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Corporate Tax Planning and Enforcement *

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Abstract

This study investigates how strategic interactions between corporate tax planning and tax enforcement are affected by two policy instruments: strengthening tax enforcement by increasing the number of specialized enforcement staff and improving tax audit technologies. I employ an economic model with a board of director's investment in a Tax Control Framework (TCF) and a tax manager's tax planning effort jointly shaping corporate tax planning and a tax auditor's technology-based audit decision. I show that the board only invests in the TCF when the enforcement environment is sufficiently strict, because it trades-off the costs and benefits of tax planning. Since strengthening tax enforcement decreases tax planning effort, the result can be less investment in a TCF in a strict enforcement environment, implying that TCF investment and enforcement can be strategic substitutes. Strikingly, I identify conditions under which improvements in tax audit technology increase corporate tax planning and impair tax audit efficiency, due to a crowding out of audit incentives. This result contradicts the view that improving audit technologies is universally effective, particularly in tax authorities with adequate staffing.

Keywords: tax control framework, tax planning, tax risk management, tax audit technology, tax enforcement
JEL classification: H26, H32, M42, M48, C70

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1 Introduction

Numerous empirical studies show that firms engage in tax planning to decrease their tax liabilities (Hanlon and Heitzman 2010, Wilde and Wilson 2018). Tax planning encompasses a continuum of strategies, ranging from risk-free tax-favored real activities to risky tax maneuvers (Hanlon and Heitzman 2010, Blouin 2014). Risky tax planning strategies can result in significant lost tax revenues for countries (Heckemeyer and Overesch 2017, Riedel 2018), and thus policymakers worldwide are seeking to improve tax enforcement by targeting these risky strategies (Slemrod 2019). For example, the Inflation Reduction Act of 2022 has allocated about \$80 billion to the U.S. Internal Revenue Service to facilitate improved enforcement (Mehboob 2022, Picchi 2024). However, recent budget cuts have renewed concerns about the agency's and its auditors' enforcement abilities (Sholli 2025).

Given the limited resources and national instruments available, two primary instruments are typically employed to improve tax enforcement. First, data-driven tax audit technologies provide tax auditors with additional information to assess firms' (risky) tax positions and tax planning strategies (Eberhartinger et al. 2022, OECD 2023).[1] Second, a higher number of enforcement staff in an agency strengthens tax enforcement (Nessa et al. 2020, De Simone et al. 2023), as it ceteris paribus increases an individual auditor's audit capacities. While there is a common understanding *that* these instruments change external tax enforcement by auditors, it is less recognized that they also impact firms' internal tax enforcement through investment in their Tax Control Framework (TCF).[2] In addition, it is unclear *how* these instruments differentially affect external and internal tax enforcement.

[1] Eberhartinger et al. (2022) report that about 90% of the tax authorities in their sample used risk profiling for tax audit case selection in 2017, which may be one component of a tax audit technology. Countries using risk-profiling include Austria, Spain, and the United States, with notable exceptions being China, Germany, and Japan. The interviewed corporate tax specialists in KPMG (2023) respond that 83% of their jurisdictions' tax authorities use technology and data to risk assess taxpayers or issues.

[2] A TCF can be defined as the "entirety of corporate practices implemented by a firm to identify, evaluate, manage, mitigate, monitor, and control corporate tax risk and to establish a beneficial internal information environment" (Brühne and Schanz 2022, p. 35). The terms "TCF" (OECD 2016, Blaufus et al. 2023, Siglé et al. 2025), "Tax Compliance Management System" (Blaufus and Trenn 2018, Schulz and Sureth-Sloane 2024), and "tax risk management" (Wunder 2009, Brühne and Schanz 2022) are used interchangeably in the literature.

I employ an economic model to investigate how corporate tax planning, which is the outcome of investments in a TCF and tax planning effort, and the audit strategy of a tax auditor are affected by two key policy instruments: the strengthening of tax enforcement and the improvement of the quality of tax audit technology. In subsequent analyses, I study how the two policy instruments affect tax audit efficiency.

The study is timely as firms increasingly implement TCFs to manage tax planning risks and unexpected enforcement outcomes (Brühne and Schanz 2022, Blaufus et al. 2023, Siglé et al. 2025). One key practice, as part of a TCF, is the implementation of a tax risk reporting line from the tax department to the board of directors, through which the board shapes its desired level of risky tax planning (Brühne and Schanz 2022, Blaufus et al. 2023). Aside from best practices on how to establish a TCF (OECD 2016, EY 2023), investments in a TCF are voluntary and vary across firms (Blaufus et al. 2023), which comports with the reality of varying firm-level costs of tax planning (Graham et al. 2014, Klassen et al. 2017, Wilde and Wilson 2018). Thus, explicitly considering the TCF's risk management function allows for a deeper understanding of heterogeneous corporate tax planning outcomes and the efficacy of tax policy instruments.[3]

My model incorporates these features. It involves three strategic players: a board of directors (it), a tax manager (he), and a tax auditor (she). The board can either invest in TCF quality upfront to manage its tax risk exposure from risky tax planning or choose a minimum TCF quality to facilitate risky tax planning. Risky tax planning is conducted by a privately informed tax manager, who aims to decrease the reported tax. He can exert effort to implement a risky tax planning strategy, where a higher quality TCF makes implementation more difficult. The

[3]Second-order functions of a TCF, such as improving tax information *for* tax planning, are only captured to the extent that a minimum TCF investment facilitates this planning. While theoretical studies neglect the role TCF investments have on corporate tax planning and enforcement, empirical studies on this interaction do not provide a clear picture. Siglé et al. (2025) find that higher TCF quality generally increases compliance but can increase intentional noncompliance (i.e., risky tax planning) in firms with an aggressive tax strategy and a low-quality TCF. Gallemore and Labro (2015) indicate that higher TCF quality could increase tax planning, as it likely relates to an improved internal information environment. Armstrong et al. (2015) indicate that a higher TCF quality as an instrument for effective governance might induce tax planning toward an optimum. These studies view the TCF as a determinant of tax planning. Blaufus et al. (2023) highlight that the TCF quality depends on the perceived tax audit environment and find that perceived audit aggressiveness is positively associated with the quality of TCFs but is not associated with devoted tax planning resources.

tax auditor observes the tax report and an additional, noisy signal from the tax audit technology. The signal indicates whether a risky tax planning strategy was implemented and thus whether an in-depth audit is promising. An in-depth audit is costly for the tax auditor, but perfectly reveals whether a risky tax planning strategy was implemented.[4]

In the model, the main factor that determines the strength of tax enforcement is the tax auditor's opportunity cost of auditing. For example, this audit cost can change when the number or expertise of tax auditors in a tax authority (Nessa et al. 2020, Laudage Teles 2023, Siglé et al. 2024, Kobilov 2025) or the burden of proof in tax enforcement changes (Rhoades 1997, LeBlanc 1998). The decisive driver of the quality of the tax audit technology is the sophistication of the IT tools and predictive models that condense corporate information from a variety of sources into a "red flag" or "green flag" (Eberhartinger et al. 2022, OECD 2023). These information sources can include information exchange agreements among tax authorities (Casi et al. 2020), private country-by-country reports (Joshi 2020, Martini et al. 2025), or financial statement information (Mills et al. 2010, Bozanic et al. 2017, Fox and Wilson 2023). While strengthening tax enforcement reduces audit costs, enhanced audit technologies provide better information to identify risky tax strategies but nevertheless require a tax auditor's personal judgment in an in-depth audit. Thus, while independent ex ante, the impact of these instruments on tax audit efficiency become interlinked when considering strategic audit decisions.[5]

I show that a strict tax enforcement environment is necessary to elicit the board's TCF investment above a minimum quality. Intuitively, the board considers the firm's costs and benefits of tax planning. Only in a strict enforcement environment are the expected costs of risky tax planning extensive, incentivizing the board to restrict a tax manager's planning effort through the TCF. In a lenient environment, the board facilitates risky tax planning through

[4] I focus on large firms that implement risky tax planning strategies and invest in TCFs. In contrast to small firms that are often randomly audited (Belnap, Hoopes, Maydew, and Turk 2024), these are permanently audited. Thus, in this paper, the tax auditor's audit decision always refers to an in-depth audit decision of a tax position.

[5] I acknowledge that some tax audit technologies aim at improving audit processes of routine tax positions. However, I exclusively focus on the increasingly prevalent technologies that provide additional information to identify non-routine, risky positions and strategies. More broadly, the model relates to the interplay between human judgment and technology, for example, in the financial auditing domain (Samiolo et al. 2024).

minimum TCF quality. The enforcement environment determines the tax manager's and tax auditor's trade-offs. In a lenient one, the effects of the TCF on the tax planning effort and audit decision are muted, while in a strict one, the TCF additionally shapes both tax planning effort and the audit decision.

I find that strengthening tax enforcement incentivizes the tax auditor to audit more often. The reason is that she audits only if the evidence from the tax audit technology is sufficiently favorable, and strengthening tax enforcement decreases her required evidence to audit. This creates an enforcement effect on tax planning, which deters the tax manager's planning effort. In a strict enforcement environment, the audit probability becomes high enough to elicit the board's TCF investment. Then, strengthening tax enforcement further increases the audit probability and investment incentives (external incentive effect), while the decreasing tax planning effort decreases investment incentives (internal incentive effect). Which of the effects dominates depends on how much the enforcement effect deters the tax manager's planning. Notably, I find that, when the internal incentive effect is strong and the strength of tax enforcement is high, strengthening tax enforcement decreases TCF investment. This finding highlights that internal and external tax enforcement can be strategic substitutes.

Next, I show that the impact of improving the tax audit technology is interlinked with the strength of tax enforcement. The key reason is that this improvement affects the tax auditor's relative importance of type I errors (auditing when no risky tax planning strategy is implemented) and type II errors (failing to audit a risky tax planning strategy). In particular, when the strength of tax enforcement is lower, the improvement increases audit incentives. However, when the strength of tax enforcement is higher, the improvement crowds out audit incentives. In equilibrium, the tax manager rationally infers the impact on the audit incentives, and he decreases (increases) tax planning effort if the strength of tax enforcement is sufficiently low (high). This result is striking on three dimensions. First, audit technology improvement would unambiguously deter tax planning effort if the auditor was nonstrategic. Second, the implications of technology improvement for tax planning effort and audit strategy are generally robust to changes in the enforcement environment. Third, the impact of technology improvement on tax planning effort determines the impact on overall corporate tax planning, even when TCF investment and tax planning effort produce opposing effects. Interestingly, an increase in tax planning as a response to technology improvement is more likely for tax aggressive firms, suggesting heterogeneous tax planning responses across firms.

In additional analyses, I study how strengthening tax enforcement and improving the audit technology affect tax audit efficiency. Like Blaufus et al. (2024), I use two equilibrium measures for tax audit efficiency: the audit probability of a risky tax planning strategy and the probability of lost tax revenues. Across both, my results suggest that strengthening tax enforcement increases tax audit efficiency. By contrast, I show that improving audit technologies impairs tax audit efficiency when the strength of tax enforcement is sufficiently high. These results imply that improving tax audit technologies cannot always serve as a substitute for strengthening tax enforcement. While conventional wisdom would suggest that improving technologies must be complemented by sufficient capacities for enforcement staff, I identify a potential downside of this complementarity: a crowding out of audit incentives. This surprising result underscores the importance of considering strategic tax auditors when evaluating policy instruments.

I contribute to the literature in three ways. First, I contribute to the literature on strategic tax audits that examines different determinants and outcomes of tax audits both for individual (e.g., Graetz et al. 1986, Beck and Jung 1989, Sansing 1993) and corporate taxpayers (e.g., Mills et al. 2010, De Simone et al. 2013, Blaufus et al. 2024, Diller et al. 2025). One of the studies most closely related to mine is Sansing (1993). He examines how additional information from a tax audit technology affects individual taxpayer audits and identifies the optimal quality of the audit technology. While I model the audit technology similarly, my study differs because it explicitly considers how TCF investments and tax planning efforts endogenously arise in a corporate taxpayer context.

Second, I contribute to the literature on financial misreporting, which is influenced by, among other things, board oversight (e.g., Laux 2010) and interactions of regulatory enforcement with internal controls (e.g., Schantl and Wagenhofer 2021) or with strategic auditors (e.g., Shibano 1990, Pae and Yoo 2001). While tax planning efforts (TCF investments) relate to financial misreporting (investments in internal controls), the tax setting differs in two important ways. First, the board might want to facilitate risky tax planning through a minimum TCF investment, as tax planning may increase firm value. Thus, unlike investments in internal controls (e.g., Schantl and Wagenhofer 2025), the board's TCF investment only occurs when the enforcement environment is sufficiently strict.[6] Second, I consider a strategic tax auditor, which allows me to additionally study the impact of tax audit technologies as a distinct enforcement instrument.[7] I thus add to Ewert and Wagenhofer (2019) by providing a deeper understanding of the differential effects of (tax) enforcement instruments.

Third, I contribute to examining the black box of tax planning. I respond to the call of Dyreng and Maydew (2018) and show that corporate tax planning is influenced by a tax manager's planning effort and the board's investment in the TCF. This view of corporate tax planning is consistent with studies that highlight tax managers' crucial role in tax planning (Armstrong et al. 2012, Feller and Schanz 2017, Barrios and Gallemore 2023, Belnap, Hoopes, and Wilde 2024, Li and Okafor 2024) and the board's role in tax risk management (Donohoe et al. 2014, Armstrong et al. 2015, Beasley et al. 2021, Brühne and Schanz 2022, Blaufus et al. 2023). Providing a unifying theory that considers all dimensions of tax planning costs as conceptualized by Wilde and Wilson (2018), I show that corporate tax planning is a consequence of tax enforcement and its distinct instruments (Hoopes et al. 2012, Ayers et al. 2019, Nessa et al. 2020, Eberhartinger et al. 2022, Reineke et al. 2023a, De Simone et al. 2023).

[6] Formally, the internal control literature focuses on interior quality levels (see also Pae and Yoo 2001, Patterson and Smith 2007 and Gao and Zhang 2019). A notable exception is Schantl and Wagenhofer (2021), where a manager's investment in internal controls can involve a minimum quality, depending on regulatory standards. Unlike their paper, I focus on strategic tax enforcement and its role for voluntary TCF investment.

[7] In most studies analyzing financial misreporting, enforcement is a random technology (Laux and Stocken 2018, Ewert and Wagenhofer 2019, Schantl and Wagenhofer 2025), with Schantl and Wagenhofer (2020) being a notable exception studying a strategic regulatory enforcer.

2 Model

2.1 Model setup

I employ an economic model with a board of directors (it), a tax manager (he), and a strategic tax auditor (she), all of whom are risk neutral. The board oversees and manages the firm's overall activities. I focus on its role in overseeing and managing the tax manager's tax planning and reporting. The firm consists of a deterministic after-tax income $\mu > 0$ from other economic activities and a representative uncertain tax position, resulting in a low or high tax liability $T \in \{T_L = 0, T_H\}$ with equal prior probability $\Pr(0) = \Pr(T_H) = 1/2$, and $T_H > 0$.[8] Like in Sansing (1993) and McClure (2023), the joint distribution of μ and T is assumed to be arbitrary.

An "uncertain tax position" refers to a tax position whose assessment is subject to interpretation, where it is unclear from observing this position in the tax return how it should be assessed (De Simone et al. 2013). The tax liability T would reflect the auditor's assessment after an in-depth audit, which I refer to as the benchmark tax (similarly, see Martini et al. 2025). The benchmark tax differs from the true tax, which would be ultimately identified through adjudication, and captures that there is a wide range of legal tax liabilities.[9] Typical examples include uncertainty about whether an expense qualifies for a tax credit or the deductibility of a tax expense (Sansing 1993, Mills et al. 2010, De Waegenaere et al. 2015) and which transfer pricing methods should be applied in an income shifting context, resulting in two point estimates (Reineke et al. 2023b). For expositional convenience, I only focus on the tax consequences of the uncertain tax position reflected in T.[10]

[8] Considering a representative uncertain tax position is for ease of exposition. Typically, there are several tax positions that must be filed via the tax return (Rhoades 1999, De Simone et al. 2013, McClure 2023). An alternative interpretation would be that the firm possesses strong facts $T_L = 0$ (a risk-free tax planning opportunity) or weak facts T_H (a risky tax planning opportunity) when claiming the uncertain tax position.

[9] The setting includes aggressive tax planning but excludes tax evasion. In addition, to avoid an overly complex model, I assume that the tax manager does not challenge a tax auditor's audit adjustment to the benchmark tax if a risky tax planning strategy has been implemented. Analyses of an additional dispute stage can be found, for example, in Jung (1995), Martini et al. (2025) and Dyck et al. (2025).

[10] Other studies explicitly consider how pre-tax income or earnings are generated, either before or simultaneously with the tax planning decision. In Jacob et al. (2019), pre-tax earnings are the uncertain realization of a productive effort by the CEO, while in Reineke et al. (2023a), pre-tax income is the realization of a risky

Tax planning and investment in a TCF. At time $t = 2$, the tax manager receives a private signal $\tau \in \{\tau_L = 0, \tau_H\}$ about the benchmark tax. For simplicity, the signal is assumed to be perfect (i.e., $\tau = T$). The tax manager must file a tax return, in which he reports the tax $r \in \{r_L = 0, r_H\}$ to the tax auditor. If $\tau = 0$, the tax manager can be sure that a report $r_L = 0$ will be accepted by the auditor. Thus, he reports $r_L = 0$ at time $t = 3$, with the associated cost being normalized to zero. However, if $\tau = \tau_H$, the tax manager may choose an unobservable tax planning effort $a \in (0,1)$, which increases the probability that a risky tax planning strategy is implemented.[11] This implementation involves a tax report $r_L = 0 < \tau_H$, in which case the tax manager obtains a utility benefit normalized to 1. The tax planning effort is privately costly to the tax manager and involves tax planning costs $a^2/2$. These tax planning implementation costs include, for example, preparing documentation and convincing the board or other tax compliance employees (Feller and Schanz 2017, Wilde and Wilson 2018, Reineke et al. 2023a) but not personal costs from an uncovered risky tax planning strategy, which are considered below.

Reasons for the tax manager's objective may include a (personal) preference for meeting a targeted low effective tax rate (Armstrong et al. 2012), the tax department being structured as a profit center (Robinson et al. 2010), or reputational concerns arising from the labor market (Li and Okafor 2024). I treat the tax manager's objective as given and focus on the board's TCF investment to manage tax risks on behalf of the firm.[12] This comports with studies highlighting

investment. With respect to these studies, my setting more adequately reflects scenarios where the generation of earnings precedes tax planning (Chen and Chu 2005, Crocker and Slemrod 2005, Jacob et al. 2019).

[11] If the tax manager's signal is about the current (future) tax liability, he chooses an ex post (ex ante) tax planning effort as defined by Feller and Schanz (2017). Therefore, I more generally use the term "tax planning effort" with the limitation that ex ante tax planning is rejected, for example, due to lack of economic substance, while there are indeed ex ante tax planning strategies that are not rejected and thus lead to lower tax rates in the long run (Dyreng et al. 2008, Gallemore and Labro 2015, Christensen et al. 2022). Alternatively, one could consider the implementation of a tax planning strategy and an unobservable effort to sustain the strategy separately (Reineke et al. 2023a). This would more closely relate to a hidden action instead of hidden information game in the spirit of Shibano (1990). However, to make the function of a TCF as clear as possible and to avoid making unclear assumptions about how the TCF affects the tax planning effort and the tax auditor's benefit of uncovering a tax planning strategy, my model design choice is more adequate.

[12] Studies that explicitly analyze the role of performance contracts in tax planning or minimization include Chen and Chu (2005), Crocker and Slemrod (2005), and Jacob et al. (2019). However, these studies neglect other important features that influence corporate tax outcomes, such as strategic tax auditing decisions and the role

tax actors' personal incentives beyond performance-based contracts (Kohlhase and Wielhouwer 2023, Li and Okafor 2024) and the resulting obstacles of these contracts (Li and Okafor 2024).

The TCF serves as a tool through which the board can set the tone at the top for tax risk management (Brühne and Schanz 2022, Blaufus et al. 2023), thereby guiding corporate tax planning toward the desired tax risk level (Armstrong et al. 2015). The board invests in the TCF with quality $q \in [0,1)$ upfront at time $t = 1$, where the TCF proportionally reduces the probability of the implementation of a risky tax planning strategy:

$$\Pr(r_L = 0|\tau_H) = (1-q)a. \tag{1}$$

TCF quality q is observed by the tax manager, but is unobservable to the tax auditor. For example, the board may establish a tax risk reporting line, through which it is informed about tax planning strategies and tax risks at regular intervals (Brühne and Schanz 2022, Blaufus et al. 2023). It might also explicitly assign tax compliance responsibilities to other tax employees (Brühne and Schanz 2022, Dyck et al. 2025), who internally monitor tax planning strategies. The board's main incentive for TCF investment comes from managing the expected corporate costs and penalties from an uncovered risky tax planning strategy, which are also considered below. I consider a benevolent board, which is for expositional convenience only.[13]

Establishing and maintaining the TCF is costly to the board, which considers costs $q^2/4$. The costs include opportunity costs of participating in tax risk meetings and costs for hiring tax consultants to implement the TCF and guarantee its effectiveness. Importantly and unique to the tax setting, a tax manager's planning effort may benefit the board if the risky planning strategy is implemented and persists after the audit decision (e.g., Hoopes et al. 2012). Hence,

of TCFs. Further, my approach resembles accounting settings that study the role of internal controls, given managers' exogenous manipulation incentives (e.g., Schantl and Wagenhofer 2025). While I acknowledge that there may be interactions between performance-based pay and oversight via internal controls (e.g., Laux 2010, Kräkel and Schöttner 2024), my model reveals the maximum effect controls might have in a tax setting.

[13]Generally, the model is agnostic about whether the board is benevolent or considers additional personal incentives in the TCF investment decision. In the former case, the board's expected utility equals firm value. In the latter case, the board's expected utility captures personal costs from risky tax planning and effort costs.

a minimum TCF investment to facilitate risky tax planning (i.e., $q^* = 0$) might be optimal for the board, depending on the characteristics of the enforcement environment.

Audit decision. At time $t = 4$, the tax auditor observes the tax report r, as in traditional strategic tax audit settings (e.g., Graetz et al. 1986, Blaufus et al. 2024). In addition, she receives a noisy signal y about the benchmark tax T from the tax audit technology. The signal may be the output of comprehensive analyses of past tax return data through IT tools (Eberhartinger et al. 2022, OECD 2023), information exchange agreements among tax authorities (e.g., Casi et al. 2020), or financial statement information used by sophisticated tax authorities (Mills et al. 2010, Bozanic et al. 2017, Fox and Wilson 2023). I formalize the signal similar to Schantl and Wagenhofer (2020) and Sansing (1993) as $y = \eta T + \varepsilon$. ε is a standard normally distributed error term, that is, $\varepsilon \sim N(0,1)$, with probability density function $f(\varepsilon)$ and cumulative distribution function $F(\varepsilon)$. I interpret a higher η as enhanced quality of the tax audit technology, because a higher η allows the tax auditor to better identify whether the signal was obtained from a low or high benchmark tax. While the signal y is only observed by the auditor, its existence and properties and the date it emerges are common knowledge.[14]

Upon observing r and y, the tax auditor decides whether to conduct an in-depth audit of the uncertain tax position. If she audits, she perfectly reveals and enforces T at time $t = 5$.[15] In particular, her incentive to audit arises from receiving a personal benefit $b > 0$ if she uncovers a risky tax planning strategy $r_L = 0 < T_H$. This is because, typically, tax auditors are evaluated based on the additional tax revenue they generate (Reineke et al. 2023a, Blaufus et al. 2024). An audit involves (opportunity) costs $c \in (0, b)$, which might vary significantly across jurisdictions, depending on, for example, the total amount of enforcement staff in an agency (Nessa et al.

[14] It is reasonable to assume that corporate taxpayers know the average quality η of the tax audit technology. This knowledge can come from previous audits, consulting tax advisors, or the expertise within the corporate tax department. In addition, there are tax authorities that are transparent regarding (parts of) their audit technology (Eberhartinger et al. 2022).

[15] The model could be extended to allow for a perfect revelation but imperfect enforcement of T, reflecting that implemented risky tax planning strategies can be sustained with positive probability. However, the effect of this modeling choice can be similarly observed in a reduction of board penalties k^B.

2020, Kobilov 2025). As the number of enforcement staff increases, an individual tax auditor is responsible for less firms, all else equal, decreasing her opportunity cost of auditing. In case the tax auditor does not audit, she accepts the tax report, which comports with similar (tax) audit settings (e.g., Ewert and Wagenhofer 2019, Blaufus et al. 2024). As I show later, her audit decision is a threshold decision in which she audits if the signal y exceeds a threshold $\rho \in (-\infty, \infty)$ and does not audit otherwise.

If the auditor uncovers a risky tax planning strategy, the tax manager and the board incur additional enforcement-related costs and penalties. For the tax manager, the penalty $k^M \in (0,1)$ includes future compliance costs from correcting the tax return or unfavorable career outcomes, such as turnover while working in the firm or longer employment gaps after exiting the firm (Li and Okafor 2024). For the board, the costs from an uncovered risky tax planning strategy are twofold. First, the firm has to pay the owed tax liability T_H, which decreases its after-tax income. Second, the board incurs a further penalty $k^B(T_H - T_L) = k^B T_H$, which proportionally increases in the size of the tax planning strategy. $k^B > 0$ captures all firm-specific extra costs, such as interest or penalty payments associated with the repayment of the tax liability, reputational costs, consumer backlash, administrative costs from preparing restatements, or legal liability associated with non-compliance (Graham et al. 2014, Jacob et al. 2019, Neuman et al. 2020, Brühne and Schanz 2022, Reineke et al. 2023a). k^B thus captures the heterogeneity in firm-level tax planning costs identified in the literature (Wilde and Wilson 2018).

Figure 1 summarizes the sequence of events.

[Figure 1 about here]

2.2 Discussion of assumptions

2.2.1 Tax audit technology

The tax audit technology generates a random signal y drawn from a normal distribution; that is, $y \sim N(\eta T, 1)$, where $\eta > 0$ captures the quality of the audit technology. Modeling the tax audit technology in this way has three benefits. First, the tax auditor's audit decision becomes a threshold decision, where she bases the decision on the received evidence. The tax audit technology either produces a "red flag" (i.e., $y > \rho$) or a "green flag" (i.e., $y \leq \rho$), which comports with information-based audit decisions that account for auditors' personal verification (Sansing 1993, Eberhartinger et al. 2022, Kobilov 2025). Second, the normal distribution has the appealing characteristic that it has identical support for the low and high benchmark tax and that it exhibits the Monotone Likelihood Ratio Property. Due to the continuous distribution, a unique audit threshold determines the audit decision.[16] Third, in line with Sansing (1993), I assume that enhanced audit technology quality (increase in η) is reflected in a mean-shift of the normal distribution. This modeling choice has the intuitive feature that, holding ρ fixed (nonstrategic tax auditor), an increase in η unambiguously increases the audit probability of a risky tax planning strategy; that is, $\frac{\partial(1-F(\rho-\eta T_H))}{\partial\eta} > 0$. Alternatively, enhanced audit technology could reduce the variance of normally distributed signals (Patterson 1993).[17] However, the mean-shift better reflects the purpose of these technologies, which target risky strategies and thus improve discrimination of tax liabilities rather than estimating exact tax liabilities.

2.2.2 Sequence of events

Like other internal control settings, the board establishes a TCF before the tax manager decides on his tax planning effort. This assumption reflects that the TCF is typically designed as a preventive tool to manage tax risks. If the board establishes the TCF simultaneously with the tax manager's planning effort, the same equilibrium remains. If the TCF were designed after the tax manager's planning effort, the board's posterior belief and thus TCF quality decision would be based on a preliminary tax planning report, which resembles other settings with

[16]Sansing (1993) considers a logistic distribution with location parameter ηT and scale parameter 1. I use the familiar normal distribution with continuous support, which has been used in the audit literature (e.g., Newman and Noel 1989, Patterson 1993) and more recently by Schantl and Wagenhofer (2020). For a more general characterization of audit technologies inducing a unique audit threshold, see Shibano (1990).

[17]This modeling choice would create a less intuitive, ambiguous effect on this audit probability in addition to the prevailing ambiguous impact on the posterior likelihood of auditing $\Pr(T_H|0,\rho;a,q)$.

multiple monitors (e.g., Ewert and Wagenhofer 2019, Schantl and Wagenhofer 2020). However, this sequence of events would not adequately reflect the purpose of a TCF.

2.2.3 Information and probability structure

I assume that the tax manager's information about the benchmark tax is perfect ($\tau = T$). Alternatively, suppose that the tax manager's information is correct with probability $\Pr(\tau_H|T_H) = \Pr(\tau_L|T_L) = \alpha \in (1/2, 1]$, and the TCF can only identify whether the tax report comports with the tax manager's private information. In that case, the tax manager would still benefit only from choosing a tax planning effort if the signal is τ_H. Further, the penalties from revealed risky tax planning k^M and k^B would be incurred with probability $\alpha(1 - F(\rho - \eta T_H))$, which increases with α. This assumption would weaken the enforcement effect on tax planning and the external incentive effect for TCF investment, extending the range in which a lenient enforcement environment is obtained. The tax auditor's audit decision remains a threshold decision, where her benefit of conducting an audit of r_L decreases with the tax manager's uncertainty: $\frac{\partial \Pr(T_H|0,\rho;a,q)}{\partial \alpha} > 0$. While the players' equilibrium strategies depend on α, the fundamental relation of the equilibrium strategies on each other nevertheless persists.

Further, I assume that the low and high tax occur with equal probability (i.e., $\Pr(T_L) = \Pr(T_H) = 1/2$). Assuming otherwise would affect the players' equilibrium strategies similar to the explained effects of a tax manager's imperfect private information α, and is also used in other internal control settings (e.g., Schantl and Wagenhofer 2025).

3 Equilibrium

In this section, I establish the equilibrium to examine how strengthening tax enforcement and improving tax audit technology affect the equilibrium behavior, namely TCF investment, tax planning effort, and the audit decision. Figure 2 depicts a reduced game tree without dominated strategies, in which the board's TCF investment q and tax manager's planning effort a are summarized into the probability that a risky tax planning strategy is implemented.

[Figure 2 about here]

The equilibrium is defined as follows.

Definition. *An equilibrium consists of the board's investment in the TCF $q \in [0,1)$, the tax manager's tax planning effort $a \in (0,1)$, and the tax auditor's audit threshold $\rho \in (-\infty, \infty)$, such that:*

i) The board chooses q to maximize its expected utility, consisting of the expected tax payments, the expected costs and penalties of an uncovered risky tax planning strategy, and the costs of TCF investment, given rational conjectures of the tax manager's planning effort $\hat{a}$ and the tax auditor's audit threshold $\hat{\rho}$.

ii) Conditional on τ, the tax manager chooses a to maximize his expected utility, consisting of the expected personal benefit from an implemented risky tax planning strategy, the expected penalty from an uncovered risky strategy, and the tax planning costs, given the board's TCF investment q and rational conjectures of the auditor's audit threshold $\hat{\rho}$.

iii) Conditional on r and y, the tax auditor conducts an in-depth audit of the uncertain tax position if her conditionally expected personal benefit of uncovering a risky tax planning strategy exceeds her audit cost, given rational conjectures of the board's TCF investment $\hat{q}$ and the tax manager's planning effort $\hat{a}$.

All players' strategies depend on the conjectures of how the other players behave in equilibrium, which is indicated by a hat on the decision variables. The game is solved by backward induction, starting with the tax auditor's audit decision, then determining the tax manager's tax planning effort, and finally the board's investment in the TCF. All formal proofs are given in the Appendix.

3.1 Tax auditor's audit decision

The tax auditor never audits when the tax manager reports r_H, because she obtains a personal benefit $b > c$ only from uncovering a risky tax planning strategy (i.e., tax manager reports r_L but $T = T_H$). However, upon observing $r_L = 0$ and the signal y from the tax audit technology, she updates her belief about uncovering a risky tax planning strategy. Conjecturing the board's TCF investment $\hat{q}$ and the tax manager's planning effort $\hat{a}$, an audit is beneficial if

$$\Pr(T_H|0,y;\hat{a},\hat{q})\, b = \frac{(1-\hat{q})\hat{a} f(y-\eta T_H)}{(1-\hat{q})\hat{a} f(y-\eta T_H)+f(y)}\, b \geq c. \tag{2}$$

As mentioned above, the tax auditor's audit decision is a threshold decision, which can be seen from how $\Pr(T_H|0,y;\hat{a},\hat{q})$ changes with respect to y.

Lemma 1. $\Pr(T_H|0,y;\hat{a},\hat{q})$ *strictly increases in y for any $\hat{q} \in [0,1)$ and $\hat{a} \in (0,1)$.*

The result in Lemma 1 is due to the Monotone Likelihood Ratio Property and resembles how the threshold decision is obtained in Sansing (1993) and Schantl and Wagenhofer (2020). Intuitively, it means that a higher signal y is more indicative of $T_H > 0$ than of $T_L = 0$, conditional on that $r_L = 0$ was reported. The threshold value $\rho \in (-\infty,\infty)$ is implicitly given by

$$\frac{(1-\hat{q})\hat{a} f(\rho-\eta T_H)}{(1-\hat{q})\hat{a} f(\rho-\eta T_H)+f(\rho)}\, b = c. \tag{3}$$

Thus, the tax auditor audits tax report $r_L = 0$ if $y > \rho$ and does not audit if $y \leq \rho$. Due to the assumption $c \in (0,b)$, there always exists an interior solution for ρ for any $\hat{a} \in (0,1)$ and $\hat{q} \in [0,1)$. Also, in line with intuition, the probability of uncovering a risky tax planning strategy $\Pr(T_H|0,y;\hat{a},\hat{q})$ increases with $\hat{a}$ and decreases with $\hat{q}$. The latter insight seems to accord with regulatory proposals encouraging firms to improve their TCF (OECD 2016, Eberhartinger and Zieser 2021, Siglé et al. 2025). However, these proposals neglect two important aspects that this study illuminates. First, the characteristics of the tax enforcement environment drive the decision to invest in the TCF. Second, a tax auditor's decision to conduct an audit is influenced by the indirect effects of an investment in the TCF q and the tax planning effort a on the conditional probability of uncovering a risky tax planning strategy. Both aspects are crucial for an overall assessment of these regulatory proposals and other instruments aimed at improving tax audit efficiency.

3.2 Tax manager's tax planning effort

The tax manager always reports $r_L = 0$ if his signal indicates a low benchmark tax $\tau_L = 0$. If his signal is τ_H, he has a tax planning incentive and can obtain one unit of utility if the risky tax planning strategy is implemented, which occurs with probability $(1-q)\,a$. However, if the risky strategy is implemented and the tax auditor audits, the tax manager incurs a penalty $k^M \in (0,1)$, which occurs with conjectured probability $(1-q)\,a\,(1-F(\hat{\rho}-\eta T_H))$. Overall, conditional on τ_H, the tax manager chooses the optimal tax planning effort solving:

$$\max_{a}\,(1-q)a-(1-q)a\,(1-F(\hat{\rho}-\eta T_H))\,k^M-a^2/2\;. \tag{4}$$

The tax manager's optimal tax planning effort is thus

$$a=(1-q)(1-(1-F(\hat{\rho}-\eta T_H))\,k^M). \tag{5}$$

Observe that the upper bound for k^M ensures that the optimal tax planning effort is always interior. Holding $\hat{\rho}$ fixed, the tax planning effort decreases in q, since an enhanced TCF decreases the likelihood that a risky tax planning strategy is implemented. I refer to this as the internal control effect on tax planning. In addition, holding q fixed, the tax planning effort decreases with the audit probability of a risky tax planning strategy, which I subsequently refer to as the enforcement effect on tax planning. Policymakers typically focus on how policy instruments affect the enforcement effect on tax planning without considering the internal control effect. I scrutinize this additional interaction.

3.3 Board's investment in the Tax Control Framework

Given the board's ex ante information about the benchmark tax and conjecturing the tax planning effort $\hat{a}$ and the audit threshold $\hat{\rho}$, the board maximizes its expected utility by choosing the optimal quality of the TCF q. An increase in the TCF quality decreases the probability that a risky tax planning strategy is implemented. This results in an increase in expected tax payments and respectively decreases the board's expected utility, because an implemented risky tax planning strategy which remains unaudited improves the firm's financial performance. This disadvantage of increasing the TCF quality is reflected in $\frac{1}{2}\left(1-(1-q)\,\hat{a}\right)T_H$. However, a higher quality TCF has the advantage that it decreases the expected corporate costs and penalties from an uncovered risky tax planning strategy, which is reflected in $\frac{1}{2}(1-q)\,\hat{a}\left(1-F\left(\hat{\rho}-\eta T_H\right)\right)T_H\left(1+k^B\right)$. This trade-off emphasizes the well-known notion that tax planning has costs and benefits (e.g., Wilde and Wilson 2018, Armstrong et al. 2015) and that the board uses the TCF to manage tax risk (Brühne and Schanz 2022, Blaufus et al. 2023). Overall, the board solves

$$\max_{q}\ \mu-\frac{1}{2}T_H\left(\left(1-(1-q)\hat{a}\right)+\left(1-F(\hat{\rho}-\eta T_H)\right)(1-q)\hat{a}(1+k^B)\right)-q^2/4. \tag{6}$$

The board's optimal investment is thus

$$q=\max\Big\{0,T_H\hat{a}\left(\left(1-F\left(\hat{\rho}-\eta T_H\right)\right)\left(1+k^B\right)-1\right)\Big\}. \tag{7}$$

For an investment in the TCF to occur (i.e., $q>0$), the board's expected benefit from risky tax planning needs to be sufficiently low compared to the expected costs and penalties, so that $\left(1-F\left(\hat{\rho}-\eta T_H\right)\right)\left(1+k^B\right)-1>0$. Only then will the tax planning effort and the resulting tax risk exceed the level the board will accept. The next observation emphasizes the importance of this condition for the board's investment in the TCF.

Corollary 1. *The board invests in the TCF if* $(1-F(\hat{\rho}-\eta T_H))\left(1+k^B\right)-1 \equiv \omega(\hat{\rho}) > 0$.

Corollary 1 implies that two firms facing an identical enforcement environment, represented by the audit probability of a risky tax planning strategy $1-F(\hat{\rho}-\eta T_H)$, can have heterogeneous TCF investments due to the heterogeneity in the firm-specific costs of uncovered tax planning k^B. When $\omega(\hat{\rho}) > 0$, observe that, holding $\hat{a}$ fixed, a higher audit probability incentivizes more TCF investment. I will refer to this as the external incentive effect on TCF investment. Further, holding $\hat{\rho}$ fixed, a higher tax planning effort $\hat{a}$ also increases the board's TCF investment. I will refer to this as the internal incentive effect. Conversely, if $\omega(\hat{\rho}) \leq 0$, the board would select a minimum quality for the TCF (i.e., $q=0$) to facilitate risky tax planning effort by the tax manager.

3.4 Unique equilibrium

Next I establish the properties of the equilibrium. The theorem states the optimal strategies, enforcing all conjectures ($\hat{q}=q, \hat{a}=a, \hat{\rho}=\rho$).

Theorem 1. *When the tax enforcement environment is lenient with* $\omega(\rho^*) \leq 0$ *or strict with* $\omega(\rho^*) > 0$ *and* $k^B \leq \overset{=}{k}^B$, *the equilibrium entails the following strategies.*

i) The board invests in the TCF with quality

$$q^* = \begin{cases} 0, & \omega(\rho^*) \leq 0 \\ \frac{T_H \gamma(\rho^*)\omega(\rho^*)}{1+T_H \gamma(\rho^*)\omega(\rho^*)}, & \omega(\rho^*) > 0. \end{cases}$$

ii) Conditional on τ_H, the tax manager chooses a tax planning effort

$$a^* = \begin{cases} \gamma(\rho^*), & \omega(\rho^*) \leq 0 \\ \frac{\gamma(\rho^*)}{1+T_H\gamma(\rho^*)\omega(\rho^*)}, & \omega(\rho^*) > 0. \end{cases}$$

iii) If the tax auditor observes r_H in the tax return, she does not audit. Otherwise she audits if $y > \rho^*$, where $\rho^* \in (-\infty, \infty)$ is implicitly defined by

$$0 = \begin{cases} \frac{1}{1+\frac{1}{\gamma(\rho^*)}\frac{f(\rho^*)}{f(\rho^*-\eta T_H)}} b - c, & \omega(\rho^*) \leq 0 \\ \frac{1}{1+\frac{[1+T_H\gamma(\rho^*)\omega(\rho^*)]^2}{\gamma(\rho^*)}\frac{f(\rho^*)}{f(\rho^*-\eta T_H)}} b - c, & \omega(\rho^*) > 0. \end{cases}$$

The terms used in the theorem are defined as

$$\omega(\rho^*) \equiv (1 - F(\rho^* - \eta T_H))(1 + k^B) - 1,$$

$$\gamma(\rho^*) \equiv 1 - (1 - F(\rho^* - \eta T_H))\, k^M,$$

$$\overline{\overline{k}}^B \equiv \frac{1 + T_H\gamma(\rho^*)F(\rho^* - \eta T_H)}{T_H\gamma(\rho^*)[1 - F(\rho^* - \eta T_H)]}.$$

Theorem 1 shows that the equilibrium crucially depends on whether the board has an incentive to invest in the TCF. When the enforcement environment is lenient (strict), this induces a minimum TCF investment $q = 0$ (a positive TCF investment $q > 0$). The upper bound on the penalties $\overline{\overline{k}}^B$ reasonably describes a setting of risky legal tax planning rather than illegal tax evasion, and ensures a unique solution in the strict enforcement environment.

The strength of tax enforcement, captured in the tax auditor's opportunity cost of an audit c, directly influences $\omega(\rho^*)$ and thus has an important role for which enforcement environment applies. Suppose for example that c is exorbitantly high ($c \to b$). Then auditing never occurs

($F\left(\rho^* - \eta T_H\right) \rightarrow 1$), and the board has no incentive to invest more than the minimum quality, independent of the size of k^B, as long as k^B is finite. Likewise, suppose that auditing is costless ($c \rightarrow 0$), and thus the auditor would always audit a low report ($F\left(\rho^* - \eta T_H\right) \rightarrow 0$). Then, even if k^B is very small, the board would invest in the TCF. Thus, there always exists a critical value $\bar{c}_\omega \in (0, b)$ for any finite k^B that induces a change in the enforcement environment. The following lemma summarizes the result.

Lemma 2. *For any finite $k^B > 0$, there exists a threshold value $\bar{c}_\omega \in (0, b)$, such that, if $c \geq \bar{c}_\omega$, the enforcement environment is lenient, and if $c < \bar{c}_\omega$, the enforcement environment is strict. $\bar{c}_\omega$ is implicitly defined by $\omega\left(\rho^*\left(\bar{c}_\omega\right)\right) = 0$ and strictly increases in k^B.*

Lemma 2 implies that regulators can create an environment for any firm where the board invests in the TCF by, for example, increasing the amount or expertise of enforcement personnel and thus reducing a tax auditor's audit cost c. This result comports with recent survey and empirical evidence (EY 2023, Blaufus et al. 2023), which describes that tax audits are perceived as more aggressive and boards react by investing in the firm's TCF.

From a policymaker perspective, it is essential to understand how strengthening tax enforcement and enhancing the quality of tax audit technology affect the equilibrium strategies and important economic outcomes. The outcomes I consider are the corporate tax planning probability CTP, the audit probability of a risky tax planning strategy AP, and the probability of lost tax revenues for the tax authority LTR. These outcomes are given by

$$CTP^* = \frac{1}{2} + \frac{1}{2}\left(1 - q^*\right) a^*, \tag{8}$$

$$AP^* = 1 - F\left(\rho^* - \eta T_H\right), \tag{9}$$

$$LTR^* = \frac{1}{2}\left(1 - q^*\right) a^* F\left(\rho^* - \eta T_H\right). \tag{10}$$

As CTP directly depends on the board's TCF quality investment and the tax manager's tax planning effort, it represents an important corporate outcome encompassing risk-free tax planning with probability $\Pr(T_L) = 1/2$ and risky tax planning with probability $\Pr(T_H) = \frac{1}{2}(1-q^*)\,a^*$. Further, I interpret AP and LTR as fundamental measures for tax audit efficiency (Blaufus et al. 2024), which directly depend on the tax auditor's audit threshold.

4 Results

4.1 Strengthening tax enforcement

In this section, I show how strengthening tax enforcement affects the equilibrium strategies, which arises when the tax auditor's audit cost c decreases. Policymakers can achieve decreasing audit costs, for example, by employing additional enforcement staff or increasing the expertise of tax auditors through training courses.

Proposition 1. *Strengthening tax enforcement (a decrease of c) has the following effects:*

(i) In a lenient enforcement environment ($c > \overline{c}_\omega$), the board's investment in the TCF is unaffected. In a strict enforcement environment ($c < \overline{c}_\omega$), there exist threshold values $\overline{k}^M \in (1/2, 1)$ and $\overline{c}_c^q \in (0, \overline{c}_\omega)$ such that:

a) If the tax manager's penalty is small $k^M < \overline{k}^M$, the board's investment in the TCF strictly increases (q^* strictly increases);

b) If the tax manager's penalty is large $k^M > \overline{k}^M$, the investment strictly increases (q^* strictly increases) if the strength of tax enforcement is relatively low ($c > \overline{c}_c^q$), and the investment strictly decreases (q^* strictly decreases) if the strength of tax enforcement is relatively high ($c < \overline{c}_c^q$);

(ii) The tax manager engages in less tax planning (a^* strictly decreases);

(iii) The tax auditor audits the uncertain tax position more often when she observes $r_L = 0$ (ρ^* strictly decreases).

Proposition 1 (ii) and (iii) yield intuitive results. Upon observing $r_L = 0$, the tax auditor audits the uncertain tax position for signals from the audit technology $y \geq \rho^*$. When the audit cost c decreases, her expected benefit of auditing exceeds the costs for more signals, decreasing her required evidence to audit ρ^*. As a result, the audit probability of a risky tax planning strategy and thus the tax manager's expected penalty k^M increases. This enforcement effect unambiguously deters his tax planning effort, independent of whether the internal control effect is muted or not.

The effect of strengthening tax enforcement on TCF investment is more intricate and depends on the enforcement environment. This is visible in the equilibrium condition:

$$q^* = T_H \underbrace{a^*}_{\substack{\text{Internal incentive}\\ \text{effect}}} \underbrace{\left((1 - F(\rho^* - \eta T_H))\left(1 + k^B\right) - 1\right)}_{\text{External incentive effect}}. \tag{11}$$

Proposition 1 (i) establishes that the board's investment in the TCF remains unaffected in a lenient enforcement environment ($c > \overline{c}_\omega$). The reason is that the external incentive effect is negative, implying that the board wants to facilitate risky tax planning through a minimum TCF quality $q^* = 0$. Even though strengthening tax enforcement also fosters the external incentive effect in a lenient enforcement environment and thus the board's tax planning benefits decrease, the decreasing benefits are yet insufficient to incentivize a TCF investment.

In a strict enforcement environment ($c < \overline{c}_\omega$), the external incentive effect turns positive and induces TCF investment. Two countervailing effects determine the impact of strengthening tax enforcement: First, for a given tax planning effort, the decreasing audit threshold incentivizes the board to manage its tax risk exposure downward through TCF investment (external incentive effect). Second, for a given audit threshold, the decreasing tax planning effort decreases investment incentives, as the tax manager strives to adjust tax planning toward the board's desired level of risk (internal disincentive effect). I identify conditions when either the internal or the external incentive effect dominates. When the enforcement effect on tax planning and thus the internal disincentive effect is sufficiently weak $k^M < \bar{k}^M$, strengthening tax enforcement unambiguously increases the board's TCF investment (Proposition 1 (i) part a)). A necessary condition for the opposite effect on TCF investment is that the internal disincentive effect is sufficiently strong $k^M > \bar{k}^M$ ((i) part b)). Then the relative importance of the internal and external incentive effect additionally depends on the strength of tax enforcement. When the strength of tax enforcement is relatively low in a strict enforcement environment ($\bar{c}_c^q < c < \bar{c}_\omega$), the external incentive effect dominates such that TCF investment increases. In this case, the board's TCF investment (internal enforcement) complements external enforcement via tax audits. When the strength of tax enforcement is relatively high ($c < \bar{c}_c^q$), the internal disincentive effect dominates such that TCF investment decreases. Thus, contrary to regulatory expectations, I identify conditions under which internal enforcement via the TCF and external enforcement are strategic substitutes.

Figure 3 illustrates the results from Proposition 1 for varying levels of board penalties.

[Figure 3 about here]

4.2 Increasing the quality of the tax audit technology

Next I establish how an increase in the tax audit technology quality η affects the equilibrium strategies. For example, regulators can establish enhanced tax audit technologies by equipping tax authorities with sophisticated IT tools, which process tax information from a variety of sources (e.g., information exchange agreements among tax authorities, financial statement information, private country-by-country reports) to risk-assess firms' tax positions.

Proposition 2. *Increasing the quality of the tax audit technology (an increase of η) has the following effects:*

(i) There exist unique threshold values $\bar{k}^M \in (1/2, 1)$ and $\bar{c}_\eta^a \in (0, b)$ such that:

a) If the tax manager's penalty is small $k^M < \bar{k}^M$, the board's investment in the TCF increases (q^* increases) if the strength of tax enforcement is sufficiently low

($c > \overline{c}_\eta^a$), and the investment decreases (q^* decreases) if the strength is sufficiently high ($c < \overline{c}_\eta^a$);

b) *If the tax manager's penalty is large $k^M > \overline{k}^M$, the investment may increase or decrease, independent of the strength of tax enforcement;*

(ii) *There exists a unique threshold value $\overline{c}_\eta^a \in (0,b)$ such that: If the strength of tax enforcement is sufficiently low ($c > \overline{c}_\eta^a$), the tax manager engages in less tax planning (a^* strictly decreases), or if it is sufficiently high ($c < \overline{c}_\eta^a$), he engages in more tax planning (a^* strictly increases);*

(iii) *There exist threshold values $\underline{c}_\eta^\rho$, $\overline{c}_\eta^\rho \in (0,b)$ with $\underline{c}_\eta^\rho \leq \overline{c}_\eta^\rho$, and $\overline{k}_2^B > 0$ such that:*
If the strength of tax enforcement is sufficiently low $(c > \overline{c}_\eta^\rho)$, the tax auditor audits more often when she observes $r_L = 0$ (ρ^* strictly decreases), or if the strength is sufficiently high ($c < \underline{c}_\eta^\rho$), she audits less often when she observes $r_L = 0$ (ρ^* strictly increases). For $k^B < \overline{k}_2^B$, the strength-dependent threshold is unique ($\underline{c}_\eta^\rho = \overline{c}_\eta^\rho$).

Proposition 2 generally establishes that the effect of tax audit technology quality η is interlinked with the strength of tax enforcement. With regard to the effect on the tax planning effort in (ii), the non-trivial impact of η is independent of the enforcement environment and thus whether the board invests in the TCF or not. To understand this result, observe the equilibrium condition determining the tax planning effort:

$$a^* = \underbrace{(1-q^*)}_{\text{Internal control effect}} \quad \underbrace{(1-(1-F(\rho^*-\eta T_H))\,k^M)}_{\text{Enforcement effect}}. \tag{12}$$

To begin, let us consider a lenient enforcement environment in which the internal control effect is muted. Then, the enforcement strength-dependent impact of tax audit technology quality η is solely driven by its impact on the enforcement effect. The impact on the enforcement effect can be decomposed into a direct and an indirect effect. First, holding the audit threshold constant (i.e., nonstrategic tax auditor), an increase in η unambiguously increases the tax manager's expected penalty (direct effect), weakening his tax planning incentives. Second, an increase in η also indirectly affects the tax auditor's conditional probability of uncovering a risky tax planning strategy and thus her trade-off between a type I error (auditing a tax position where no risky strategy was implemented $r_L = T_L$) and a type II error (failing to audit a risky strategy $r_L < T_H$). When the strength of tax enforcement is sufficiently low (high), the effect of η on the type II error (type I error) dominates, providing (crowding out) audit incentives. The tax manager rationally anticipates this indirect effect and, in equilibrium, the ambiguous impact prevails and depends on a unique threshold value $\bar{c}^a_\eta$. Figure 4 demonstrates these effects when the strength of tax enforcement is low (panel a) or high (panel b) in a lenient environment.

[Figure 4 about here]

In a strict enforcement environment, the tax manager additionally anticipates the impact of η on the internal control effect, while the impact on the enforcement effect is still at work. The internal control effect can also be decomposed into two sub-effects. First, holding the audit threshold ρ fixed, an increase in η directly fosters the external incentive effect and thus the board's TCF investment incentives, which decreases the tax manager's willingness to engage in tax planning. Second, an increase in η has an indirect effect on TCF investment incentives, as the decreasing (increasing) audit threshold translates into increasing (decreasing) TCF investment incentives if the strength of tax enforcement is low (high). Overall, the second sub-effect dominates and induces a board's enforcement strength-dependent equilibrium response, and, via the internal control effect, an enforcement strength-dependent reaction by the tax manager. Strikingly, the unique threshold $\bar{c}^a_\eta$ captures the nontrivial enforcement and internal control effects simultaneously.

Next, consider the effect of increasing the technology quality η on TCF investment q^* (Proposition 2 (i)). The intuition is similar to the effect of η on the tax planning effort. Two key differences are important. First, the threshold value $\bar{c}^a_\eta$ in part a) represents how

η affects the internal and external incentive effect as presented in equation (11). When the internal incentive effect is sufficiently weak (i.e., $k^M \leq \overline{k}^M$), $\overline{c}^a_\eta$ fully captures how the effect of η on q^* is interlinked with the strength of tax enforcement. However, q^* need not *strictly* increase or decrease, as this additionally depends on the enforcement environment (Lemma 2). Depending on the size of board penalties, q^* only *weakly* increases or decreases.[18] Second, when $k^M > \overline{k}^M$, the direction of the enforcement strength-dependent effect can flip, as the internal disincentive becomes more important than the external incentive effect when $c < \overline{c}^q_c$ (Proposition 1, (i)). Then, depending on a jurisdiction's prevailing quality of tax audit technology that also determines $\overline{c}^q_c(\eta)$, an increase of η can (dis-)incentivize TCF investment, independent of the strength of tax enforcement. Figure 5 below numerically illustrates the results.[19]

Audit technology quality η also yields an enforcement strength-dependent impact on the audit threshold ρ^* (Proposition 2 (iii)). Consider low board penalties $k^B < \overline{k}^B_2$, such that $\overline{c}_\omega$ is small (Lemma 2), and the lenient environment obtains for many values $c > \overline{c}_\omega$. Then, the intuition for the enforcement-strength dependent result resembles the one for the tax planning effort in (ii). The difference is, however, that the adverse effect of η on the tax auditor's audit incentives is even stronger, as we have $\overline{c}^a_\eta < \underline{c}^\rho_\eta = \overline{c}^\rho_\eta$. Hence, unlike an increasing tax planning effort, an increasing audit threshold also occurs in situations with $\overline{c}^a_\eta < c < \underline{c}^\rho_\eta = \overline{c}^\rho_\eta$. With high board penalties $k^B > \overline{k}^B_2$, I can only establish a partial result regarding the impact of η, because the TCF investment becomes relatively more important and directly and indirectly affects ρ^*.

[18] For example, if $k^B < \underline{k}^B$ ($\underline{k}^B$ is defined in the proof of Proposition 2 for $c > \overline{c}_\omega$), q^* weakly decreases if $c \in (\overline{c}_\omega, \overline{c}^a_\eta)$ and strictly decreases if $c < \overline{c}_\omega$. If $k^B > \underline{k}^B$, q^* strictly increases for $c \in (\overline{c}^a_\eta, \overline{c}_\omega)$ and weakly increases for $\overline{c}_\omega < c$.

[19] The graphs on the left-hand side in Figure 5 particularly illustrate the case $k^M > \overline{k}^M$. Panel a) shows that TCF investment is inversely U-shaped in tax audit technology quality η when the strength of tax enforcement is relatively low. The decreasing part in η particularly occurs because the threshold $\overline{c}^a_\eta$ is a function of η, as will be explained in more detail below. Panel b) shows that TCF investment has both a U-shaped (with a local minimum) and inversely U-shaped part (with a local maximum) in η when the strength of tax enforcement is relatively high. Further numerical simulations suggest that the latter pattern is not generalizable. For example, the local minima in panel b) drop out when plotting q^* for $c = 0.15$, all else equal, leading again to an inversely U-shaped TCF investment function in η.

In any case, ρ^* increases if the strength of tax enforcement is sufficiently high ($c < \underline{c}_\eta^\rho$), and ρ^* decreases if the strength is sufficiently low ($c > \overline{c}_\eta^\rho$). If the strength takes an intermediate value $\underline{c}_\eta^\rho < c < \overline{c}_\eta^\rho$, the effect on ρ^* cannot be unambiguously identified, but additional simulations suggest that an increase of ρ^* occurs in most feasible situations.

Proposition 2 especially highlights two adverse effects of enhancing tax audit technology quality: an increasing tax planning effort and an increasing audit threshold. The adverse effects occur if the strength of tax enforcement is sufficiently high, and can occur independent of the individual enforcement environment a board with costs k^B faces. In general, a sufficiently high strength of tax enforcement is more likely to be observed in tax authorities of developed as compared to developing countries (Kobilov 2025). Notably, the adverse results obtain for a *marginal* increase in audit technology quality. Due to the model's complexity, the enforcement-strength dependent threshold value $\overline{c}_\eta^a$ also depends on η. The higher the level of η for a given strength of tax enforcement, the lower is the likelihood for a relatively high strength of tax enforcement. Corollary 2 formally establishes the result.

Corollary 2. *If a sufficiently low strength of tax enforcement is given ($c < \overline{c}_\eta^a(\eta)$), an increasing tax planning effort a^* is the result of enhancing low quality tax audit technologies ($\eta < \overline{\eta}^a$). This response is more likely in firms with lower enforcement-related tax planning costs k^B.*

The observation explains the u-shaped functions in Figure 4, panel b). Concerning empirical studies, the observation implies that adverse effects are likely to be observed if the strength of tax enforcement is sufficiently high and if audit technology qualities are additionally poor. Interestingly, I show that this adverse effect is a more likely for firms with lower enforcement-related tax planning costs k^B. In empirical studies, these firms are likely to be identified as more "tax aggressive" (De Waegenaere et al. 2015).

4.3 Effects on economic outcomes

Next I examine the implications of strengthening tax enforcement and improving the tax audit technology quality on three economic outcomes: the corporate tax planning probability, the audit probability of a risky tax planning strategy, and the lost tax revenues. Proposition 3 summarizes the results with respect to all economic outcomes.

Proposition 3. *The corporate tax planning probability CTP^*, the audit probability of a risky tax planning strategy AP^*, and the lost tax revenues LTR^*, are affected as follows:*

(i) Strengthening tax enforcement (a decrease of c) decreases the corporate tax planning probability, increases the audit probability of a risky tax planning strategy, and decreases the lost tax revenues;

(ii) There exists a unique threshold value $\overline{c}^a_\eta \in (0,b)$ such that increasing the tax audit technology quality (an increase of η)

a) decreases the corporate tax planning probability, increases the audit probability of a risky tax planning strategy, and decreases the lost tax revenues if the strength of tax enforcement is sufficiently low ($c > \overline{c}^a_\eta$),

b) increases the corporate tax planning probability, decreases the audit probability of a risky tax planning strategy, and increases the lost tax revenues if the strength of tax enforcement is sufficiently high ($c < \overline{c}^a_\eta$).

Proposition 3 (i) implies that strengthening tax enforcement unambiguously decreases corporate tax planning CTP^*. Although this result is intuitive, the economics are more intricate, as a decreasing tax planning effort and an increasing TCF investment can occur simultaneously and have opposing effects on CTP^* (Proposition 1 (i) and (ii)). My results indicate that the impact on the tax planning effort dominates, such that corporate tax planning decreases. By contrast, Proposition 3 (ii) identifies situations in which corporate tax planning increases when tax audit technology quality η improves, particularly if the strength of tax enforcement is sufficiently high. While the individual effects of η on TCF investment do not follow a straightforward pattern, particularly when $k^M > \bar{k}^M$, I show that the direction of the audit technology's impact follows the same pattern as for the tax manager's planning effort. This result aligns with tax managers' crucial role in corporate tax planning (Feller and Schanz 2017, Belnap, Hoopes, and Wilde 2024). Figure 5 illustrates these insights.

[Figure 5 about here]

Further, I show that strengthening tax enforcement increases tax audit efficiency (measured by audit probability AP^* and lost tax revenues LTR^*). Both results are intuitive, as, first, the increasing AP^* is solely determined through the impact on the auditor's audit threshold (Proposition 1 (iii)), and second, the impact on LTR^* is the combined effect of the unambiguous effects on audit probability AP^* and corporate tax planning CTP^*. Proposition 3 (ii) indicates that the impact of increasing the quality of tax audit technology η on both tax audit efficiency measures depends on a unique threshold $\bar{c}^a_\eta$. This result obtains even though the impact of technology quality on the audit threshold cannot unambiguously identified. Most importantly, the impact on AP^* is uniquely interlinked with the strength of tax enforcement. As LTR^* comprises the combined impact of increasing audit technology quality on AP^* and CTP^*, the economic consequences again depend on enforcement strength-dependent threshold $\bar{c}^a_\eta$.

Two final aspects should be emphasized. First, the key driver for the enforcement strength-dependent efficiency implications is the tax auditor's trade-off between a type I and type II error. While she infers the effects of the quality of tax audit technology on overall corporate tax planning, including TCF investment, the board's TCF investment cannot mitigate the undesirable effects of the quality of tax audit technology for corporate tax planning and tax audit efficiency. Second, internal and external tax enforcement can be strategic substitutes whenever the enforcement effect on tax planning is sufficiently strong ($k^M > \bar{k}^M$). Thus, the increasingly observable TCF investment of firms does not reliably indicate tax audit efficiency.

5 Conclusions

This study investigates strategic interactions between corporate tax planning and tax enforcement. Contrary to previous theoretical models, the model incorporates two important and contemporary features. First, the board of directors can invest in the firm's Tax Control Framework (TCF) to manage tax risks associated with tax planning. Second, tax enforcement decisions are based on additional information from sophisticated tax audit technologies.

I find that a strict tax enforcement environment is necessary to induce TCF investment. Policymakers can create an enforcement environment in which a TCF as an internal enforcement device is voluntarily established by any firm. However, since internal and external enforcement can be strategic substitutes, internal enforcement can be misleading about tax audit efficiency. Further, I show that strengthening tax enforcement by increasing specialized enforcement staff improves tax audit efficiency. Yet this can be challenging (or costly) when skilled enforcement staff is scarce, as seen recently in many countries. My results imply that improvements in tax audit technology are an effective alternative instrument when the strength of tax enforcement is lower, such as in many developing countries. However, especially when the strength of tax enforcement is higher, such as in most developed countries, these improvements increase corporate tax planning and hurt tax audit efficiency, due to a crowding out of audit incentives.

Lastly, I derive empirically testable predictions. First, the effect of strengthening tax enforcement on TCF investment depends on the prevailing strength of tax enforcement: If the prevailing level is low, TCF investment is unaffected. If it is intermediate, investment increases, while if it is high, the firm's and the manager's characteristics determine whether more or less investment occurs. Second, the impact of improvements in audit technologies also depends on the prevailing strength of tax enforcement. If the prevailing level is low, firms' effective tax rates increase. If the level is high, effective tax rates decrease, which should be particularly pronounced for tax aggressive firms and when audit technologies are also poor.

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Appendix

Lemma 1

Note that $y \sim N(\eta T, 1)$, which is equivalent to $y = \eta T + \varepsilon$ with $\varepsilon \sim N(0,1)$. Then, the probability density and cumulative distribution function are given by

$$f(y-\eta T) = \frac{1}{\sqrt{2\pi}} \exp\left(-\frac{1}{2}(y-\eta T)^2\right),$$
$$F(y-\eta T) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{y} \exp\left(-\frac{1}{2}(y-\eta T)^2\right) dy = \frac{1}{2} \operatorname{erfc}\left(\frac{\eta T - y}{\sqrt{2}}\right),$$

where $\operatorname{erfc}(\cdot)$ is the complementary error function. As $\Pr(T_H|0,y;\hat{a},\hat{q}) = \frac{(1-\hat{q})\hat{a} f(y-\eta T_H)}{(1-\hat{q})\hat{a} f(y-\eta T_H)+f(y)} = \frac{1}{1+\frac{1}{(1-\hat{q})\hat{a}}\frac{f(y)}{f(y-\eta T_H)}}$, the derivative of $\Pr(T_H|0,y;\hat{a},\hat{q})$ with respect to y is given by

$$\frac{\delta}{\delta y}\left\{\frac{1}{1+\frac{1}{(1-\hat{q})\hat{a}}\frac{f(y)}{f(y-\eta T_H)}}\right\} = \frac{\delta}{\delta y}\left\{\frac{1}{1+\frac{1}{(1-\hat{q})\hat{a}}\exp\left(-\frac{1}{2}\left(y^2-(y-\eta T_H)^2\right)\right)}\right\}$$
$$= \frac{\delta}{\delta y}\left\{\frac{1}{1+\frac{1}{(1-\hat{q})\hat{a}}\exp\left(-\frac{\eta T_H}{2}(2y-\eta T_H)\right)}\right\} = \eta T_H \frac{\frac{1}{(1-\hat{q})\hat{a}}\exp\left(-\frac{\eta T_H}{2}(2y-\eta T_H)\right)}{\left[1+\frac{1}{(1-\hat{q})\hat{a}}\exp\left(-\frac{\eta T_H}{2}(2y-\eta T_H)\right)\right]^2}$$
$$= \eta T_H \Pr(T_H|0,y;\hat{a},\hat{q})\left(1-\Pr(T_H|0,y;\hat{a},\hat{q})\right) > 0.$$

This result stems from the Monotone Likelihood Ratio Property.

Corollary 1

The condition can be observed straightforwardly from equation (7).

Theorem 1

I start with the equilibrium in a lenient enforcement environment, assuming $\omega(\rho) \leq 0$. Equating the decision variables with their rational conjectures ($a = \hat{a}, \rho = \hat{\rho}, q = \hat{q} = 0$),[20] the equilibrium

[20] I insert $q = 0$ later to implicitly characterize an equilibrium in which the TCF quality q is exogenous.

is defined by the system of equations (3), (5), and (7):

$$a = (1-q)(1-(1-F(\rho-\eta T_H))k^M),$$
$$c = \frac{(1-q)af(\rho-\eta T_H)}{(1-q)af(\rho-\eta T_H)+f(\rho)}\, b.$$

Rearranging the above equations yields

$$\Phi_a = \frac{1}{a}(1-q)(1-(1-F(\rho-\eta T_H))k^M)-1=0,$$
$$\Phi_\rho = \frac{(1-q)af(\rho-\eta T_H)}{(1-q)af(\rho-\eta T_H)+f(\rho)} - \frac{c}{b} = 0.$$

The Jacobian matrix (i.e., the matrix of partials of the two equilibrium conditions) with respect to a and ρ is

$$J_1 = \begin{pmatrix} \frac{\partial\Phi_a}{\partial a} & \frac{\partial\Phi_a}{\partial\rho} \\ \frac{\partial\Phi_\rho}{\partial a} & \frac{\partial\Phi_\rho}{\partial\rho} \end{pmatrix},$$

where

$\frac{\partial\Phi_a}{\partial a} = -\frac{1}{a^2}(1-q)(1-(1-F(\rho-\eta T_H))k^M) < 0,$

$\frac{\partial\Phi_a}{\partial\rho} = \frac{1}{a}(1-q)f(\rho-\eta T_H)k^M > 0,$

$\frac{\partial\Phi_\rho}{\partial a} = (1-q)\underbrace{\frac{f(\rho-\eta T_H)f(\rho)}{((1-q)af(\rho-\eta T_H)+f(\rho))^2}}_{:=G>0} = (1-q)G > 0,$

$\frac{\partial\Phi_\rho}{\partial\rho} = \eta T_H(1-q)aG > 0.$

Observe that $Det(J_1) = \frac{\partial\Phi_a}{\partial a}\frac{\partial\Phi_\rho}{\partial\rho} - \frac{\partial\Phi_a}{\partial\rho}\frac{\partial\Phi_\rho}{\partial a} = -\frac{G}{a}\left[\eta T_H\gamma(\rho)+f(\rho-\eta T_H)k^M\right] < 0$, where $\gamma(\rho) \equiv 1-(1-F(\rho-\eta T_H))k^M$. Thus, there exists a single solution. Also, note that, for any $a \in (0,1)$ and exogenous $q \in [0,1)$,

$$\lim_{\rho\to\infty}\Phi_\rho = 1-\frac{c}{b} > 0 \text{ and } \lim_{\rho\to-\infty}\Phi_\rho = -\frac{c}{b} < 0,$$

due to $c \in (0,b)$. Since Φ_ρ is continuous, this implies that the audit threshold ρ must have a real solution in a lenient enforcement environment. Also, because $k^M \in (0,1)$ and the audit probability $1-F(\rho-\eta T_H) \in (0,1)$, a is also interior for any ρ. Thus, both ρ and a are interior. Inserting $q=0$ in equation (5), I obtain $a=\gamma(\rho)$. The condition for the audit threshold is obtained by inserting $q=0$ and $a=\gamma(\rho)$ in equation (3).

Next, I derive the equilibrium strategies in a strict enforcement environment with $\omega(\rho) \equiv (1-F(\rho-\eta T_H))\left(1+k^B\right)-1>0$. Equating all decision variables with their rational conjectures ($q=\hat{q}>0, a=\hat{a}, \rho=\hat{\rho}$), the equilibrium is defined by the system of equations (3), (5), and (7):

$$
\begin{aligned}
a &= (1-q)(1-(1-F(\rho-\eta T_H))k^M), \\
q &= T_H a\left((1-F(\rho-\eta T_H))(1+k^B)-1\right), \\
c &= \frac{(1-q)af(\rho-\eta T_H)}{(1-q)af(\rho-\eta T_H)+f(\rho)}\, b.
\end{aligned}
$$

Rearranging the above equations yields

$$
\begin{aligned}
\Phi_a &= \frac{1}{a}(1-q)(1-(1-F(\rho-\eta T_H))k^M)-1=0, \\
\Phi_q &= \frac{1}{q}a\left((1-F(\rho-\eta T_H))(1+k^B)-1\right)-\frac{1}{T_H}=0, \\
\Phi_\rho &= \frac{(1-q)af(\rho-\eta T_H)}{(1-q)af(\rho-\eta T_H)+f(\rho)}-\frac{c}{b}=0.
\end{aligned}
$$

The Jacobian matrix, that is, the matrix of partials of the three equilibrium conditions with respect to a, q and ρ, is

$$
J_2 = \begin{pmatrix}
\frac{\partial \Phi_a}{\partial a} & \frac{\partial \Phi_a}{\partial q} & \frac{\partial \Phi_a}{\partial \rho} \\
\frac{\partial \Phi_q}{\partial a} & \frac{\partial \Phi_q}{\partial q} & \frac{\partial \Phi_q}{\partial \rho} \\
\frac{\partial \Phi_\rho}{\partial a} & \frac{\partial \Phi_\rho}{\partial q} & \frac{\partial \Phi_\rho}{\partial \rho}
\end{pmatrix}.
$$

where

$\frac{\partial \Phi_a}{\partial a} = -\frac{1}{a^2}(1-q)(1-(1-F(\rho-\eta T_H))k^M) < 0,$

$\frac{\partial \Phi_a}{\partial q} = -\frac{1}{a}(1-(1-F(\rho-\eta T_H))k^M) < 0$

$\frac{\partial \Phi_a}{\partial \rho} = \frac{1}{a}(1-q)f(\rho-\eta T_H)k^M > 0$

$\frac{\partial \Phi_q}{\partial a} = \frac{1}{q}\left((1-F(\rho-\eta T_H))(1+k^B)-1\right) > 0$

$\frac{\partial \Phi_q}{\partial q} = -\frac{1}{q^2}a\left((1-F(\rho-\eta T_H))(1+k^B)-1\right) < 0$

$\frac{\partial \Phi_q}{\partial \rho} = -a\frac{1}{q}(1+k^B)f(\rho-\eta T_H) < 0$

$\frac{\partial \Phi_\rho}{\partial a} = (1-q)\frac{f(\rho-\eta T_H)f(\rho)}{((1-q)af(\rho-\eta T_H)+f(\rho))^2} = (1-q)G > 0$

$\frac{\partial \Phi_\rho}{\partial q} = -aG < 0$

$\frac{\partial \Phi_\rho}{\partial \rho} = \eta T_H(1-q)aG > 0$

The determinant of J_2 is

$Det(J_2) = \frac{\partial \Phi_a}{\partial a}\frac{\partial \Phi_q}{\partial q}\frac{\partial \Phi_\rho}{\partial \rho} + \frac{\partial \Phi_a}{\partial q}\frac{\partial \Phi_q}{\partial \rho}\frac{\partial \Phi_\rho}{\partial a} + \frac{\partial \Phi_a}{\partial \rho}\frac{\partial \Phi_q}{\partial a}\frac{\partial \Phi_\rho}{\partial q} - \frac{\partial \Phi_a}{\partial \rho}\frac{\partial \Phi_q}{\partial q}\frac{\partial \Phi_\rho}{\partial a} - \frac{\partial \Phi_a}{\partial a}\frac{\partial \Phi_q}{\partial \rho}\frac{\partial \Phi_\rho}{\partial q} - \frac{\partial \Phi_a}{\partial q}\frac{\partial \Phi_q}{\partial a}\frac{\partial \Phi_\rho}{\partial \rho}.$

Inserting and simplifying yields

$$\begin{aligned}
Det(J_2) = \frac{1-q}{q}G \times \Big\{ & 2\left(1+k^B\right)f(\rho-\eta T_H)(1-(1-F(\rho-\eta T_H))k^M) \\
& + \frac{1-q}{q}\left((1-F(\rho-\eta T_H))(1+k^B)-1\right)\left(\eta T_H(1-(1-F(\rho-\eta T_H))k^M)+f(\rho-\eta T_H)k^M\right) \\
& + \left((1-F(\rho-\eta T_H))(1+k^B)-1\right)\left(\eta T_H(1-(1-F(\rho-\eta T_H))k^M)-f(\rho-\eta T_H)k^M\right)\Big\}
\end{aligned}$$

$Det(J_2)$ is proportional to the bracket term. Further simplification using $\omega(\rho)$ and $\gamma(\rho)$ yields

$$Det(J_2) \propto 2\, q\, f(\rho-\eta T_H)\left[\left(1+k^B\right)\gamma(\rho) - k^M\omega(\rho)\right] + \omega(\rho)\, f(\rho-\eta T_H)k^M + \tag{13}$$

$$T_H\gamma(\rho)\,\omega(\rho)\,\eta \tag{14}$$

Note that (14) is unambiguously positive. Further, note that (13) is positive for any $\rho \in (-\infty, \infty)$ if $k^B \leq \overline{\overline{k}}^B$ guarantees $q \leq 1/2$. Then, $Det(J_2) > 0$ is given. The upper bound $\overline{\overline{k}}^B$ is defined as

$$\overline{\overline{k}}^B \equiv \frac{1 + T_H \gamma(\rho) F(\rho - \eta T_H)}{T_H \gamma(\rho) [1 - F(\rho - \eta T_H)]}. \tag{15}$$

Simultaneously solving $\Phi_a = 0$ and $\Phi_q = 0$, the only feasible solution for q and a can be shown to be:

$$a = \frac{\gamma(\rho)}{1 + T_H \gamma(\rho) \omega(\rho)},$$
$$q = \frac{T_H \gamma(\rho) \omega(\rho)}{1 + T_H \gamma(\rho) \omega(\rho)}.$$

Observe that a and q are always interior for any $\omega(\rho) \in (0, \infty)$ and any $\gamma(\rho) \in (0, 1)$, which is guaranteed by $k^M \in (0, 1)$. The assumption $k^B \leq \overline{\overline{k}}^B$ guarantees that, in equilibrium, Φ_ρ varies monotonically for all $\rho \in (-\infty, \infty)$ in a strict enforcement environment. Then, there exists a unique solution $\rho \in (-\infty, \infty)$, implying a unique interior solution $a \in (0, 1)$ and $q \in (0, 1/2]$. Overall, the equilibrium condition for the audit threshold is obtained by inserting the interior solution for q and a in equation (3). As will become clear from the later analyses, $\overline{\overline{k}}^B = 1/\left[T_H \left(1 - k^M\right)\right]$ if $k^M \leq \overline{k}^M := \frac{1+k^B}{1+2k^B}$ and $\overline{\overline{k}}^B = \left.\frac{1+T_H\gamma(\rho)F(\rho-\eta T_H)}{T_H\gamma(\rho)[1-F(\rho-\eta T_H)]}\right|_{\rho=\rho(\overline{c}_c^q)}$ if $k^M > \overline{k}^M$.

Lemma 2

The result $\frac{d\rho^*}{dc} > 0$ and thus $\frac{d(1-F(\rho^*-\eta T_H))}{dc} < 0$ is shown in the proof of Proposition 1 (iii). When evaluated at $\omega(\rho^*) + \kappa = 0$ with $\kappa > 0$ being sufficiently small, k^B strictly increases $\omega(\rho^*) + \kappa$ as $\frac{d\rho^*}{dk^B} = 0$ in a lenient enforcement environment. Thus, $\overline{c}_\omega$ increases in k^B.

Proposition 1 and 2

To begin, I show the results for a lenient enforcement environment (assuming $c > \overline{c}_\omega$), then for a strict enforcement environment (assuming $c < \overline{c}_\omega$), and lastly, summarize the result as established in Propositions 1 and 2. Since the mechanics of both Propositions' proofs are identical, I show them together. Where necessary, I use the index 1 (2) for a lenient (strict) enforcement environment.

Lenient enforcement environment Using a two-variable version of the Implicit Function Theorem for an arbitrary parameter $z \in \{c, \eta\}$, I solve the following system of equations for $\frac{da^*}{dz}$ and $\frac{d\rho^*}{dz}$:

$$J_1 \cdot \begin{pmatrix} \frac{da^*}{dz} \\ \frac{d\rho^*}{dz} \end{pmatrix} = - \begin{pmatrix} \frac{\partial \Phi_a}{\partial z} \\ \frac{\partial \Phi_\rho}{\partial z} \end{pmatrix}.$$

This yields

$$\begin{aligned}
\frac{da^*}{dz} &= \left[-\frac{1}{Det(J_1)}\right]\left\{\frac{\partial \Phi_\rho}{\partial \rho^*}\frac{\partial \Phi_a}{\partial z} - \frac{\partial \Phi_a}{\partial \rho^*}\frac{\partial \Phi_\rho}{\partial z}\right\} \propto \frac{\partial \Phi_\rho}{\partial \rho^*}\frac{\partial \Phi_a}{\partial z} - \frac{\partial \Phi_a}{\partial \rho^*}\frac{\partial \Phi_\rho}{\partial z} \\
\frac{d\rho^*}{dz} &= \left[-\frac{1}{Det(J_1)}\right]\left\{\frac{\partial \Phi_a}{\partial a^*}\frac{\partial \Phi_\rho}{\partial z} - \frac{\partial \Phi_\rho}{\partial a^*}\frac{\partial \Phi_a}{\partial z}\right\} \propto \frac{\partial \Phi_a}{\partial a^*}\frac{\partial \Phi_\rho}{\partial z} - \frac{\partial \Phi_\rho}{\partial a^*}\frac{\partial \Phi_a}{\partial z}
\end{aligned}$$

A change in c only affects Φ_ρ, as $\frac{\partial \Phi_\rho}{\partial c} = -\frac{1}{b} < 0$ and $\frac{\partial \Phi_a}{\partial c} = 0$. This directly translates into $\frac{da^*}{dc} > 0$ due to $-\frac{\partial \Phi_a}{\partial \rho}\frac{\partial \Phi_\rho}{\partial c} > 0$ (see (ii)) and $\frac{d\rho^*}{dc} > 0$ due to $\frac{\partial \Phi_a}{\partial a}\frac{\partial \Phi_\rho}{\partial c} > 0$ (see (iii)). $\frac{dq^*}{dc} = 0$ follows immediately from $c > \overline{c}_\omega$ (see (i)). This shows Proposition 1 if $c > \overline{c}_\omega$.

The effect of a change in η is less straightforward. Note that

$$\begin{aligned}
\frac{\partial \Phi_a}{\partial \eta} &= (1-q)\frac{k^M}{a}\frac{\partial F(\rho - \eta T_H)}{\partial \eta} = -(1-q)\frac{k^M}{a} T_H f(\rho - \eta T_H) < 0, \\
\frac{\partial \Phi_\rho}{\partial \eta} &= -\Pr(T_H|0,\rho;a,q)(1-\Pr(T_H|0,\rho;a,q))\frac{\partial - \frac{\eta T_H}{2}(2\rho - \eta T_H)}{\partial \eta} \\
&= \Pr(T_H|0,\rho;a,q)(1-\Pr(T_H|0,\rho;a,q))T_H(\rho - \eta T_H).
\end{aligned}$$

Then, the effect of η on a^* is given by

$$\frac{da^*}{d\eta} \propto \frac{\partial\Phi_\rho}{\partial\rho}\frac{\partial\Phi_a}{\partial\eta} - \frac{\partial\Phi_a}{\partial\rho}\frac{\partial\Phi_\rho}{\partial\eta} = G(1-q^*)^2 f(\rho^*-\eta T_H)k^M T_H\left(-\eta T_H - (\rho^*-\eta T_H)\right) \propto -\rho^*$$

Implicitly define $\overline{c}^{\#}$ as $\rho^*\left(\overline{c}^{\#}\right) = \eta T_H > 0$. Since $\lim\limits_{c\to 0} -\rho^* = \infty$ and $\lim\limits_{c\to\overline{c}^{\#}} -\rho^* = -\eta T_H$, and considering $\frac{d\rho^*}{dc} > 0$, there exists a unique threshold value $\overline{c}^a_\eta \in (0,\overline{c}^{\#})$ with $\overline{c}^{\#} < b$, such that if $c > \overline{c}^a_\eta$ ($c < \overline{c}^a_\eta$), it follows that $\frac{da^*}{d\eta} < 0$ ($\frac{da^*}{d\eta} > 0$). From Lemma 2, recall that $\overline{c}_\omega$ strictly increases in k^B. Also, we have $\lim\limits_{k^B\to 0} \overline{c}_\omega = 0$. Thus, there exist $k^B < \underline{k}^B \in (0,\overline{\overline{k}}^B)$, such that $\overline{c}_\omega < c < \overline{c}^a_\eta$ and thus $\frac{da^*}{d\eta} > 0$, and otherwise $\frac{da^*}{d\eta} < 0$ in a lenient environment (see (ii)).

The effect of η on ρ^* is given by

$$\frac{d\rho^*}{d\eta} \propto \frac{\partial\Phi_a}{\partial a}\frac{\partial\Phi_\rho}{\partial\eta} - \frac{\partial\Phi_\rho}{\partial a}\frac{\partial\Phi_a}{\partial\eta} = T_H G\frac{(1-q^*)^2}{a^*}\Omega^\rho_{1,\eta} \propto \Omega^\rho_{1,\eta},$$

where

$$\Omega^\rho_{1,\eta} \equiv k^M f(\rho^*-\eta T_H) - \left[1-(1-F(\rho^*-\eta T_H))k^M\right](\rho^*-\eta T_H).$$

Observe that $\Omega^\rho_{1,\eta} > 0$ if $c \le \overline{c}^{\#}$ (i.e., $\rho^* \le \eta T_H$). Further, $\Omega^\rho_{1,\eta}$ has the following limits:

$$\lim_{c\to\overline{c}^{\#}} \Omega^\rho_{1,\eta} \widehat{=} \lim_{\rho^*\to\eta T_H} \Omega^\rho_{1,\eta} = \frac{k^M}{\sqrt{2\pi}} > 0 \text{ and } \lim_{c\to b} \Omega^\rho_{1,\eta} \widehat{=} \lim_{\rho^*\to\infty} \Omega^\rho_{1,\eta} = -\infty < 0.$$

Also, for $c > \overline{c}^{\#}$, $\Omega^\rho_{1,\eta}$ is decreasing in c, since

$$\frac{\partial\Omega^\rho_{1,\eta}}{\partial\rho^*}\frac{d\rho^*}{dc} = \left[-2k^M f(\rho^*-\eta T_H)(\rho^*-\eta T_H) - \gamma(\rho^*)\right]\left.\frac{d\rho^*}{dc}\right|_{\rho^*>\eta T_H} < 0.$$

Taken together, the monotonicity for $c > \overline{c}^{\#}$ implies that there exists a unique threshold value $\overline{c}^\rho_{1,\eta} \in (\overline{c}^{\#}, b)$, such that if $c > \overline{c}^\rho_{1,\eta}$ ($c < \overline{c}^\rho_{1,\eta}$), it follows that $\frac{d\rho^*}{d\eta} < 0$ ($\frac{d\rho^*}{d\eta} > 0$). Note that $\overline{c}^a_\eta < \overline{c}^\rho_{1,\eta}$, which implies that $\overline{c}_\omega < c < \overline{c}^\rho_{1,\eta}$ exists if $0 < k^B < \overline{k}^B_1$. Then, we have $\frac{d\rho^*}{d\eta} > 0$, and otherwise $\frac{d\rho^*}{d\eta} < 0$ in a lenient environment (see (iii)). $\frac{dq^*}{d\eta} = 0$ follows immediately from $c > \bar{c}_\omega$ (see (i)). This shows Proposition 2 if $c > \bar{c}_\omega$.

Strict enforcement environment Now, I assume that $c < \bar{c}_\omega$. Using a three-variable version of the Implicit Function Theorem for an arbitrary parameter z, I solve the following system of equations for $\frac{d\Phi_a}{dz}$, $\frac{d\Phi_q}{dz}$ and $\frac{d\Phi_\rho}{dz}$, where the functions are defined in the Proof of Theorem 1:

$$J_2 \cdot \begin{pmatrix} \frac{da^*}{dz} \\ \frac{dq^*}{dz} \\ \frac{d\rho^*}{dz} \end{pmatrix} = - \begin{pmatrix} \frac{\partial\Phi_a}{\partial z} \\ \frac{\partial\Phi_q}{\partial z} \\ \frac{\partial\Phi_\rho}{\partial z} \end{pmatrix}.$$

This yields

$$\frac{da^*}{dz} = \left[-\frac{1}{Det(J_2)}\right]\left\{\left[\frac{\partial\Phi_q}{\partial q^*}\frac{\partial\Phi_\rho}{\partial\rho^*} - \frac{\partial\Phi_q}{\partial\rho^*}\frac{\partial\Phi_\rho}{\partial q^*}\right]\frac{\partial\Phi_a}{\partial z} + \left[\frac{\partial\Phi_a}{\partial\rho^*}\frac{\partial\Phi_\rho}{\partial q^*} - \frac{\partial\Phi_a}{\partial q^*}\frac{\partial\Phi_\rho}{\partial\rho^*}\right]\frac{\partial\Phi_q}{\partial z} + \left[\frac{\partial\Phi_a}{\partial q^*}\frac{\partial\Phi_q}{\partial\rho^*} - \frac{\partial\Phi_a}{\partial\rho^*}\frac{\partial\Phi_q}{\partial q^*}\right]\frac{\partial\Phi_\rho}{\partial z}\right\},$$
$$\frac{dq^*}{dz} = \left[-\frac{1}{Det(J_2)}\right]\left\{\left[\frac{\partial\Phi_q}{\partial\rho^*}\frac{\partial\Phi_\rho}{\partial a^*} - \frac{\partial\Phi_q}{\partial a^*}\frac{\partial\Phi_\rho}{\partial\rho^*}\right]\frac{\partial\Phi_a}{\partial z} + \left[\frac{\partial\Phi_a}{\partial a^*}\frac{\partial\Phi_\rho}{\partial\rho^*} - \frac{\partial\Phi_a}{\partial\rho^*}\frac{\partial\Phi_\rho}{\partial a^*}\right]\frac{\partial\Phi_q}{\partial z} + \left[\frac{\partial\Phi_a}{\partial\rho^*}\frac{\partial\Phi_q}{\partial a^*} - \frac{\partial\Phi_a}{\partial a^*}\frac{\partial\Phi_q}{\partial\rho^*}\right]\frac{\partial\Phi_\rho}{\partial z}\right\},$$
$$\frac{d\rho^*}{dz} = \left[-\frac{1}{Det(J_2)}\right]\left\{\left[\frac{\partial\Phi_q}{\partial a^*}\frac{\partial\Phi_\rho}{\partial q^*} - \frac{\partial\Phi_q}{\partial q^*}\frac{\partial\Phi_\rho}{\partial a^*}\right]\frac{\partial\Phi_a}{\partial z} + \left[\frac{\partial\Phi_a}{\partial q^*}\frac{\partial\Phi_\rho}{\partial a^*} - \frac{\partial\Phi_a}{\partial a^*}\frac{\partial\Phi_\rho}{\partial q^*}\right]\frac{\partial\Phi_q}{\partial z} + \left[\frac{\partial\Phi_a}{\partial a^*}\frac{\partial\Phi_q}{\partial q^*} - \frac{\partial\Phi_a}{\partial q^*}\frac{\partial\Phi_q}{\partial a^*}\right]\frac{\partial\Phi_\rho}{\partial z}\right\}.$$

Note from the Proof of Theorem 1 that $Det(J_2) > 0$. When $c < \bar{c}_\omega$, a change in c only affects Φ_ρ, as $\frac{\partial\Phi_\rho}{\partial c} = -\frac{1}{b} < 0$ and $\frac{\partial\Phi_a}{\partial c} = \frac{\partial\Phi_q}{\partial c} = 0$. This implies that $\frac{da^*}{dc} > 0$ due to $\left[\frac{\partial\Phi_a}{\partial q^*}\frac{\partial\Phi_q}{\partial\rho^*} - \frac{\partial\Phi_a}{\partial\rho^*}\frac{\partial\Phi_q}{\partial q^*}\right] > 0$ and $\frac{d\rho^*}{dc} > 0$ due to $\left[\frac{\partial\Phi_a}{\partial a^*}\frac{\partial\Phi_q}{\partial q^*} - \frac{\partial\Phi_a}{\partial q^*}\frac{\partial\Phi_q}{\partial a^*}\right] > 0$. This completes the proof of (ii) and (iii) of Proposition 1. In addition, observe that

$$\frac{dq^*}{dc} \propto \left[\frac{\partial\Phi_a}{\partial\rho^*}\frac{\partial\Phi_q}{\partial a^*} - \frac{\partial\Phi_a}{\partial a^*}\frac{\partial\Phi_q}{\partial\rho^*}\right] = \frac{(1-q^*)}{q^*}\frac{f(\rho^* - \eta T_H)}{a^*}\Omega_c^q,$$

where $\Omega_c^q \equiv k^M \left((1-F(\rho^*-\eta T_H))(1+k^B)-1\right)-\left[1-(1-F(\rho^*-\eta T_H))k^M\right]\left(1+k^B\right)$. Also, note that $\frac{dq^*}{dc} \propto \Omega_c^q$. The properties of Ω_c^q with respect to c are as follows:

$$
\begin{aligned}
&\frac{d\Omega_c^q}{dc} = \frac{\partial \Omega_c^q}{\partial \rho^*}\frac{d\rho^*}{dc} \propto \frac{\partial \Omega_c^q}{\partial \rho^*} = -2f(\rho^*-\eta T_H)\left(1+k^B\right)k^M < 0, \\
&\lim_{c\to 0}\Omega_c^q \widehat{=} \lim_{\rho^*\to -\infty}\Omega_c^q = k^M\left(1+2k^B\right)-\left(1+k^B\right), \\
&\lim_{c\uparrow \bar{c}_\omega}\Omega_c^q \widehat{=} \lim_{\omega(\rho^*)\downarrow 0}\Omega_c^q = -\left[1-(1-F(\rho^*-\eta T_H))k^M\right]\left(1+k^B\right) < 0.
\end{aligned}
$$

The effect of c thus depends on $\lim_{c\to 0}\Omega_c^q$, which is positive for $k^M > \frac{1+k^B}{1+2k^B} := \bar{k}^M \in (1/2,1)$ and negative for $k^M \leq \bar{k}^M$. Thus, if $k^M > \bar{k}^M$, the monotonicity of Ω_c^q implies that there exists a threshold value $\bar{c}_c^q \in (0,\bar{c}_\omega)$, such that if $c > \bar{c}_c^q$ ($c < \bar{c}_c^q$), it follows that $\frac{dq^*}{dc} < 0$ ($\frac{dq^*}{dc} > 0$). For $k^M \leq \bar{k}^M$, $\frac{dq^*}{dc} < 0 \; \forall \; c \in (0,\bar{c}_\omega)$. This completes (i) of Proposition 1.

Now, I complete the proof of Proposition 2. η affects the equilibrium conditions as follows.

$$
\begin{aligned}
\frac{\partial \Phi_a}{\partial \eta} &= -(1-q)\frac{k^M}{a}T_H f(\rho-\eta T_H) < 0, \\
\frac{\partial \Phi_q}{\partial \eta} &= \frac{a}{q}\left(1+k^B\right)T_H f(\rho-\eta T_H) > 0, \\
\frac{\partial \Phi_\rho}{\partial \eta} &= \Pr(T_H|0,\rho;a,q)\left(1-\Pr(T_H|0,\rho;a,q)\right)T_H(\rho-\eta T_H).
\end{aligned}
$$

Considering that $\frac{\partial \Phi_a}{\partial \eta}\frac{\partial \Phi_q}{\partial \rho}\frac{\partial \Phi_\rho}{\partial q} - \frac{\partial \Phi_q}{\partial \eta}\frac{\partial \Phi_a}{\partial \rho}\frac{\partial \Phi_\rho}{\partial q} = 0$, the equilibrium effect of η on a^* is given by

$$
\begin{aligned}
\frac{da^*}{d\eta} &\propto -\left\{\frac{\partial \Phi_q}{\partial q^*}\frac{\partial \Phi_\rho}{\partial \rho^*}\frac{\partial \Phi_a}{\partial \eta} - \frac{\partial \Phi_a}{\partial q^*}\frac{\partial \Phi_\rho}{\partial \rho^*}\frac{\partial \Phi_q}{\partial \eta} + \left[\frac{\partial \Phi_a}{\partial q^*}\frac{\partial \Phi_q}{\partial \rho^*} - \frac{\partial \Phi_a}{\partial \rho^*}\frac{\partial \Phi_q}{\partial q^*}\right]\frac{\partial \Phi_\rho}{\partial \eta}\right\} \\
&= -T_H\frac{1-q^*}{q^*}a^* G f(\rho^*-\eta T_H)\left[k^M\frac{1-q^*}{q^*}\omega(\rho^*)+\gamma(\rho^*)\left(1+k^B\right)\right]\rho^* \propto -\rho^*.
\end{aligned}
$$

Thus, as already shown for $c > \bar{c}_\omega$, there exists a unique threshold value $\bar{c}_\eta^a$, such that if $c > \bar{c}_\eta^a$ ($c < \bar{c}_\eta^a$), it follows that $\frac{da^*}{d\eta} < 0$ ($\frac{da^*}{d\eta} > 0$), completing (ii) of Proposition 2.

Next, considering that $\frac{\partial \Phi_a}{\partial \eta}\frac{\partial \Phi_q}{\partial \rho}\frac{\partial \Phi_\rho}{\partial a} - \frac{\partial \Phi_q}{\partial \eta}\frac{\partial \Phi_a}{\partial \rho}\frac{\partial \Phi_\rho}{\partial a} = 0$, the equilibrium effect of η on q^* is given by

$$\begin{aligned}
\frac{dq^*}{d\eta} &\propto -\left\{-\frac{\partial \Phi_q}{\partial a^*}\frac{\partial \Phi_\rho}{\partial \rho^*}\frac{\partial \Phi_a}{\partial \eta} + \frac{\partial \Phi_a}{\partial a^*}\frac{\partial \Phi_\rho}{\partial \rho^*}\frac{\partial \Phi_q}{\partial \eta} + \left[\frac{\partial \Phi_a}{\partial \rho^*}\frac{\partial \Phi_q}{\partial a^*} - \frac{\partial \Phi_a}{\partial a^*}\frac{\partial \Phi_q}{\partial \rho^*}\right]\frac{\partial \Phi_\rho}{\partial \eta}\right\} \\
&= -T_H \frac{(1-q^*)^2}{q^*} a^* G f(\rho^* - \eta T_H)\, \rho^* \Omega_c^q \propto -\rho^* \Omega_c^q \equiv \Omega_\eta^q.
\end{aligned}$$

Observe that if $k^M \leq \overline{k}^M$, $\Omega_c^q < 0 \;\forall\; c \in (0, \overline{c}_\omega)$. This implies that $\Omega_\eta^q \propto \rho^*$ and thus there exists a threshold value $\overline{c}_\eta^a$, such that if $c > \overline{c}_\eta^a$ ($c < \overline{c}_\eta^a$), it follows that $\frac{dq^*}{d\eta} > 0$ ($\frac{dq^*}{d\eta} < 0$). For $k^M > \overline{k}^M$, $\overline{c}_\eta^a$ has similar implications as long as $\overline{c}_c^q < c$ additionally holds, but the implications of $\overline{c}_\eta^a$ flip if $c < \overline{c}_c^q$. This completes (i) of Proposition 2.

Lastly, the equilibrium effect of η on ρ^* is given by

$$\begin{aligned}
\frac{d\rho^*}{d\eta} \propto & -\left[\frac{\partial \Phi_q}{\partial a^*}\frac{\partial \Phi_\rho}{\partial q^*} - \frac{\partial \Phi_q}{\partial q^*}\frac{\partial \Phi_\rho}{\partial a^*}\right]\frac{\partial \Phi_a}{\partial \eta} - \left[\frac{\partial \Phi_a}{\partial q^*}\frac{\partial \Phi_\rho}{\partial a^*} - \frac{\partial \Phi_a}{\partial a^*}\frac{\partial \Phi_\rho}{\partial q^*}\right]\frac{\partial \Phi_q}{\partial \eta} \\
& -\left[\frac{\partial \Phi_a}{\partial a^*}\frac{\partial \Phi_q}{\partial q^*} - \frac{\partial \Phi_a}{\partial q^*}\frac{\partial \Phi_q}{\partial a^*}\right]\frac{\partial \Phi_\rho}{\partial \eta} \\
& \propto T_H \frac{1-q^*}{(q^*)^2} G\, \Omega_{2,\eta}^\rho,
\end{aligned}$$

where

$$\Omega_{2,\eta}^\rho \equiv f(\rho^* - \eta T_H)\left[k^M \omega(\rho^*)(1-2q^*) + 2\gamma(\rho^*)(1+k^B)q^*\right] - \gamma(\rho^*)\,\omega(\rho^*)(\rho^* - \eta T_H)$$

Observe that $\Omega_{2,\eta}^\rho > 0$ if $\rho^* \leq \eta T_H$ (i.e., $c \leq \overline{c}^\#$). Further, we have $\lim_{c \uparrow \overline{c}_\omega} \Omega_{2,\eta}^\rho \,\widehat{=} \lim_{\omega(\rho^*) \downarrow 0} \Omega_{2,\eta}^\rho = 0$. Now, the equilibrium effects depend on the size of $\overline{c}_\omega$, which strictly increases in k^B (Lemma 2). There are two cases: First, consider $\overline{c}_\omega < \overline{c}^\#$, which occurs if $0 < k^B < \overline{k}_2^B$, where $\overline{k}_2^B$ is implicitly defined as $\overline{c}_\omega(\overline{k}_2^B) \stackrel{!}{=} \overline{c}^\#$. Then, the above characteristics imply $\Omega_{2,\eta}^\rho > 0 \Leftrightarrow \frac{d\rho^*}{d\eta} > 0 \;\forall\; c \in (0, \overline{c}_\omega)$. Second, consider $\overline{c}^\# < \overline{c}_\omega$, which requires $k^B > \overline{k}_2^B$. Feasibility requires $\overline{k}_2^B < \overline{\overline{k}}^B$. It can be verified that $\overline{k}_2^B < \overline{\overline{k}}^B$ can occur, as $\overline{c}_\omega > \overline{c}^\#$ is equivalent to $\lim_{c \to \overline{c}^\#} \omega(\rho^*) \,\widehat{=} \lim_{\rho^* \to \eta T_H} \omega(\rho^*) = \frac{1+k^B}{2} -$

$1 > 0$. For $k^M < \overline{k}^M$, we have $\overline{\overline{k}}^B = 1/\left[T_H(1-k^M)\right]$, such that if $1/\left[T_H(1-k^M)\right] > 1$, $\overline{c}_\omega > \overline{c}^\#$ is satisfied. Then, the sign of $\frac{d\rho^*}{d\eta}$ is indeterminate $\forall\, c \in (\overline{c}^\#, \overline{c}_\omega)$ but $\frac{d\rho^*}{d\eta} > 0 \;\forall\, c \in (0, \overline{c}^\#)$.

Lastly, we can summarize the insights. If $k^B < \overline{k}_2^B$, there exists a unique threshold value $\overline{c}^\rho_{1,\eta} \in (\overline{c}^\#, b)$, such that if $c > \overline{c}^\rho_{1,\eta}$ ($c < \overline{c}^\rho_{1,\eta}$), we have $\frac{d\rho^*}{d\eta} < 0$ ($\frac{d\rho^*}{d\eta} > 0$). If $k^B > \overline{k}_2^B$ and $\overline{c}_\omega < \overline{c}^\rho_{1,\eta}$, we have $\frac{d\rho^*}{d\eta} > 0$ if $c < \underline{c}^\rho_\eta = \overline{c}^\#$ and $\frac{d\rho^*}{d\eta} < 0$ if $c > \overline{c}^\rho_\eta = \overline{c}^\rho_{1,\eta}$. If $k^B > \overline{k}_2^B$ and $\overline{c}_\omega > \overline{c}^\rho_{1,\eta}$, with existence following from $\lim_{k^M \to 0} \overline{c}^\# = \overline{c}^\rho_{1,\eta}$, we have $\frac{d\rho^*}{d\eta} > 0$ if $c < \underline{c}^\rho_\eta = \overline{c}^\#$ and $\frac{d\rho^*}{d\eta} < 0$ if $c > \overline{c}^\rho_\eta = \overline{c}_\omega$. This completes Proposition 2 (iii).

Corollary 2

As established in the proof of Proposition 2, $\overline{c}^a_\eta \in (0, \overline{c}^\#)$ and $\underline{c}^\rho_\eta \in [\overline{c}^\#, b)$, implying $\overline{c}^a_\eta < \underline{c}^\rho_\eta$. Then, observe that since $\overline{c}^a_\eta < \underline{c}^\rho_\eta$, we also have $\frac{d\rho^*}{d\eta} > 0$ when $c < \overline{c}^a_\eta$. As $c < \overline{c}^a_\eta$ requires $\rho^*(\eta) < 0$ and $\overline{c}^a_\eta$ is defined at $\rho^*(\eta) = 0$, an increase of η decreases the range in which $\frac{da^*}{d\eta} > 0$ obtains. Thus, there is a threshold value $\overline{\eta}^a > 0$, such that only if $\eta < \overline{\eta}^a$, we have $\frac{da^*}{d\eta} > 0$. Lastly, observe that $\frac{d\rho^*}{dk^B} \propto \left[\frac{\partial \Phi_a}{\partial a^*}\frac{\partial \Phi_\rho}{\partial q^*} - \frac{\partial \Phi_a}{\partial q^*}\frac{\partial \Phi_\rho}{\partial a^*}\right] > 0$ and thus $\overline{\eta}^a$ increases in k^B.

Proposition 3

Lenient enforcement environment When $c > \overline{c}_\omega$, we have $CTP^* = \frac{1}{2}(1 + a^*)$, implying $\frac{dCTP^*}{dz} \propto \frac{da^*}{dz}$ with $z \in \{c, \eta\}$. The tax audit efficiency measures are $AP^* = 1 - F(\rho^* - \eta T_H)$ and $LTR^* = a^* F(\rho^* - \eta T_H)$. As $a^* = \gamma(\rho^*) = 1 - k^M AP^*$ with $k^M \in (0,1)$, we know that $\frac{da^*}{dz} \propto -\frac{dAP^*}{dz} \propto \frac{dF(\rho^* - \eta T_H)}{dz}$. Taking Propositions 1 and 2 into account, the effect on the tax audit efficiency measures depends on the sign of $\frac{da^*}{dz}$ only, with the sign of $\frac{da^*}{d\eta}$ depending on the threshold value $\overline{c}^a_\eta$.

Strict enforcement environment When $c < \overline{c}_\omega$, we have $CTP^* = \frac{1}{2}(1 + (1 - q^*)a^*)$. The first-order condition of $z \in \{c, \eta\}$ with respect to CTP^* is $\frac{dCTP^*}{dz} = \frac{\partial CTP^*}{\partial q^*}\frac{dq^*}{dz} + \frac{\partial CTP^*}{\partial a^*}\frac{da^*}{dz} =$

$\frac{1}{2}\left((1-q^*)\frac{da^*}{dz}-a^*\frac{dq^*}{dz}\right)$. This gives

$$\frac{dCTP^*}{dc} \propto 2\left(1+k^B\right)\gamma(\rho^*)+k^M f\left(\rho^*-\eta T_H\right)\omega\left(\rho^*\right)\frac{1-2q^*}{q^*}>0,$$
$$\frac{dCTP^*}{d\eta} \propto -\rho^*\left[\left(1+a^*\right)\left(1+k^B\right)\gamma(\rho^*)+k^M\left(\frac{1-q^*}{q^*}-a^*\right)\right] \propto -\rho^*,$$

since $k^B \leq \overline{\overline{k}}^B$ implies $\frac{1-2q^*}{q^*} \geq 0$ and $\frac{1-q^*}{q^*}-a^*>0$. Thus, for $\frac{dCTP^*}{d\eta}$, the same result as in a lenient enforcement environment applies.

Next, the behavior of z with respect to AP^* is $\frac{dAP^*}{dz}=-\left[\frac{\partial F(\rho^*-\eta T_H)}{\partial z}+\frac{\partial F(\rho^*-\eta T_H)}{\partial \rho^*}\frac{d\rho^*}{dz}\right]$. This yields $\frac{dAP^*}{dc}\propto -\frac{d\rho^*}{dc}<0$. Further, observe that

$$\frac{dAP^*}{d\eta}=f\left(\rho^*-\eta T_H\right)\left(T_H-\frac{d\rho^*}{d\eta}\right)\propto 1-\frac{\Omega^{\rho}_{2,\eta}}{\Omega^{\rho}_{2,\eta}+\gamma(\rho^*)\omega(\rho^*)\rho^*}.$$

Since $Det(J_2)>0$ implies $\Omega^{\rho}_{2,\eta}+\gamma(\rho^*)\omega(\rho^*)\rho^*>0$, it holds that $\frac{dAP^*}{d\eta}\propto\rho^*$, with the enforcement-strength dependent implications as already established.

Lastly, the effect on LTR^* is $\frac{dLTR^*}{dz}=\frac{1}{2}\left(\frac{d(1-q^*)a^*}{dz}F\left(\rho^*-\eta T_H\right)-\frac{dAP^*}{dz}(1-q^*)a^*\right)$. This yields $\frac{dLTR^*}{dc}>0$ due to $\frac{d(1-q^*)a^*}{dc}>0$ and $\frac{dAP^*}{dc}<0$ as shown above, as well as $\frac{dLTR^*}{d\eta}\propto-\rho^*$ because $\frac{dCTP^*}{d\eta}\propto-\rho^*$ and $-\frac{dAP^*}{d\eta}\propto-\rho^*$, with the enforcement-strength dependent implications as already established.

Figures

Figure 1: Timeline

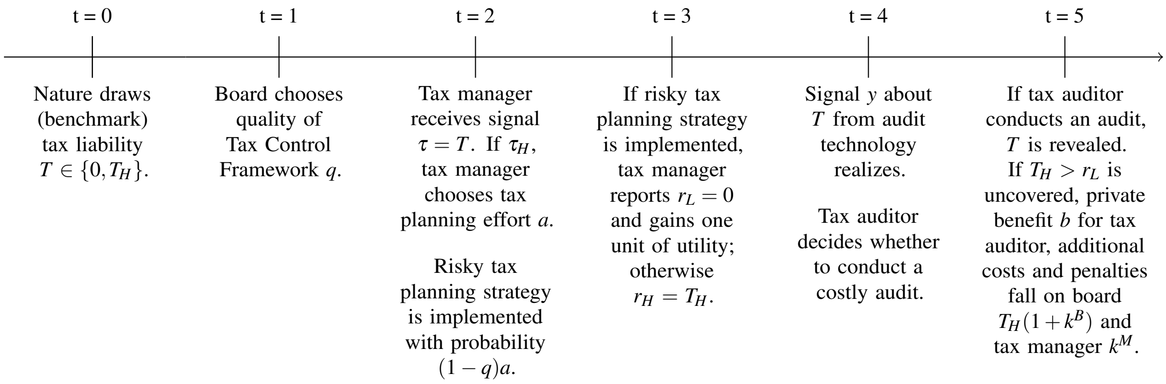


Figure 2: Reduced game tree without dominated strategies

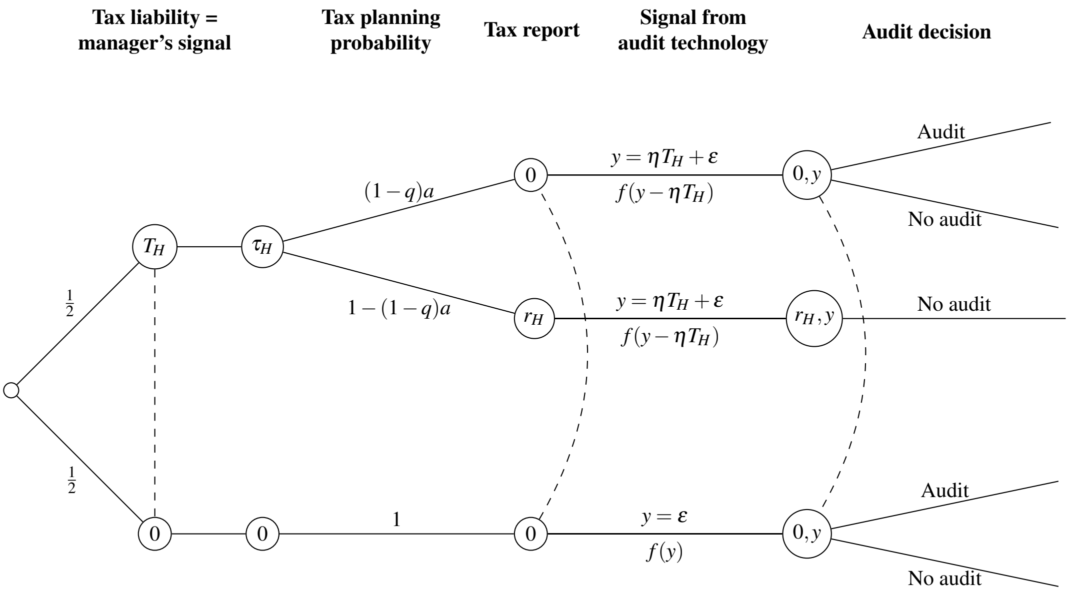
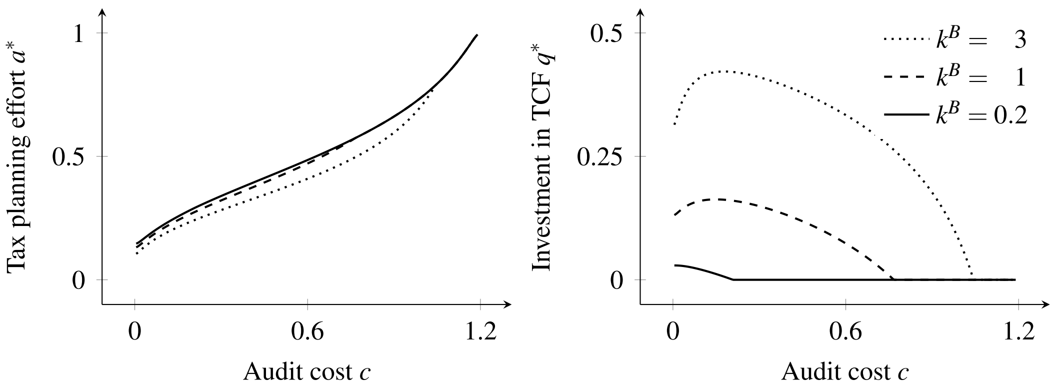
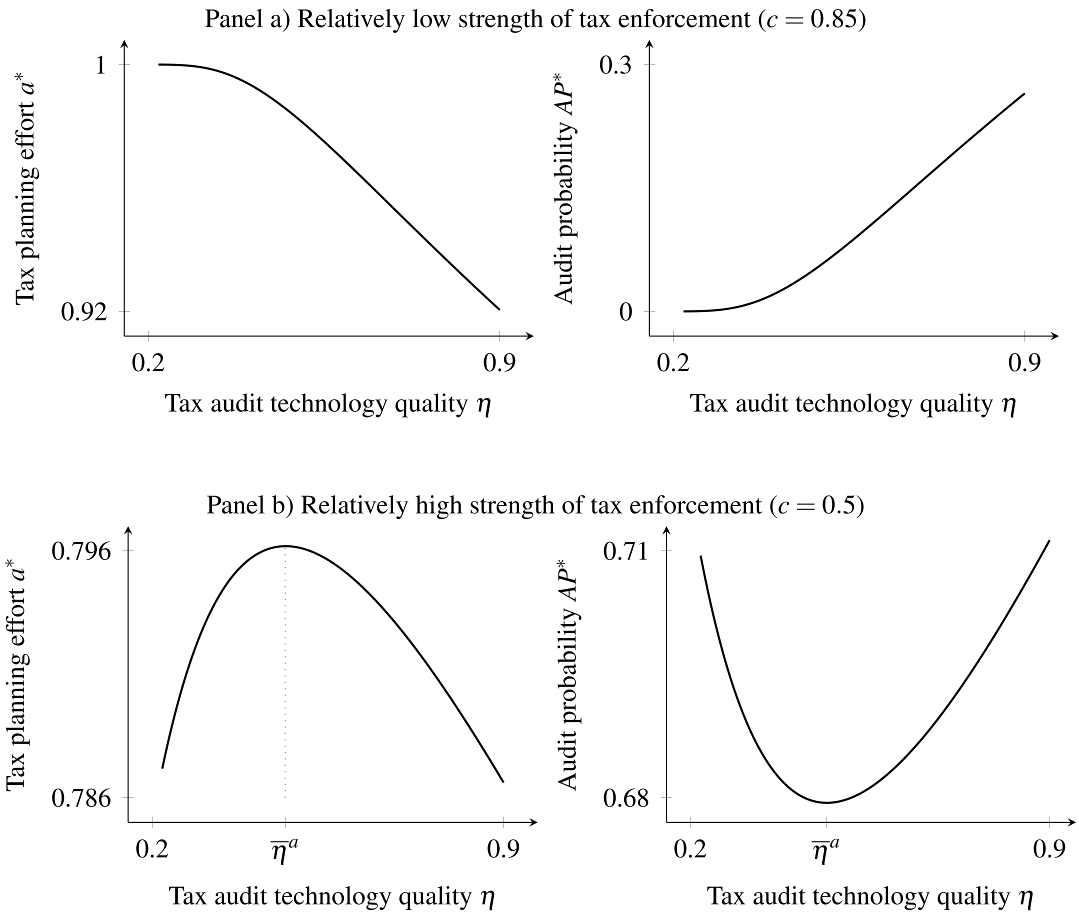


Figure 3: Effects of strengthening tax enforcement on tax planning effort and investment in the Tax Control Framework



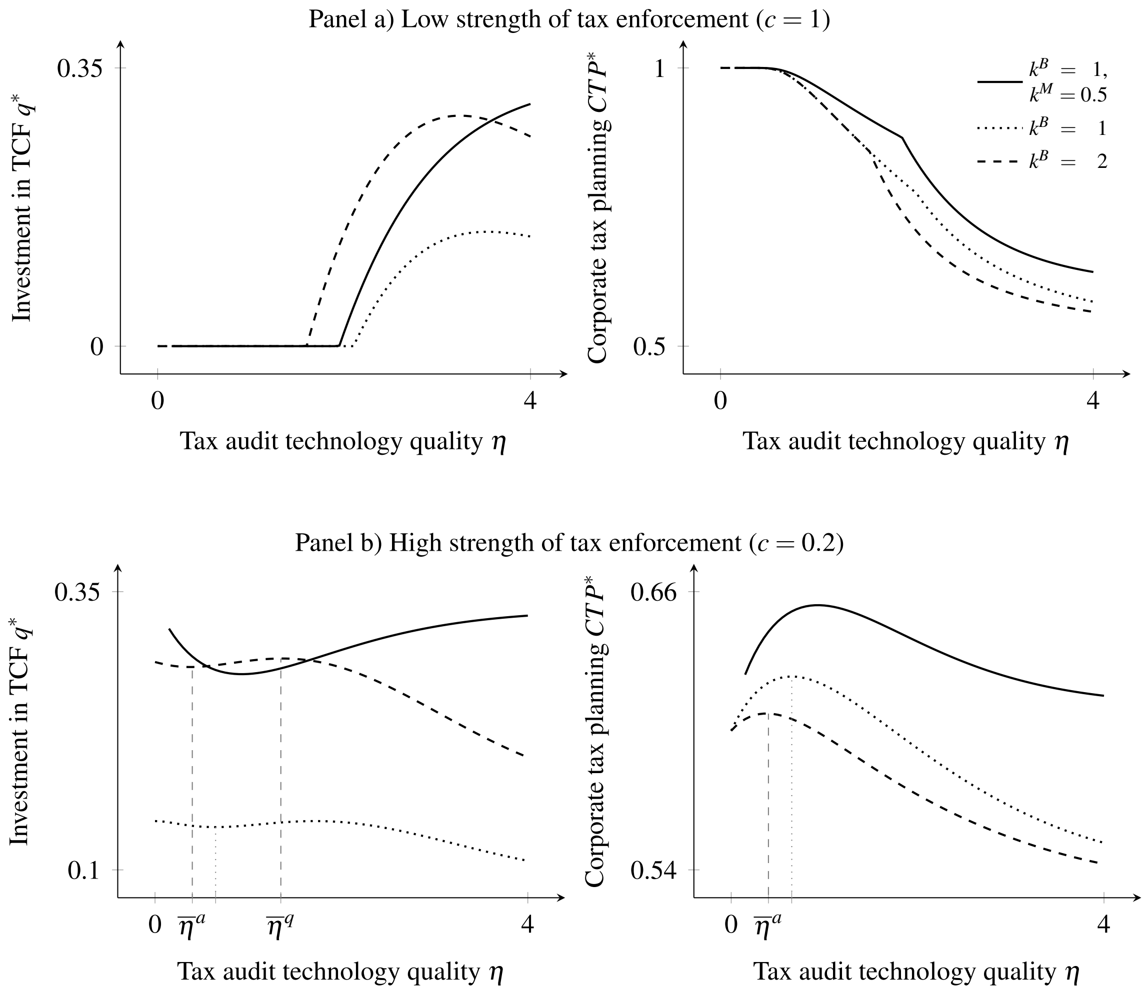
Notes: This figure illustrates Proposition 1 for three different levels of board penalties k^B. The figure shows that a decrease in audit costs c (i.e., strengthening tax enforcement) unambiguously decreases the tax manager's planning effort. Further, for $k^B = 1$ (dashed line) and $k^B = 3$ (dotted line), the board's TCF investment is an inversely U-shaped function in a strict enforcement environment, while for $k^B = 0.2$ (straight line), decreasing audit costs unambiguously increase TCF investment. The figure also demonstrates that higher board penalties increase the domain in which a TCF investment occurs (Lemma 2). The other parameters are chosen as $b = 1.2, k^M = 0.85, T_H = 1, \eta = 1.5$.

Figure 4: Effects of increasing the tax audit technology quality on tax planning effort and audit probability



Notes: This figure illustrates Proposition 2 (ii). η is restricted to be in the interval $\eta \in (0.2, 0.9)$ to guarantee a lenient enforcement environment when $c = 0.5$. Also, in a lenient environment, observe that we have $a^* = 1 - AP^* \cdot k^M$, highlighting the inverse patterns of tax planning effort a^* and audit probability AP^*. Panel a) shows that an increase in the tax audit technology quality η unambiguously decreases the tax manager's tax planning effort a^* and increases the audit probability AP^* if the strength of tax enforcement is low ($c = 0.85$) in a lenient enforcement environment (i.e., relatively low). Panel b) highlights that tax planning effort increases (audit probability decreases) if the strength of tax enforcement is relatively high ($c = 0.5$) and the status quo tax audit technology quality is low $\eta < \overline{\eta}^a \approx 0.47$ if $c = 0.5$. The upper bound $\overline{\eta}^a$ arises because, for a given strength of tax enforcement, $\overline{c}^a_\eta$ decreases in η (see Corollary 2). The other parameters are chosen as $b = 1.2, k^M = 0.3, T_H = 1, k^B = 0.4 < \underline{k}^B$.

Figure 5: Effects of increasing the tax audit technology quality on investment in the Tax Control Framework and corporate tax planning



Notes: This figure illustrates Propositions 2 (i) and 3, and Corollary 2. The left graph illustrates the effect of increasing tax audit technology quality η on TCF investment q^*, and the right graph on the corporate tax planning probability CTP^*. The tax manager's planning effort a^* and the lost tax revenues LTR^* (the audit probability of a risky tax planning strategy AP^*) follow the same pattern (follows the inverse pattern) as $CTP^*(\eta)$. The results are illustrated for high tax manager penalties ($k^M = 0.9$) with low ($\underline{k}^B < k^B = 1$, dotted lines) and high board penalties ($k^B = 2$, dashed lines). In addition, the solid line depicts how the low board penalty case changes when $k^M = 0.5 < \overline{k}^M$ is guaranteed. If the strength of tax enforcement is low ($c = 1$, panel a), an increase in η unambiguously decreases CTP^*, and unambiguously increases q^* only for $k^M = 0.5$. For $k^M = 0.9$, q^* first increases and then decreases in η, as at some sufficiently high η, we get $c = 1 < \overline{c}_c^q(\eta)$. If the strength of tax enforcement is high ($c = 0.2$, panel b), CTP^* increases (decreases) for $\eta < \overline{\eta}^a$ ($\eta > \overline{\eta}^a$), with the inverse pattern for q^* only occurring when $k^M = 0.5$. Observe that for $k^B = 1$, the domain for the adverse effect of η is greater ($\overline{\eta}^a|_{k^B=1} > \overline{\eta}^a|_{k^B=2}$), suggesting that the efficacy of this policy instrument is weaker for firms with lower vis-à-vis higher enforcement-induced costs from tax planning. Lastly, for $c = 0.2$ and $k^M = 0.9$, the direction of the effect of η on q^* flips two times, as for $\eta < \overline{\eta}^a$, we have $\overline{c}_\eta^a(\eta) > 0.2 > \overline{c}_c^q(\eta)$, for $\overline{\eta}^a < \eta < \overline{\eta}^q$, we additionally get $0.2 > \overline{c}_\eta^a(\eta)$, and for $\overline{\eta}^q < \eta$, we have $\overline{c}_\eta^a(\eta) > c > \overline{c}_c^q(\eta)$. The other parameters are $b = 1.2$ and $T_H = 1$.

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