Hold-Up, Innovation, and Platform Governance*

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Abstract

Motivated by large digital platforms, I study a model of platforms choosing fees, upgrades, and governance to compete over a two-sided market of producers and consumers. By solving an interoperability-driven hold-up problem, giving producers governance power over fee changes increases producer investment in product quality; however, by preventing fee-adjustments, it causes platforms to under-invest in upgrades. This trade-off persists even if platforms choose their preferred level of interoperability, which is higher without such governance than with. When governance is necessary for producers to invest in quality, platforms under-provide governance relative to the social optimum. However, when producers invest in quality regardless of governance, platforms over-provide governance.

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Platform markets—from social media and internet search to gaming engines and online marketplaces—are characterized by lock-in. For a variety of reasons including network externalities, search or switching costs, and imperfect interoperability, the larger and more successful a platform, the more difficult it is to switch to a competitor (Rochet and Tirole, 2003; Farrell and Klemperer, 2007; Akerlof, Holden and Rayo, 2024).

The presence of lock-in creates the potential for a hold-up problem (Klein, Crawford and Alchian, 1978; Williamson, 1975, 1979; Rogerson, 1992). As platform users become locked-in, platforms are tempted to extract rents by raising fees. Anticipating this, producers may refrain from making social surplus-generating investments which can, in turn, undermine the value of the platform. But lock-in may have benefits as well. For instance, platform owners' ability to capture rents by raising fees may incentivize them to invest in surplus-generating upgrades to the platform itself.

Many examples from online commerce point to the existence of lock-in based hold-up problems. As its App Store has become increasingly dominant, for instance, Apple has repeatedly and substantially increased the per-transaction fees it charges for in-app purchases.[1] Spotify responded to one such rate hike by stating: "Once again, Apple has demonstrated that they will stop at nothing to protect the profits they exact on the backs of developers and consumers under their app store monopoly."[2] And, perhaps as a result, when Apple launched its Vision Pro virtual reality headset, important developers including Netflix, YouTube, and Spotify declined to make their apps available on the new platform.[3]

Apple is not alone in responding to the incentives created by lock-in. Amazon and Etsy have similarly leveraged their market positions at the expense of third-party sellers.[4] The Unity game engine sparked a revolt among developers with a proposed new fee structure

[1] See, for example, Sarah Perez, "Apple's in-app purchase prices jumped 40% year over year, likely tied to privacy changes," *Tech Crunch*, September 13, 2022 https://techcrunch.com/2022/09/13/apples-in-app-purchase-prices-jumped-40-year-over-year-likely-tied-to-privacy-changes/; "Apple to hike App Store prices across Europe and some parts of Asia next month," *The Verge*, September 20, 2022 https://www.theverge.com/2022/9/20/23362635/apple-app-store-price-increase-europe-asia.

[2] Daniel Howley and Alexis Keenan. "Apple's App Store rule changes draw sharp rebuke from critic," *yahoo!finance*, January 18, 2024 https://finance.yahoo.com/news/apples-app-store-rule-changes-draw-sharp-rebuke-from-critics-150047160.html

[3] Mark Gurman, "Apple's Testy Developer Relationships Threaten to Hamper Vision Pro," *Bloomberg*, January 21, 2024 https://www.bloomberg.com/news/newsletters/2024-01-21/apple-vision-pro-lack-of-netflix-youtube-app-store-tensions-threaten-device-lrnjwjb3.

[4] Candice Norwood, "Why Etsy's latest fee increase has inspired thousands of sellers, including its most marginalized, to strike," *PBS*, April 19, 2022 https://www.pbs.org/newshour/economy/why-etsys-latest-fee-increase-has-inspired-thousands-of-sellers-including-its-most-marginalized-to-strike; Spencer Soper, "Amazon Is Taking Half of Each Sale From Its Merchants" *Bloomberg*, February 13, 2023 https://www.bloomberg.com/news/articles/2023-02-13/amazon-amzn-takes-half-of-each-sale-from-2-million-small-businesses.

that game designers claimed would erode the profits expected from years of investment in code that was incompatible with alternative game engines.[5] And Google recently lost a lawsuit related to its use of lock-in driven market power in its Google Play App store.[6]

A familiar intuition is that if the hold-up problem is sufficiently severe, platforms themselves may wish to find a solution through vertical integration or formal contracts (Hart, 1995). But there are a variety of reasons these approaches might be of limited efficacy. In the technology sector, opportunities for vertical integration are constrained by regulation (see, for example Federal Trade Commission, 2021)) and there are at least some circumstances under which vertical integration might exacerbate rather than alleviate hold-up (Allain, Chambolle and Rey, 2016). And because platforms may have many tools to extract rents—e.g., fee changes, releasing competing versions of popular products, altering recommendation algorithms—it may be difficult to write contracts that sufficiently reassure producers. Moreover, enforcement costs may be high for small users relative to large platforms.

As an alternative to direct contracting, platforms might consider other commitment mechanisms to help address hold-up. One possibility is what we might think of as *devolved governance*, such as giving producers who sell on the platform formal voting rights over some class of business decisions (e.g., the power to veto changes to fee structures or recommendation algorithms). Another might be creating less formal pathways for producers' voices to play a role in shaping platform decision making, as occurred when Unity backed away from its fee increases in response to a developer revolt.

While we have not seen platforms formally devolve power over fee setting, major technology companies are engaged in a variety of experiments in democratizing governance rights over business decisions more broadly. For instance, both OpenAI and Anthropic have allow users to weigh in on the rules governing AI tools.[7] Meta created an Oversight Board of outside experts with governance rights over content moderation policy and has experimented with assemblies that allow various constituents to make governance decisions for

[5]Mega Farokhmanesh, "Unity May Never Win Back the Developers It Lost in Its Fee Debacle," *Wired*, September 22, 2023 `https://www.wired.com/story/unity-walks-back-policies-lost-trust/`.

[6]Greg Bensinger and Mike Carcella, "Epic Games wins antitrust case against Google over Play app store," Reuters, December 11, 2023. `https://www.reuters.com/legal/google-epic-games-face-off-app-antitrust-trial-nears-end-2023-12-11/`

[7]Kyle Wiggers, "With new grant program, OpenAI aims to crowdsource AI regulation," *Tech Crunch*, May 25, 2023 `https://techcrunch.com/2023/05/25/when-new-grant-program-openai-aims-to-crowdsources-ai-regulation/`; Kevin Roose, "What if We Could All Control A.I.?," *New York Times*, October 17, 2023 `https://www.nytimes.com/2023/10/17/technology/ai-chatbot-control.html`

other products.[8] X (formerly Twitter) has also experimented with allowing users to vote on policy decisions.[9] And democratized governance over business decisions implemented through tokenization is a key idea underlying a variety of web3 projects operating on the blockchain (Hall and Oak, 2023; Messias et al., 2023). Moreover, Unity's concessions over fees in response to objections from game designers suggests a kind of implicit veto power.

Of course, committing not to change fees may entail important trade-offs. Tying hands reduces hold-up. However, the flexibility to shift business terms may also be important for platform owners' willingness to make surplus-generating upgrades to the platform itself. For instance, testifying in an anti-trust suit brought by EPIC games regarding App Store fees, Apple CEO Tim Cook argued that fee increases were needed to recoup research and development costs associated with platform upgrades that improve the user experience, including regarding the provision of privacy and security.[10] Thus, governance (or other commitment devices) need not be unequivocally good for platforms or social welfare.

Motivated by this set of concerns, I study a two-period model in which two platforms repeatedly compete for a two-sided market populated by a producer and a unit mass of consumers. Platforms compete on multiple dimensions—the fees charged, the quality of the platform, and the presence of governance-based commitment not to change fees. The producer decides whether to invest in providing a higher-quality product, sets prices, and decides which platform to do business on. Consumers decide whether to purchase the good on the platform. There is lock-in due to limited interoperability: the value to consumers of an investment in product quality by the producer goes down if the product is sold on a platform other than the one it was originally produced for.

I first consider the model without governance-based commitment—in particular, the platform can raise fees between periods if it likes. Equilibrium is characterized by a hold-up problem. The producer under-invests in product quality because fee hikes by the platform in the second period erode some of the producer's rents. The producer will pay these increased fees because limited interoperability reduces the value of the producer's outside option. That said, conditional on product quality, platform upgrades are efficiently provided

[8] Aviv Ovadya, "Meta Ran a Giant Experiment in Governance. Now It's Turning to AI," *Wired*, July 10, 2023 `https://www.wired.com/story/meta-ran-a-giant-experiment-in-governance-now-its-turning-to-ai`

[9] Alex Veiga, "Musk restores Trump's Twitter account after online poll," *Associated Press*, November 19, 2022 `https://apnews.com/article/elon-musk-biden-twitter-inc-technology-congress-d88e3de4b3cc095926dc133f53dc3320`

[10] Rishi Iyengar, "Tim Cook defends Apple in blockbuster Fortnite trial: 'It has nothing to do with money'," *cnn.com* May 21, 2021 `https://www.cnn.com/2021/05/21/tech/tim-cook-testimony-apple-epic/index.html`

because a platform's freedom to raise fees allows it to capture the rents associated with such upgrades. For the platform, the optimal level of interoperability is partial. It wants just enough interoperability to incentivize the producer to invest in quality, but no more, because further interoperability reduces the platform's bargaining power.

I then consider the model with *asymmetric* governance—one of the two platforms gives the producer the power to veto any change to fees between periods. Asymmetric governance eliminates hold-up. That is, in the second period, the platform would like to raise fees but the producer uses its governance power to prevent the platform from doing so. As a result, the platform with governance wins the competition between the two platforms and is better able to incentivize investment in quality. But this comes at a cost in terms of inefficient under-provision of platform upgrades. There are social surplus-generating platform upgrades that the platform owner forgoes because they can't raise fees to capture enough of the rents to make the upgrades worth the private costs. The platform owner wants as little interoperability as possible when it has asymmetric governance because it no longer needs interoperability to solve the hold-up problem, so the only effect of interoperability for the platform is to weaken its bargaining position.

With *symmetric* governance—i.e., when both platforms grant the producer veto rights—the two platforms compete one another all the way down to zero fees and zero profits. In the model where the platforms decide endogenously whether to implement governance, there is never symmetric governance in a pure strategy equilibrium.

Having characterized these equilibria, I calculate both the platform owners' and the utilitarian social planner's willingness to pay (WTP) for asymmetric governance. These can be positive or negative. Crucially, the social planner's and platform owners' WTP diverge from one another in just two cases.

First, when governance is necessary and sufficient for incentivizing investment in product quality by the producer, the social planner's WTP is higher than either platform owners' WTP. This is because some of the surplus from quality investment is captured by the producer and consumers. In this circumstance, platforms endogenously competing over whether to provide governance under-provide it relative to the utilitarian social optimum. Second, when there is equilibrium investment in product quality regardless of governance, the two platform owners have different WTP—the platform owner that will end up the market loser in the event that neither platform implements governance has a higher WTP because governance can turn it from a loser into a winner. Moreover, this platform owner's WTP is higher than the social planner's because the social planner does not care which platform wins. In this circumstance, governance is over-provided relative to the social optimum. Thus, if endogenously chosen by the platforms, governance is under-provided precisely when its presence matters for incentivizing product quality and is over-provided when its presence does not matter for incentivizing quality.

Finally, I show that all of these trade-offs persist in an extended model where the platforms endogenously choose the level of interoperability.

1 Related Literature

This paper builds on ideas from two canonical literatures in industrial organization and contract theory. The first studies the hold-up problem and its solutions (e.g., Klein, Crawford and Alchian, 1978; Williamson, 1975, 1979; Rogerson, 1992). The second studies two-sided platform markets (see Rochet and Tirole, 2006; Rysman, 2009; Weyl, 2010, for discussions and reviews of this literature). My model abstracts away from many of the issues platform economics has studied because I am not here concerned with the important questions of pricing formulas and market structure that have been the focus of much of the literature.

In the platform economics literature, my model is related to Ekmekci, White and Wu (2023), who study competition between platforms and, motivated by technology platforms as I am, provide results on the effects of interoperability. However, that model is focused on canonical questions about pricing, demand, mergers, and regulation and does not address product quality or platform upgrades; whereas the analysis here is focused on the provision of internal governance and its effects on quality and upgrades. I also follow Hagiu and Lee (2011) in studying a model of platforms competing for content providers. They are focused on whether platforms or providers control the price charged to consumers and how that affects the decision about whether providers multihome or affiliate with a single platform. By contrast, I focus on whether platforms or producers control decision rights over changes to fees and how that affects investment in product and platform quality.

The platforms and producer in my model, like in Hagiu and Lee's (2011), are analogous to the retailers and manufacturer, respectively, in the literature on vertical contracting (Hart and Tirole, 1990; O'Brien and Shaffer, 1992; McAfee and Schwartz, 1994). As Hagiu and Lee point out, there are also important differences between a platform model like this one and canonical vertical contracting models: competition for consumers on the other side of the market, the location of bargaining power in the relationship between platforms and producers, and most importantly in the case of my model, the opportunity for platforms to invest in quality-enhancing upgrades after negotiating with the producer.

The trade-off studied here between incentivizing producers to invest in product quality and platform owner's to invest in platform upgrades is an instance of the problem of double-sided moral hazard, where outcomes depend on effort choices by multiple agents (Romano, 1994; Bhattacharyya and Lafontaine, 1995; Kim and Wang, 1998). The double-sided moral hazard literature is primarily focused on optimal contracts in fairly general contracting settings between a principal and agent. Here, instead, I embed the double-sided moral hazard problem in a model of competition between platforms, with a limited contracting space motivated by the application (more on this in Section 2.1). Moreover, the distortions that occur in my model are not driven by hidden actions, but rather by commitment problems.

My model is also related to work in political economy on the idea that democratization might be a solution to certain commitment problems (Acemoglu and Robinson, 2001; Boix, 2003). In Acemoglu and Robinson (2001) and Boix (2003), the relevant commitment problem involves the willingness of an elite-controlled government to redistribute, whereas in my setting it is a hold-up problem associated with an incumbent platform changing business terms.

Finally, this work is related to a literature inspired by the growth of interest in online governance associated with blockchains. Holden and Malani (2019) study conditions under which smart contracts can serve as a commitment device to address hold-up problems. Sockin and Xiong (2023) and Reuter (2023) study when blockchain-based governance is beneficial to a company that suffers from a lock-in based hold-up problem. Reuter's model of decentralizing decision rights over monetization and revenue sharing is the closest to my model. That model and this one differ from and complement one another in several ways. Reuter's fully dynamic game provides insight into the dynamic path of governance, lock-in, and the value of the enterprise. To focus on these dynamics, Reuter studies one firm facing a one-sided market and takes a reduced-form approach to the source of the rents and the price setting that determines revenue sharing. By contrast, my model has only two-periods, so does not provide the rich dynamics Reuter's does. However, the model here explicitly micro-founds both the distribution of rents and the presence of lock-in. It also allows for an analysis of competition between two platforms that are facing a two-sided market, asking how this affects lock-in, the willingness to pay for governance, and the divergence between equilibrium and socially optimal governance.

2 The Model

There are two platforms (A and B), one producer, and a unit mass of consumers indexed by i. Each consumer has per period demand for one unit of a good made by the producer.

The game takes place over two periods, $t = 1, 2$.

In each period, the producer produces a good at zero marginal cost. To sell the good to consumers, it must do so on a platform. The producer can only sell on one platform per period. The platforms charge the producer a per-transaction fee for this service, consumers use the platform for free. Consumers face opportunity costs for each platform they access. User i has opportunity cost x_i. I assume the x's are uniformly distributed on $[0, 1]$ and are commonly known by all players.

The value of the good to the consumers depends on choices made by the producer and the platform. At the beginning of the game, the producer chooses whether or not to invest in producing a *high-quality* good, $q \in \{1, \theta\}$, with $\theta > 1$. It costs the producer $k_\theta > 0$ to invest in high quality ($q = \theta$). Quality is partially platform specific. If the producer invests in quality in the first period and then switches platforms in the second period, quality is reduced to $\alpha \cdot \theta$, with $\alpha \in (\frac{1}{\theta}, 1)$ in the second period. I refer to α as measuring *interoperability*, with $\alpha = 1$ representing perfect interoperability and $\alpha = \frac{1}{\theta}$ representing no interoperability.

Between the first and the second period, the incumbent platform can invest in quality-enhancing upgrades, $r \in \{1, \mu\}$, with $\mu > 1$. Upgrading the platform to $r = \mu$ has cost $k_\mu > 0$. If a good of quality θ is offered on a platform with upgrade r, it's value to consumers is $v = r \cdot \theta$. But a good of quality $q = 1$ is always of value 1, regardless of upgrades to the platform. To ensure interior solutions, I assume that $\mu \cdot \theta \leq 2$.

The timeline of the baseline game without governance is as follows:

Period 1

1. Platforms set first-period fees: $\phi_1^A, \phi_1^B \geq 0$
2. Producer chooses whether to enter the market (if it does not the game ends). If the producer enters the market it chooses:
   - Which platform to join: A or B
   - Quality: $q \in \{1, \theta\}$
   - Price for product: $p_1 \geq 0$
3. Consumers decide whether to purchase the product.

Period 2

1. The incumbent platform decides whether to upgrade: $r \in \{1, \mu\}$

2. Each platform sets second-period fees: $\phi_2^A, \phi_2^B \geq 0$
3. Producer chooses:
   - Which platform to join: A or B
   - Price for product: $p_2 \geq 0$
4. Consumers decide whether to purchase the product.

Let v_t be the value of the good to consumers and p_t the price of the good in period t. Consumer i's payoff in each period in which she purchases the good is

$$v_t - p_t - x_i.$$

Her payoff in periods in which she does does not purchase the good is zero.

Let N_t be the measure of consumers who purchase the good in period t and ϕ_t be the fee of the platform on which the good is sold in period t. The producer's payoff for the game is:

$$N_1(p_1 - \phi_1) + N_2(p_2 - \phi_2) - \mathbb{I}_{q=\theta} \cdot k_\theta.$$

In each period in which the good is sold on a given platform, that platform's revenue is

$$N_t \cdot \phi_t.$$

A platform also bears cost k_μ if it upgrades.

In the model without governance, platforms can change the fee they charge between periods unrestrictedly. In the model with *asymmetric governance*, if the producer joins platform A in period 1, then the producer has the right to veto any proposed fee change by platform A in period 2; however, this is not the case if the producer joins platform B in period 1. In the model with *symmetric governance*, the producer has veto rights over fee changes on whichever platform she joins in the first period.

After analyzing these versions of the game, I consider two extensions: allowing a period 0 in which the platforms simultaneously choose whether to implement governance at cost $c > 0$ and allowing the platforms to endogenously choose the level of interoperability.

The solution concept is pure strategy, subgame perfect Nash equilibrium, which I refer to as simply *equilibrium*.

2.1 Comments

A few features of the model merit further comment. These include that platform upgrades only enhance the value of high-quality products not all products, the absence of multihoming, and the restricted contracting environment. It will be clearest to discuss the assumptions about platform upgrades and multihoming after analyzing the model. As such, I defer this discussion until Section 8.

But it is worth commenting up front about two features of the restricted set of contracts considered here: (i) platforms can use governance to commit to holding fees fixed, but not to commit to investing in upgrades and (ii) platforms use simple contracts with per-transaction fees. With respect to governance, of course, if platforms could commit ex ante to fees and upgrades, they would face no frictions other than the need to incentivize investment by the producer. This complete contracting assumption, however, seems unrealistic. An important difference between platform upgrades and fee increases is that producers directly observe the fees they pay, whereas a variety of platform upgrades that affect producer outcomes occur in the background without their awareness. Thus, producers likely lack the expertise to evaluate ex ante the menu of potential future upgrades; as such, it seems more realistic to assume a contracting environment where the producers cannot govern upgrades and must instead depend on the platforms' incentives. With respect to the restriction to transaction fee-based contracts, it is important to note that, as an empirical matter, this is the form of contract used overwhelmingly by the online platforms that motivate the model (Cachon, Dizdarer and Tsoukalas, 2023; Gan, Tsoukalas and Netessine, forthcoming). While optimal contract are clearly of interest, to gain insight into the trade-offs those platforms face between hold-up and platform upgrades, it is also useful to analyze contracts similar in form to those they actually use.

3 Equilibrium without Governance

First consider the game without governance. I solve by backward induction.

3.1 Second Period

In the second period, if the producer offers a good of value v_2 at price p_2 on one of the platforms, a consumer i purchases if and only if:

$$v_2 - p_2 - x_2 \geq 0.$$

Therefore demand is:

$$N^*(p_2, v_2) = \begin{cases} 1 & \text{if } v_2 - p_2 \geq 1 \\ v_2 - p_2 & \text{if } v_2 - p_2 \in (0,1) \\ 0 & \text{if } v_2 - p_2 \leq 0. \end{cases} \tag{1}$$

If the producer sells on a platform with fee $\phi_2 \leq v_2$, she sets the price of the good to solve:

$$\max_p (p - \phi_2) \cdot N^*(p_2, v_2).$$

This implies that:

$$p^*(v_2, \phi_2) = \begin{cases} v_2 - 1 & \text{if } \frac{v_2 - \phi_2}{2} \geq 1 \\ \frac{v_2 + \phi_2}{2} & \text{if } \frac{v_2 - \phi_2}{2} \in [0, 1). \end{cases}$$

The producer charges a price that leads to zero demand if $\phi_2 \geq v_2$. The fact that $\mu \cdot \theta \leq 2$ implies that the optimal price always leads to interior demand, so for any (v_2, ϕ_2), we have:

$$p^*(v_2, \phi_2) = \frac{v_2 + \phi_2}{2} \quad \text{and} \quad N^*(p^*(v_2, \phi_2), v_2) = \frac{v_2 - \phi_2}{2}. \tag{2}$$

This implies that for $\phi_2 \leq v_2$, the producer's payoff in the second period is:

$$\left(\frac{v_2 - \phi_2}{2}\right)^2$$

and the platform's revenue in the second period is:

$$\pi_2(v_2, \phi_2) = \phi_2 \cdot \frac{v_2 - \phi_2}{2}. \tag{3}$$

What fees will the platforms charge in the second period? An important starting observation is that, regardless of the upgrading decisions, the consumers' value from a high-quality good is higher on the incumbent platform than on the other platform (this follows from $\mu \cdot \alpha < 1$), while the consumers' value from a low-quality good is the same on both platforms. This means that if the good is high quality, the incumbent platform has an advantage in the second period and can retain the producer. In equilibrium, the other platform charges a fee of zero and the incumbent platform chooses a positive fee that leaves the producer just indifferent between the two platforms.[11] If the producer has not invested

[11] The fact that the incumbent platform leaves the producer just indifferent makes use of $\mu \cdot \theta \leq 2$, which ensures that the unconstrained revenue maximizing fee for a platform is larger than the fee that leaves the

in quality, then the producer is indifferent and so the platforms compete one another all the way down to fees of zero. These intuitions are formalized in Lemma 1. (All proofs are in the appendix.)

Lemma 1 *Let I be the incumbent platform and O be the other platform. In the game without governance, in equilibrium:*

- *If $v_2^I = v_2^O$, then $\phi_2^I = \phi_2^O = 0$ and the producer goes to either platform.*
- *If $v_2^I > v_2^O$, then $\phi_2^I = v_2^I - v_2^O$, $\phi_2^O = 0$ and the producer goes to the incumbent platform.*

Lemma 1 implies that if the producer has invested in quality, the incumbent platform wins charging positive fees that depend on upgrading decisions, summarized as follows:

$$\phi_2^{NG}(q, r_I, r_O) = \begin{cases} 0 & \text{if } q = 1 \\ \theta(1-\alpha) & \text{if } q = \theta, r = 1 \\ \theta(\mu - \alpha) & \text{if } q = \theta, r = \mu. \end{cases} \tag{4}$$

Plugging the equilibrium fee into the revenue from Equation 3, we have that the incumbent platform's revenue in the second period is:

$$\pi_2(v_2, \phi_2^{NG}(q, r)) = \begin{cases} 0 & \text{if } q = 1 \\ \frac{(v_2^I - v_2^O)v_2^O}{2} & \text{if } q = \theta. \end{cases}$$

In equilibrium, if $q = \theta$, the incumbent platform upgrades if and only if:

$$\pi_2(\theta \cdot \mu, \phi_2^{NG}(\theta, (\mu, 1))) - \pi_2(\theta, \phi_2^{NG}(\theta, (1, 1))) \geq k_\mu.$$

Substituting, this is equivalent to:

$$k_\mu \leq \frac{(\mu - 1)\alpha\theta^2}{2} \equiv \hat{k}_\mu^{NG}. \tag{5}$$

This allows for a direct calculation of second period payoffs for each choice of r and q, as shown in Table 1.

A few observations are worth highlighting. First, we can see the beginning of the hold-up problem. Because interoperability is only partial, the value of an investment in quality

producer indifferent.

Table 1: Second Period Payoffs without Governance

	$\mathbf{q=1}$	$\mathbf{q=\boldsymbol{\theta}}$	
		$r=1$	$r=\mu$
Aggregate of Consumers	$\frac{1}{8}$	$\frac{\alpha^2\theta^2}{8}$	$\frac{\alpha^2\theta^2}{8}$
Producer	$\frac{1}{4}$	$\frac{\alpha^2\theta^2}{4}$	$\frac{\alpha^2\theta^2}{4}$
Incumbent Platform	0	$\frac{\alpha(1-\alpha)\theta^2}{2}$	$\frac{\alpha(\mu-\alpha)\theta^2}{2} - k_\mu$
Other Platform	0	0	0

by the producer is only partially reflected in their outside option. This gives the incumbent platform bargaining power to claim some of the rents associated with quality investment. The less interoperability across platforms (lower α), the higher the second-period fee charged by the incumbent platform when the producer has invested in quality. Second, there is some pass through of fees from producers to consumers. As such, conditional on the producer investing in quality, the less interoperability the better off the platform is and the worse off the producer and consumers are. Third, the producer and consumers are indifferent as to whether or not the platform invests in upgrades—by adjusting the fee, the platform fully captures the value of upgrades. This also implies that the platform invests in upgrades efficiently, doing so if and only if the upgrade increases total social surplus, as stated in Remark 1.

Remark 1 *In the continuation game of the model without governance, the incumbent platform implements upgrades if and only if doing so maximizes social surplus.*

3.2 First Period

Consumer demand and producer pricing in the first period are again as described in Equations 1 and 2. Moreover, from the producer's perspective, in the first period the two platforms are identical in terms of continuation values. Thus, the producer will join whichever platform charges the lower fee in the first period. Since there are future rents associated with being the incumbent platform, this implies that the platforms compete away all the first-period rents, charging fees of $\phi_1^A = \phi_1^B = 0$. All that remains, then, is to determine whether the producer will invest in quality.

If the producer chooses low quality ($q = 1$), it makes a payoff of $\frac{1}{4}$ in each period. If instead it invests in high quality ($q = \theta$), its first period payoff is $\frac{\theta^2}{4} - k_\theta$ and its second period payoff, as shown in Table 1, is $\frac{\alpha^2\theta^2}{4}$. Thus, in equilibrium, the producer invests in quality if and only if:

$$\frac{(1+\alpha^2)\theta^2}{4} - k_\theta \geq \frac{1}{2} \iff k_\theta \leq \frac{(\alpha^2+1)\theta^2 - 2}{4} \equiv \hat{k}_\theta^{NG}. \tag{6}$$

Notice, the producer is indifferent as to which platform it joins in the first period and there are equilibria where it joins either. The platforms, of course, are not indifferent between these equilibria—the platform that the producer joins makes second period rents while the other platform makes a payoff of zero for the game. This multiplicity doesn't matter for an analysis of outcomes in the model with no governance. But it will matter later when I consider endogenous investment in governance since the willingness to pay for governance of the platform that will (for arbitrary reasons) be chosen in the first period absent governance will differ from the willingness to pay for governance of the platform that will not be chosen. So it will be useful to have terminology for these two platforms. I refer to the platform that will be chosen in the first period when there is no governance and the producer is indifferent as the *winning* platform and the platform that will not be chosen in the first period when there is no governance as the *losing* platform. It is important to distinguish between the *winning platform* and the *incumbent platform.* The winning platform is a ex ante concept having to do with equilibrium selection: it is the platform that will win in a given equilibrium in the first period of the game without governance. The incumbent platform is an ex post concept independent of equilibrium: it is the platform that won in the first period (in the game without or with governance). Thus, in equilibrium in the game without governance, the winning platform becomes the incumbent platform. But the two terms are conceptually distinct and the distinction will be important.

3.3 No Governance Results

The analysis above describes equilibrium outcomes in the game with no governance. (Proposition 10 in the supplemental appendix provides a complete statement of equilibrium strategies.) Figure 1 illustrates, for fixed values of all parameters other than k_θ and k_μ, the equilibrium investment and upgrade decisions. I can now describe a few key substantive results.

First, while the losing platform always makes a payoff of zero and the producer and aggregate consumers always make positive payoffs, the winning platform makes strictly positive payoffs if and only if the producer invests in quality. This is because if the producer

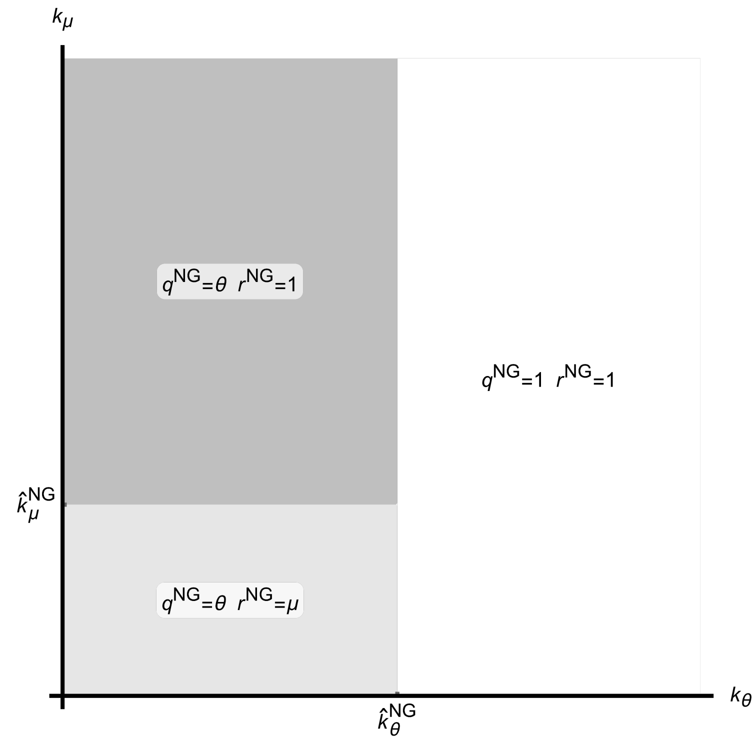

Figure 1: Equilibrium investment and upgrade decisions without governance as a function of the costs of investment and upgrades.

does not invest in quality, the two platforms are undifferentiated at both the first and second period and so compete down to fees of zero. This fact is recorded in Proposition 1.

Proposition 1 *Fix parameter values other than k_θ in the model with no governance.*

- *For any k_θ, the producer and aggregate consumer have positive payoffs for the game and the losing platform has a payoff of zero.*
- *The winning platform has a strictly positive payoff for any $k_\theta < \hat{k}_\theta^{NG}$ and a payoff of zero otherwise.*

Second, the producer is more likely to invest in quality when the cost of such investment (k_θ) is low, when the value of such investment (θ) is high, and when interoperability (α) is high. The first two of these are intuitive. The third is a consequence of the hold-up problem—when interoperability is high the producer loses less bargaining power to the platform after making an investment in quality. This is evident from the fact that the producer's second-period payoff is increasing in α and, conditional on quality, the second-period fee is decreasing in α. Thus, interoperability is a potential solution to the hold-up problem. These observations are recorded in Proposition 2.

Proposition 2 *In the model with no governance:*

- *For each (α, θ), there exists a $\hat{k}_\theta^{NG} \geq 0$ such that the producer chooses $q = \theta$ if and only if $k_\theta \leq \hat{k}_\theta^{NG}$;*
- *For each (α, k_θ) satisfying $k_\theta \leq \alpha^2 + \frac{1}{2}$, there exists a $\hat{\theta}^{NG} \in [1, 2]$ such that the producer chooses $q = \theta$ if and only if $\theta \geq \hat{\theta}^{NG}$;*
- *For each (θ, k_θ) satisfying $k_\theta \leq \frac{\theta^2-1}{2}$, there exists an $\hat{\alpha}^{NG} \leq 1$ such that the producer chooses $q = \theta$ if and only if $\alpha \geq \hat{\alpha}^{NG}$. Moreover, $\hat{\alpha}^{NG} > \frac{1}{\theta}$ if $k_\theta > \frac{\theta^2-1}{4}$.*

A third implication is closely related. Assuming costs are not so high that the producer won't consider investing in quality ($k_\theta \leq \frac{\theta^2-1}{2}$) and not so low that the producer will invest in quality no matter what ($k_\theta \geq \frac{\theta^2-1}{4}$), increasing interoperability has several effects. First, it incentivizes investment in quality by the producer ($q = \theta$ if and only if $\alpha \geq \hat{\alpha}^{NG}$). Second, conditional on quality investment, increased interoperability reduces fees in the second period by reducing the platform's bargaining power (see Equation 4). Third, conditional on quality investment, increased interoperability increases incentives for the incumbent platform to upgrade (see Equation 5). Thus, increasing interoperability benefits the producer and consumers (some of the decrease in fees passes through to consumers, as reflected in Equation 2). However, there are competing effects for the winning platform. On the one hand, the platform benefits from increased producer incentives to invest in quality. On the other hand, conditional on such an investment, the platform is hurt by a decrease in bargaining power. Consequently, for $k_\theta \in (\frac{\theta^2-1}{4}, \frac{\theta^2-1}{2})$, the platform's expected payoff for the game is non-monotone in interoperability. The platform wants just enough interoperability to induce quality investment and no more. These facts are recorded in Proposition 3 and illustrated in Figure 2.

Proposition 3 *For any (θ, k_θ):*

- *If $k_\theta \in \left(\frac{\theta^2-1}{4}, \frac{\theta^2-1}{2}\right)$:*
  - *In the second period, the incumbent platform's willingness to pay for upgrades is constant in α for $\alpha < \hat{\alpha}^{NG}$ and increasing in α for $\alpha \geq \hat{\alpha}^{NG}$ with a discontinuous jump up at $\alpha = \hat{\alpha}^{NG}$.*

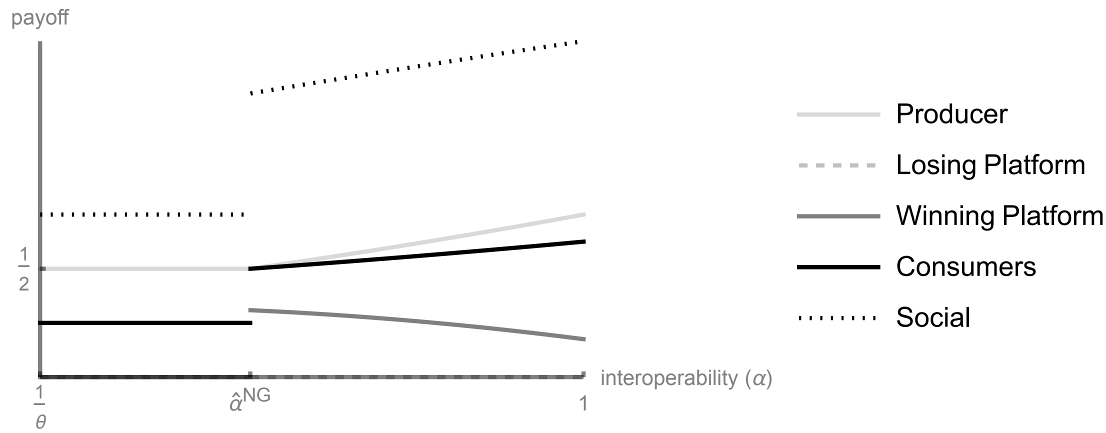

Figure 2: Producer, platform, aggregate consumer, and utilitarian social planner's payoff from the game without governance as a function of interoperability (α), for the case of $k_\theta \in \left(\frac{\theta^2-1}{4}, \frac{\theta^2-1}{2}\right)$.

- *Producer, aggregate consumer, and total social welfare from the game are increasing in α;*
- *The winning platform's welfare from the game is non-monotone in α—it is constant for $\alpha < \hat{\alpha}^{NG}$, jumps up discontinuously at $\hat{\alpha}^{NG}$, and decreases from there.*

- *If $k_\theta < \frac{\theta^2-1}{4}$:*
  - *In the second period, the incumbent platform's willingness to pay for upgrades is increasing in α;*
  - *Producer, aggregate consumer, and total social welfare from the game are increasing in α;*
  - *The winning platform's welfare from the game is decreasing in α;*
- *If $k_\theta > \frac{\theta^2-1}{2}$, in the second period the incumbent platform's willingness to pay for upgrades and all payoffs from the game are constant in α.*

4 Equilibrium with Asymmetric Governance

Now consider the variant of the model in which platform A has implemented governance but platform B has not. As a result, if A is the incumbent platform, it cannot choose $\phi_2^A \neq \phi_1^A$

without the consent of the producer.

4.1 Second Period

The functions describing consumer demand and producer pricing are unchanged by governance and so are again as described in Equations 1 and 2. If B is the incumbent platform, the second-period continuation game is identical in the case of asymmetric governance to the case of no governance. Thus, the analysis from the previous section stands. But matters can be different if A is the incumbent platform, so in what follows I focus on that case.

Since upgrading decisions are already made by the time the producer decides which platform to join, the producer's payoff is decreasing in ϕ_2^A. As such, if A is the incumbent platform, the producer will never agree to an increase in fees—so platform A is constrained to choose $\phi_2^A \leq \phi_1^A$.

What fees will the platforms charge in the second period if A is the incumbent platform? As in the case of no governance, if the producer did not invest in quality, the value of the good is equal on the two platforms, while if the producer invested in quality, the good is strictly more valuable on the incumbent platform. Thus, if the good is high quality, the incumbent platform has an advantage in the second period. But if that incumbent platform is A it faces a new constraint due to governance—it cannot raise fees. This gives us Lemma 2, which differs from Lemma 1 only in admitting of the possibility that ϕ_1^A is a binding constraint on ϕ_2^A.

Lemma 2 *Suppose that platform A is the incumbent and has governance.*

- *If $v_2^A = v_2^B$, then $\phi_2^A = \phi_2^B = 0$ and the producer can go to either platform in equilibrium.*
- *If $v_2^A > v_2^B$, then $\phi_2^A = \min\{\phi_1^A, v_2^A - v_2^B\}$, $\phi_2^B = 0$, and the producer goes to platform A.*

From Lemma 2, when A is the incumbent platform, it charges fees summarized as follows:

$$\phi_2^G(q, r, \phi_1^A) = \begin{cases} 0 & \text{if } q = 1 \\ \min\{\phi_1^A, \theta(1-\alpha)\} & \text{if } q = \theta, r = 1 \\ \min\{\phi_1^A, \theta(\mu-\alpha)\} & \text{if } q = \theta, r = \mu. \end{cases} \tag{7}$$

Thus, platform A's revenue in the second period when it is the incumbent is:

$$\pi_2^G(q, r, \phi_1^A) = \left(\frac{q \cdot r_A - \phi_2^G(q, r, \phi_1^A)}{2}\right) \phi_2^G(q, r, \phi_1^A). \tag{8}$$

Platform A will upgrade if $q = \theta$ and:

$$\pi_2^G(\theta, (\mu, 1), \phi_1^A) - \pi_2^G(\theta, (1, 1), \phi_1^A) \geq k_\mu.$$

In the event that $q = \theta$ and the first-period fee is not binding, the analysis of when platform A upgrades is just as in the game without governance. But matters are different if the first-period fee is binding in the second period—that is, platform A could increase its fee and still be preferred by the producer to platform B, but such an increase would be vetoed by the producer. Moreover, whether the first-period fee is binding can depend on whether or not the platform upgrades. Thus, there are three cases to consider.

If $\phi_1^A < \theta(1-\alpha)$, then ϕ_1^A is binding on the second-period fee whether or not the platform upgrades. As such, the platform upgrades if and only if:

$$k_\mu \leq \frac{\theta\,(\mu - 1)\,\phi_1^A}{2}.$$

If $\phi_1^A \in [\theta(1-\alpha), \theta(\mu - \alpha)]$, then ϕ_1^A is binding on the second-period fee if the platform upgrades, but not if the platform does not upgrade. As such, the platform upgrades if and only if:

$$k_\mu \leq \frac{(\mu\theta - \phi_1^A)\phi_1^A}{2} - \frac{\alpha(1-\alpha)\theta^2}{2},$$

where the second term is the platform's payoff in the second period (from Table 1) if the first-period fee is not binding. Finally, if $\phi_1^A > \theta(\mu - \alpha)$, then ϕ_1^A is not binding on the second-period fee and the analysis is as in the model without governance. Thus, if $q = \theta$, the platform upgrades if k_μ is less than

$$\hat{k}_\mu^G(\phi_1^A) = \begin{cases} \frac{\theta(\mu-1)\phi_1^A}{2} & \text{if } \phi_1^A < \theta(1-\alpha) \\ \frac{(\mu\theta-\phi_1^A)\phi_1^A}{2} - \frac{\alpha(1-\alpha)\theta^2}{2} & \text{if } \phi_1^A \in [\theta(1-\alpha), \theta(\mu-\alpha)] \\ \frac{(\mu-1)\alpha\theta^2}{2} & \text{if } \phi_1^A \geq \theta(\mu-\alpha). \end{cases} \tag{9}$$

It will be useful to have the following notation for platform A's equilibrium upgrading behavior:

$$r^{*,G}(q, k_\mu, \phi_1^A) = \begin{cases} \mu & \text{if } q = \theta \text{ \& } k_\mu \leq \hat{k}_\mu^G(\phi_1^A) \\ 1 & \text{else.} \end{cases}$$

A key observation is that whenever the first-period fee is binding on platform A's second-period fee, platform A is less willing to upgrade than it would be absent governance. This is because the presence of governance restricts platform A's ability to raise fees and extract surplus created by upgrades. As such, there are social surplus-generating upgrades that the platform does not make under governance because the producer will not approve the increase in fees that would be necessary to make the upgrade worthwhile for the platform. This fact is recorded in Remark 2.

Remark 2 *For any $\phi_1^A < \theta(\mu - \alpha)$, in the continuation game there is under-provision of platform upgrades relative to the social optimum; that is, $\hat{k}_\mu^G(\phi_1^A) < \hat{k}_\mu^{NG}$.*

4.2 First Period

Consumer demand and producer pricing in the first period are exactly analogous to the second-period demand and pricing described in Equations 1 and 2. But, unlike without governance, the two platforms do not offer the producer identical continuation values. Governance commits platform A to not raise its fee in the second period. This has two effects. First, holding fixed platform upgrades, in the event that the first-period fee is binding, it leaves the producer with higher second-period payoffs. Second, it reduces platform A's willingness to pay for upgrades. However, platform B does not benefit competitively from its greater willingness to upgrade because, as is evident in Table 1, it changes fees to extract all the rents associated with upgrading and this is anticipated by the producer. Thus, the producer does not care that platform B is more willing to upgrade than is platform A.

As in the case without governance, if the producer does not invest in quality, then the two platforms are identical from the producer's perspective and the platforms compete one another down to a fee of zero in each period. But if the producer does invest in quality, the producer prefers A to B if the two platforms charge the same fee, strictly so if the fee is binding on A in the second period (because B would increase fees in the second period). As such, there are two possible equilibrium outcomes. The producer does not invest in quality and fees are zero or the producer does invest in quality and joins A at a fee that will be binding in the second period. This observation is recorded in Lemma 3.

Lemma 3 *There are no equilibria of the model with asymmetric governance that do not include either:*

- $\phi_1^A = \phi_1^B = 0$ *and* $q = 1$, *or*
- $\phi_1^A \in \left(0, \phi_2^{NG}(\theta, r^{*,G}(\theta, k_\mu, \phi_1^A))\right)$, $\phi_1^B = 0$, $q = \theta$.

Lemma 3 leaves open two possibilities for equilibrium. Which occurs depends on the value of k_θ. To see why, and to characterize the exact fee platform A will charge in the latter case, we need to think through several constraints.

Platform A makes positive rents if it can incentivize the producer to invest in quality and join A at a positive fee, whereas it makes a payoff of zero if it charges a fee of zero. Thus, if it is possible to incentivize $q = \theta$ at positive ϕ_1^A, that is what happens in equilibrium. Otherwise, all fees are zero and $q = 1$. When is it feasible to incentivize quality investment?

In order for the producer to choose $q = \theta$ and join A at $(\phi_1^A > 0, \phi_1^B = 0)$, the producer must prefer doing so to (i) investing in high quality and joining B and (ii) not investing in high quality. The constraints imposed by each of these considerations depend on whether, looking forward, the producer expects A to invest in upgrading the platform—because A cannot revise fees to capture all the rents from platform upgrades, the producer is not indifferent over platform upgrades when there is governance. In particular, the producer is more willing to invest in quality if it anticipates that the platform will upgrade. Thus, we have two sets of constraints describing the highest fee platform A can charge while incentivizing investment in quality and attracting the producer to platform A. These constraints and their relationship are recorded in Lemma 4 and illustrated in Figure 3.

Lemma 4 *In the model in which platform A has asymmetric governance, it is a best response for the producer to invest in quality and join A if either:*

- *The producer believes A will invest in upgrades in the continuation game and ϕ_1^A is less than or equal to*

$$\overline{\phi}_A^\mu \equiv \min\left\{\frac{\theta(\mu+1) - \theta\sqrt{(\mu+1)^2 - 2(\mu^2-\alpha^2)}}{2}, \frac{\theta(\mu+1) - \sqrt{(2\mu-1-\mu^2)\theta^2 + 4(1+2k_\theta)}}{2}\right\}$$

- *The producer believes A will not invest in upgrades in the continuation game and ϕ_1^A is less than or equal to*

$$\overline{\phi}_A^1 \equiv \min\left\{\theta\left(1 - \sqrt{\frac{1+\alpha^2}{2}}\right), \theta - \sqrt{1+2k_\theta}\right\}.$$

Moreover,

- $\overline{\phi}_A^\mu \geq 0$ *if and only if* $k_\theta \leq \frac{(\mu^2+1)\theta^2-2}{4}$
- $\overline{\phi}_A^1 \geq 0$ *if and only if* $k_\theta \leq \frac{\theta^2-1}{2}$
- $\overline{\phi}_A^\mu > \overline{\phi}_A^1$ *for all* $k_\theta \leq \frac{(\mu^2+1)\theta^2-2}{4}$.

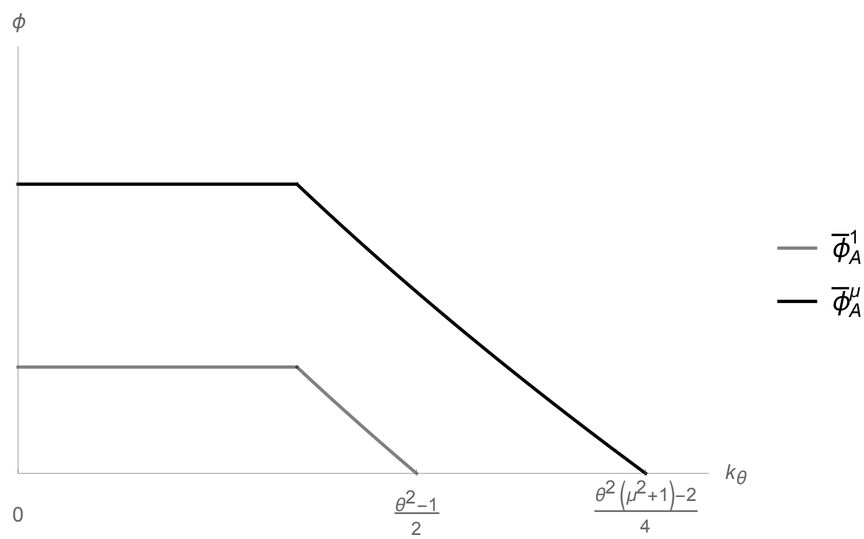

Figure 3: The highest fees platform A can charge while inducing quality investment by the producer, as a function of whether A will upgrade and the cost of quality investment.

Conditional on incentivizing $q = \theta$, platform A wants to charge the highest fee it can. This is true even though raising the fee may result in later choosing to upgrade—since the platform only upgrades when doing so is profit maximizing, regardless of implications for upgrading, platform A's payoff is increasing in the fee. This fact is recorded in Lemma 5.

Lemma 5 *In the model with asymmetric governance, Platform A's payoff from equilibrium in the continuation game is increasing in* ϕ_1^A*, as long as* ϕ_1^A *is consistent with the producer investing in quality.*

Since $\overline{\phi}_A^\mu > \overline{\phi}_A^1$, the highest fee platform A can charge while incentivizing $q = \theta$ is $\overline{\phi}_A^\mu$, as long as (i) it is positive and (ii) at that fee, the producer anticipates the platform will upgrade. As shown in Lemma 4, $\overline{\phi}_A^\mu$ is positive as long as $k_\theta \leq \frac{(\mu^2+1)\theta^2-2}{4}$. And from

Equation 9, the producer anticipates platform upgrades at $\overline{\phi}_A^\mu$ if $k_\mu \leq \hat{k}_\mu^G(\overline{\phi}_A^\mu)$. Thus, if these two conditions hold, platform A charges $\overline{\phi}_A^\mu$.

If, however, the latter condition does not hold, so that the producer does not anticipate platform upgrades, the platform has to charge a lower fee. In particular, if $k_\mu > \hat{k}_\mu^G(\overline{\phi}_A^\mu)$, but $\overline{\phi}_A^1 > 0$, the highest fee the producer can charge while incentivizing $q = \theta$ is $\overline{\phi}_A^1 < \overline{\phi}_A^\mu$. At this lower fee, the platform is not willing to upgrade the platform ($k_\mu > \hat{k}_\mu^G(\overline{\phi}_A^\mu)$ implies $k_\mu > \hat{k}_\mu^G(\overline{\phi}_A^1)$). But the producer is willing to invest in quality despite this because of the lower fee. Of course, this is only in platform A's interest if $\overline{\phi}_A^1$ is positive, which from Lemma 4 is true if $k_\theta \leq \frac{\theta^2-1}{2}$. If neither of these conditions hold, then there is no way for platform A to incentivize $q = \theta$ and so the equilibrium involves low quality and fees of zero.

4.3 Results from Asymmetric Governance

The analysis above gives a characterization of equilibrium play in the model with asymmetric governance. (Proposition 11 in the supplemental appendix provides a complete statement of equilibrium strategies.) Proposition 4 summarizes the key results.

Proposition 4 *Let $\hat{k}_\mu^G(\cdot)$ be as defined in Equation 9, and $\overline{\phi}_A^\mu$ and $\overline{\phi}_A^1$ be as defined in Lemma 4.*

In the model where platform A has asymmetric governance, outcomes are as follows on the equilibrium path:

- *In period 1, platform B sets a fee of zero and platform A sets a fee of:*

$$\phi_A^{*,G} = \begin{cases} \overline{\phi}_A^\mu & \text{if } k_\theta \leq \frac{(\mu^2+1)\theta^2-2}{4} \ \& \ k_\mu \leq \hat{k}_\mu^G(\overline{\phi}_A^\mu) \\ \overline{\phi}_A^1 & \text{if } k_\theta \leq \frac{\theta^2-1}{2} \ \& \ k_\mu > \hat{k}_\mu^G(\overline{\phi}_A^\mu) \\ 0 & \text{else.} \end{cases} \tag{10}$$

- *Given this fee choice, if either (i) $k_\theta \leq \frac{(\mu^2+1)\theta^2-2}{4}$ and $k_\mu \leq \hat{k}_\mu^G(\overline{\phi}_A^\mu)$ or (ii) $k_\theta \leq \frac{\theta^2-1}{2}$, the producer joins A and invests in quality. Otherwise, the producer does not invest in quality and can join either platform.*

- *If $k_\theta \leq \frac{(\mu^2+1)\theta^2-2}{4}$ and $k_\mu \leq \hat{k}_\mu^G(\overline{\phi}_A^\mu)$, given that the producer invests in quality and joins A, platform A upgrades in the second period, otherwise it does not.*

These results are summarized in Figure 4, which shows equilibrium investment decisions, platform upgrades, and fees as a function of k_θ and k_μ. As illustrated in the two panels

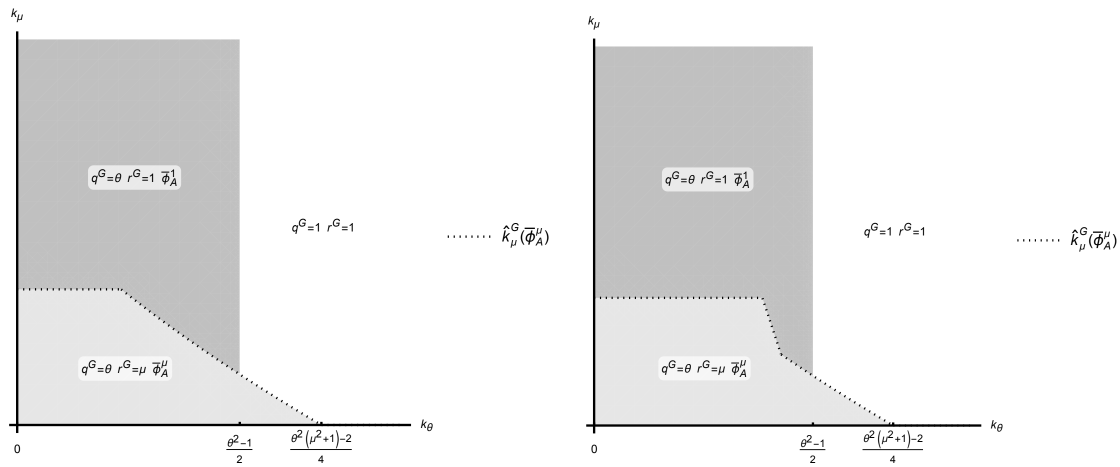

Figure 4: Equilibrium investment, upgrades, and fees in the game with asymmetric governance. In the left-hand panel, the parameters are such that at $k_\theta = 0$, $\overline{\phi}_A^\mu < \theta(1-\alpha)$, whereas in the right-hand panel, at $k_\theta = 0$, $\overline{\phi}_A^\mu > \theta(1-\alpha)$.

of the figure, the exact shape of $\hat{k}_\mu^G(\overline{\phi}_A^\mu)$ depends on whether, at $k_\theta = 0$, $\overline{\phi}_A^\mu$ is greater or less than $\theta(1-\alpha)$, since this determines whether $\hat{k}_\mu^G(\overline{\phi}_A^\mu)$ starts as $\frac{(\mu\theta - \overline{\phi}_A^\mu)\overline{\phi}_A^\mu}{2} - \frac{\alpha(1-\alpha)\theta^2}{2}$ and switches to $\frac{\theta(\mu-1)\overline{\phi}_A^\mu}{2}$ for k_θ sufficiently large (so that $\overline{\phi}_A^\mu$ is sufficiently small), or starts and remains $\frac{\theta(\mu-1)\overline{\phi}_A^\mu}{2}$ for all $k_\theta < \frac{\theta^2(\mu^2+1)-2}{4}$. (See Equation 9 and surrounding discussion.) But, either way, the basic structure of equilibrium is the same and nothing in the subsequent analysis depends on which case we are in (thus, for future figures, I will only draw one case).

As in the model without governance, with asymmetric governance, the producer is more likely to invest in quality when the cost of such investment (k_θ) is low and when the value of such investment (θ) is high. However, unlike without governance, with asymmetric governance interoperability (α) does not effect whether there is quality investment, while the cost of upgrades (k_μ) does. The former follows from the fact that governance substitutes for interoperability in solving the hold-up problem. The latter follows from the fact that governance prevents the platform from extracting all the rents from upgrades through fee adjustments in the second period and, thus, investing in quality is more attractive to the producer if the platform will upgrade.

While interoperability does not affect the likelihood of quality investment without governance, it still matters for welfare through the fee charged by platform A. This effect comes from the fact that the producer's outside option includes the possibility of investing in quality and joining platform B in the first period. Were the producer to do so, its second period payoff would be increasing in α, making the outside option more attractive. Hence, the larger α is, the less platform A can charge in fees while still attracting the producer. These observations are recorded in Proposition 5.

Proposition 5 *In the model with asymmetric governance, the fee the platform with governance charges and that platform's payoff for the game are decreasing in interoperability (α).*

5 The Effects of Governance

Comparing outcomes without governance to outcomes with asymmetric governance, two questions are of central concern. First, how does governance affect the likelihood of quality investment and platform upgrades? Second, what are the welfare effects of governance for platforms, consumers, producers, and society as a whole? From this latter analysis we can calculate the platforms' and the utilitarian social planner's willingness to pay for asymmetric governance, which will be important inputs into the analysis of endogenous governance in the next section.

5.1 Quality and Upgrades with and without Governance

Asymmetric governance induces a (partial) trade-off between quality investment and platform upgrades. Because governance addresses the hold-up problem, the producer invests in quality for higher costs (k_θ) with asymmetric governance than without. But because the platform cannot raise fees in the second period when there is governance, conditional on investing in quality, the platform upgrades for higher costs (k_μ) without governance than with. This trade-off, however, is only partial. Opportunities for platform upgrades occur less often without governance because, by assumption, upgrades are only productive when there has been quality investment, which happens less often without governance.[12] These results are recorded in Proposition 6 and illustrated in Figure 5.

Starting with this proposition and figure, it will be useful to introduce some new notation. First, slightly abusing notation, write $\hat{k}_\mu^G$ for the value of $\hat{k}_\mu^G(\overline{\phi}_A^\mu)$ at $k_\theta = 0$. That is:

$$\hat{k}_\mu^G \equiv \hat{k}_\mu^G \left(\frac{\theta(\mu+1) - \theta\sqrt{(\mu+1)^2 - 2(\mu^2 - \alpha^2)}}{2} \right). \tag{11}$$

[12] As such, the trade-off between quality and upgrades is even stronger in a version of the model where platform upgrades also enhance value. I return to this point in Section 8.

Second, for any k_μ, write $\hat{k}_\theta^G(k_\mu)$ for the highest value of k_θ such that there is quality investment in equilibrium with asymmetric governance. That is:

$$\hat{k}_\theta^G(k_\mu) = \begin{cases} \frac{\theta^2(\mu^2+1)-2}{4} & \text{if } k_\mu \leq \hat{k}_\mu^G(\overline{\phi}_A^\mu) \\ \frac{\theta^2-1}{2} & \text{if } k_\mu > \hat{k}_\mu^G(\overline{\phi}_A^\mu). \end{cases} \tag{12}$$

Proposition 6 *Let $\hat{k}_\mu^G(\cdot)$ and $\hat{k}_\theta^G(\cdot)$ be as defined in Equations 9 and 12 and let $\overline{\phi}_A^\mu$ be as defined in Lemma 4.*

1. *There is more quality investment with asymmetric governance than without governance. That is, for any k_μ, there exist two positive numbers $\hat{k}_\theta^{NG} < \hat{k}_\theta^G(k_\mu)$ such that there is quality investment without governance if and only if $k_\theta \leq \hat{k}_\theta^{NG}$ and there is quality investment with asymmetric governance if and only if $k_\theta \leq \hat{k}_\theta^G(k_\mu)$.*

2. *The effect of governance on platform upgrades depends on quality investment.*

   - *If $k_\theta \leq \hat{k}_\theta^{NG}$, so that $q = \theta$ with or without governance, then there are more platform upgrades without governance. That is, for any $k_\theta \leq \hat{k}_\theta^{NG}$, there exist two numbers $\hat{k}_\mu^{NG} > \hat{k}_\mu^G(\overline{\phi}_A^\mu)$ such that there are platform upgrades without governance if and only if $k_\mu \leq \hat{k}_\mu^{NG}$ and there are platform upgrades with asymmetric governance if and only if $k_\mu \leq \hat{k}_\mu^G(\overline{\phi}_A^\mu)$.*
   - *If $k_\theta \in (\hat{k}_\theta^{NG}, \hat{k}_\theta^G(k_\mu))$, so that $q = \theta$ with asymmetric governance but $q = 1$ without governance, then there are more platform upgrades with asymmetric governance. In particular, for any $k_\theta \in (\hat{k}_\theta^{NG}, \frac{\theta^2(\mu^2+1)-2}{4})$, there is never a platform upgrade without governance, but there is a platform upgrade with asymmetric governance if $k_\mu \leq \hat{k}_\mu^G(\overline{\phi}_A^\mu)$.*

5.2 Willingness to Pay for Governance

I now turn to the welfare effects of governance. A comparison of the platforms' and the utilitarian social planner's willingness to pay for governance is of particular interest, both normatively and for the analysis of endogenous governance in the next section.

I define a platform's willingness to pay for asymmetric governance as the difference between that platform's payoff from the game where it has asymmetric governance and its payoff from the game where neither platform has governance. The utilitarian social planner's willingness to pay for asymmetric governance is the difference in the sum of the

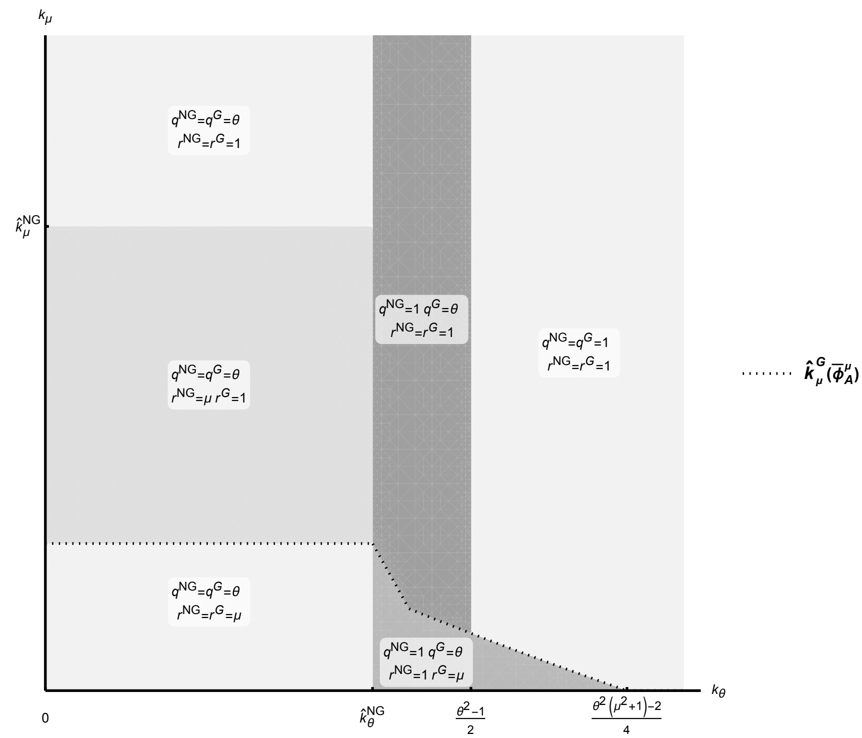

Figure 5: Comparing outcomes with and without governance.

platforms', producer's, and consumers' payoffs from the game with asymmetric governance and the game without governance. (The social planner doesn't care which platform has asymmetric governance.)

Write π^*_{NG}, u^*_{NG} and U^*_{NG}, respectively, for the equilibrium payoffs of the winning platform, producer, and aggregate consumers in the game with no governance. The losing platform always makes a payoff of zero. And write π^*_G, u^*_G, and U^*_G, respectively, for the equilibrium payoffs of the platform with governance, the producer, and the aggregate consumers in the game with asymmetric governance. The platform without governance makes a payoff of zero. (Note, in a slight abuse of notation, π^* represents total payoffs, not revenue.) Then, we have that the winning platform's willingness to pay is:

$$\text{WTP}_{WP} = \pi^*_G - \pi^*_{NG},$$

the losing platform's willingness to pay is:

$$\text{WTP}_{LP} = \pi_G^*,$$

and the utilitarian social planner's willingness to pay is:

$$\text{WTP}_{SP} = [\pi_G^* + u_G^* + U_G^*] - [\pi_{NG}^* + u_{NG}^* + U_{NG}^*].$$

Importantly, the two platforms can have different willingnesses to pay. If $k_\theta < \hat{k}_\theta^{NG}$, then the winning platform—i.e., the platform that the producer joins without governance—makes positive payoffs if it has asymmetric governance or if there is no governance. By contrast, the losing platform—i.e., the platform the producer does not join without governance—always makes a payoff of zero if there is no governance.

Together, Figures 6 and 7 illustrate these willingnesses to pay. Figure 6 divides the parameter space into four categories based on different values of k_μ, which is useful for graphing willingness to pay as a function of k_θ in Figure 7. Proposition 7 records the results illustrated in these figures. Recall that $\hat{k}_\mu^G$ denotes the value of $\hat{k}_\mu^G(\overline{\phi}_A^\mu)$ at $k_\theta = 0$.

A few key points are worth highlighting. First, the losing platform always has weakly higher willingness to pay than the winning platform. The inequality is strict if and only if $k_\theta < \hat{k}_\theta^{NG}$ so that $\pi_{NG}^* > 0$. Substantively, obtaining asymmetric governance has an extra benefit for the losing platform—not only does governance solve the hold-up problem, it turns the losing platform into a winner. Thus, governance is more attractive to the losing platform than the winning platform precisely when the winning platform makes positive profits without governance, which is true whenever there is quality investment both without governance and with asymmetric governance.

Second, several things happen when governance leads to quality investment that would not occur in its absence (i.e., either (i) $k_\theta \in (\hat{k}_\theta^{NG}, \frac{\theta^2(\mu^2+1)-2}{4}]$ and $k_\mu \leq \hat{k}_\mu^G(\overline{\phi}_A^\mu)$ or (ii) $k_\theta \in (\hat{k}_\theta^{NG}, \frac{\theta^2-1}{2}]$ and $k_\mu > \hat{k}_\mu^G(\overline{\phi}_A^\mu)$). Since there is no quality investment without governance, $\pi_{NG}^* = 0$, which means that the winning and losing platforms have the same willingness to pay. The platforms' willingness to pay and the social planner's willingness to pay jump up discontinuously when governance becomes necessary for quality investment. And, most importantly, the social planner's willingness to pay is strictly higher than the platforms'. The reason for this divergence is that the surplus from quality investment is shared across all agents—because the producer has a positive outside option, the platform only extracts some of the rents through higher fees, some of the rents remain with the producer and some pass through to the consumers. Thus, the platforms' willingness to pay for quality-creating governance is strictly lower than the social planner's.

Third, even when governance is not needed to incentivize quality and has no effect on upgrades (i.e., $k_\theta < \hat{k}_\theta^{NG}$ and either $k_\mu < \hat{k}_\mu^G$ or $k_\mu > \hat{k}_\mu^{NG}$), the winning platform and social planner still have a positive willingnesses to pay. Moreover, their willingnesses to pay are equal. This result is perhaps a bit surprising. Let's start by seeing why they are equal. When the winning platform has governance, it chooses a fee that leaves the producer just indifferent between the two platforms. Since the other platform has no governance, this implies leaving the producer indifferent between governance and no governance. When the producer is indifferent, so too are the consumers in aggregate (see Lemma 6 in the appendix). Thus, the social planner's willingness to pay comes entirely from the difference between the two platforms' payoffs with asymmetric governance ($\pi_G^* + 0$) and the two platforms' payoffs without governance ($\pi_{NG}^* + 0$), which is the same as the winning platform's willingness to pay. This willingness to pay is positive, even though governance does not change quality or upgrades because under asymmetric governance the winning platform charges a higher fee in the first period and a lower fee in the second period. Holding fixed total fees, spreading out the fees is surplus creating for producers and consumers. Thus, the platform can extract more in total fees with asymmetric governance, leading to a positive willingness to pay.

Finally, when governance has no effect on quality investment but prevents platform upgrades that would occur in its absence, it is possible for the winning platform and the social planner to have a negative willingness to pay (see Figure 7, III(a)). But this circumstance need not generate a negative willingness to pay. For some parameter values, the winning platform and social planner have positive willingnesses to pay even here because of the spreading-out effect discussed above (see Figure 7, III(b)). Regardless of whether their willingness to pay in this region is negative or positive, for the same reasons already discussed, they are equal. The losing platform's willingness to pay is always weakly positive.

Proposition 7 *Let $\hat{k}_\mu^{NG}$, $\hat{k}_\mu^G(\cdot)$, and $\hat{k}_\mu^G$ be as defined in Equations 5, 9, and 11, respectively, $\overline{\phi}_A^\mu$ be as defined in Lemma 4, and $\hat{k}_\theta^G$ and $\hat{k}_\theta^{NG}$ be as defined in Proposition 6.*

1. *For any $k < \hat{k}_\theta^{NG}$, $\mathrm{WTP}_{WP} = \mathrm{WTP}_{SP} < \mathrm{WTP}_{LP}$. Moreover:*
   - *If $k_\mu \leq \hat{k}_\mu^G$ or $k_\mu > \hat{k}_\mu^{NG}$, $\mathrm{WTP}_{WP} = \mathrm{WTP}_{SP} > 0$.*
   - *Otherwise, $\mathrm{WTP}_{LP} > 0$, but $\mathrm{WTP}_{WP} = \mathrm{WTP}_{SP}$ can be positive or negative depending on other parameter values.*
2. *For (k_θ, k_μ) satisfying either (i) $k_\theta \in [\hat{k}_\theta^{NG}, \frac{\theta^2(\mu^2+1)-2}{4})$ and $k_\mu \leq \hat{k}_\mu^G(\overline{\phi}_A^\mu)$ or (ii) $k_\theta \in [\hat{k}_\theta^{NG}, \frac{\theta^2-1}{2})$ and $k_\mu > \hat{k}_\mu^G(\overline{\phi}_A^\mu)$), the following are true:*

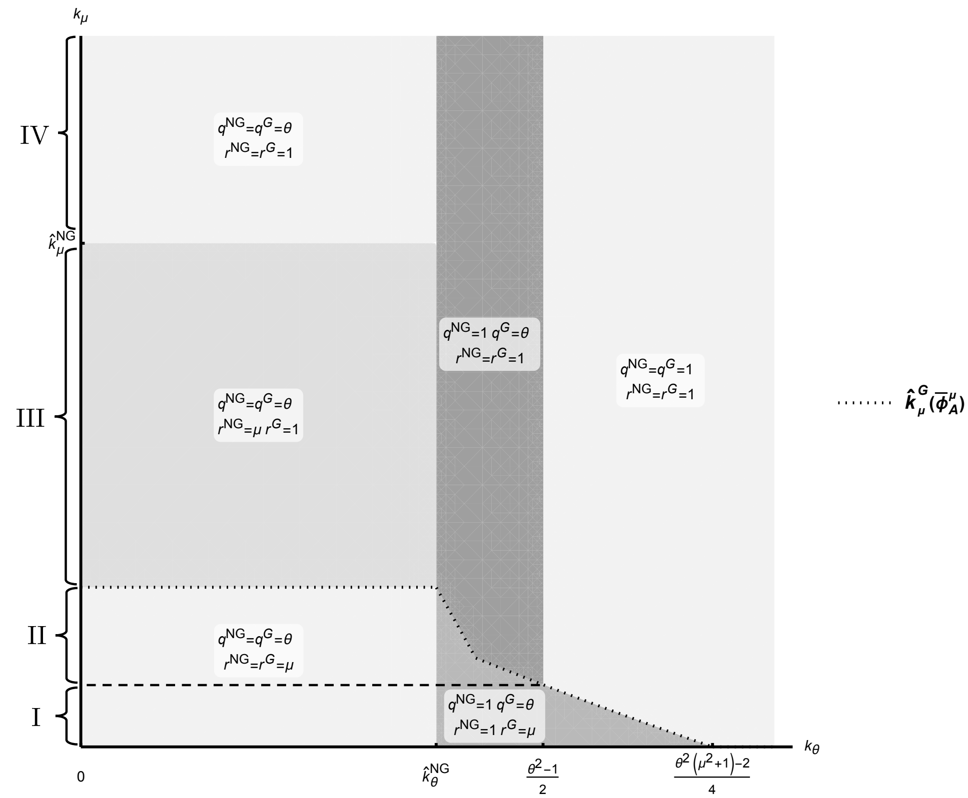

Figure 6: It is convenient to calculate willingness to pay for governance as a function or k_θ by partitioning the parameter space into four cells based on k_μ.

- $0 < \mathrm{WTP}_{WP} = \mathrm{WTP}_{LP} < \mathrm{WTP}_{SP}$
- *The platforms' and social planner's willingness to pay jump up discontinuously at* $k_\theta = \hat{k}_\theta^{NG}$

3. *For* (k_θ, k_μ) *satisfying* $k_\theta > \frac{\theta^2-1}{2}$ *and* $k_\mu > \hat{k}_\mu^G(\overline{\phi}_A^\mu)$*, both the platforms and the social planner have a willingness to pay of zero.*

6 Endogenous Governance

Suppose that at the beginning of the game each platform can choose whether or not to implement governance at cost $c > 0$. When is governance provided in equilibrium?

To answer this question, we need one more piece of analysis: What happens if both platforms have governance? It is straightforward that in the game with symmetric governance—

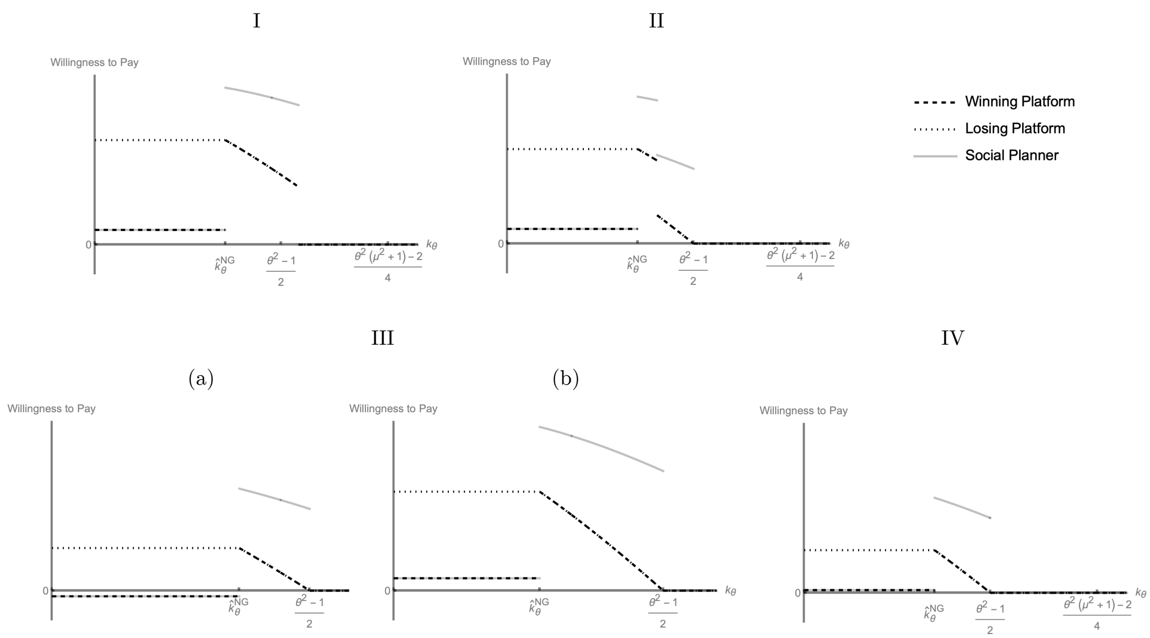

Figure 7: Platforms' and Social Planner's willingness to pay for governance as a function of k_θ based on the four categories of k_μ illustrated in Figure 6.

i.e., where both platforms give the producer a veto over fee changes on their platform—the platforms compete down to a fee of zero in the first period. Since the producer's payoff is strictly decreasing in the fee, it will go to whichever platform charges less. Thus, each platform wants to charge a slightly lower first-period fee than its competitor and the unique equilibrium involves both charging a fee of zero and making a profit of zero.

Given this, we can now solve for equilibrium behavior in the endogenous governance decision stage of the game. Without loss of generality, assume that platform A is the winning platform and platform B is the losing platform if neither provides governance. Applying backward induction, the endogenous governance stage entails the following game:

		Platform B	
		Governance	No Governance
Platform A	Governance	$-c, -c$	$\pi_G^* - c, 0$
	No Governance	$0, \pi_G^* - c$	$\pi_{NG}^*, 0$

There are three cases to consider. If $c \leq \text{WTP}_{WP} = \pi_G^* - \pi_{NG}^*$, then for both platforms providing governance is a best response to the other platform not providing governance and not providing governance is a best response to the other platform providing governance. Thus, there are pure strategy SPNE of the full game corresponding to two pure-strategy equilibria of this game, each with asymmetric governance. If $c \in (\text{WTP}_{WP}, \text{WTP}_{LP}]$, then the winning platform (here, A) has a dominant strategy not to provide governance. But for the losing platform, it is still the case that governance is a best response to no governance and no governance is a best response to governance. Thus, there is a unique equilibrium; the losing platform has asymmetric governance. Finally, if $c > \text{WTP}_{LP}$, then both platforms have a dominant strategy not to provide governance and there is no governance in equilibrium. Taken together, this implies that in the game with endogenous governance, there is asymmetric governance whenever $c \leq \text{WTP}_{LP}$ and otherwise there is no governance. There is never symmetric governance.

Recall from Proposition 7 that $\text{WTP}_{LP} \neq \text{WTP}_{SP}$ in two cases. If governance is necessary and sufficient for equilibrium investment in quality by the producer (i.e., (i) $k_\theta \in [\hat{k}_\theta^{NG}, \frac{\theta^2(\mu^2+1)-2}{4})$ and $k_\mu < \hat{k}_\mu^G(\overline{\phi}_A^\mu)$ or (ii) $k_\theta \in [\hat{k}_\theta^{NG}, \frac{\theta^2-1}{2})$ and $k_\mu > \hat{k}_\mu^G(\overline{\phi}_A^\mu)$), then $\text{WTP}_{LP} < \text{WTP}_{SP}$. This is because the platform does not internalize the benefits of quality investment that flow to the producer and consumers. And if quality investment occurs whether or not there is governance (i.e., $k_\theta < \hat{k}_\theta^{NG}$), then $\text{WTP}_{LP} > \text{WTP}_{SP}$. This is because investing in governance turns the losing platform into a winner, which it values but which the social planner does not (since the social planner does not care whether rents flow to platform A or platform B).

These facts, coupled with the equilibrium analysis above, show that governance can be under-provided or over-provided in equilibrium relative to the utilitarian social optimum. Governance is under-provided whenever it is necessary for quality investment. That is, there are values of c for which governance is utilitarian social welfare enhancing but is not provided. And governance is over-provided whenever quality is provided regardless of governance. That is, there are values of c for which governance lowers utilitarian social welfare and yet is provided. These observations are recorded in Proposition 8.

Proposition 8

- *In any pure strategy equilibrium of the game with endogenous governance, there is asymmetric governance if* $c < \mathrm{WTP}_{LP}$ *and no governance if* $c > \mathrm{WTP}_{LP}$.

- *For any* (k_θ, k_μ) *for which there is quality investment with asymmetric governance and no quality investment without governance—i.e.,* (i) $k_\theta \in [\hat{k}_\theta^{NG}, \frac{\theta^2(\mu^2+1)-2}{4})$ *and* $k_\mu < \hat{k}_\mu^G(\overline{\phi}_A^\mu)$ *or* (ii) $k_\theta \in [\hat{k}_\theta^{NG}, \frac{\theta^2-1}{2})$ *and* $k_\mu > \hat{k}_\mu^G(\overline{\phi}_A^\mu)$*—if* $c \in (\mathrm{WTP}_{LP}, \mathrm{WTP}_{SP})$*, there is no governance in equilibrium, but utilitarian social welfare in the continuation game would be higher with asymmetric governance.*

- *For any* $k_\theta < \hat{k}_\theta^{NG}$*, if* $c \in (\mathrm{WTP}_{SP}, \mathrm{WTP}_{LP})$*, there is asymmetric governance in equilibrium, but utilitarian social welfare in the continuation game would be higher without governance.*

- *For any other* (k_θ, k_μ)*, the equilibrium governance choice maximizes utilitarian social welfare given equilibrium play in the continuation game.*

7 Endogenous Interoperability

The analysis in Section 5.1 compares outcomes with and without governance for a fixed level of interoperability. In some circumstances, where interoperability is a fundamental constraint in the system, this is the natural question. But in other settings one might think that governance and interoperability are both chosen by the platforms. In that case, it might be more relevant to compare no governance and asymmetric governance at the interoperability level the platforms would choose.

To get at this idea, consider an extension with endogenous interoperability. At the beginning of the game, each platform, P, can unobservably implement a level of interoperability (α_P) at cost ϵ. Platforms cannot impose more interoperability than the other platform wants. So if either platform implements a new level of interoperability, the final interoperability is the lowest level chosen by one of them: $\alpha = \min\{\alpha_A, \alpha_B\}$. If neither implements a new level of interoperability, there is a default $\alpha = \alpha_0$. I focus on equilibria as ϵ goes to zero. In such equilibria, as recorded in Proposition 9, the level of interoperability is the one that maximizes the payoff from the game of the platform that attracts the producer.

Proposition 9 *In the extended model with endogenous interoperability:*

1. *With no governance:*
   - *If* $k_\theta \geq \frac{\theta^2-1}{2}$*, neither platform proposes a change to interoperability;*
   - *If* $k_\theta < \frac{\theta^2-1}{2}$*, there exists an* $\epsilon' > 0$ *such that for any* $\epsilon < \epsilon'$*:*
     - *The level of interoperability in equilibrium maximizes the winning platform's payoff in the continuation game:*

$$\alpha^* = \begin{cases} \frac{1}{\theta} & \text{if } k_\theta \leq \frac{\theta^2-1}{4} \\ \hat{\alpha}^{NG} & \text{if } k_\theta \in \left(\frac{\theta^2-1}{4}, \frac{\theta^2-1}{2}\right) \end{cases};$$

     - *The producer invests in quality.*

2. *With asymmetric governance:*
   - *If either (*i*)* $k_\theta \geq \frac{\theta^2-1}{2}$ *and* $k_\mu \geq \hat{k}_\mu^G(\overline{\phi}_1^\mu)$ *evaluated at* $\alpha = \frac{1}{\theta}$ *or (*ii*)* $k_\theta \geq \frac{\theta^2(\mu^2+1)-2}{4}$*, neither platform proposes a change in interoperability;*
   - *Otherwise, there exists an* $\epsilon'' > 0$ *such that for any* $\epsilon < \epsilon''$ *the level of interoperability in equilibrium is* $\alpha = \frac{1}{\theta}$*.*

As we saw in the earlier analysis, interoperability does not affect whether the producer invests in quality when there is asymmetric governance (Proposition 4), but it does without governance (Proposition 3). In particular, whenever $k_\theta < \frac{\theta^2-1}{2}$, without governance, the platform's optimal level of interoperability incentivizes the producer to invest in quality. As such, as show in Proposition 9, allowing the platforms to choose the level of interoperability increases the range of k_θ for which there is quality investment without governance up to $k_\theta < \frac{\theta^2-1}{2}$.[13] This has several implications which are immediate corollaries of Proposition 9. First, it reduces the range of investment costs for which there is quality investment with governance but not without. Second, in so doing, it eliminates the circumstance in which asymmetric governance leads to quality and no platform upgrade while no governance leads to neither quality nor a platform upgrade. Nonetheless, governance still remains a valuable

[13] Put differently, at $\alpha = \hat{\alpha}^{NG}$, $\hat{k}_\theta^{NG} = \frac{\theta^2-1}{2}$.

tool for incentivizing quality investment—for $k_\theta \in (\frac{\theta^2-1}{2}, \frac{\theta^2(\mu^2+1)-2}{4})$, there can be quality investment with governance (if k_μ is sufficiently low), but there is never quality investment without governance, even at the optimal levels of interoperability. These observations are illustrated in Figure 8, which shows that the basic trade-offs identified in the model with exogenous interoperability persist in the model with endogenous interoperability.

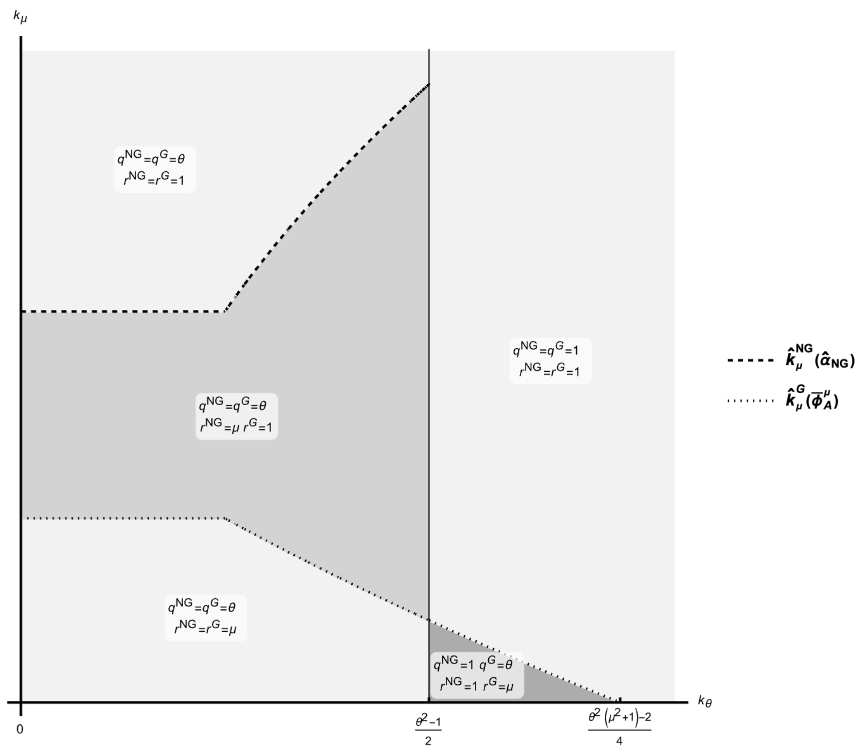

Figure 8: Comparing outcomes with and without governance when interoperability is set at the platform's optimum in each model for the case of $k_\theta \in \left(\frac{\theta^2-1}{4}, \frac{\theta^2-1}{2}\right)$. The upper boundary, $\hat{k}_\mu^{NG}(\hat{\alpha}^{NG})$, is a function of k_θ because $\hat{\alpha}^{NG}$ is a function of k_θ.

8 Discussion and Conclusion

Now that we have seen how the model works, I return to discuss two assumptions highlighted in Section 2.1. I then conclude.

First, I assume that platform upgrades only affect the value of high-quality products. There may be settings where this assumption of a strong complementarity between quality and upgrades, or something close to it, is accurate—for instance, improvements to the speed or physics of a gaming engine may matter substantially more for premium games than for more basic games. But, more importantly, while this assumption simplifies the analysis, it actually works against a key takeaway of the model: the trade-off governance induces between quality and upgrades. Because upgrades only affect the value of high-quality goods, the trade-off is only partial in the current model. (See point 2 of Proposition 6 and the surrounding discussion.) When governance is necessary for quality, there are actually more upgrades under asymmetric governance than without governance (where there are none). Thus, in a version of the model where upgrades were of value even for a low-quality product, the trade-off would be stronger, though it would still only be partial if there remained a (weaker) complementarity between quality and upgrades.

Second, I assume that there is no multi-homing; the producer sells on only one platform. In the current model, since consumers face the same opportunity cost for accessing each platform, this assumption is innocuous (but does substantially simplify notation). The producer cannot increase demand by selling on multiple platforms. Thus, if multi-homing were allowed, if quality remains platform specific (or if investing in quality is separately costly for each platform), it would not occur in equilibrium.

Of course, matters could become more interesting in a model with multiple producers, heterogeneous demand (e.g., some consumers who prefer the low-quality product at a low price and some who prefer a high-quality product at a higher price), and multi-homing. In such a setting, the platforms might have incentives to segment the market. This raises the interesting possibility of a platform with high-quality goods that is more willing to pay for governance but under-provides upgrades and a platform with low-quality goods that is less willing to pay for governance and efficiently provides upgrades. Multiple producers with differentiated products also create the possibility for more interesting political economy considerations in governance decisions. I leave these intriguing questions for future research.

In the current paper, motivated by observations of business practices in large digital platforms and recent experiments in devolved governance on such platforms, I studied a model of platforms competing over a two-sided market through fees, upgrades, and governance. I showed that giving producers governance rights over fee increases is a potential solution to a lock-in based hold-up problem, but it creates a trade-off. Such governance improves incentives for quality investment by producers, but leads to inefficient under-investment in platform upgrades. This is true even when platforms choose their preferred level of interoperability, which is higher without governance than with. When governance is a necessary condition for quality, it is under-provided relative to the utilitarian optimum. However, when quality investment occurs regardless of governance, governance is over-provided. The model suggests that experiments in platform governance could be important for outcomes in the digital economy and are worthy of further research.

A Proofs

Proof of Lemma 1. First consider the case of $v_2^A = v_2^B$. The producer's payoff is maximized by choosing whichever platform charges the lower fee. If the fees are not equal and are both positive, the platform charging the higher fee makes zero profit and has a profitable deviation to a fee below their competitors. If the fees are not equal and one is zero, the platform choosing zero makes zero profit and has a profitable deviation to a fee above zero but below its competitors'. If both fees are zero, both platforms make zero profits at the fee charged or at any deviation, so both are playing a best response.

Next, consider $v_2^A > v_2^B$. Since the producer's payoff is strictly increasing in v_2, if both platforms propose the same fee, A wins. Consider the possible cases:

- B wins with a non-zero fee: If A deviated to the same fee as B it would win and make positive profits, so A has a profitable deviation.
- B wins with a zero fee: A can deviate to a fee above B's but below A's current fee, win, and make positive profits, so A has a profitable deviation.
- B loses with a non-zero fee: Either B could win with a smaller fee, in which case B has a profitable deviation, or it cannot. If it cannot, that means A is demanding a fee at which it wins even if B offers a fee of 0. That means at the current fees, the producer strictly prefers A, so A has a profitable deviation to a higher fee.

This implies that equilibrium requires that B loses with a fee of $\phi_2^B = 0$. It follows from $\mu \cdot \theta < 2$ that A's revenue maximizing fee, $\frac{v_2^A}{2}$, is higher than the fee that leaves the producer just indifferent when $\phi_2^B = 0$, which implies that A chooses the fee that leaves the producer just indifferent: $\phi_2^A = v_2^A - v_2^B$. ■

Proof of Remark 1. If $q = 1$, upgrades create negative surplus equal to $-k_\mu$ and the incumbent platform never upgrades.

If $q = \theta$, utilitarian social welfare without upgrades is:

$$\frac{\alpha^2\theta^2}{8} + \frac{\alpha^2\theta^2}{4} + \frac{\alpha(1-\alpha)\theta^2}{2}$$

and with upgrades it is:

$$\frac{\alpha^2\theta^2}{8} + \frac{\alpha^2\theta^2}{4} + \frac{\alpha(\mu-\alpha)\theta^2}{2} - k_\mu.$$

Thus, upgrades increase social welfare if and only if

$$k_\mu < \hat{k}_\mu^{NG}.$$

■

Proof of Proposition 1. It is immediate from the analysis in the text that for $k_\theta < \hat{k}_\theta^{NG}$, payoffs are:

- Aggregate consumer: $\frac{(1+\alpha^2)\theta^2}{8}$
- Producer: $\frac{(1+\alpha^2)\theta^2}{4} - k_\theta$
- Winning Platform: $\max\left\{\frac{\alpha(1-\alpha)\theta^2}{2}, \frac{\alpha(\mu-\alpha)\theta^2}{2} - k_\mu\right\}$
- Losing Platform: 0

It follows from the definition of $\hat{k}_\theta^{NG}$ that the first three are strictly positive.

For $k_\theta \geq \hat{k}_\theta^{NG}$, payoffs are:

- Aggregate consumer: $\frac{1}{4}$
- Producer: $\frac{1}{2}$
- Losing Platform: 0
- Winning Platform: 0

■

Proof of Proposition 2. Rearranging Equation 6 shows the producer chooses $q = \theta$ if and only if:

$$k_\theta \leq \frac{(\alpha^2+1)\theta^2 - 2}{4} \equiv \hat{k}_\theta^{NG}. \tag{13}$$

The fact that $\alpha \geq \frac{1}{\theta}$ implies that $\hat{k}_\theta^{NG} \geq 0$ for every (α, θ).

Rearranging Equation 6 shows the producer invests if and only if:

$$\theta \geq \sqrt{\frac{4k_\theta + 2}{\alpha^2 + 1}} \equiv \hat{\theta}^{NG}. \tag{14}$$

From $\alpha \leq 1$ it is immediate that $\hat{\theta}^{NG} \geq 1$. And $k_\theta < \alpha^2 + \frac{1}{2}$ implies $\hat{\theta}^{NG} < 2$.

Rearranging Equation 6 shows the producer invests if and only if:

$$\alpha \geq \sqrt{\frac{4k_\theta + 2 - \theta^2}{\theta^2}} \equiv \hat{\alpha}^{NG}, \tag{15}$$

if $4k_\theta + 2 - \theta^2 > 0$ and $\alpha \geq 0$ otherwise. The bounds follow immediately.

■

Proof of Proposition 3.

- First consider $k_\theta \in \left(\frac{\theta^2-1}{4}, \frac{\theta^2-1}{2}\right)$:

  The results on the incumbent platform's willingness to pay for upgrades are immediate from inspection of $\hat{k}_\mu^{NG}$.

  From Propositions 1 and 2, for $\alpha < \hat{\alpha}^{NG}$ the producer's payoff from the game is $\frac{1}{2}$. For $\alpha \geq \hat{\alpha}^{NG}$, her payoff is $\frac{(1+\alpha^2)\theta^2}{4} - k_\theta$. This latter is increasing in α. Moreover, at $\alpha = \hat{\alpha}^{NG}$, it is equal to $\frac{1}{2}$.

  From Propositions 1 and 2, for $\alpha < \hat{\alpha}^{NG}$ the aggregate consumer payoff from the game is $\frac{1}{4}$. For $\alpha \geq \hat{\alpha}^{NG}$, the aggregate consumer payoff is $\frac{(1+\alpha^2)\theta^2}{8}$. This latter is increasing in α. Moreover, at $\alpha = \hat{\alpha}^{NG}$ we have:

  $$\frac{(1 + (\hat{\alpha}^{NG})^2)\theta^2}{8} = \frac{2\hat{k}_\mu^{NG} + 1}{4} > \frac{1}{4}.$$

  Thus, there is a discontinuous jump up at $\hat{\alpha}^{NG}$.

  From Propositions 1 and 2, for $\alpha < \hat{\alpha}^{NG}$ the platform's payoff from the game is 0. For $\alpha \geq \hat{\alpha}^{NG}$, its payoff is $\max\{\frac{\alpha(1-\alpha)\theta^2}{2}, \frac{\alpha(\mu-\alpha)\theta^2}{2} - k_\mu\}$. The former is constant in α and it is immediate from inspection that it is less than the latter. Thus, there is a discontinuous jump up at $\hat{\alpha}^{NG}$. Differentiating, the latter is decreasing in α if $\alpha > \frac{1}{2}$ (for $k_\mu > \hat{k}_\mu^{NG}$) or $\alpha > \frac{\mu}{2}$ (for $k_\mu \leq \hat{k}_\mu^{NG}$), both of which hold.

  From Propositions 1 and 2, for $\alpha < \hat{\alpha}^{NG}$ total social welfare is $\frac{3}{4}$. For $\alpha \geq \hat{\alpha}^{NG}$, total social welfare is $\max\{\frac{\theta^2(3+3\alpha^2+4\alpha(1-\alpha))}{8} - k_\theta, \frac{\theta^2(3+3\alpha^2+4\alpha(\mu-\alpha))}{8} - k_\theta - k_\mu\}$. The former is constant in α and it is immediate from inspection that it is less than the latter. Thus, there is a discontinuous jump up at $\hat{\alpha}^{NG}$. Moreover, it is clearly increasing in α for $\alpha < 1$. This establishes the result.

- The same argument, plus the fact that the producer always invests in quality for $k_\theta < \frac{\theta^2-1}{4}$, establishes this result.

- The fact that the producer never invests in quality for $k_\theta > \frac{\theta^2-1}{2}$ establishes this result.

■

Proof of Lemma 2. The proof is identical to the proof of Lemma 1, adding in the constraint that $\phi_2^A \leq \phi_1^A$. ■

Proof of Remark 2. From Equation 5, we have $\hat{k}_\mu^{NG} = \frac{(\mu-1)\alpha\theta^2}{2}$.

For $\phi_1^A < \theta(1-\alpha)$, $\hat{k}_\mu^G(\phi_1^A)$ is strictly increasing in ϕ_1^A, so it suffices to show $\hat{k}_\mu^G(\phi_1^A) \leq \hat{k}_\mu^{NG}$ at $\phi_1^A = \theta(1-\alpha)$. This requires:

$$\frac{(\mu-1)\alpha\theta^2}{2} \geq \frac{(\mu-1)(1-\alpha)\theta^2}{2},$$

which is true if $\alpha \geq 1-\alpha$, which follows from $\alpha \geq \frac{1}{\theta}$ and $\theta < 2$.

For $\phi_1^A \in [\theta(1-\alpha), \theta(\mu-\alpha)]$, differentiating, $\hat{k}_\mu^G(\cdot)$ is increasing in ϕ_1^A if $\mu\theta - 2\phi_1^A > 0$. Substituting $\phi_1^A = \theta(\mu-\alpha)$ and rearranging, $\hat{k}_\mu^G(\cdot)$ is increasing for all $\phi_1^A \in [\theta(1-\alpha), \theta(\mu-\alpha)]$ if $\mu < 2\alpha$, which follows from $\mu{\cdot}\theta < 2$ and $\alpha \geq \frac{1}{\theta}$. Thus, it suffices to show $\hat{k}_\mu^G(\phi_1^A) \leq \hat{k}_\mu^{NG}$ at $\phi_1^A = \theta(\mu-\alpha)$. This requires:

$$\frac{\alpha\theta^2(\mu-\alpha)}{2} - \frac{\alpha(1-\alpha)\theta^2}{2} \leq \frac{(\mu-1)\alpha\theta^2}{2}.$$

Cancelling terms, the two sides of this inequality are equal.

The comparison to the social optimum now follows from Remark 1. ■

Proof of Lemma 3. I proceed by ruling out all other possibilities.

Suppose $\phi_1^A > 0$ and $\phi_1^B > 0$. There are two possibilities

- The producer is indifferent between A and B and chooses one of them. The losing platform makes a payoff of zero. But if it deviated to a lower initial fee it would win and make positive rents, so it was not playing a best response.

- The producer is not indifferent and a platform wins. The producer's payoff is continuous in the first-period fee, so given the strict preference, the winning platform could increase its fee, still win, and make a higher payoff. Thus, the winning platform was not playing a best response.

This implies that at least one of the platforms must choose a fee of 0.

Suppose $\phi_1^A = 0$ and $\phi_1^B > 0$. Given that A cannot raise its fees in the second period, $\phi_2^A = 0$ and A does not upgrade, so the producer's payoff from joining A is:

$$\frac{\theta^2}{4} + \frac{\theta^2}{4}.$$

The producers' payoff from joining B is:

$$\max\left\{\frac{(\theta - \phi_1^B)^2}{4} + \frac{\theta^2\alpha^2}{4} - k_\theta, \frac{(1 - \phi_1^B)^2}{4} + \frac{1}{4}\right\}.$$

It follows from $\alpha < 1$ and $\phi_1^B > 0$ that the payoff from joining A is strictly higher, so the producer joins A. But, given that the producer's payoff is continuous in ϕ_1^A and the preference is strict, A could raise its fee and still win, so A is not playing a best response.

This implies that $\phi_1^B = 0$ in any equilibrium.

Suppose $\phi_1^A \geq \phi_2^{NG}(\theta, r^{*,G}(\theta, k_\mu, \phi_1^A))$ and $\phi_1^B = 0$. Since ϕ_1^A is not binding in the second period, the producer's payoff from joining A is:

$$\max\left\{\frac{(\theta - \phi_1^A)^2}{4} + \frac{\theta^2\alpha^2}{4} - k_\theta, \frac{(1 - \phi_1^A)^2}{4} + \frac{1}{4}\right\}.$$

The producer's payoff from joining B is:

$$\max\left\{\frac{\theta^2}{4} + \frac{\theta^2\alpha^2}{4} - k_\theta, \frac{1}{2}\right\}.$$

It follows from $\alpha < 1$ and $\phi_1^A > 0$ that the payoff from joining B is strictly higher, so the producer joins B. But, given that the producer's payoff is continuous and the preference is strict, B could raise its fee and still win, so is not playing a best response.

This implies $\phi_1^A < \phi_2^{NG}(\theta, r^{*,G}(\theta, k_\mu, \phi_1^A))$ and $\phi_1^B = 0$ in any equilibrium.

Now consider $\phi_1^A = 0, \phi_1^B = 0$, and $q = \theta$. Since ϕ_1^A is binding, the producer's payoff from joining A is:

$$\frac{\theta^2}{4} + \frac{\theta^2}{4} - k_\theta$$

The producer's payoff from joining B is

$$\frac{\theta^2}{4} + \frac{\theta^2\alpha^2}{4} - k_\theta.$$

The producer strictly prefers A. But this implies that A could raise fees and still win. Thus, A is not playing a best response.

Now consider $\phi_1^A \in (0, \phi_2^{NG}(\theta, r^{*,G}(\theta, k_\mu, \phi_1^A))$, $\phi_1^B = 0$, and $q = 1$.

The producer's payoff from joining A is:

$$\frac{(1-\phi_1^A)^2}{4} + \frac{1}{4}$$

and from joining B is

$$\frac{1}{4} + \frac{1}{4}.$$

The producer strictly prefers B. But this means B could raises fees and still win, so is not playing a best response.

This leaves only two possibilities:

- $\phi_1^A = \phi_1^B = 0$ and $q = 1$, or
- $\phi_1^A \in \big(0, \phi_2^{NG}(\theta, r^{*,G}(\theta, k_\mu, \phi_1^A))\big)$, $\phi_1^B = 0$, $q = \theta$,

as required. ■

Proof of Lemma 4. As show in Conditions 23–24 and Conditions 27–28 in Proposition 11, there are three constraints to consider and for each we must consider the case where there will and will not be subsequent platform upgrades.

First, the producer must prefer platform A over platform B at high quality. If platform A is not going to upgrade at high quality, this requires:

$$\frac{2(\theta-\phi_1^A)^2}{4} \geq \frac{\theta^2(1+\alpha^2)}{4} \iff \phi_1^A \leq \theta\left(1-\sqrt{\frac{1+\alpha^2}{2}}\right). \tag{16}$$

If platform A is going to upgrade at high quality, it requires:

$$\frac{(\theta-\phi_1^A)^2 + (\mu\theta-\phi_1^A)^2}{4} \geq \frac{\theta^2(1+\alpha^2)}{4} \iff \phi_1^A \leq \frac{\theta(\mu+1) - \theta\sqrt{(\mu+1)^2 - 2(\mu^2-\alpha^2)}}{2}, \tag{17}$$

Second, at high quality, the producer must prefer to stay with platform A in the second period. If the platform does not upgrade, this requires:

$$\frac{(\theta-\phi_1^A)^2}{4} \geq \frac{\alpha^2\theta^2}{4}.$$

If the platform does upgrade, it requires:

$$\frac{(\mu\theta - \phi_1^A)^2}{4} \geq \frac{\alpha^2\theta^2}{4}. \tag{18}$$

Each of these are less stringent than the previous constraints, so they do not bind.

Third, the producer must prefer platform A at high quality over platform B at low quality in the first period. If platform A is not going to upgrade, this requires

$$\frac{2(\theta - \phi_1^A)^2}{4} - k_\theta \geq \frac{1}{2} \iff \phi_1^A \leq \theta - \sqrt{1 + 2k_\theta} \tag{19}$$

If platform A is going to upgrade, it requires:

$$\frac{(\theta - \phi_1^A)^2 + (\mu\theta - \phi_1^A)^2}{4} - k_\theta \geq \frac{1}{2} \iff \phi_1^A \leq \frac{\theta(\mu+1) - \sqrt{(2\mu - 1 - \mu^2)\theta^2 + 4(1 + 2k_\theta)}}{2} \tag{20}$$

Fourth, the producer must prefer platform A at high quality to platform A at low quality in the first period. If the platform will not upgrade at high quality, this requires:

$$\frac{2(\theta - \phi_1^A)^2}{4} - k_\theta \geq \frac{(1 - \phi_1^A)^2}{4} + \frac{1}{4}.$$

If the platform will upgrade at high quality, it requires:

$$\frac{(\theta - \phi_1^A)^2 + (\mu\theta - \phi_1^A)^2}{4} - k_\theta \geq \frac{(1 - \phi_1^A)^2}{4} + \frac{1}{4}.$$

These are less stringent than the previous constraints and so do not bind.

Putting all of this together, we have that the highest fee platform A can charge while inducing quality investment by the producer if it will not subsequently upgrade is:

$$\overline{\phi}_A^1 \equiv \min\left\{\theta\left(1 - \sqrt{\frac{1+\alpha^2}{2}}\right), \theta - \sqrt{1 + 2k_\theta}\right\}$$

And the highest fee that platform A can charge while inducing quality investment by the producer if it will subsequently upgrade is:

$$\overline{\phi}_A^\mu \equiv \min\left\{\frac{\theta(\mu+1) - \theta\sqrt{(\mu+1)^2 - 2(\mu^2 - \alpha^2)}}{2}, \frac{\theta(\mu+1) - \sqrt{(2\mu - 1 - \mu^2)\theta^2 + 4(1 + 2k_\theta)}}{2}\right\}$$

The conditions for the two maximal fees to be positive and the fact that $\overline{\phi}_A^\mu > \overline{\phi}_A^1$ are immediate.

■

Proof of Lemma 5.

Suppose $k_\mu > \hat{k}_\mu^G(\phi_1^A)$ so that the producer correctly anticipates that the platform will not upgrade. If ϕ_1^A induces quality investment and is binding in the second period, the platform's payoff from the game is:

$$\frac{(\theta - \phi_1^A)\phi_1^A}{2} + \frac{(\theta - \phi_1^A)\phi_1^A}{2}.$$

Differentiating with respect to ϕ_1^A, we have that the platform's payoff from the game is increasing if $\theta - 2\phi_1^A > 0$, which follows from

$$\begin{aligned} \phi_1^A &\leq \theta\left(1 - \sqrt{\frac{1+\alpha^2}{2}}\right) \\ &< \frac{\theta}{2}, \end{aligned}$$

where the first inequality follows from Condition 16 and the second from $\alpha > 0$.

Now suppose $k_\mu \leq \hat{k}_\mu^G(\phi_1^A)$ so that the producer correctly anticipates that the platform will upgrade. If ϕ_1^A induces quality investment and is binding in the second period, the platform's payoff from the game is:

$$\frac{(\theta - \phi_1^A)\phi_1^A}{2} + \frac{(\mu\theta - \phi_1^A)\phi_1^A}{2} - k_\mu.$$

Differentiating with respect to ϕ_1^A, we have that the platform's payoff from the game is increasing if $\theta(\mu+1) - 4\phi_1^A > 0$, which is equivalent to $\phi_1^A < \frac{\theta(\mu+1)}{4}$. From Condition 17 we have:

$$\phi_1^A \leq \frac{\theta(\mu+1) - \theta\sqrt{(\mu+1)^2 - 2(\mu^2-\alpha^2)}}{2}.$$

Thus, it suffices to show

$$\frac{\theta(\mu+1) - \theta\sqrt{(\mu+1)^2 - 2(\mu^2-\alpha^2)}}{2} < \frac{\theta(\mu+1)}{4}.$$

Rearranging, this is equivalent to

$$8(\mu^2 - \alpha^2) < 3(\mu+1)^2.$$

The left-hand side is decreasing in α. Note that $\alpha \geq \frac{1}{\theta}$ and $\mu \cdot \theta < 2$ imply $\alpha > \frac{\mu}{2}$. Thus, it suffices to show that the left-hand side holds at $\alpha = \frac{\mu}{2}$. Making this substitution and rearranging, it suffices to show:

$$3\mu^2 - 6\mu - 3 < 0,$$

which follows from $\mu < 2$.

All that remains is to show that there isn't a jump down in the platform's payoff at the ϕ_1^A where the platform switches from not upgrading to upgrading.

A jump down in the platform's payoff requires:

$$\pi_2^G(\theta, 1, \phi_1^A) > \pi_2^G(\theta, \mu, \phi_1^A) - \hat{k}_\mu^G,$$

But by the definition of $\hat{k}_\mu^G$ the left- and right-hand sides are equal. ■

Proof of Proposition 4.

- Platform B's fee being zero follows from Lemma 3. Lemma 5 implies that A will charge the highest fee consistent with Lemma 4 and Equation 9. $\phi_A^{*,G}$ follows from $\overline{\phi}_A^\mu > \overline{\phi}_A^1$, the conditions for each of these to be positive, and Equation 9.
- The second point follows immediately.
- The third point follows from Equation 9.

■

Proof of Proposition 5. Interoperability (α) only enters the platform's payoff for the game through the fee it charges. And from Lemma 5, the platform's payoff for the game is increasing in that fee as long as it induces quality investment. Thus, it suffices to show that $\phi_A^{*,G}$ is decreasing in α. It is immediate from inspection that each of $\overline{\phi}_A^1$ and $\overline{\phi}_A^\mu$ are decreasing in α. There are now three cases to consider:

- Suppose that at $k_\theta = 0$, $k_\mu > \hat{k}_\mu^G(\overline{\phi}_A^\mu)$: If $k_\theta \leq \frac{\theta^2-1}{2}$, $\phi_A^{*,G} = \overline{\phi}_A^1$ for all α, so the fact that $\overline{\phi}_A^1$ is decreasing in α establishes the result. If $k_\theta > \frac{\theta^2-1}{2}$, $\phi_A^{*,G} = 0$ for all α.
- Suppose we have that at $k_\theta = 0$, $k_\mu < \hat{k}_\mu^G(\overline{\phi}_A^\mu)$ but at at $k_\theta = \frac{\theta^2-1}{2}$ we have $k_\mu > \hat{k}_\mu^G(\overline{\phi}_A^\mu)$: The fact that $\overline{\phi}_A^\mu$ is decreasing in α means that the fee switches from $\overline{\phi}_A^\mu$ to $\overline{\phi}_A^1$ as α increases. Since $\overline{\phi}_A^\mu > \overline{\phi}_A^1$ and each of $\overline{\phi}_A^\mu$ and $\overline{\phi}_A^1$ is decreasing in α, this establishes the result.

- Suppose we have that at $k_\theta = \frac{\theta^2-1}{2}$, $k_\mu < \hat{k}_\mu^G(\overline{\phi}_A^\mu)$: If $k_\theta \leq \frac{\theta^2(\mu^2+1)-2}{4}$, then $\phi_A^{*,G} = \overline{\phi}_A^\mu$ for all α, so the fact that $\overline{\phi}_A^\mu$ is decreasing in α establishes the result. If $k_\theta > \frac{\theta^2(\mu^2+1)-2}{4}$, $\phi_A^{*,G} = 0$ for all α.

■

Proof of Proposition 6.

1. Follows from $\frac{\theta^2(\mu^2+1)-2}{4} > \frac{\theta^2-1}{2} > \frac{(\alpha^2+1)\theta^2-2}{4} = \hat{k}_\theta^{NG}$.

2.
   - For $k_\theta < \hat{k}_\theta^{NG}$ it suffices to show that

$$\hat{k}_\mu^{NG} = \frac{(\mu-1)\alpha\theta^2}{2} > \hat{k}_\mu^G(\overline{\phi}_A^\mu).$$

   There are two cases to consider.

     – If $\overline{\phi}_A^\mu < \theta(1-\alpha)$, we have:

$$\hat{k}_\mu^G(\overline{\phi}_A^\mu) = \frac{\theta(\mu-1)\overline{\phi}_A^\mu}{2}.$$

   Thus, in this case it suffices to show

$$\overline{\phi}_A^\mu < \alpha\theta.$$

   The left-hand side is increasing, so it suffices to check at $\overline{\phi}_A^\mu = \theta(1-\alpha)$. Substituting, this requires $\alpha > \frac{1}{2}$ which follows from $\mu\theta < 2$ and $\alpha > \frac{1}{\theta}$.

     – For $\overline{\phi}_A^\mu \in [\theta(1-\alpha), \theta(\mu-\alpha)]$, we need

$$\frac{(\mu\theta - \overline{\phi}_A^\mu)\overline{\phi}_A^\mu}{2} - \frac{\alpha(1-\alpha)\theta^2}{2} < \frac{(\mu-1)\alpha\theta^2}{2}.$$

   Since the left-hand side is increasing in $\overline{\phi}_A^\mu$ on this domain, it suffices to show that this holds at $\overline{\phi}_A^\mu = \theta(\mu-\alpha)$. Substituting, this requires:

$$\theta(\mu-1) < 1,$$

   which follows from $\mu\theta < 2$ and $\theta > 1$.

- For $k_\theta \in (\hat{k}_\theta^{NG}, \frac{\theta^2(\mu^2+1)-2}{4})$, it follows immediately from the fact that there cannot be upgrades with no governance and $\hat{k}_\mu^G(\overline{\phi}_A^\mu) > 0$.

■

Proof of Proposition 7.

The following result will be useful.

Lemma 6 *Consider two vector of fees $\phi = (\phi_1, \phi_2)$ and $\phi' = (\phi_1', \phi_2')$ such that prices and demand are interior and quality (q) is the same. If* $\text{WTP}_{producer}(\phi) = \text{WTP}_{producer}(\phi')$*, then* $\text{WTP}_{aggregate\ consumer}(\phi) = \text{WTP}_{aggregate\ consumer}(\phi')$.

Proof. Given that quality is the same, whether or not platform upgrades are the same, the producer's willingness to pay is:

$$\left[\frac{(v_1-\phi_1)^2}{8} + \frac{(v_2-\phi_2)^2}{8}\right] - \left[\frac{(v_1'-\phi_1')^2}{8} + \frac{(v_2'-\phi_2')^2}{8}\right].$$

Similarly, the aggregate consumer willingness to pay is

$$\left[\frac{(v_1-\phi_1)^2}{4} + \frac{(v_2-\phi_2)^2}{4}\right] - \left[\frac{(v_1'-\phi_1')^2}{4} + \frac{(v_2'-\phi_2')^2}{4}\right],$$

from which the result is immediate.

■

1. For $k_\theta < \hat{k}_\theta^{NG}$, under asymmetric governance, the fee is chosen to make the producer indifferent between A with governance and B without governance. This implies that the producer's willingness to pay for governance is zero. It follows from Lemma 6 that aggregate consumer willingness to pay is zero. Thus, the social planner's willingness to pay is entirely determined by the platforms' payoffs. Under asymmetric governance, the platform with governance makes π_G^* and the platform without governance makes 0. Under no governance, the winning platform makes π_{NG}^* and the losing platform makes zero. Thus

$$\text{WTP}_{SP} = \text{WTP}_{WP} = \pi_G^* - \pi_{NG}^*$$

and

$$\text{WTP}_{LP} = \pi_G^* > 0.$$

- To see that WTP_{WP} is positive if $k_\mu < \hat{k}^G_\mu$ or $k_\mu > \hat{k}^{NG}_\mu$ take the two cases in turn. If $k_\mu < \hat{k}^G_\mu$, the winning platform (and social planner's) willingness to pay is:
$$\text{WTP}_{WP} = \frac{(\theta - \overline{\phi}^\mu_A)\overline{\phi}^\mu_A}{2} + \frac{(\mu\theta - \overline{\phi}^\mu_A)\overline{\phi}^\mu_A}{2} - \frac{\alpha(\mu-\alpha)\theta^2}{2}$$
Substituting for $\overline{\phi}^\mu_A$ and rearranging, we get
$$\text{WTP}_{WP} = \frac{\theta^2}{4}\left(\mu^2 - 2\mu(1+\alpha) - 1 + (\mu+1)\sqrt{(\mu+1)^2 - 2(\mu^2-\alpha^2)}\right).$$
Differentiating, we have:
$$\frac{\partial\, \text{WTP}_{WP}}{\partial\alpha} = \frac{2\alpha(\mu+1)}{\sqrt{1+2\alpha^2+2\mu-\mu^2}} - 2\mu,$$
which is negative for all $(\alpha,\mu) \in (\frac{1}{2}, 1] \times (1, 2\alpha]$, which is the relevant range because $\theta\mu < 2$ and $\alpha > \frac{1}{\theta}$. Thus, it suffices to show WTP_{WP} is positive at $\alpha = 1$. Substituting, this requires
$$\mu^2 - 4\mu - 1 + (\mu+1)\sqrt{3+2\mu-\mu^2} > 0.$$
This is increasing in μ, thus it suffices to check at $\mu = 1$, where it equals zero. Thus, for any $\mu > 1$ or $\alpha > \frac{\mu}{2}$ the winning platform's willingness to pay and the social planner's willingness to pay are strictly positive.
If $k_\mu > \hat{k}^{NG}_\mu$, the winning platform's willingness to pay is:
$$\text{WTP}_{WP} = \frac{(\theta - \overline{\phi}^1_A)\overline{\phi}^1_A}{2} + \frac{(\theta - \overline{\phi}^1_A)\overline{\phi}^1_A}{2} - \frac{\alpha(1-\alpha)\theta^2}{2}$$
Substituting for $\overline{\phi}^1_A$ and rearranging, we get
$$\text{WTP}_{WP} = \theta^2\left(\sqrt{\frac{1+\alpha^2}{2}}\left(1 - \sqrt{\frac{1+\alpha^2}{2}}\right)\right) - \frac{\alpha(1-\alpha)\theta^2}{2}.$$
Rearranging, this is positive if and only if:
$$\sqrt{\frac{1+\alpha^2}{2}} > \frac{1+\alpha}{2},$$
which holds for every $\alpha < 1$.

- To see that $\mathrm{WTP}_{WP} = \mathrm{WTP}_{SP}$ can take either sign, consider two cases:
  - $(\theta = \frac{59}{32}, k_\theta = \frac{5}{16}, \alpha = \frac{19}{32}, \mu = \frac{69}{64}, k_\mu = \frac{7}{128})$. In this instance, we have $\mathrm{WTP}_{WP} > .062$ and, thus, positive. Moreover, we satisfy all of the relevant assumptions: $1 > \alpha = \frac{19}{32} > \frac{32}{59} = \frac{1}{\theta}$; $1 < \mu = \frac{69}{64} < \frac{19}{18} = 2\alpha$; and the relevant hypotheses: $k_\theta = \frac{5}{16} < \frac{2{,}724{,}033}{4{,}194{,}304} = \hat{k}_\theta^{NG}$ and $\frac{\theta(\mu-1)\overline{\phi}_A^\mu(k_\theta)}{<}.029 < \frac{7}{128} = k_\mu < \frac{330{,}695}{4{,}194{,}304} = \hat{k}_\mu^{NG}$.
  - $(\theta = \frac{13}{8}, k_\theta = \frac{5}{16}, \alpha = \frac{13}{16}, \mu = \frac{69}{64}, k_\mu = \frac{11}{256})$. In this instance, we have $\mathrm{WTP}_{WP} < -.028$ and, thus, negative. Moreover, we satisfy all of the relevant assumptions: $1 > \alpha = \frac{13}{16} > \frac{8}{13} = \frac{1}{\theta}$; $1 < \mu = \frac{69}{64} < \frac{13}{8} = 2\alpha$; and the relevant hypotheses: $k_\theta = \frac{5}{16} < \frac{39{,}057}{65{,}536} = \hat{k}_\theta^{NG}$ and $\frac{\theta(\mu-1)\overline{\phi}_A^\mu(k_\theta)}{<}.029 < \frac{11}{256} = k_\mu < \frac{330{,}695}{4{,}194{,}304} = \hat{k}_\mu^{NG}$.

2. For any $k_\theta > \hat{k}^{NG}$, there is no quality investment without governance and so the platform's payoff is zero. This immediately implies $\mathrm{WTP}_{WP} = \mathrm{WTP}_{LP}$. Now consider the two cases separately.

   - For (k_θ, k_μ) satisfying $k_\theta \in [\hat{k}_\theta^{NG}, \frac{\theta^2(\mu^2+1)-2}{4})$, and $k_\mu < \hat{k}_\mu^G(\overline{\phi}_A^\mu)$ with governance there is quality investment and upgrading and without governance there is neither. Since the platforms' payoffs without governance are zero, their willingness to pay is simply the payoff with governance. First consider the platforms' willingness to pay:

     $$\mathrm{WTP}_{WP} = \frac{\left(\theta(\mu+1) - 2\overline{\phi}_A^\mu\right)\overline{\phi}_A^\mu}{2} - k_\mu.$$

     Since $\overline{\phi}_A^\mu$ is constant in k_μ, the willingness to pay is strictly decreasing in k_μ. Thus, to see that it is positive it suffices to show that it is weakly positive at $k_\mu = \hat{k}_\mu^G(\overline{\phi}_A^\mu)$.

     There are now two sub-cases to consider:
     - If $\overline{\phi}_A^\mu < \theta(1-\alpha)$, then $\hat{k}_\mu^G(\overline{\phi}_A^\mu) = \frac{\theta(\mu-1)\overline{\phi}_A^\mu)}{2}$. Making this substitution and substituting for $\overline{\phi}_A^\mu$, the platform's willingness to pay is positive if:

       $$\frac{\mu\theta\sqrt{4(1+2k_\theta) - (\mu-1)^2\theta^2} - (\mu-1)\theta^2 - 2(1+2k_\theta)}{2} > 0. \qquad (21)$$

       Differentiating the left-hand side with respect to k_θ we have:

       $$\frac{\partial\,\mathrm{WTP}_{WP}}{\partial k_\theta} = \frac{2\mu\theta}{\sqrt{4(1+2k_\theta) - (\mu-1)^2\theta^2}} - 2.$$

This derivative is itself decreasing in k_θ. Thus, to see that the derivative is negative, it suffices to see that it is weakly negative at $k_\theta = \frac{(\alpha^2+1)\theta^2-2}{4}$. Making this substitution, we have that the derivative is negative if:

$$\frac{\mu}{\sqrt{1+2\alpha^2+2\mu-\mu^2}} - 2 < 0$$

This is equivalent to:

$$\mu^2 - \mu < 1 + 2\alpha^2.$$

The left-hand side is increasing in μ and we know that $\mu < 2\alpha$ so it suffices to check at $\mu = 2\alpha$, where it follows from $\alpha < 1$. Since its left-hand side is decreasing in k_θ, it suffices to show that Condition 21 to show that the left-hand side is weakly positive at $k_\theta = \hat{k}_\theta^{NG} = \frac{\theta^2(\mu^2+1)-2}{4}$. Making this substitution, the right-hand side equals zero. This establishes that the WTP is strictly positive for any (k_θ, k_μ) satisfying $k_\theta \in (\hat{k}_\theta^{NG}, \frac{\theta^2(\mu^2+1)-2}{4})$, and $k_\mu < \frac{\theta^2(\mu-1)\overline{\phi}_A^\mu(k_\theta)}{2}$.

– If $\overline{\phi}_A^\mu \in (\theta(1-\alpha), \theta(\mu-\alpha))$, then $\hat{k}_\mu^G(\overline{\phi}_A^\mu) = \frac{(\mu\theta-\overline{\phi}_A^\mu)\overline{\phi}_A^\mu-\alpha(1-\alpha)\theta^2}{2}$. Making this substitution and substituting for the first instance of $\overline{\phi}_A^\mu$, the platform's willingness to pay is positive if:

$$\frac{\left(\mu\theta + \sqrt{(2\mu-1-\mu^2)\theta^2+4(1+2k_\theta)}\right)\overline{\phi}_A^\mu + \alpha(1-\alpha)\theta^2}{2} > 0,$$

which clearly holds by virtue of the fact that $\overline{\phi}_A^\mu > 0$.

Now turn to the social planner. Note that $\overline{\phi}_A^\mu$ is chosen to make the producer indifferent with low quality under no governance. Thus, the producer's willingness to pay is zero. Now consider the aggregate consumer willingness to pay.

The aggregate consumer willingness to pay is:

$$\text{WTP}_{\text{aggregate consumer}} = \frac{(\theta-\overline{\phi}_A^\mu)^2}{8} + \frac{(\mu\theta-\overline{\phi}_A^\mu)^2}{8} - \frac{1}{4}.$$

The fact that the producer is indifferent implies the following:

$$\frac{(\theta-\overline{\phi}_A^\mu)^2}{4} + \frac{(\mu\theta-\overline{\phi}_A^\mu)^2}{4} - \frac{1}{2} = k_\theta.$$

Dividing by two and substituting, this implies:

$$\text{WTP}_{\text{aggregate consumer}} = \frac{k_\theta}{2} > 0.$$

Taken together, this implies that the platform and social planner having positive willingness to pay and that the social planner's WTP is strictly higher than the platform's.

All that remains is to show that they jump discontinuously at $k_\theta = \hat{k}_\theta^{NG}$. First consider the platform's willingness to pay. Note that the $\overline{\phi}_A^\mu$ is continuous at $k_\theta = \hat{k}_\theta^{NG}$ and neither q nor r changes, so the platform's payoff under governance is continuous at $k_\theta = \hat{k}_\theta^{NG}$. However, the platform's payoff without governance is $\frac{\alpha(\mu-\alpha)\theta^2}{2} - k_\mu$ for $k_\theta < \hat{k}_\theta^{NG}$ and 0 for $k_\theta \geq \hat{k}_\theta^{NG}$. Thus, the platform's willingness to pay jumps up discontinuously.

The arguments above show that the producer's WTP is zero for $k_\theta < \hat{k}_\theta^{NG}$ and for $k_\theta \geq \hat{k}_\theta^{NG}$.

Finally, consider the aggregate consumers. The arguments above show that WTP is zero for $k_\theta < \hat{k}_\theta^{NG}$ and is strictly positive for $k_\theta \geq \hat{k}_\theta^{NG}$.

Thus, both the the platform's and the social planner's WTP jump discontinuously up at $k_\theta = \hat{k}_\theta^{NG}$.

- For (k_θ, k_μ) satisfying $k_\theta \in (\hat{k}_\theta^{NG}, \frac{\theta^2-1}{2})$ and $k_\mu > \hat{k}_\mu^G(\overline{\phi}_A^\mu)$ we have that there is quality investment but no platform upgrade with governance and neither quality investment nor platform upgrades without governance. Since the platform's payoff without governance is zero, its willingness to pay is simply the payoff with governance:

$$\text{WTP}_{WP} = \frac{(\theta - \overline{\phi}_A^1)\overline{\phi}_A^1}{2} + \frac{(\theta - \overline{\phi}_A^1)\overline{\phi}_A^1}{2},$$

which is strictly positive.

The fee $\overline{\phi}_A^1$ is chosen to leave the producer indifferent between quality investment and no upgrade at that fee and no quality investment and no governance. Thus, the producer's willingness to pay is zero.

The aggregate consumer willingness to pay is:

$$\text{WTP}_{\text{aggregate consumer}} = \frac{(\theta - \overline{\phi}_A^1)^2}{8} + \frac{(\mu\theta - \overline{\phi}_A^1)^2}{8} - \frac{1}{4}.$$

The fact that the producer is indifferent implies the following:

$$\frac{(\theta - \overline{\phi}_A^1)^2}{4} + \frac{(\mu\theta - \overline{\phi}_A^1)^2}{4} - \frac{1}{2} = k_\theta.$$

Dividing by two and substituting, this implies:

$$\text{WTP}_{\text{aggregate consumer}} = \frac{k_\theta}{2} > 0.$$

Taken together, this implies that the platform and social planner having positive willingness to pay and that the social planner's WTP is strictly higher than the platform's.

All that remains is to show that they jump discontinuously at $k_\theta = \hat{k}_\theta^{NG}$. First consider the platform's willingness to pay. Note that the $\overline{\phi}_A^1$ is continuous at $k_\theta = \hat{k}_\theta^{NG}$ and neither q^G nor r^G changes, so the platform's payoff under governance is continuous at $k_\theta = \hat{k}_\theta^{NG}$. However, the platform's payoff without governance is $\frac{\alpha(1-\alpha)\theta^2}{2}$ for $k_\theta < \hat{k}_\theta^{NG}$ and 0 for $k_\theta \geq \hat{k}_\theta^{NG}$. Thus, the platform's willingness to pay jumps up discontinuously.

The arguments above show that the producer's WTP is zero for $k_\theta < \hat{k}_\theta^{NG}$ and for $k_\theta \geq \hat{k}_\theta^{NG}$.

Finally, consider the consumer aggregate WTP. The arguments above show that WTP is zero for $k_\theta < \hat{k}_\theta^{NG}$ and is strictly positive for $k_\theta \geq \hat{k}_\theta^{NG}$.

Thus, both the the platform's and the social planner's WTP jump discontinuously up at $k_\theta = \hat{k}_\theta^{NG}$.

3. For any (k_θ, k_μ) satisfying $k_\theta > \frac{\theta^2-1}{2}$ and $k_\mu > \hat{k}_\mu^G(\overline{\phi}_A^\mu$, there is no quality investment or platform upgrade with or without governance. Thus, prices are zero in all periods with or without governance, leaving all players indifferent.

■

Proof of Proposition 8. The equilibrium analysis follows from the argument in the text.

The next two points follow immediately from Proposition 7 and the definition of WTP_{SP}.

■

Proof of Proposition 9.

1. Consider the game without governance. The case of $k_\theta \geq \frac{\theta^2-1}{2}$ follows from Proposition 3. For any α, there is no quality investment and both platforms make zero. Thus, for any $\epsilon > 0$, the platforms will not propose a change in interoperability.

   For $k_\theta < \frac{\theta^2-1}{2}$, for any final α, either A or B is the winning platform. Suppose, without loss of generality, that A is the winner at $\alpha = \alpha^*$. Then for ϵ sufficiently small, the unique equilibrium is $\alpha_A = \alpha^*$ and $\alpha_B = 0$.

   Let's first see that this is an equilibrium. Proposition 3 shows the winning platform's payoff from the game is maximized at $\alpha = \alpha^*$ and is strictly decreasing away from it. Thus, A does not have a profitable deviation to another α_A. And for $\alpha_0 \neq \alpha^*$, there is an $\epsilon' > 0$ such that for $\epsilon < \epsilon'$, Platform A will implement $\alpha_A = \alpha^*$ rather than making no proposal. Proposition 3 shows that both platforms' payoffs are zero for any $\alpha < \alpha^*$. So even if B is the winning platform for some $\alpha_B < \alpha^*$, B will not implement that level of interoperability for any $\epsilon > 0$. Hence, $(\alpha_A = \alpha^*, \alpha_B = 0)$ is an equilibrium for ϵ sufficiently small.

   Now let's see that there is no other equilibrium. As we've just seen, for $\epsilon > 0$, there can be no equilibrium where either player makes a proposal and $\alpha < \alpha^*$ nor can there be an equilibrium where both players make a proposal. So consider an equilibrium with $\alpha > \alpha^*$. If A is the winning platform, it would have been better off choosing $\alpha_A = \alpha^*$. If B is the winning platform, A could have won and made a strictly positive payoff by proposing $\alpha_A = \alpha^*$. Thus, there is an $\epsilon' > 0$ such that for $\epsilon < \epsilon'$ A prefers to propose $\alpha_A = \alpha^*$.

   The fact that the producer invests in quality follows immediately from Proposition 3 and the definition of $\hat{\alpha}^{NG}$.

2. Consider the game with asymmetric governance where A has governance and B does not.

   If either (i) $k_\theta \geq \frac{\theta^2-1}{2}$ and $k_\mu \geq \hat{k}_\mu^G(\overline{\phi}_1^\mu)$ evaluated at $\alpha = \frac{1}{\theta}$ or (ii) $k_\theta \geq \frac{\theta^2(\mu^2+1)-2}{4}$, then Proposition 2 implies that there is never quality investment for any α and both platforms make a payoff of zero. Thus, for any $\epsilon > 0$, the platforms will not propose a change in interoperability.

   For the alternative case, for any level of interoperability, platform B's payoff is zero, so B doesn't make a proposal for any $\epsilon > 0$. By contrast, Proposition 5 shows that A's optimal level of interoperability is $\frac{1}{\theta}$ and that A's payoff is strictly decreasing as α increases. Thus, for any $\alpha_0 > \frac{1}{\theta}$, there is an $\epsilon'' > 0$ such that for $\epsilon < \epsilon''$, Platform

A will implement $\alpha_A = \frac{1}{\theta}$.

■

B Supplemental Appendix: Full Statements of Equilibria

Proposition 10 *A pure strategy SPNE of the game with no governance exists.*

Behavioral strategies in any pure strategy SPNE of the game with no governance satisfy:

- ***Consumers****: In each period a consumer i purchases if and only if $v_t - p_t - x_i \geq 0$.*
- ***Producer****:*
  - *Period 2:*
    - *In any subgame with fee ϕ_2 to sell on a platform with product quality v_2, charge $p^*(v_2, \phi_2)$ as described in Equation 2;*
    - *In any subgame where $v_A = v_B$, sell on whichever platform charges the lower fee. If fees are equal, selling on either platform can be supported in equilibrium;*
    - *In any subgame where $v_A > v_B$, sell on A if $\left(\frac{v_A - \phi_2^A}{2}\right)^2 \geq \left(\frac{v_B - \phi_2^B}{2}\right)^2$ and on B otherwise. (And symmetrically if $v_B > v_A$).*
  - *Period 1:*
    - *In any subgame with fee ϕ_1 to sell on a platform with product quality v_1, charge $p^*(v_1, \phi_1)$;*
    - *Join whichever platform charges a lower first-period fee, if they are equal joining either can be supported in equilibrium;*
    - *Invest in quality if $k_\theta \leq \hat{k}_\theta^{NG}$ and don't otherwise.*
- ***Platforms****:*
  - *Period 2:*
    - *Incumbent platform*
      - *In any subgame with $q = 1$, choose $\phi_2 = 0$ and do not upgrade ($r = 1$).*
      - *In any subgame with $q = \theta$, choose $\phi_2 = \theta(r - \alpha)$.*
      - *In any subgame with $q = \theta$, choose $r = \mu$ if and only if $k_\mu \leq \hat{k}_\mu^{NG}$.*
    - *Other platform: In any subgame choose $\phi_2 = 0$.*

- *Period 1:*
    - *Choose $\phi_1 = 0$.*

Proof. Existence follows from direct construction in the text.

- Consumer behavior follows from the analysis around Equation 1.
- For producer:
  - Period 2
    - Pricing strategy follows from the analysis around Equation 2.
    - If quality on platform j is v_j producer payoffs from listing on platform j at fee ϕ_j are first period payoffs plus $\left(\frac{v_j - \phi_j}{2}\right)^2$, from which the platform joining strategy follows.
  - Period 1:
    - Pricing strategy follows from the analysis around Equation 2.
    - Since, given quality decisions both platforms play the same in the continuation game and this play is invariant to their first-period fee, the payoff from joining platform j in period 1 is strictly decreasing in its period 1 fee. From this, platform joining behavior follows.
    - The quality investment strategy follows from the analysis around Equation 6.
- Platform
  - Follows from Lemma 1 and Equation 5.
  - In period 1, the winner is the platform with the lowest first-period fee. The winner makes second period rents and the loser makes zero from the game. Thus, in any profile with either fee positive, at least one of the platforms is not best responding and equilibrium requires $\phi_1^A = \phi_1^B = 0$.

■

Proposition 11 *A pure strategy SPNE equilibrium of the game with asymmetric governance exists.*

Behavioral strategies in any pure strategy SPNE of the game where A has asymmetric governance satisfy:

- ***Consumers**: In each period a consumer i purchases if and only if $v_t - p_t - x_i \geq 0$.*
- ***Producer**:*
  - *Period 2:*
    - *At any history where A is the incumbent and $\phi_2^A \geq \phi_1^A$, veto the fee change. For all other histories, approve fee changes.*
    - *In any subgame with fee ϕ_2 to sell on a platform with product quality v_2, charge $p^*(v_2, \phi_2)$;*
    - *In any subgame where $v_A = v_B$, sell on whichever platform charges the lower fee. If fees are equal, selling on either platform can be supported in equilibrium;*
    - *In any subgame where $v_A > v_B$, sell on A if $\left(\frac{v_A - \phi_2^A}{2}\right)^2 \geq \left(\frac{v_B - \phi_2^B}{2}\right)^2$ and on B otherwise. (And symmetrically if $v_B > v_A$).*
  - *Period 1:*
    - *In any subgame with fee ϕ_1 to sell on a platform with product quality v_1, charge $p^*(v_1, \phi_1)$;*
    - *For any subgame with (ϕ_1^A, ϕ_1^B):*
      - *Choose $q = \theta$ and join A if the following all hold:*

$$\pi_2^G(\theta, \mu, \phi_1^A) - \pi_2^G(\theta, 1, \phi_1^A) \geq k_\mu \tag{22}$$

$$\frac{(\theta - \phi_1^A)^2 + (\mu\theta - \phi_1^A)^2}{4} \geq \frac{(\theta - \phi_B)^2}{4} + \frac{\alpha^2\theta^2}{4} \tag{23}$$

$$\frac{(\theta - \phi_1^A)^2 + (\mu\theta - \phi_1^A)^2}{4} - k_\theta \geq \frac{(1 - \phi_B)^2}{4} + \frac{1}{4} \tag{24}$$

$$\frac{(\theta - \phi_1^A)^2 + (\mu\theta - \phi_1^A)^2}{4} - k_\theta \geq \frac{(1 - \phi_1^A)^2}{4}. \tag{25}$$

or if the following all hold:

$$\pi_2^G(\theta, \mu, \phi_1^A) - \pi_2^G(\theta, 1, \phi_1^A) < k_\mu \tag{26}$$

$$\frac{(\theta - \phi_1^A)^2 + (\theta - \phi_1^A)^2}{4} \geq \frac{(\theta - \phi_B)^2}{4} + \frac{\alpha^2\theta^2}{4} \tag{27}$$

$$\frac{(\theta - \phi_1^A)^2 + (\theta - \phi_1^A)^2}{4} - k_\theta \geq \frac{(\theta - \phi_B)^2}{4} + \frac{1}{4} \tag{28}$$

$$\frac{(\theta-\phi_1^A)^2+(\theta-\phi_1^A)^2}{4}-k_\theta \geq \frac{(1-\phi_1^A)^2}{2}. \tag{29}$$

· *Choose $q=\theta$ and join B if the following all hold:*

$$\pi_2^G(\theta,\mu,\phi_1^A)-\pi_2^G(\theta,1,\phi_1^A \geq k_\mu \tag{30}$$

$$\frac{(\theta-\phi_B)^2}{4}+\frac{\alpha^2\theta^2}{4} \geq \frac{(\theta-\phi_1^A)^2+(\mu\theta-\phi_1^A)^2}{4} \tag{31}$$

$$\frac{(\theta-\phi_B)^2}{4}+\frac{\alpha^2\theta^2}{4}-k_\theta \geq \frac{(1-\phi_B)^2}{4}+\frac{1}{4} \tag{32}$$

$$\frac{(\theta-\phi_B)^2}{4}+\frac{\alpha^2\theta^2}{4}-k_\theta \geq \frac{(1-\phi_1^A)^2}{4}+\frac{1}{4}. \tag{33}$$

or the following all hold:

$$\pi_2^G(\theta,\mu,\phi_1^A)-\pi_2^G(\theta,1,\phi_1^A \geq k_\mu \tag{34}$$

$$\frac{(\theta-\phi_B)^2}{4}+\frac{\alpha^2\theta^2}{4} > \frac{(\theta-\phi_1^A)^2+(\theta-\phi_1^A)^2}{4} \tag{35}$$

$$\frac{(\theta-\phi_B)^2}{4}+\frac{\alpha^2\theta^2}{4}-k_\theta \geq \frac{(1-\phi_B)^2}{4}+\frac{1}{4} \tag{36}$$

$$\frac{(\theta-\phi_B)^2}{4}+\frac{\alpha^2\theta^2}{4}-k_\theta \geq \frac{(1-\phi_1^A)^2}{4}+\frac{1}{4}. \tag{37}$$

· *Otherwise, choose $q=1$ and join platform with lower fee. If fees are equal, join either.*

- ***Platform A**:*
  - *Period 2:*
    - *At any history where A is the incumbent platform*
      - · *If $q=1$, choose $\phi_2=0$ and do not upgrade ($r=1$).*
      - · *If $q=\theta$: Choose $\phi_2=\phi_2^G(q,r,\phi_1^A)$ as defined in Equation 7.*
      - · *At any subgame with $q=\theta$ and ϕ_2: Choose $r=\mu$ if and only if $\pi_2^G(\theta,\mu,\phi_2)-\pi_2^G(\theta,1,\phi_2)\geq k_\mu$.*
    - *At any history where A is the challenger, choose $\phi_2=0$.*
  - *Period 1:*
    - *Choose $\phi_1=\phi_A^{*,G}$ as defined in Equation 10.*

- ***Platform B**:*
  - *Period 2:*
    - *If B is incumbent platform*
      - *In any subgame with $q = 1$, choose $\phi_2 = 0$ and do not upgrade ($r = 1$).*
      - *In any subgame with $q = \theta$, choose $\phi_2 = \theta(r - \alpha)$.*
      - *In any subgame with $q = \theta$, choose $r = \mu$ if and only if $k_\mu \leq \hat{k}_\mu^{NG}$.*
    - *If B is other platform: In any subgame choose $\phi_2 = 0$.*
  - *Period 1:*
    - *Choose $\phi_1 = 0$.*

Proof. Existence follows from direct construction in the text.

- Consumer behavior follows from the analysis around Equation 1.
- For producer:
  - Period 2
    - The producer's second period payoff if they sell on A in the second period at quality v is $\frac{v-\phi_2^A)^2}{4}$ which is strictly decreasing in ϕ_2^A, from which the veto strategy follows.
    - Pricing strategy follows from the analysis around Equation 2.
    - If quality on platform j is v_j producer payoffs from listing on platform j at fee ϕ_j are first period payoffs plus $\left(\frac{v_j-\phi_j}{2}\right)^2$, from which platform joining strategy follows.
  - Period 1:
    - Pricing strategy follows from the analysis around Equation 2.
    - If Condition 22 holds, then under the proposed strategy profile, the producer anticipates platform A will upgrade if it is the incumbent. Moreover, given the proposed strategy profile, the platform that wins in the first period continues to win in the second period. Conditions 23–25, then, are the conditions for the producer to prefer A and $q = \theta$ over B and $q = \theta$, B and $q = 1$, and A and $q = 1$, respectively, when there will be upgrades. If all of these hold, then A and $q = \theta$ is a best response.

If Condition 26 holds, then under the proposed strategy profile, the producer anticipates platform A will not upgrade if it is the incumbent. Moreover, given the proposed strategy profile, the platform that wins in the first period continues to win in the second period. Conditions 27–29, then, are the conditions for the producer to prefer A and $q = \theta$ over B and $q = \theta$, B and $q = 1$, and A and $q = 1$, respectively, given no upgrade. If all of these hold, then A and $q = \theta$ is a best response. Note that Conditions 22 and 26 are mutually exclusive so only one of these can hold.

The conditions for joining B at $q = \theta$ are analogous.

If none of these sets of conditions are satisfied, then neither platform can incentivize $q = \theta$. At $q = 1$, the joining strategy follows from the producer's payoff being strictly decreasing in the fee.

- Platform A
  - The choice of fee follows from Lemma 2 and the upgrading decision is from the direct comparison of payoffs.
  - The period 1 fee follows from Proposition 4.
- Platform B is as in the model without governance.
  - Behavior if incumbent in period 2 follows from Lemma 1 and Equation 5.
  - In period 1, the winner is the platform with the lowest first-period fee. The winner makes second period rents and the loser makes zero from the game. Thus, in any profile with either fee positive, at least one of the platforms is not best responding and equilibrium requires $\phi_1^A = \phi_1^B = 0$.

■

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