Lobbying and uniform disclosure regulation

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Abstract

This study examines the costs and benefits of uniform accounting regulation in the presence of heterogeneous firms who can lobby the regulator. A commitment to uniform regulation reduces economic distortions caused by lobbying by creating a free-rider problem between lobbying firms at the cost of forcing the same treatment on heterogeneous firms. Resolving this trade-off, an institutional commitment to uniformity is socially desirable when firms are sufficiently homogeneous or the costs of lobbying to society are large. We show that regulatory intensity for a given firm can be increasing or decreasing in the degree of uniformity, even though uniformity always reduces lobbying. Our analysis sheds light on the determinants of standard-setting institutions and their effects on corporate governance and lobbying efforts.

Keywords: Disclosure, Regulation, Lobbying

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1 Introduction

The question of whether to standardize disclosure regulation is a fundamental and unanswered problem in accounting research (Dye and Sunder [2001]; Bertomeu and Cheynel [2013]). Individualized regulation (IR) allows for tailoring accounting policies to the characteristics of each regulated firm. Yet, for the most part, accounting rules take a uniform regulation (UR) approach in which, for example, the principles of US GAAP or IFRS are applied across different firms and industries.[1] Common arguments in favor of UR are that investors may not understand excessive diversity in standards and that uniformity promotes comparability (e.g., Ray [2012]). We offer an alternative, lesser known benefit of uniformity. Because firms must lobby over the same set of rules, uniform regulations imply that each lobbyist's personally costly lobbying effort benefits other lobbyists. Uniformity thus creates a free-rider problem between lobbyists, and greater uniformity exacerbates this free-riding problem. Hence, uniform rules are less vulnerable to political influence and serve to reduce equilibrium lobbying efforts and their social costs.[2]

In the spirit of Peltzman [1976] and Stigler [1971], and recently Bertomeu and Magee [2011], we model a regulator that is in charge of disclosure regulation for multiple firms. Each firm faces an agency problem in that an insider (e.g., a blockholder) can take an action that benefits her while imposing a cost on outsiders (e.g., dispersed investors). As a motivating example, we focus on asset diversion (e.g., Shleifer and Vishny [1997]), which is inefficient because the cost to outsiders exceeds the insider's benefit. Regulation can improve social welfare by reducing insiders' ability to divert firm resources for their own gain.

To capture trade-offs between UR and IR systems, we include a cost to the regulator of

[1] The current FASB chairman, Russel Golden, espoused the benefits of standards in recent remarks Golden [2013], stating that "standardized financial reporting in the late 19th and early 20th Centuries helped develop the nation's steel manufacturing capacity."

[2] In this vein, Representative John Dingell (D-MI) said in reference to the FASB: "Their job is to promulgate accounting standards of high quality that do not favor any particular industry or interest group and that maintain the credibility of our financial reporting system. The unparalleled success of the U.S. capital markets is due in no small part to the high quality of the financial reporting and accounting standards promulgated by FASB." (as quoted in Beresford [2001])

setting different regulation for different firms. A higher cost of setting different regulation represents a more uniform regulatory environment. In our model, this cost operationalizes an institutional commitment to common standards, for example in the form of conceptual statements or the established preferences of standard-setters. Absent lobbying, the regulator chooses the intensity of regulation to minimize diversion, subject to the costs of regulation. While expected diversion decreases in regulatory intensity, the direct costs of regulation also increase in regulatory intensity and, potentially, in regulatory heterogeneity.

In our model, insiders can lobby to weaken disclosure regulation, which enables them to misreport and divert cash.[3] We show how a commitment to uniform regulation can increase regulatory intensity and social welfare. Specifically, more uniform regulation reduces insiders' incentives to lobby the regulator. As a stark example, consider a perfectly uniform regulatory system. Here, the regulator sets identical regulatory intensities for all firms based only on aggregate rather than firm-specific lobbying. Therefore, relative to individualized regulation, each insider's lobbying has a stronger effect on the regulation faced by all other firms but a weaker impact on the regulation she faces. Because lobbying is individually costly to insiders, they free-ride on each other's efforts. This free-rider problem, driven by regulatory uniformity, hurts insiders but benefits society because it reduces insiders' incentives to lobby.[4]

When firms are heterogeneous, which we capture with differences in the magnitude of the diversion problem across firms, changes in regulatory uniformity have two effects. We term the first the convergence effect. It causes the regulatory intensities for the firms to converge because of the increased cost of heterogeneous regulation to the regulator. A firm with a

[3]Lobbying has played a central role in securities regulation – in particular in the context of accounting rules where new standards are (tacitly) approved by political bodies. For example, discussions in Coates [2007] and Gipper, Lombardi, and Skinner [2013] highlight the influence of political forces on regulation related to securities law and accounting, including political campaign contributions, the "revolving door" (see, e.g., GAO [2011]; POGO [2011]), public persuasion strategies (Condon [2012]), and quid pro quo arrangements. Similarly, Hochberg, Sapienza, and Vissing-Jørgensen [2009] suggests that managers lobbied against SOX to maintain insider benefits.

[4]In a similar vein, Rodrik [1986], suggests that industry-wide tariffs are socially preferable to firm-specific subsidies because they promote free-riding on firms' tariff-seeking. Although the intuition is similar, our study focuses on agency conflicts between investors and managers rather than problems of under- or over-production caused by product market distortions.

higher (lower) regulatory intensity experiences a decrease (increase) in regulatory intensity. The convergence effect is welfare-reducing because it reflects an increasing constraint on the regulator to target regulations at the average firm rather than at each individual firm's optimum. In our setting, the firm with the larger agency problem faces more intense regulation, and the convergence effect causes its regulatory intensity to decrease.

In addition to the convergence effect, an increase in uniformity increases each insider's free-riding on the other's lobbying, as described above. We term this the free-riding effect. In contrast to the convergence effect, the free-riding effect reduces the insiders' influence on the regulator and is, therefore, welfare increasing. For the firm with the smaller agency problem, convergence and free-riding each imply a higher regulatory intensity. For the firm with the larger agency problem, convergence reduces regulatory intensity and free-riding increases it. Which of these two effects dominates depends on how problematic lobbying is in the economy. The convergence effect dominates if lobbying is prohibitively costly to insiders. In contrast, the free-riding effect dominates if insiders bear relatively low personal costs for lobbying.

In an extension to our model, we consider the optimal degree of uniformity from the perspective of an ex-ante planner (e.g., a legislature) concerned with minimizing the welfare losses from diversion and the implementation costs borne by the regulator. We show that the optimal degree of regulatory uniformity from the planner's perspective decreases with firm heterogeneity and increases with the magnitude of the agency problems related to lobbying and diversion. Additionally, allowing the degree of regulatory uniformity to be endogenously chosen by the planner changes how agency problems related to lobbying affect equilibrium regulatory quality.

Within the context of our model, we find that regulatory uniformity reduces lobbying activities. This suggests that jurisdictions where lobbying is relatively easy should feature institutions with high uniformity (and vice-versa). Similarly, jurisdictions with more diversity in economic activity should feature institutions with low uniformity. These predictions can be tested with inter-jurisdictional comparisons and in settings where there is a change in the degree of uniformity of standards (e.g., exchange mergers). Furthermore, public comment letters and lobbying expenditures offer a setting in which lobbying actions may be partly observed.

Our results speak to the benefits of uniform regulation in a number of settings. These include settings where regulation can be industry-specific or uniform across industries, where an economy either has one financial exchange or multiple exchanges that are regulated separately, where accounting standards are either domestic (local GAAP) or multinational (IFRS), and where the auditing environment is characterized by one auditor with a consistent set of policies or numerous auditors each with their own policies. In each of these settings, there are benefits to allowing entity-specific treatments that address firm heterogeneity and uniform treatment that promotes free riding and thereby mitigates agency problems.

The foundation for our study is the early literature on regulatory choice in economics (e.g., Arrow [1950]) and accounting (e.g., Demski [1973, 1974]). Both streams of literature help explain observed regulatory choices by highlighting how lobbying and regulatory capture cause regulators to choose non-welfare-maximizing regulations (e.g., Stigler [1971] and Watts and Zimmerman [1978]). Recent research in this stream of literature has examined how various institutional features (e.g., voting rules) affect the interaction between special interest groups and regulators. For example, Bebchuk and Neeman [2010] investigate a model where different groups lobby the regulator over the level of investor protection in a perfectly uniform regulatory regime. Similar to our analysis, Bebchuk and Neeman [2010] assume that regulation helps to reduce rent seeking activities by insiders. The model in Chung [1999] features managerial lobbying over accounting regulation, allowing for free riding but focusing on issues related to whether outsiders can observe managers' lobbying. In Bertomeu and Magee [2014], regulatory outcomes are chosen by a combination of a majoritarian vote by firms and the standard setter's bliss point. There, political pressure need not result in the investors' preferred regulation but, instead, can lead to cycles of increased regulation and sudden deregulation. Finally, Perotti and Volpin [2008] predict that political accountability of the regulator and investor protections are positively associated. To our knowledge, our study is the first to formally capture the effects of uniformity in a model centered on agency conflicts and lobbying.

On the topic of uniform versus individualized standard-setting, Sunder [1988] broadly discusses the economics and mechanisms of standardization, and Gao, Wu, and Zimmerman [2009] highlight the compliance costs imposed on heterogeneous firms by the one-size-fits-all Sarbanes-Oxley Act. One way to impose individualized regulation is to allow firms to choose from a set of multiple standards devised by competing standard-setters. Mahoney [1997] and Kahan [1997] discuss arguments for and against federal securities regulation as opposed to exchanges that compete for listings and volume by using different regulatory policies. Similarly, Dye and Sunder [2001] examine arguments for and against allowing US firms to choose whether to report following US GAAP or IFRS, and Bertomeu and Cheynel [2013] show that firms' market values can be higher when they can choose between competing reporting standards. Ray [2012] models a setting in which individualized regulation is costly because it forces outsiders and regulators to adjust to different types of regulation, leading to an otherwise avoidable multiplication of costly efforts. Our model shows instead that uniform standards can reduce harmful lobbying by inducing a free-rider problem between lobbyists.

In our model, disclosure is used as a regulatory solution to the problem of managerial diversion. Several studies have examined disclosure's effect on diversion in settings that abstract from regulatory choices and focus on firm-level governance. In Gao [2013] and Caskey and Laux [2015], for example, better disclosures reduce a manager's ability to divert through privately beneficial overinvestment. In Beyer, Guttman, and Marinovic [2014], a manager can manipulate the disclosure on which his compensation is based, providing a contractual connection between disclosure quality and the ability to divert. Armstrong, Guay, and Weber [2010] provide an empirically-oriented review of the interaction between disclosure and corporate governance. Our study contributes to this literature by showing that the commitment to uniform disclosure regulation can help to alleviate the diversion problem. Another strand of literature examines optimal standard setting in which the objective is to maximize social welfare. This literature abstracts away from frictions in the regulatory process such as lobbying. Friedman, Hughes, and Saouma [2016], for example, examine costs and benefits of mandated reporting biases (e.g., conservatism) in an oligopolist product market and suggest that biased reporting is warranted because it has positive welfare implications. Chen, Hemmer, and Zhang [2007] show that certain disclosure properties can improve risk sharing. Gao, Sapra, and Xue [2016] show that, to reduce the extent of manipulative behavior, optimal regulation entails a mixture of principals- and rules-based standards. Our study focuses on a political friction, lobbying, that influences regulatory choice.

2 The model

2.1 Model setup

We develop a model of political influence and investor protection in a capital market, similar in spirit to Bebchuk and Neeman [2010]. We begin with a baseline model that features a conflict between firm insiders and outsiders that potentially differs across firms, a regulator who can help mitigate the conflicts, and the ability for insiders to influence the regulator.

There are two firms, denoted by $i \in \{1, 2\}$, and a regulatory agency. The two firms could also be interpreted as two lobbies, each representing a set of different firms.[5] Firms are composed of risk-neutral insiders and outsiders and there exists an agency problem between these two parties. This conflict is representative of conflicts between managers and shareholders, shareholders and debtholders, or blockholders and dispersed owners, for example. While outsiders have a claim on the assets or cash flows of the firm, insiders have an opportunity to pursue private benefits, for example, through diversion of funds or

[5] We take the two firms (or lobbies) as given, consistent with Grossman and Helpman [1994].

consumption of perks and slack.[6] To fix language, we will refer to the personally beneficial action that the insider takes as diversion.

Specifically, when the insider diverts funds, she gains $D_i > 0$, but this imposes a cost on outsiders of $A_i = (1 + \lambda) D_i$, where $\lambda > 0$.[7] Insider diversion of funds is therefore socially inefficient and imposes a net welfare loss of $D_i \lambda > 0$. Our assumption of $D_i > 0$ implies that the insider always prefers to take the personally beneficial action.[8] Furthermore, we assume that (i) firm i's cash flows, $\tilde{x}_i \in \mathbb{R}$, are randomly distributed with a mean of μ_i; (ii) the insider can divert even if realized cash flows, x_i, are negative; and (iii) cash flows are not contractible. Assumptions (i) and (ii) imply that outsiders cannot perfectly infer whether the insider has diverted funds, and thus cannot write a forcing contract. Assumption (iii) is made to simplify the exposition, but is not essential for the main intuition.[9]

We introduce $q \in [0, 1)$ to parameterize firm heterogeneity. Specifically, $D_1 = D(1 - q)$ and $D_2 = D(1 + q)$, such that D is the average potential diversion in the economy. If $q = 0$, the firms are homogeneous. For $q > 0$, firm 2 faces a larger potential diversion problem than firm 1, since $D_2 > D_1$. For ease of exposition, we refer below to firm 2 as the bad firm and firm one as the good firm because firm 2 has a (weakly) more severe diversion problem.

Regulation limits the insider's opportunity to divert by requiring the disclosure of asset values or cash flow realizations. Empirically, for example, Perotti and Volpin [2008] use accounting standards as a measure of investor protection, consistent with standards helping protect investors from expropriation. Formally, if the insider is forced to truthfully disclose

[6] Albuquerue and Wang [2008] assumes that insiders "steal" cash flows at a personal cost. Shleifer and Vishny [1997] and [2000] discuss managerial diversion and expropriation of value from investors, noting their close relation to agency problems and perquisite consumption as outlined in Jensen and Meckling [1976]. Schipper [1981] provides an early explicit reference to asset diversion by highlighting how insiders "maximize their own wealth by diverting firm assets to their private use" (p. 87).

[7] Firms in our model are heterogeneous in the size of the potential diversion, although they are homogeneous in the proportional costs of diversion, $1 + \lambda$.

[8] We assume the cost, A_i is borne only by the outsiders.

[9] We require only that cash flows are sufficiently random to preclude a contract that forces the insider not to divert. Technically, our assumptions imply that cash flows to outsiders have non-moving support. In an earlier version of this paper, we relaxed assumption (iii) and showed that contracting on cash flows allows the outsiders to mitigate (and for some parameterizations, eliminate) the problems related to diversion and lobbying.

cash flows $\tilde{x}_i$, then she will not have the opportunity to divert A_i, consume D_i, and misreport net cash flows of $\tilde{x}_i - A_i$ to outsiders. Specifically, we model the intensity of regulation governing each firm i as the probability π_i that an insider is unable to divert.[10] The insider can misreport and expropriate value from outsiders with probability $(1 - \pi_i)$.[11]

Finally, before the regulator specifies the regulatory intensities, each insider can exert effort B_i to lobby the regulator to relax the regulatory intensity for his firm. In the model, neither outsiders nor insiders can form lobbying groups of any kind. This is consistent with, for instance, small, disorganized, competitive investors and disparate firms. Insiders and outsiders also cannot contract on the type of lobbying activity we model, nor can insiders commit *ex ante* not to lobby *ex post*. The inability to contract or commit on this dimension of influence seems plausible, as, for example, it would be difficult for arms-length investors to determine what exact policies managers were promoting in private meetings with regulators, i.e., whether managers were pursuing beneficial trade protections or harmful regulatory slack. Table 1 shows the timeline.

Table 1: Timeline

$t = 1$	$t = 2$	$t = 3$
Insiders choose lobbying efforts B_i	Regulator chooses regulatory intensities π_i	Insider diversion may or may not occur

Insiders are risk neutral. To focus on the central tensions in our model, we assume that insiders have no claims on the firms' cash flows, $\tilde{x}_i$, and benefit only from potential diversion. Insiders incur a personal cost of lobbying the regulator, $\frac{c}{2}B_i^2$. We interpret the parameter

[10] For instance, a higher π_i could represent a regulator's more stringent interpretation of existing regulation (e.g., the SEC's interpretations of the Dodd-Frank Act) or legislative actions that adjust existing rules (e.g., the 1964 Securities Acts Amendments). As modeled, π_i also encompasses enforcement, which can have a significant influence on regulatory efficacy (Christensen, Hail, and Leuz [2013]).

[11] Note that regulation leads to an ex ante probability of truthful disclosure. This is similar to Bertomeu and Magee [2015], where firms have to reveal all signals below a threshold and withhold all signals above the threshold, meaning that higher regulatory thresholds increase the ex ante probability of truthful disclosure because more signal realizations will be disclosed. In our model, an insider has to disclose the firm's cash flows truthfully with probability π_i, independent of the realization of cash flows. With probability $1 - \pi_i$, insiders can manipulate the report, claim that the cash flows were lower, and divert the difference.

$c > 0$ as reflecting the ability of outsiders to effectively monitor and deter insiders' lobbying. A higher value of c reflects a less severe insider-outsider agency problem on lobbying that facilitates the subsequent diversion problem. Each insider's expected utility is given by

$$U_i = (1 - \pi_i) D_i - \frac{c}{2} B_i^2. \tag{1}$$

With probability $(1 - \pi_i)$, the insider is able to take the personally beneficial action and consume D_i. Insiders always bear the cost of lobbying because they lobby the regulator before potential diversion occurs. Outsiders receive (unmodeled) payments net of the (modeled) costs of insider diversion. The collective expected utility of outsiders in firm i, which is also equal to the value of the outsiders' claim, is given by $V_i = \mu_i - (1 - \pi_i) A_i$.

The timeline above implies that when the regulator decides on the regulatory intensity at $t = 2$, the costs of lobbying, $\frac{c}{2} B_i^2$, are sunk. The regulator influences aggregate utility by using regulation to reduce the expected losses from diversion:

$$L(\pi_1, \pi_2; D_1, D_2, \lambda) = -\lambda D_1 (1 - \pi_1) - \lambda D_2 (1 - \pi_2) \tag{2}$$

The welfare-interested regulator is only concerned about diversion because of the welfare loss, λD_i, that it imposes on society.[12] This welfare loss occurs with probability $(1 - \pi_i)$, for each firm i. The regulator wants to minimize this welfare loss subject to the costs of regulation.[13]

[12] Note that this implies that the regulator would optimally allow insiders to divert when $\lambda = 0$. In a more general model, allowing insiders to divert could reduce outsiders' ex ante investment incentives, leading to a welfare-destroying under-investment problem.

[13] Note that c, λ, and π_i all capture facets of the regulatory and enforcement environment. We believe the most direct interpretations of these variables are as follows. First, c captures regulatory corruption and outsiders' ability to limit insiders' wasteful activities (as c parameterizes the personal cost to the insider of lobbying in the model). Second, λ relates to the protection of property rights (as λ parameterizes the loss of resources conditional on diversion). Finally, π_i relates closely to disclosure quality and protections against self-dealing (as π_i parameterizes the probability that a insider will be able to divert resources, potentially by misreporting financial results; see also Djankov et al. [2008]). In our model, π_i is endogenous, while c and λ are exogenous because we view corruption and property rights protections to be deeper institutional parameters than rules and enforcement actions related to disclosure quality and self-dealing.

We model three costs associated with regulation. First, we assume a convex cost of regulation in and of itself, $\frac{1}{2}\pi_1^2 + \frac{1}{2}\pi_2^2$, which avoids bang-bang solutions to the regulatory choice problem. Second, each insider can influence the regulator through lobbying activity B_i, which increases the cost of regulatory intensity by $B_i \pi_i$. We refer to the costs $\frac{1}{2}\pi_1^2 + \frac{1}{2}\pi_2^2 + B_1\pi_1 + B_2\pi_2$ as "implementation costs" that capture both compliance costs imposed on firms and social costs of implementing regulation. Third, we impose costs of regulatory heterogeneity, $\frac{k}{2}(\pi_1 - \pi_2)^2$, as heterogeneous regulation plausibly requires greater care in drafting regulation and increased expenditures in enforcement (e.g., staff costs). When $k = 0$, the regulator is free to choose individualized regulation without incurring any penalty (IR). As $k \to \infty$, the regulator will set the same regulatory intensity for both firms, thereby choosing a one-size-fits-all regime (UR). Note that k can be interpreted as a technical constraint on the regulator or an institutional commitment (for example, a mission statement) to regulate different firms in a similar fashion. To capture these alternatives, we first model the cost parameter k as exogenous and in Section 3 consider an ex-ante planner (e.g., a legislative body) that chooses k to minimize the welfare losses and implementation costs.

Thus, the total cost of regulation is given by

$$C(\pi_1, \pi_2; B_1, B_2, k) = \frac{1}{2}\pi_1^2 + \frac{1}{2}\pi_2^2 + B_1\pi_1 + B_2\pi_2 + \frac{k}{2}(\pi_1 - \pi_2)^2, \tag{3}$$

and the regulator's expected utility is

$$U_R = L(\pi_1, \pi_2; D_1, D_2, \lambda) - C(\pi_1, \pi_2; B_1, B_2, k). \tag{4}$$

That is, the regulator chooses the regulatory intensity for both firms to minimize the expected losses from diversion net of the cost of regulation.

2.2 The equilibrium

We examine the subgame-perfect Nash equilibrium defined as follows. In period 2, the regulator chooses optimal regulatory intensities, $\{\pi_1^*, \pi_2^*\}$ to maximize its objective function in (4), given $\{B_1^*, B_2^*\}$. In period 1, each insider i chooses B_i^* to maximize her expected utility in (1) given rational conjectures about the regulator's strategy in period 2 and the other insider's conjectured optimal choice of B_j^*.

We solve the equilibrium by backward induction. We begin in period 2, when the regulator chooses the regulatory intensities. We impose the following two conditions to ensure interior solutions.

Condition 1 *Firms' lobbying costs are sufficiently high,* $c > \frac{1}{\lambda}\frac{1+k}{1+2k}$.

Condition 2 *Welfare losses from diversion are not too high,* $D < \frac{1+2k}{1+2k+q}\left(\lambda - \frac{1}{c}\frac{1+k}{1+2k}\right)^{-1}$.

If $c < \frac{1}{\lambda}\frac{1+k}{1+2k}$, then lobbying pushes the optimal regulatory strengths to zero. If $D > \frac{1+2k}{1+2k+q}\left(\lambda - \frac{1}{c}\frac{1+k}{1+2k}\right)^{-1}$, then the regulator's interest in inhibiting diversion outweighs the implementation costs and the regulator sets $\pi_i^* = 1$ for at least one firm. For the remainder of the paper we assume Conditions 1 and 2 are satisfied.

The regulator's expected utility is concave and has the following first-order conditions:

$$\lambda D_i - B_i - k\left(\pi_i^* - \pi_j^*\right) - \pi_i^* = 0, \tag{5}$$

for $i, j \in \{1, 2\}$ and $i \neq j$. The equations in (5) imply

$$\pi_i^* = \frac{(1+k)(\lambda D_i - B_i) + k(\lambda D_j - B_j)}{1+2k}. \tag{6}$$

Note that both $\partial\pi_i^*/\partial B_i$ and $\partial\pi_i^*/\partial B_j$ are negative, so that more lobbying from either insider reduces the regulatory intensity for both firms for any $k > 0$. Higher values of k, i.e., greater uniformity, imply that an insider's lobbying has a lower effect on the regulatory intensity his firm faces, since $\partial^2 \pi_i^* / (\partial k \partial B_i) = (1+2k)^{-2} > 0$. This mitigates the negative effect of B_i on π_i^*. In contrast, the influence of insider i's lobbying on the regulatory intensity of firm j is increasing in k, since $\partial^2 \pi_i^* / (\partial k \partial B_j) = -(1+2k)^{-2} < 0$. In our model, k captures the cost to the regulator of setting different regulatory strengths for the two firms. Intuitively, higher values of k imply that the regulator chooses more similar regulatory intensities for the two firms, so that one firm's lobbying has a greater spillover effect on the regulatory intensity of the other firm, making the negative effect of B_j on π_i^* stronger.

Given the anticipated choice of the regulator, insiders choose their influence activities to maximize U_i in (1). Substituting π_i^* into U_i and taking the derivative yields the first-order conditions. Solving the first-order conditions[14] implies that the optimal B_i are given by

$$B_i^* = \frac{1}{c} \frac{1+k}{1+2k} D_i. \tag{7}$$

This shows that higher personal benefits of misbehavior, D_i, are associated with higher lobbying efforts from insiders, B_i^*. Furthermore, note that an increase in k decreases both insiders' lobbying efforts, $\partial B_i^* / \partial k = -\frac{1}{c} D_i (1+2k)^{-2}$, which is due to the effect that an increase in k has on the regulator's response to lobbying efforts.

The equilibrium in terms of exogenous parameters is shown in the following proposition, which follows straightforwardly from substituting B_i^* from (7) into (6) and solving these two equations for π_1^* and π_2^*. All proofs can be found in the appendix.

Proposition 1 *There is a unique interior equilibrium with* $\pi_i^* \in (0,1)$ *for* $i \in \{1,2\}$ *defined*

[14] The first order conditions are $\frac{1+k}{1+2k} D_i - cB_i = 0$. The second order conditions are satisfied as $\frac{d}{dB_i}\left(\frac{1+k}{2k+1} D_i - cB_i\right) = -c < 0$.

by

$$\begin{aligned}\pi_1^* &= D\left(\lambda - \frac{1}{c}\frac{1+k}{1+2k}\right)\frac{1+2k-q}{1+2k}, \\ \pi_2^* &= D\left(\lambda - \frac{1}{c}\frac{1+k}{1+2k}\right)\frac{1+2k+q}{1+2k}, \\ B_1^* &= \frac{1}{c}\frac{1+k}{1+2k}D\left(1-q\right),\ \textit{and} \\ B_2^* &= \frac{1}{c}\frac{1+k}{1+2k}D\left(1+q\right).\end{aligned}$$

To understand the characteristics of the equilibrium, it is helpful to investigate the equilibrium regulatory intensities. Note that equation (6) implies that two factors influence a firm's regulatory intensity: potential losses from diversion and insiders' lobbying efforts. More specifically, denoting $\omega = \frac{1}{1+2k}$, firm i's regulatory intensity is a weighted average of firm i's potential loss from diversion and lobbying effort and the average potential loss from diversion and lobbying effort:

$$\pi_i^* = \omega\left(\lambda D_i - B_i^*\right) + \left(1-\omega\right)\left(\lambda D - \bar{B}^*\right). \tag{8}$$

B_i^* is defined in equation (7) and $\bar{B}^* = \left(B_1^* + B_2^*\right)/2 = \frac{1}{c}\frac{1+k}{1+2k}D$. Under pure IR, the average diversion and lobbying have no impact (as $\lim_{k\to 0}\left(1-\omega\right) = 0$), while under pure UR, it is only the average diversion and lobbying that matter (as $\lim_{k\to\infty}\omega = 0$). Note that $q \in [0,1)$ implies that $D_2 \geq D_1$ and that $\pi_2^* \geq \pi_1^*$.

The expression for π_i^* in equation (8) illustrates three important forces in our model. First, as lobbying becomes prohibitively costly to insiders, i.e., $c \to \infty$, insiders cease lobbying. Absent lobbying, the regulator sets the optimal regulatory strength for firm i as a weighted average of only the expected loss from diversion for the target firm (with deadweight loss λD_i) and the expected loss from diversion for the "average firm" (with deadweight loss λD).

Second, the degree of uniformity, k, influences the weights on firm-specific and average factors in (8), as $\omega = \frac{1}{1+2k}$. Increases in regulatory uniformity increase the regulator's weight on D and $\bar{B}^*$ in equation (8) relative to the weight on D_i and B_i^*. Uniformity thus pushes regulatory qualities toward each other. We call this the convergence effect of regulatory uniformity. Naturally, the convergence effect pushes the higher (lower) regulatory intensity down (up). If firms are homogeneous, i.e., $q = 0$, then $D_1 = D_2 = D$, and the convergence effect is trivial. Absent lobbying (i.e., as $c \to \infty$), π_2^* decreases and π_1^* increases with an increase in k for any $q > 0$. When firms are homogeneous and cannot lobby, regulatory uniformity, k, plays no role in our model.

Third, as discussed above, there is an additional effect of regulatory uniformity on each firm's regulatory intensity, via $\partial B_i^*/\partial k < 0$ and $\partial \bar{B}^*/\partial k < 0$. This is the free-rider effect in our model. It reduces both insiders' lobbying efforts and thereby increases both firms' regulatory intensities, since B_i^* and $\bar{B}^*$ both enter negatively in (8).

2.3 Equilibrium characteristics

Corollaries 1-3 present our comparative statics results for the baseline model. Corollary 1 summarizes the effects of changes in the cost of lobbying and the efficiency of diversion.

Corollary 1 ***Lobbying and the deadweight loss from diversion***

(a) As the cost of lobbying, c, increases, (i) the lobbying efforts of both insiders decrease and (ii) the regulatory intensities for both firms increase.

(b) As the proportional deadweight loss from diversion, λ, increases, (i) the lobbying efforts of both insiders are unchanged and (ii) the regulatory intensities for both firms increase.

Corollary 1 shows that insiders lobby less when their costs of lobbying increase, but their lobbying efforts do not respond directly to the costs their diversion imposes on outsiders. When insiders lobby less, regulatory intensities increase, and, as a result, the expected value of the future payouts to investors increases. Note that a change in c only has a direct effect on the insiders; regulatory intensities are only affected indirectly. Changes in λ, however, only have a direct effect on regulatory intensities, an effect which operates through the regulator's preferences for lower inefficiency regardless of lobbying efforts. When λ increases, the regulator is more interested in high regulatory intensity because the deadweight loss from diversion decreases.

Corollary 2 analyzes the effects of increases in firm heterogeneity and the average potential diversion from the firms, both of which are operationalized by the amounts that insiders can divert, D_1 and D_2. Specifically, recall that $D_1 = D(1-q)$ and $D_2 = D(1+q)$ such that average diversion is given by $D = \frac{D_1+D_2}{2}$ and heterogeneity is given by $q = \frac{D_2-D_1}{2D}$.

Corollary 2 ***Firm heterogeneity and average potential diversion***

(a) As firms become more heterogeneous (i.e., q increases), (i) the lobbying effort of the the bad firm's insider and the regulatory intensity for the bad firm increase; (ii) the lobbying effort of the good firm's insider and the regulatory intensity for the good firm decrease; and (iii) total lobbying is unchanged.

(b) As average potential diversion, D, increases, (i) both insiders lobby the regulator more, and (ii) the regulatory intensities for both firms increase.

Corollary 2 (a) analyzes the effect of increased heterogeneity between firms. First note that an increase in heterogeneity implies that for firm 2 (1) there is more (less) cash for the insider to divert and a higher (lower) potential deadweight loss that the regulator would like to prevent. While the resulting increase in lobbying effort from firm 2's insider acts to decrease firm 2's regulatory intensity, the increased deadweight loss acts to increase π_2^*. The latter effect dominates the former such that firm 2's regulatory intensity increases despite the increased lobbying effort from firm 2's insider. The opposite occurs for firm 1, which becomes less important to the regulator and whose smaller amount of diversion provides a weaker motivation to the insider to lobby. The effects of heterogeneity on each firm's lobbying are equal and opposite, implying no net effect of heterogeneity on total lobbying.

Part (b) shows that with an increase in average potential diversion in the economy, both insiders have more resources available to divert, and thus increase their lobbying efforts. However, since the potential deadweight loss also increases, the regulator is interested in higher regulatory intensities and, despite the increased lobbying, increases π_1^* and π_2^*. If the potential for diversion D increases in the firms' realized or expected cash flows, our model suggests greater lobbying in macroeconomic expansions than contractions, in contrast to the prediction in Bertomeu and Magee [2011].

Finally, we analyze the effect of a change in k, which represents the degree of UR relative to IR. Denote $\bar{c} = \frac{1}{2\lambda}\left(2 + \frac{1+q}{q}\right)$ and $\underline{c} = \frac{1}{2\lambda}\frac{q+1}{q}$.[15]

Corollary 3 ***Degree of uniformity:*** *As the cost to the regulator of individualized regulation, k, increases, (i) the lobbying efforts of both insiders decrease; (ii) the regulatory intensity for the good firm increases; (iii) the regulatory intensity for the bad firm decreases for $c > \bar{c}$, first increases then decreases for $\bar{c} > c > \underline{c}$, and always increases for $c < \underline{c}$; and (iv) the average regulatory intensity increases.*

As discussed in the introduction, constraining the regulator to set similar regulatory intensities for different firms introduces two effects, the convergence effect and the free-rider effect. The convergence effect arises because an increase in k makes the regulator more inclined to apply the same regulatory intensity to both firms. Therefore, π_1^* and π_2^* are set closer to each other in equilibrium. This effect pushes the higher π_2^* down and the lower π_1^* up. The free-rider effect occurs because, when the regulator chooses more similar values for π_1^* and π_2^*, the lobbying efforts of firm i's insider have a stronger effect on the regulatory intensity of firm j. This leads to a more intense free-rider problem on insiders' lobbying in that each insider relies more on the other insider's lobbying efforts to economize on his own efforts. Insiders therefore reduce their overall lobbying efforts, which increases π_i^* for both firms.

The net effects of an increase in k on insiders' lobbying are unambiguous. So, too, are the net effects of an increase in k on regulatory intensity for the good firm, as the convergence and free-rider effects both act to increase π_1^*. However, the net effects of the convergence and free-rider effects on regulatory strengths for the bad firm are ambiguous. For π_2^*, the convergence and free-rider effects oppose each other, and either may dominate, yielding implications for π_2^* that depend on parameter values. When the agency problem is sufficiently severe ($c < \underline{c}$), such that both firms heavily lobby the regulator, the free-rider effect dominates,

[15] When $q = 0$, we set $\underline{c}|_{q=0} = \lim_{q\to 0} \underline{c} = \infty$ and $\bar{c}|_{q=0} = \lim_{q\to 0} \bar{c} = \infty$.

causing π_2^* to be increasing in k. When the agency problem is sufficiently mild ($c > \bar{c}$), the convergence effect dominates, causing π_2^* to be decreasing in k. Finally, when the agency problem has intermediate strength ($\bar{c} > c > \underline{c}$), the free-riding effect dominates for low values of k, such that $d\pi_2^*/dk > 0$, but the convergence effect dominates for high values of k, such that $d\pi_2^*/dk < 0$.[16] Ultimately, when k approaches infinity, the regulator sets $\pi_1^* = \pi_2^*$, irrespective of c. Overall, the free-rider effect and the convergence effect complement each other for the firm with the lower regulatory intensity and conflict with each other for the firm with the higher regulatory intensity. Given that lobbying for both firms decreases, the average regulatory intensity increases.

The parameter k reflects the extent to which the regulator is bound to apply the same regulatory intensity to both firms. As capital market equilibria and the regulatory system likely evolve together, we next analyze the effect of allowing k to be chosen by an ex-ante planner concerned with minimizing the welfare losses from diversion and the implementation costs of regulation.

3 The optimal regulatory system

In this section we examine the optimal choice of balance between uniform and individualized regulation, i.e., the choice of k, from the perspective of an ex-ante planner concerned with the welfare loss from diversion and the implementation costs of regulation. We interpret k as a deep institutional parameter that is set for the long run (or ex ante) and is not subject to lobbying influence.

We assume that the planner is interested in minimizing the loss from diversion subject to the costs of implementation.[17] While considering implementation costs, we assume that the

[16] Specifically, if $c > \underline{c}$, then $d\pi_2^*/dk < 0$ if and only if $k > \frac{1}{2}\left(\frac{1}{\lambda(c-\underline{c})} - 1\right)$.

[17] This is similar to maximizing outsiders' expected utility net of the regulator's implementation costs. In a competitive stock market where the outsiders represent marginal investors, the outsider's expected utility, $\mu_i - (1-\pi_i)(1+\lambda) D_i$, would be closely related to the stock price. This suggests an interpretation of the planner as an exchange choosing its degree of uniformity to maximize market capitalization net of regulatory implementation costs.

planner does not consider the direct costs she imposes on the regulator through her choice of k, which are $(k/2)(\pi_1 - \pi_2)^2$, or the costs that managers personally bear for socially undesirable lobbying, which are $(c/2)B_1^2 + (c/2)B_2^2$.[18]

The planner's objective function is given by

$$U_S = -(1-\pi_1)\lambda D(1-q) - (1-\pi_2)\lambda D(1+q) - \frac{1}{2}\left(\pi_1^2 + \pi_2^2\right) - B_1\pi_1 - B_2\pi_2. \quad (9)$$

Recall from Proposition 1 that $\pi_1^* > 0$ and $\pi_2^* > 0$ requires Condition 1 to hold, i.e., $\lambda > \frac{1}{c}\frac{1+k}{1+2k}$. We therefore restrict our attention to $\lambda > \frac{1}{c}$ such that the regulator will choose positive π_1^* and π_2^* for any $k \in [0,\infty)$, chosen by the planner. The solution is given in the following proposition.

Proposition 2 *When $q^2(2c\lambda - 1) - 1 \leq 0$, the planner chooses a perfectly uniform regulatory system, $k^\dagger \to \infty$. When $q^2(2c\lambda - 1) - 1 > 0$, the planner chooses*

$$k^\dagger = \frac{1 + q^2(2 - c\lambda) + q\sqrt{2(1+q^2) + q^2(1-c\lambda)^2}}{2\left(q^2(2c\lambda - 1) - 1\right)}. \quad (10)$$

The threshold in Proposition 2 is related to the importance of regulatory uniformity in improving regulatory intensities and to the cost imposed by uniform regulation. Because the economic forces that drive the decision to choose a perfectly uniform system ($k^\dagger \to \infty$) are the same forces that lead to an increase in $k^\dagger$, we focus our discussion on the comparative statics presented in the following corollary.

Corollary 4 *The optimal degree of uniformity from the planner's perspective, $k^\dagger$, (i) weakly decreases in insiders' personal costs of lobbying, c; (ii) weakly decreases in the deadweight loss from insiders' diversion, λ; (iii) is independent of mean firm size, D; and (iv) weakly decreases in the degree of firm heterogeneity, q.*

[18] Including the costs of heterogeneity imposed on the regulator in the planner's objective (mechanically) decreases the optimal k. We view these not as true economic costs but rather as a modeling device to represent a commitment to more or less uniform regulation. Including the managers' costs of lobbying in the planner's objective implies that the legislature prefers to make managerial opportunism cheaper, which seems unreasonable.

Corollary 4 shows that it is more valuable to constrain the extent to which the regulator can individualize regulation when lobbying-related agency problems are severe (low c), firms are similar (low q), or managerial diversion is efficient (low λ). Furthermore, these comparative statics are monotone over the whole parameter range. For example, starting at a high c, decreases in c first continuously increase $k^{\dagger}$. As c decreases further and $q^2(2c\lambda - 1) - 1 \to 0$ from above, the optimal regulatory system approaches perfect uniformity, i.e., $k^{\dagger} \to \infty$. The first two results in the corollary directly point to our two main economic forces: while free-riding on lobbying reduces the impact of the agency problem and makes UR more preferable, firm heterogeneity makes regulatory heterogeneity and IR more preferable. The third result is similar in that low values of λ push the potential welfare losses from diversion in either firm towards zero and thus towards each other, implying similar results to low heterogeneity driven by low q. Mean firm size, D, does not affect the optimal $k^{\dagger}$, as it is a scaling factor in the planner and regulator's utilities given equilibrium lobbying efforts.

The following corollary explores how the equilibrium regulatory strengths, $\pi_i^{\dagger}$, and lobbying efforts, $B_i^{\dagger}$, change with changes in the underlying parameters when $k^{\dagger}$ is endogenously set by the planner.

Corollary 5 *When the planner optimally chooses an interior degree of uniformity (i.e., $q^2(2c\lambda - 1) - 1 > 0$),*

(i) *the lobbying efforts of (a) both insiders decrease in lobbying costs, c; (b) insider 1, $B_1^{\dagger}$, is non-monotonic in firm heterogeneity, q; (c) insider 2, $B_2^{\dagger}$, increases in firm heterogeneity, q; and (d) both insiders increase in potential diversion, D, and the welfare loss from diversion, λ;*

(ii) *total lobbying, $B_1^{\dagger} + B_2^{\dagger}$, is decreasing in lobbying costs, c, and increasing in firm heterogeneity, q, potential diversion, D, and the welfare loss from diversion, λ.*

(iii) *the regulatory intensity for (a) firm 1, $\pi_1^{\dagger}$, decreases in lobbying costs, c, and firm heterogeneity, q; (b) firm 2, $\pi_2^{\dagger}$, increases in lobbying costs, c, and firm heterogeneity, q; and (c) for both firms increase in potential diversion, D, and the welfare loss from diversion, λ.*

When $k^{\dagger}$ is endogenously chosen by the planner, any change in an exogenous parameter affects regulatory strength and lobbying efforts through two channels. First, they have direct effects as indicated in the corollaries in Section 2.3. Second, they have indirect effects on regulatory strength and lobbying efforts through their effects on $k^\dagger$. Taking lobbying costs as a representative example, an increase in c directly decreases both insiders' lobbying efforts and increases both firms' regulatory intensities. However, the optimal $k^\dagger$ decreases when c increases, as lobbying becomes less problematic. The less uniform regulatory system allows the regulator to respond more strongly to the individual characteristics of each firm. Even though both lobbying efforts decrease, the effect of a reduced $k^\dagger$ dominates such that $\pi_1^\dagger$ decreases and $\pi_2^\dagger$ increases.

Similarly, the extent of regulatory uniformity decreases when firm heterogeneity, q, increases. The decrease in $k^\dagger$ works to increase lobbying efforts and to generally decrease regulatory intensities. (Note that the bad firm's regulatory intensity may increase due to the reduced convergence effect.) Furthermore, the increase in q directly reduces the lobbying effort of the good firm's insider, which causes $B_1^\dagger$ to be non-monotonic in q. Firm 1's regulatory intensity, however, always decreases as the diversion amount gets smaller. In contrast, for the bad firm, the direct and the indirect effects of q on lobbying reinforce each other such that $B_2^\dagger$ increases. However, the regulator's interest in reducing the loss from diversion in firm 2 increases in q such that $\pi_2^\dagger$ increases despite the increased lobbying. As shown in part (ii) of Corollary 5, total lobbying always increases with firm heterogeneity, q, and the welfare loss from diversion, λ. In contrast, when uniformity is exogenous, q and λ have no net effects on total lobbying. Specifically, when k is exogenous, λ has no direct effect on either firm's lobbying, and the effects of changes in heterogeneity on B_1 and B_2 exactly cancel each other out. When, instead, k is endogenous, increases in q and λ decrease $k^\dagger$, which causes total lobbying to increase.

Finally, Corollary 4 shows that changes in D have no effect of $k^\dagger$, this implies that the results from the setting with an exogenous k are unchanged. However, while lobbying efforts were constant in λ with a constant degree of uniformity, an increase in λ lowers $k^\dagger$ such that both insiders' lobbying efforts increase in λ when k is chosen endogenously by the planner as $k^\dagger$. Table 2 lists the comparative statics for the baseline model and the extension with an endogenous $k^\dagger$.

Table 2: Comparative Static Results

Cells in the table body are directional predictions for $\frac{d[Col]}{d[Row]}$, where Col is the column header variable and Row is the row header variable. $+$ and $-$ indicate positive and negative directional predictions, respectively. 0 indicates no relation between the variables. $+/-$ indicates non-monotonic predictions that depend on the values of parameters. Comparative statics are applicable for parameter regions with $\pi_i^*, \pi_i^\dagger \in (0,1), i \in 1, 2$.

	Exogenous k					Endogenous $k^\dagger$					
	B_1^*	B_2^*	$B_1^* + B_2^*$	π_1^*	π_2^*	$k^\dagger$	$B_1^\dagger$	$B_2^\dagger$	$B_1^\dagger + B_2^\dagger$	$\pi_1^\dagger$	$\pi_2^\dagger$
c	$-$	$-$	$-$	$+$	$+$	$-$	$-$	$-$	$-$	$-$	$+$
λ	0	0	0	$+$	$+$	$-$	$+$	$+$	$+$	$+$	$+$
q	$-$	$+$	0	$-$	$+$	$-$	$+/-$	$+$	$+$	$-$	$+$
D	$+$	$+$	$+$	$+$	$+$	0	$+$	$+$	$+$	$+$	$+$
k	$-$	$-$	$-$	$+$	$+/-$						

4 Conclusion

Disclosure regulation and interactions between firms or sectors of the economy both have significant impacts on capital markets. We investigate the effects of uniform (i.e., one-size-fits-all) versus individualized (i.e., firm- or industry-specific) regulation in a model where insiders can lobby the regulatory agency for favorable regulation. Each firm is composed of an insider who can divert cash flows, where such diversion imposes an inefficient cost on the firm's outsiders. The regulator is charged with limiting the ability of the insiders to divert. While the regulator is concerned about the welfare effects of regulatory intensity, he can be influenced by insiders' lobbying.

Our main finding is that a regime with uniform regulation (UR) can enhance welfare by exacerbating a free-rider problem among insiders who can lobby the regulator for privately beneficial but socially harmful regulatory slack. When firms are not too heterogeneous, this effect makes UR preferable to individualized regulation (IR). When firms are very different, however, the benefit of UR in reducing lobbying is outweighed by the costs of setting similar regulatory intensities for heterogeneous firms.

Through analysis of the model, we provide several empirical implications, which we hope will be helpful in understanding the effects of the regulatory regime on lobbying and the quality of disclosure regulation. For example, we predict that regulatory regimes will tend towards uniformity when agency problems between investors and managers are more severe or when it is less costly for insiders to lobby the regulator.

Our model suggests that lobbying could be more difficult when regulatory standards are principles-based and apply broadly (even across jurisdictions) as under IFRS, than when regulatory standards are rules-based and can be tailored firms' and industries' particular circumstances, as under US GAAP (Herz [2003]). In line with this interpretation, the IASB might be in effect more immune to political pressure, as suggested by Canham [2009]. Zeff [2002] observes that Swiss CFOs displayed a preference for US GAAP over IFRS in part due to preparers' ability to influence regulatory standards in the U.S. Our comparison of rules-based GAAP and principles-based IFRS suggests that jurisdictions characterized by weaker agency problems between insiders and outsiders might be more likely to delay or avoid transitions from GAAP to IFRS, while jurisdictions with significant agency problems would seek out commitments to regulatory uniformity. This may have been one of several reasons for the delays in US convergence to IFRS, and might also contribute to other countries' delays in adopting IFRS.

Similarly, some of the divergence between code and common law legal systems (see, e.g., La Porta et al. [2000]) could relate to uniformity in de facto regulations. In common-law jurisdictions, judicial rulings establish precedents that apply relatively uniformly, while in code law systems precedents are not established by judicial rulings. This implies that there is greater de facto uniformity in common-law jurisdictions, which is consistent with the stronger legal protections of outside investors and enforcement of these rules in common law countries relative to code law countries (e.g., La Porta et al. [1998]).

We generate results in a setting with a single regulator who is potentially constrained to set uniform regulation. The intuition easily extends to related institutional design problems, including whether to have a single or multiple accounting standard-setters and the effects of auditor and financial exchange mergers.[19] In the US, for example, there have been arguments and movements both in favor of UR, through merging the FASB and IASB or standards convergence, and in favor of IR, through allowing firms to choose to report under US GAAP or IFRS. Our results imply that changes in regulatory uniformity have implications for lobbying and regulatory intensity. Different auditors or financial exchanges can have different policies regarding disclosure, suggesting that mergers of auditing firms can also be seen as movements towards uniformity. Mergers of auditors and exchanges can help reduce managerial influence over their disclosure policies, which we show can be beneficial overall.

[19] When comparing settings with a single or multiple regulators (or standard-setters), it is important to also consider economic forces related to decentralization that we have not included in our model, such as information asymmetry, goal congruence, and coordination across regulators (e.g., Harris, Kriebel, and Raviv [1982]).

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Appendix

Proposition 1: The solution to our game is given by the values of four unknowns, B_i and π_i for $i \in \{1,2\}$, that solve a constrained system of four linear equations: either the four FOC's, (7) and (6); or corner solutions replacing any of the FOCs, such as $B_i = 0$, $\pi_i = 0$, or $\pi_i = 1$, for $i \in \{1,2\}$. For the interior solution, $D_i > 0$ implies $B_i^* > 0$. Substituting B_i^* from (7) into (6) yields

$$\pi_i^* = \left(\lambda - \frac{1}{c}\frac{1+k}{1+2k}\right)\frac{(1+k)\,D_i + kD_j}{1+2k}. \tag{11}$$

Since $\pi_1^* < \pi_2^*$ implies that $\pi_2^* < 1 \Rightarrow \pi_1^* < 1$, we have an interior equilibrium, i.e., $\pi_i^* \in (0,1)$, if and only if

$$\begin{aligned} c &> \frac{1}{\lambda}\frac{1+k}{1+2k}, \text{ which ensures } \pi_i^* > 0 \text{ for } i \in \{1,2\}\,, \text{ and} \\ D\left(\lambda - \frac{1}{c}\frac{1+k}{1+2k}\right)\left(1 + \frac{q}{1+2k}\right) &< 1, \text{ which ensures } \pi_2^* < 1. \end{aligned}$$

The first inequality, $c > \frac{1}{\lambda}\frac{1+k}{1+2k}$, is Condition 1. The second inequality, $D\left(\lambda - \frac{1}{c}\frac{1+k}{1+2k}\right)\left(1 + \frac{q}{1+2k}\right) < 1$, implies Condition 2. The expressions in Proposition 1 follow directly.

Corollaries 1, 2, and 3: These proofs follow by straightforward differentiation of the expressions for π_1^*, π_2^*, B_1^*, and B_2^* given in Proposition 1. Derivatives are provided in the table below, where each cell gives $\frac{d[\text{Column header}]}{d[\text{Row header}]}$:

	B_1^*	B_2^*	π_1^*	π_2^*
c	$-\frac{1}{c^2}\frac{1+k}{1+2k}D(1-q)$	$-\frac{1}{c^2}\frac{1+k}{1+2k}D(1+q)$	$D\left(1+k^\dagger\right)\frac{2k+1-q}{c^2(2k+1)^2}$	$D(1+k)\frac{2k+1+q}{c^2(2k+1)^2}$
λ	0	0	$D\frac{2k+1-q}{2k+1}$	$D\frac{2k+1+q}{2k+1}$
q	$-\frac{1}{c}\frac{1+k}{1+2k}D$	$\frac{1}{c}\frac{1+k}{1+2k}D$	$-\frac{D}{1+2k}\left(\lambda-\frac{1}{c}\frac{1+k}{1+2k}\right)$	$\frac{D}{1+2k}\left(\lambda-\frac{1}{c}\frac{1+k}{1+2k}\right)$
D	$\frac{1}{c}\frac{1+k}{1+2k}D(1-q)$	$\frac{1}{c}\frac{1+k}{1+2k}D(1+q)$	$\left(\lambda-\frac{1}{c}\frac{1+k}{1+2k}\right)\frac{1+2k-q}{1+2k}$	$\left(\lambda-\frac{1}{c}\frac{1+k}{1+2k}\right)\frac{1+2k+q}{1+2k}$
k	$-D\frac{1-q}{c(2k+1)^2}$	$-D\frac{1+q}{c(2k+1)^2}$	$D\frac{(1+q(2c\lambda-1))(1+2k)-2q}{c(1+2k)^3}$	$D\frac{(1+q-2qc\lambda)(1+2k)+2q}{c(1+2k)^3}$

For Corollary 3, part (iv), the average regulatory intensity is given by $\frac{\pi_1^*+\pi_2^*}{2}=D\frac{c\lambda(1+2k)-(1+k)}{c(1+2k)}$, and the derivative is given by $\frac{d}{dk}\left(\frac{\pi_1^*+\pi_2^*}{2}\right)=D\frac{1}{c(2k+1)^2}>0$. The signs of the derivatives in the table are immediate, except for $\frac{d\pi_i^*}{dk}$.[20] To show Corollary 3, part (ii), we have

$$\begin{aligned}\frac{d\pi_1^*}{dk} &= \frac{D}{c(1+2k)^3}\left((1-q)(1+2k)-2q+2c\lambda q(1+2k)\right)\\ &> \frac{D}{c(1+2k)^3}\left((1-q)(1+2k)-2q+2(1+k)q\right)\\ &= \frac{D(2k+1-q)}{c(1+2k)^3}>0,\end{aligned}$$

where the first inequality follows from Condition 1. For Corollary 3, part (iii), the derivative of π_2^* with respect to k can be written as

$$\frac{d\pi_2^*}{dk}=\frac{2qD}{(2k+1)^2}\left(\frac{1}{2c}\left(2+\frac{1+q}{q}\right)-\lambda-2\frac{k}{c(2k+1)}\right)$$

The derivative is always negative when $\frac{1}{2c}\left(2+\frac{1+q}{q}\right)-\lambda<0$, i.e., when $c>\bar{c}=\frac{1}{2\lambda}\left(2+\frac{1+q}{q}\right)$.

[20] Recall that Condition 1 ensures that $\lambda-\frac{1}{c}\frac{1+k}{1+2k}>0$.

That is, $\frac{\partial \pi_2^*}{\partial k} < 0$ when c is sufficiently large. The above derivative is positive when

$$\begin{aligned} & \frac{1}{2c}\left(2+\frac{1+q}{q}\right)-\lambda-2\frac{k}{c\left(2k+1\right)}>0 \\ \Leftrightarrow\quad & \frac{1}{2\lambda}\left(2+\frac{1+q}{q}-2\frac{2k}{2k+1}\right)>c \end{aligned}$$

The term in parentheses ranges from $\frac{1+q}{q}$ to $2+\frac{1+q}{q}$ because $2\frac{2k}{(2k+1)}$ ranges from 0 to 2. This implies that $\frac{\partial \pi_2^*}{\partial k} > 0$ whenever $c < \underline{c} = \frac{1}{\lambda}\frac{1+q}{2q}$, i.e. when c is sufficiently small. Finally, for intermediate values of c, when $\bar{c} > c > \underline{c}$, the derivative is positive for $k = 0$ and is negative when $\frac{k}{2k+1} > \left(\frac{1}{2c}\left(2+\frac{1+q}{q}\right)-\lambda\right)\frac{c}{2}$, i.e., when $k > \frac{1}{2}\left(\frac{1}{\lambda(c-\underline{c})}-1\right)$.

Proposition 2: To prove the Proposition, we (I) establish the first-order condition, which (II) has three solutions. We then rule out two of the three by showing that (III) one of the solutions is a local minimum, and (IV) another is negative for feasible parameter values. We (V) establish a condition for the third solution to be a global maximum. Finally, we (VI) show that if the condition is violated, the optimum is a corner solution with $k^\dagger \to \infty$.

I. Substituting expressions for π_i^* and B_i^* from (6) and (7) into U_S in (9) yields,

$$\begin{aligned} U_S^* &= U_S\left(\pi_1^*,\pi_2^*,B_1^*,B_2^*\right) \\ &= D\frac{\left(2D\left(1+q^2+4k\left(1+k+q^2\right)\right)\left(1+k-c\left(1+2k\right)\lambda\right)^2-4c^2\left(1+2k\right)^4\lambda\right)}{2c^2\left(1+2k\right)^4} \end{aligned} \quad (12)$$

and maximizing U_S^* with respect to k gives the following FOC:

$$2D^2\frac{1+q^2+4k\left(1+k+q^2\left(2+k\right)\right)-4ck\left(1+2k\right)q^2\lambda}{c^2\left(1+2k\right)^5}\left(c\lambda-1+k\left(2c\lambda-1\right)\right)=0. \quad (13)$$

II. The FOC is satisfied for $k^0 = \frac{1-c\lambda}{2c\lambda-1}$,

$$k^+ = \frac{1+q^2(2-c\lambda)+\sqrt{q^2\left(2+q^2\left(3-2c\lambda+c^2\lambda^2\right)\right)}}{-2+q^2(-2+4c\lambda)}, \text{ and}$$
$$k^- = \frac{1+q^2(2-c\lambda)-\sqrt{q^2\left(2+q^2\left(3-2c\lambda+c^2\lambda^2\right)\right)}}{-2+q^2(-2+4c\lambda)}.$$

III. It is straightforward to show that $k^- < 0$ for the relevant values of c, q, and λ (i.e., $c > 0$, $\lambda > 0$, and $0 \leq q \leq 1$).

IV. $k^0 > 0$ if and only if $1 < 2c\lambda \leq 2$, but in this range, the SOC,

$$\frac{d^2U_S^*}{dk^2}|_{k=k^0} = -\frac{2D^2}{c^2}(1-2c\lambda)^4\left(q^2(2c\lambda-3)(2c\lambda-1)-1\right) < 0,$$

is violated, implying that k^0, if it is a feasible critical point, gives a local minimum. Furthermore, $k^0 < 0 \forall \lambda > \frac{1}{c}$.

V. $k^+ \geq 0$ if and only if $q^{-2}+1 < 2c\lambda$. The SOC is $\frac{d^2U_S^*}{dk^2}|_{k=k^+} < 0$, and is satisfied for parameters that satisfy $q^{-2}+1 < 2c\lambda$. Therefore, we require the restriction that $q^{-2}+1 < 2c\lambda$, which cannot be satisfied as $q \to 0$. Given this restriction, $k^\dagger = k^+$.

VI. When $q^{-2}+1 > 2c\lambda$, we do not have an interior solution. We compare $\lim_{k\to 0} U_S^*$ and $\lim_{k\to\infty} U_S^*$ to determine whether the planner will in this case set a perfectly uniform or individualized system. We have

$$\lim_{k\to 0} U_S^* = \frac{D\left(-8c^2\lambda+4D\left(1+q^2\right)(1-c\lambda)^2\right)}{4c^2}, \text{ and}$$
$$\lim_{k\to\infty} U_S^* = \frac{D\left(-8c^2\lambda+D(1-2c\lambda)^2\right)}{4c^2},$$

Comparing these, we have

$$
\begin{aligned}
\lim_{k\to 0} U_S^* &> \lim_{k\to\infty} U_S^* \\
\Leftrightarrow \frac{D\left(-8c^2\lambda + 4D\left(1+q^2\right)(1-c\lambda)^2\right)}{4c^2} &> \frac{D\left(-8c^2\lambda + D\left(1-2c\lambda\right)^2\right)}{4c^2} \\
\Leftrightarrow q^2 &> \frac{4c\lambda - 3}{4\left(c\lambda - 1\right)^2} \qquad (14)
\end{aligned}
$$

It is algebraically straightforward but tedious to verify that $US_S^*|_{k=k^+}$ is greater than $\lim_{k\to 0} U_S^*$ and $\lim_{k\to\infty} U_S^*$ when $2c\lambda > q^{-2} + 1$. So, we next combine the condition in (14) with the condition for not having an interior maximum, $q^{-2} + 1 > 2c\lambda$, which is equivalent to $(2c\lambda - 1)^{-1} > q^2$ when $\lambda > \frac{1}{c}$. We seek to determine if there are values of q satisfying both conditions, i.e., if there exist values of q in $[0, 1)$ such that $(2c\lambda - 1)^{-1} > q^2$ and $q^2 > \frac{4c\lambda-3}{4(c\lambda-1)^2}$. For existence of such a q, we require

$$
\begin{aligned}
\frac{1}{(2c\lambda - 1)} &> \frac{4c\lambda - 3}{4\left(c\lambda - 1\right)^2} \\
\Leftrightarrow 4\left(c\lambda - 1\right)^2 - (4c\lambda - 3)(2c\lambda - 1) &> 0 \\
\Leftrightarrow -c\left(\lambda - \frac{1}{c}\right)(3c\lambda + 1) &> c^2\lambda^2, \qquad (15)
\end{aligned}
$$

but (15) contradicts $\lambda > \frac{1}{c}$. So, there is no feasible q that satisfies both conditions, which implies that $\lim_{k\to 0} U_S^* < \lim_{k\to\infty} U_S^*$ for all relevant parameter values and the planner chooses $k^\dagger \to \infty$ whenever $q^{-2} + 1 > 2c\lambda$.

Corollary 4: The derivatives are given by

$$\begin{aligned}
\frac{dk^\dagger}{dc} &= -\frac{1}{2}\lambda q^2 \frac{q\left(c\lambda\left(1-q^2\right)+5q^2+3\right)+\left(3q^2+1\right)\sqrt{2\left(1+q^2\right)+q^2\left(1-c\lambda\right)^2}}{\left(1-2c\lambda q^2+q^2\right)^2\sqrt{2\left(1+q^2\right)+q^2\left(1-c\lambda\right)^2}} < 0, \\
\frac{dk^\dagger}{d\lambda} &= -\frac{1}{2}cq^2 \frac{q\left(c\lambda\left(1-q^2\right)+5q^2+3\right)+\left(3q^2+1\right)\sqrt{2\left(1+q^2\right)+q^2\left(1-c\lambda\right)^2}}{\left(1-2c\lambda q^2+q^2\right)^2\sqrt{2\left(1+q^2\right)+q^2\left(1-c\lambda\right)^2}} < 0, \\
\frac{dk^\dagger}{dD} &= 0, \text{ and} \\
\frac{dk^\dagger}{dq} &= -\frac{2q^2+c^2q^2\lambda^2+1+q\sqrt{2\left(1+q^2\right)+q^2\left(1-c\lambda\right)^2}\left(c\lambda+1\right)}{\left(1-2c\lambda q^2+q^2\right)^2\sqrt{2\left(1+q^2\right)+q^2\left(1-c\lambda\right)^2}} < 0.
\end{aligned}$$

Corollary 5: The comparative statics follow from applying the chain rule using the results from Corollaries 1-4. When applying the chain rule below, we use the following identities: $\frac{\partial X^\dagger}{\partial Y} = \frac{dX^*}{dY}$ for $X \in \{B_i, \pi_i\}_{i=1,2}$ and $Y \in \{c, \lambda, q, D\}$; and $\frac{\partial X^\dagger}{\partial k^\dagger} = \frac{dX^*}{dk}$ for $X \in \{B_i, \pi_i\}_{i=1,2}$. To facilitate the following computations, we begin by deriving expressions for $\frac{1+k^\dagger}{1+2k^\dagger}$ and $\left(1+k^\dagger\right)\left(1+2k^\dagger\right)$ and then express two derivatives from Corollary 4 as functions of $k^\dagger$. First, substituting $k^\dagger$ and rearranging terms yields:

$$\frac{1+k^\dagger}{1+2k^\dagger} = \frac{3cq^2\lambda-1+q\sqrt{2q^2+q^2\left(1-c\lambda\right)^2+2}}{2q^2+2cq^2\lambda+2q\sqrt{2q^2+q^2\left(1-c\lambda\right)^2+2}}, \tag{16}$$

$$\frac{1+k^\dagger}{1+2k^\dagger} = \frac{1}{4}\left(3+c\lambda-\frac{\sqrt{2\left(1+q^2\right)+q^2\left(1-c\lambda\right)^2}}{q}\right), \text{ and} \tag{17}$$

$$\begin{aligned}
\left(1+k^\dagger\right)\left(1+2k^\dagger\right) &= q\frac{q+cq\lambda+\sqrt{2\left(1+q^2\right)+q^2\left(1-c\lambda\right)^2}}{2\left(1-2cq^2\lambda+q^2\right)^2} \\
&\quad\times\left(3cq^2\lambda-1+q\sqrt{2\left(1+q^2\right)+q^2\left(1-c\lambda\right)^2}\right).
\end{aligned} \tag{18}$$

Second, using $k^\dagger$ from equation (10) in $\frac{dk^\dagger}{dc}$ and $\frac{dk^\dagger}{dq}$ yields

$$\frac{dk^\dagger}{dc} = -q\lambda\frac{1+q^2(3-2c\lambda)+2q\sqrt{2(1+q^2)+q^2(1-c\lambda)^2}}{(-1+q^2(3+4c\lambda))\sqrt{2(1+q^2)+q^2(1-c\lambda)^2}}\left(1+k^\dagger\right)\left(1+2k^\dagger\right) \text{ and} \tag{19}$$

$$\frac{dk^\dagger}{dq} = -\frac{q(3+c\lambda)+\sqrt{2(1+q^2)+q^2(1-c\lambda)^2}}{q(q^2(3+4c\lambda)-1)\sqrt{2(1+q^2)+q^2(1-c\lambda)^2}}\left(1+k^\dagger\right)\left(1+2k^\dagger\right) \tag{20}$$

In what follows we first derive the comparative statics for B_1 and B_2 (numbered items 1–6), for B_1+B_2 (item 7), and then for π_1 and π_2 (items 8–14).

1. $\frac{dB_1^\dagger}{dc}$: Using the chain rule and (19) yields

$$\begin{aligned}\frac{dB_1^\dagger}{dc} &= \frac{\partial B_1^\dagger}{\partial c}+\frac{\partial B_1^\dagger}{\partial k}\frac{dk^\dagger}{dc}\\ &= \frac{D(1-q)\left(1+k^\dagger\right)}{c^2\left(1+2k^\dagger\right)}\times A_1 < 0,\end{aligned} \tag{21}$$

where

$$A_1 = \frac{qc\lambda(1+q^2(3-2c\lambda))+\left((1-2cq^2\lambda-3q^2)\sqrt{2(1+q^2)+q^2(1-c\lambda)^2}\right)}{(q^2(3+4c\lambda)-1)\sqrt{2(1+q^2)+q^2(1-c\lambda)^2}}.$$

The inequality, $\frac{dB_1^\dagger}{dc}<0$, holds because, first, for $k^*=k^\dagger$ (i.e., when the optimal k is finite), it has to be the case that $q^{-2}+1<2c\lambda$, which implies that $(q^2(2c\lambda-1)-1)>0$. Second, for the denominator of A_1:

$$\begin{aligned}\left(q^2(3+4c\lambda)-1\right) &\geq \left(q^2(2c\lambda-1)-1\right)\\ \left(q^2(3+4c\lambda)-1\right)-\left(q^2(2c\lambda-1)-1\right) &\geq 0\\ 2q^2(c\lambda+2) &\geq 0.\end{aligned}$$

Third, the numerator of A_1 is given by

$$
\begin{aligned}
& qc\lambda\left(1+q^2(3-2c\lambda)\right)+\left(\left(1-q^2(2c\lambda+3)\right)\sqrt{2\left(1+q^2\right)+q^2(1-c\lambda)^2}\right) \\
= \; & -qc\lambda\left(q^2(2c\lambda-1)-1-2q^2\right)-\left(\left(q^2(2c\lambda-1)-1+4q^2\right)\sqrt{2\left(1+q^2\right)+q^2(1-c\lambda)^2}\right) \\
= \; & -\left(q^2(2c\lambda-1)-1\right)\left(qc\lambda+\sqrt{2\left(1+q^2\right)+q^2(1-c\lambda)^2}\right) \\
& +2q^2\left(qc\lambda-2\sqrt{2\left(1+q^2\right)+q^2(1-c\lambda)^2}\right)
\end{aligned}
$$

The first term, $-\left(q^2(2c\lambda-1)-1\right)\left(qc\lambda+\sqrt{2\left(1+q^2\right)+q^2(1-c\lambda)^2}\right)$, is negative by our assumption that $q^{-2}+1>2c\lambda$. The second term, $2q^2\left(qc\lambda-2\sqrt{2\left(1+q^2\right)+q^2(1-c\lambda)^2}\right)$, is also negative, as

$$
\begin{aligned}
& qc\lambda-\left(2\sqrt{2\left(1+q^2\right)+q^2(1-c\lambda)^2}\right)<0 \\
\Leftrightarrow \; & (qc\lambda)^2<4\left(2\left(1+q^2\right)+q^2(1-c\lambda)^2\right) \\
\Leftrightarrow \; & 0<8\left(1+q^2\right)+3q^2(1-c\lambda)^2+q^2(1-c\lambda)^2-(qc\lambda)^2 \\
\Leftrightarrow \; & 0<2q^2(c\lambda-2)^2+4q^2+8+q^2c^2\lambda^2.
\end{aligned}
$$

So, the numerator of A_1 is negative and the denominator is positive. As the leading fraction in (21), $\frac{D(1-q)\left(1+k^\dagger\right)}{c^2\left(1+2k^\dagger\right)}$, is positive, $\frac{dB_1^\dagger}{dc}<0$.

2. $\frac{dB_2^\dagger}{dc}$: Using the chain rule and (19) yields

$$
\frac{dB_2^\dagger}{dc}=\frac{D(1+q)\left(1+k^\dagger\right)}{c^2\left(1+2k^\dagger\right)}A_1<0. \tag{22}
$$

The expression in (22) is negative, because $\frac{dB_2^\dagger}{dc}=\frac{dB_1^\dagger}{dc}*\frac{1+q}{1-q}$, and $\frac{1+q}{1-q}>0$.

3. $\frac{dB_1^\dagger}{dq}$: Using the chain rule and (20) yields

$$\frac{dB_1^\dagger}{dq} = \frac{D\left(1+k^\dagger\right)}{c\left(1+2k^\dagger\right)} \times A_2 \gtreqless 0, \tag{23}$$

where

$$A_2 = \frac{(1-q)\,q\,(3+c\lambda) + \left(1-4cq^3\lambda - 3q^3\right)\sqrt{2\left(1+q^2\right)+q^2\left(1-c\lambda\right)^2}}{q\left(q^2\left(3+4c\lambda\right)-1\right)\sqrt{2\left(1+q^2\right)+q^2\left(1-c\lambda\right)^2}}.$$

The leading fraction, $\frac{D\left(1+k^\dagger\right)}{c\left(1+2k^\dagger\right)}$, is positive, and A_2 is positive (negative) for $q = 1/4$, $c = 1$, and $\lambda = 19$ ($\lambda = 32$).

4. $\frac{dB_2^\dagger}{dq}$: The chain rule yields

$$\frac{dB_2^\dagger}{dq} = \frac{\partial B_2^\dagger}{\partial q} + \frac{\partial B_2^\dagger}{\partial k^\dagger}\frac{dk^\dagger}{dq} > 0.$$

The inequality holds because $\frac{\partial B_2^\dagger}{\partial q} = \frac{dB_2^*}{dq} > 0$, $\frac{\partial B_2^\dagger}{\partial k^\dagger} = \frac{dB_2^*}{dk} < 0$, and $\frac{dk^\dagger}{dq} < 0$.

5. $\frac{dB_1^\dagger}{dD}$ and $\frac{dB_2^\dagger}{dD}$: The chain rule yields

$$\begin{aligned}\frac{dB_1^\dagger}{dD} &= \frac{\partial B_1^\dagger}{\partial D} + \frac{\partial B_1^\dagger}{\partial k^\dagger}\frac{dk^\dagger}{dD} > 0 \text{ and}\\ \frac{dB_2^\dagger}{dD} &= \frac{\partial B_2^\dagger}{\partial D} + \frac{\partial B_2^\dagger}{\partial k^\dagger}\frac{dk^\dagger}{dD} > 0,\end{aligned}$$

where $\frac{\partial B_1^\dagger}{\partial D} = \frac{dB_1^*}{dD} > 0$, $\frac{\partial B_2^\dagger}{\partial D} = \frac{dB_2^*}{dD} > 0$, and $\frac{dk^\dagger}{dD} = 0$.

6. $\frac{dB_1^\dagger}{d\lambda}$ and $\frac{dB_2^\dagger}{d\lambda}$: The chain rule yields

$$\begin{aligned}\frac{dB_1^\dagger}{d\lambda} &= \frac{\partial B_1^\dagger}{\partial \lambda} + \frac{\partial B_1^\dagger}{\partial k^\dagger}\frac{dk^\dagger}{d\lambda} > 0 \text{ and}\\ \frac{dB_2^\dagger}{d\lambda} &= \frac{\partial B_2^\dagger}{\partial \lambda} + \frac{\partial B_2^\dagger}{\partial k^\dagger}\frac{dk^\dagger}{d\lambda} > 0,\end{aligned}$$

where $\frac{\partial B_1^\dagger}{\partial \lambda} = \frac{\partial B_2^\dagger}{\partial \lambda} = \frac{dB_1^*}{d\lambda} = \frac{dB_2^*}{d\lambda} = 0$, $\frac{\partial B_1^\dagger}{\partial k^\dagger} = \frac{dB_1^*}{dk} < 0$, $\frac{\partial B_2^\dagger}{\partial k^\dagger} = \frac{dB_2^*}{dk} < 0$, and $\frac{dk^\dagger}{d\lambda} < 0$.

7. From Corollary 5, it is clear that $\frac{d\left[B_1^\dagger + B_2^\dagger\right]}{dc} < 0$, $\frac{d\left[B_1^\dagger + B_2^\dagger\right]}{d\lambda} > 0$, and $\frac{d\left[B_1^\dagger + B_2^\dagger\right]}{dD} > 0$. For $\frac{d\left[B_1^\dagger + B_2^\dagger\right]}{dq}$, from the chain rule, $B_1^\dagger + B_2^\dagger = \frac{2D}{c}\frac{1+k^\dagger}{1+2k^\dagger}$ and $\frac{\partial\left[\frac{1+k^\dagger}{1+2k^\dagger}\right]}{\partial k^\dagger} = -\frac{1}{\left(1+2k^\dagger\right)^2}$, we have $\frac{d\left[B_1^\dagger + B_2^\dagger\right]}{dq} = -\frac{2D}{c}\frac{1}{\left(1+2k^\dagger\right)^2}\frac{dk^\dagger}{dq} \geq 0$, where the inequalities follow from $\frac{dk^\dagger}{dq} \leq 0$ and $\frac{dk^\dagger}{d\lambda} \leq 0$ as shown in Corollary 4.

8. $\frac{d\pi_1^\dagger}{dc}$: The chain rule yields

$$\begin{aligned}\frac{d\pi_1^\dagger}{dc} &= D\left(1+k^\dagger\right)\frac{\left(2k^\dagger+1\right)-q}{c^2\left(2k^\dagger+1\right)^2} \\ &\quad + \left(D\frac{\left(1+q\left(2c\lambda-1\right)\right)\left(1+2k^\dagger\right)-2q}{c\left(1+2k^\dagger\right)^3}\right)\left(-\frac{q\lambda k^\dagger\left(1+2k^\dagger\right)}{\sqrt{2\left(1+q^2\right)+q^2\left(1-c\lambda\right)^2}}\right).\end{aligned}$$

We substitute $k^\dagger$ and rearrange terms to get

$$\frac{d\pi_1^\dagger}{dc} = -\frac{D}{4qc^2\sqrt{2\left(1+q^2\right)+q^2\left(1-c\lambda\right)^2}}\tau,$$

where

$$\begin{aligned}\tau &= 2-4q+3q^2-6q^3+\left(2q^3-q^2\right)c\lambda+q^3\left(c\lambda\right)^2\left(1-c\lambda\right) \\ &\quad + \left(1-3q+3q^2+q^2\left(c\lambda\right)^2\right)\sqrt{2\left(1+q^2\right)+q^2\left(1-c\lambda\right)^2}.\end{aligned}$$

Next, we reduce the dimensionality and simplify the range of parameters by substituting $c\lambda = y+1$, where $c\lambda > 1 \Rightarrow y > 0$. We denote the result ty:

$$\begin{aligned}ty &= 2-4q+3q^2-6q^3+\left(2q^3-q^2\right)\left(y+1\right)-q^3\left(y+1\right)^2 y \\ &\quad + \left(1-3q+3q^2+q^2\left(y+1\right)^2\right)\sqrt{2\left(1+q^2\right)+q^2y^2} \\ &= ty_A+ty_B+ty_C+ty_D,\end{aligned}$$

where

$$
\begin{aligned}
ty_A &= -q^3y^3 + q^2y^2\sqrt{2+q^2\left(2+y^2\right)}, \\
ty_B &= -2y^2q^3 + 2yq^2\sqrt{2+q^2\left(2+y^2\right)}, \\
ty_C &= -yq^2\left(1-q\right) + q\left(1-q\right)\sqrt{2+q^2\left(2+y^2\right)}, \text{ and} \\
ty_D &= 2\left(1-2q\right)\left(q^2+1\right) + \left(\left(1-2q\right)^2+q^2\right)\sqrt{2+q^2\left(2+y^2\right)}.
\end{aligned}
$$

(i) Note that ty_A is positive, as

$$
\begin{aligned}
ty_A &> 0 \\
&\Leftrightarrow \left(y^2q^2\sqrt{2+q^2\left(2+y^2\right)}\right)^2 > \left(q^3y^3\right)^2 \\
&\Leftrightarrow 2y^4q^4\left(q^2+1\right) > 0.
\end{aligned}
$$

(ii) ty_B is positive, as

$$
\begin{aligned}
ty_B &> 0 \\
&\Leftrightarrow \left(2q^2y\sqrt{2+q^2\left(2+y^2\right)}\right)^2 > \left(2y^2q^3\right)^2 \\
&\Leftrightarrow 8y^2q^4\left(q^2+1\right) > 0.
\end{aligned}
$$

(iii) ty_C is positive, as

$$
\begin{aligned}
ty_C &> 0 \\
&\Leftrightarrow \left(q\left(1-q\right)\sqrt{2+q^2\left(2+y^2\right)}\right)^2 > \left(yq^2\left(1-q\right)\right)^2 \\
&\Leftrightarrow 2q^2\left(q^2+1\right)\left(1-q\right)^2 > 0.
\end{aligned}
$$

(iv) Finally, each term in ty_D is weakly positive for $q \leq 1/2$, such that $ty_D \geq 0$ holds for $q \leq 1/2$. This implies that $ty > 0$ for $q \in (0, 1/2]$, because each of the components,

ty_A through ty_A, is strictly positive and ty_D is weakly positive in this range of q. Next, to show that ty is positive for $q \in (1/2, 1)$, rewrite ty as

$$ty = ty_A + ty_{BCD},$$

where

$$\begin{aligned} ty_A &= -q^3y^3 + q^2y^2\sqrt{2 + q^2\left(2 + y^2\right)} \text{ and} \\ ty_{BCD} &= \left(2yq^2 + q\left(1 - q\right)\right)\left(\sqrt{2 + q^2\left(2 + y^2\right)} - qy\right) \\ &\quad +2\left(1 - 2q\right)\left(q^2 + 1\right) + \left(\left(2q - 1\right)^2 + q^2\right)\sqrt{2 + q^2\left(2 + y^2\right)}. \end{aligned}$$

We first show that the derivative of each part with respect to y is positive when $q > 1/2$, which implies that the derivative of ty with respect to y is positive when $q > 1/2$. This further implies that ty is minimized when y approaches its lower bound. We then show that the minimum of ty is positive, which implies that ty is positive everywhere. That is, first,

$$\frac{dty_{BCD}}{dty} = q^2\frac{y\left(2q - 1\right)^2 + 4q^2 + 4 + qy + 4q^2y^2 - \left(1 - q + 4qy\right)\sqrt{2 + q^2\left(2 + y^2\right)}}{\sqrt{2 + q^2\left(2 + y^2\right)}}$$

and this term is positive for $q > 1/2$, as

$$\begin{aligned} \tfrac{dty_{BCD}}{dty} &> 0 \\ &\Leftrightarrow \left(y\left(2q - 1\right)^2 + 4q^2 + 4 + qy + 4q^2y^2\right)^2 > \left(\left(1 - q + 4qy\right)^2\left(2 + q^2\left(2 + y^2\right)\right)\right) \\ &\Leftrightarrow 2\left(2q + 7q^2 + 7 + 4y\left(2q - 1\right)\left(3q - 1\right)\right)\left(q^2 + 1\right) \\ &\quad + \left(\left(2q - 1\right)^2 + q^2\right)\left(1 - 2q + 8q^2y + 3q^2\right)y^2 > 0. \end{aligned}$$

Next, we show that $\frac{dty_A}{dy} > 0$, which follows as

$$\begin{aligned}
\frac{dty_A}{dy} &= \left(4q^2 + 3q^2y^2 - 3qy\sqrt{2q^2 + q^2y^2 + 2} + 4\right) \frac{q^2 y}{\sqrt{2q^2 + q^2y^2 + 2}} > 0 \\
&\Leftrightarrow \; 4q^2 + 3q^2y^2 + 4 - 3qy\sqrt{2q^2 + q^2y^2 + 2} > 0 \\
&\Leftrightarrow \; \left(4q^2 + 3q^2y^2 + 4\right)^2 - \left(3qy\sqrt{2q^2 + q^2y^2 + 2}\right)^2 > 0 \\
&\Leftrightarrow \; 2\left(q^2 + 1\right)\left(8q^2 + 3q^2y^2 + 8\right) > 0.
\end{aligned}$$

Finally, we show that $\min_y ty > 0$. Because $\frac{dty}{dy} > 0$, $\min_y ty$ is achieved at the lower bound for y, where $y > \frac{1-q^2}{2q^2}$ follows from $q^2(2c\lambda - 1) - 1 > 0$ and $y = c\lambda - 1$. Therefore,

$$\min_y ty = \lim_{y \to \frac{1-q^2}{2q^2}} ty = q^{-1}\left(q + 2q^2 + 1\right)(1 - q) > 0.$$

That is, $ty > 0$ holds everywhere. Therefore, $\frac{d\pi_1^\dagger}{dc} < 0$, as $\frac{d\pi_1^\dagger}{dc} \propto -\frac{dty}{dy}$.

9. $\frac{d\pi_2^\dagger}{dc}$: The chain rule yields

$$\frac{d\pi_2^\dagger}{dc} = \frac{\partial \pi_2^\dagger}{\partial c} + \frac{\partial \pi_2^\dagger}{\partial k^\dagger}\frac{dk^\dagger}{dc}.$$

As shown in the proof of Corollary (3), the derivative $\frac{\partial \pi_2^\dagger}{\partial k^\dagger} = \frac{d\pi_2^*}{dk}$ is always negative when

$$\begin{aligned}
\frac{1}{2c}\left(2 + \frac{1+q}{q}\right) - \lambda &< 0, \text{ which is equivalent to} \\
q(2c\lambda - 1) - 1 &> 0.
\end{aligned} \tag{24}$$

The condition in (24) is implied by the condition for interior $k^\dagger$, $q^2(2c\lambda - 1) - 1$, and $0 < q < 1$, as

$$q(2c\lambda - 1) - 1 > q^2(2c\lambda - 1) - 1.$$

Therefore, $q^2(2c\lambda - 1) - 1 \Rightarrow q(2c\lambda - 1) - 1 \Rightarrow \frac{\partial \pi_2^\dagger}{\partial k^\dagger} < 0$ for the feasible range. Furthermore, $\frac{\partial \pi_2^\dagger}{\partial c} = \frac{d\pi_2^*}{dc} > 0$ and $\frac{dk^\dagger}{dc} < 0$, so $\frac{d\pi_2^\dagger}{dc} = \frac{\partial \pi_2^\dagger}{\partial c} + \frac{\partial \pi_2^\dagger}{\partial k^\dagger}\frac{dk^\dagger}{dc}$ is the sum of two positive terms in the relevant range, implying $\frac{d\pi_2^\dagger}{dc} > 0$.

10. $\frac{d\pi_1^\dagger}{dq}$: The chain rule yields

$$\frac{d\pi_1^\dagger}{dq} = \frac{\partial\pi_1^\dagger}{\partial q} + \frac{\partial\pi_1^\dagger}{\partial k^\dagger}\frac{dk^\dagger}{dq} < 0.$$

The inequality holds because $\frac{\partial\pi_1^\dagger}{\partial q} = \frac{d\pi_1^*}{dq} < 0$, $\frac{\partial\pi_1^\dagger}{\partial k^\dagger} = \frac{d\pi_1^*}{dk} > 0$, and $\frac{dk^\dagger}{dq} < 0$.

11. $\frac{d\pi_2^\dagger}{dq}$: The chain rule yields

$$\frac{d\pi_2^\dagger}{dq} = \frac{\partial\pi_2^\dagger}{\partial q} + \frac{\partial\pi_2^\dagger}{\partial k^\dagger}\frac{dk^\dagger}{dq} > 0.$$

The inequality holds because $\frac{\partial\pi_2^\dagger}{\partial q} = \frac{d\pi_2^*}{dq} > 0$, $\frac{\partial\pi_2^\dagger}{\partial k^\dagger} = \frac{d\pi_2^*}{dk} < 0$, and $\frac{dk^\dagger}{dq} < 0$, where we show that $\frac{\partial\pi_2^\dagger}{\partial k^\dagger} < 0$ for the relevant range of parameters in the proof of $\frac{d\pi_2^\dagger}{dc} > 0$.

12. $\frac{d\pi_1^\dagger}{dD}$ and $\frac{d\pi_2^\dagger}{dD}$: The chain rule yields

$$\begin{aligned}\frac{d\pi_1^\dagger}{dD} &= \frac{\partial\pi_1^\dagger}{\partial D} + \frac{\partial\pi_1^\dagger}{\partial k^\dagger}\frac{dk^\dagger}{dD} > 0 \text{ and}\\ \frac{d\pi_2^\dagger}{dD} &= \frac{\partial\pi_2^\dagger}{\partial D} + \frac{\partial\pi_2^\dagger}{\partial k^\dagger}\frac{dk^\dagger}{dD} > 0.\end{aligned}$$

The inequalities hold because $\frac{\partial\pi_1^\dagger}{\partial D} = \frac{d\pi_1^*}{dD} > 0$, $\frac{\partial\pi_2^\dagger}{\partial D} = \frac{d\pi_2^*}{dD} > 0$, and $\frac{dk^\dagger}{dD} = 0$.

13. $\frac{d\pi_1^\dagger}{d\lambda}$: We can write

$$\frac{d\pi_1^\dagger}{d\lambda} = \frac{D}{4\sqrt{2\left(1+q^2\right)+q^2\left(1-c\lambda\right)^2}}\sigma,$$

where

$$\sigma = 2 + q^2\left(5 + c\lambda\left(2c\lambda - 5\right)\right) - q + qc\lambda + \left(3 - q - 2qc\lambda\right)\sqrt{2\left(1+q^2\right)+q^2\left(1-c\lambda\right)^2}.$$

Next, define $c\lambda = y + 1$, and σy as σ after substituting y for $c\lambda - 1$:

$$\sigma y = \left(yq - \sqrt{2 + q^2\left(2 + y^2\right)}\right)^2 + yq\left(1 - q\right) + 3\left(1 - q\right)\sqrt{2 + q^2\left(2 + y^2\right)}.$$

which is the sum of three positive terms, given $y > 0$ and $0 < q < 1$. Finally, $\sigma y > 0 \Rightarrow \sigma > 0 \Rightarrow \frac{d\pi_1^\dagger}{d\lambda} > 0$.

14. $\frac{d\pi_2^\dagger}{d\lambda}$: The chain rule yields

$$\frac{d\pi_2^\dagger}{d\lambda} = \frac{\partial\pi_2^\dagger}{\partial\lambda} + \frac{\partial\pi_2^\dagger}{\partial k^\dagger}\frac{dk^\dagger}{d\lambda} > 0.$$

The inequality holds because $\frac{\partial\pi_2^\dagger}{\partial\lambda} = \frac{d\pi_2^*}{d\lambda} > 0$, $\frac{\partial\pi_2^\dagger}{\partial k^\dagger} = \frac{d\pi_2^*}{dk} < 0$, and $\frac{dk^\dagger}{d\lambda} < 0$. We show that $\frac{\partial\pi_2^\dagger}{\partial k^\dagger} < 0$ for the relevant range of parameters in the proof of $\frac{d\pi_2^\dagger}{dc} > 0$.