tau^s$, both a specialist and a generalist choose higher effort on their own, so their expected costs of audit do not change in τ^* and neither does the synergy of being a specialist.

For intermediate standards $\tau^s < \tau^* < \tau^g$, a generalist still chooses a higher effort τ^g on her own, but a specialist has to increase the effort to τ^* to comply with the standard. Since the effort is suboptimal from the point of view of the specialist, her expected cost increases, while the expected cost of the generalist remains the same. Consequently, the synergy of being a specialist decreases.

For high standards, $\tau^* > \tau^g$, both a specialist and a generalist have to increase their effort to τ^* to comply with the standard. This is equivalent to the case of a rigid standard described in Lemma 3. We showed there that the synergy either decreases or has an inverse U-shape with respect to τ^*. Let us further prove that only the first case is possible here, that is the synergy of being a specialist decreases for $\tau^* > \tau^g$.

In order to prove that, it is enough to show that the synergy of being a specialist when the standard binds both for a specialist and a generalist decreases at $\tau^* = \tau^g$. In the proof of Lemma 11, we show that the synergy of being a specialist when the standard binds both for a specialist and a generalist decreases in the standard τ^* if and only if

$$\rho^2 \left(\left(\tau^0\right)^3 - (3-\rho^2)\tau^0 \left(\tau^*\right)^2 - 2(1-\rho^2) \left(\tau^*\right)^3 \right) < 0$$

Substituting $\tau^* = \tau^g = \frac{1}{\sqrt{c}} - \tau^0$, we obtain

$$\begin{aligned} & \rho^2 \left(\left(\tau^0\right)^3 - (3-\rho^2)\tau^0 \left(\tau^*\right)^2 - 2(1-\rho^2) \left(\tau^*\right)^3 \right) \\ = \; & \frac{-\rho^2}{c\sqrt{c}} \left(2 - 3\sqrt{c}\tau^0 - \rho^2 \left(2 - \sqrt{c}\tau^0\right) \left(1 - \sqrt{c}\tau^0\right)^2 \right) \end{aligned}$$

Now compare this to the inequality (9) in the proof of Lemma 1: we have that

$$2 - 3\sqrt{c}\tau^0 - \rho^2 \left(2 - \sqrt{c}\tau^0\right) \left(1 - \sqrt{c}\tau^0\right)^2 > 0$$

if and only if $\tau^s < \tau^g$. Since we have that $\tau^s < \tau^g$, then necessarily

$$\rho^2 \left(\left(\tau^0\right)^3 - (3-\rho^2)\tau^0 \left(\tau^g\right)^2 - 2(1-\rho^2) \left(\tau^g\right)^3 \right) < 0\,.$$

Summarizing the findings, the synergy is constant for $\tau^* < \tau^s$, and decreases for $\tau^s < \tau^*$.■

Proof of Lemma 12: The proof follows from combining the proof of Lemma 4 and Lemma 5.■

Proof of Corollary 3: The result follows directly from combining the result of Lemma 11 and Lemma 7. ■

Proof of Lemma 13:

First, let us show that the optimal minimum standard in the benchmark τ_{opt}^{B} is always larger than the endogenously chosen standard τ^{g}. In the benchmark case there are no specialist's synergies $Syn = 0$, and the ex ante firm i's value is

$$F_i = \frac{1}{2L_i}\left(Var\left[\mu_i\right] - Var\left[\mu_i | R_1^g, R_2^g\right]\right) - E[C_i^g] + A^2\delta/2\,.$$

Observe that choosing τ^* below τ^g won't essentially change the auditor's behavior, so we only consider $\tau^* > \tau^g$. As we showed in Lemma 10, the optimal audit standard solves the first order condition (10), which is a concave problem. At $\tau^* = \tau_g$, we have that

$$\left(-\frac{1}{2L_i}\frac{\partial Var\left[\mu_i | R_1^g, R_2^g\right]}{\partial \tau^*} - \frac{\partial E[C_i^g]}{\partial \tau^*}\right)\Bigg|_{\tau^*=\tau^g} = -\frac{1}{2L_i}\frac{\partial Var\left[\mu_i | R_1^g, R_2^g\right]}{\partial \tau^*}\Bigg|_{\tau^*=\tau^g} > 0\,,$$

so it follows that the optimal minimum standard in the benchmark is always above the endogenous choice of a generalist: $\tau_{opt}^{B} > \tau^{g}$.

Now observe that for small correlations, τ^s is close to τ^g and the optimal solution of a regulator who internalizes the effect of specialist's synergies is close to the optimal minimum standard in the benchmark. Consequently, the standard also binds and the results of the Lemma 13 hold for a minimum standard as well. ■

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