Platform governance*

Tat-How Teh†

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Abstract

Platforms that intermediate trades, such as Amazon, Airbnb, and eBay play a regulatory role in deciding how to govern the "marketplaces" they create. We propose a framework to analyze a platform's non-price governance designs and its incentive to act in a welfare-enhancing manner. We show that the platform's governance designs can be distorted towards inducing insufficient or excessive seller competition, depending on the nature of the fee instrument employed by the platform. These results are illustrated with micro-founded applications to a platform's control over seller entry, information provision and recommendations, quality standards, and search design choices.

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†School of Management and Economics and Shenzhen Finance Institute, The Chinese University of Hong Kong, Shenzhen, China, e-mail: tehtathow@gmail.com

1 Introduction

A growing number of proprietary platforms operate as marketplaces through which buyers and third-party sellers trade. Well-known examples include third-party marketplaces Amazon and eBay; accommodation sharing site Airbnb, software distribution platforms such as Google's Playstore, Steam, and Apple's Appstore; and video game consoles such as Sony's PS4, as well as brick-and-mortar shopping malls. Much like a government regulator that runs an economy, a platform regulates the behavior of platform users by setting rules or governance designs. Several policy reports have highlighted the importance of the governance role of platforms (Furman et al., 2019; Scott Morton et al., 2019). Most notably, Section 4.III of the EC Competition Report states:

"Platforms impose rules and institutions that reach beyond the pure matching service and shape the functioning of the marketplace and, potentially, the relationship between the various platform sides, e.g. by regulating access to and exclusion from the platform, by regulating the way in which sellers can present their offers, the data and APIs they can access, setting up grading systems, regulating access to information that is generated on the platform, imposing minimum standards... Such rule-setting and 'market design' determine the way in which competition takes place [on a platform]." — Crémer, de Montjoye, and Schweitzer (2019)

Given the increasingly prominent roles played by dominant platforms in the economy, the EC Report and other observers have pointed out that these platforms have a responsibility to write good rules to ensure that competition on their platforms is fair and pro-user. However, an important question is whether a proprietary platform necessarily has an incentive to act in a way that maximizes welfare (or joint value on its ecosystem). In this paper, we provide a framework to examine the incentives and trade-offs a platform faces in its governance designs, and study how its designs can be distorted away from what is optimal for the entire marketplace or from a total welfare perspective.

In practice, the scope of platform governance is wide. We focus on governance designs that have two characteristics: (i) they (indirectly) influence the gross transactional value generated on the platform for buyers (V); and (ii) they influence the intensity of on-platform seller competition, as measured by the competitive markup enjoyed by sellers (M). For instance:

- *Example 1:* A platform can regulate the effective number of competing sellers by carefully selecting, for each category, how many sellers to admit and display to buyers. Admitting and displaying more sellers improves product variety (higher V) and intensifies seller competition (lower M).[1]

- *Example 2:* A platform can determine how its recommendation system allocates weights between product price and product match (or relevance). Emphasizing the price dimension intensifies competition between sellers (lower M) but may result in a worse product match (lower V).[2]

[1] This is a common logic of standard competition models with horizontal product differentiation, e.g., Salop (1979) and Perloff and Salop (1985).

[2] See, e.g. Dinerstein et al. (2018) and Armstrong and Zhou (2020) for empirical and theoretical analysis of this trade-off in ranking design.

Beyond these two examples, this formulation for platform governance is rich enough to cover several other design decisions, including those regarding quality control, the extent of advertisement targeting and personalization, and on-platform search friction.

Using this framework, we compare the optimal governance design by a profit-maximizing platform with the governance design that maximizes welfare to determine the source of any welfare distortion. In our framework, there is a platform that facilitates transactions between buyers and price-setting sellers, and it chooses its governance design and the fee(s) charged to sellers. Each buyer wants to buy one unit of a single product and to purchase it from the seller of their choice. Seller are ex-ante homogenous when they make their participation decisions. Our main result identifies a class of models in which the sign of the welfare distortion can be related precisely to the fee instrument employed by the platform.

We start by analyzing the case in which the platform fee is purely transaction-based, which can be either a proportional fee or a per-transaction fee. With proportional fees, which are used by many online platforms, we show that the platform's profit can be interpreted as a weighted sum of seller profit and transaction volume, and so its governance design aims to balance the interest of these two components. When the marginal cost of sellers is small relative to the elasticity of buyer demand (with respect to the net utility offered), the platform's profit — which is proportional to seller revenue — approximates seller profit. Therefore, the platform benefits from a governance design that relaxes seller competition and sustains a high markup for sellers. The profit-maximizing design tends to be distorted towards relaxing on-platform seller competition (compared with the welfare benchmark). However, as sellers' marginal cost increases, the platform's profit begins to diverge from seller profit, given that it does not internalize sellers' marginal cost. Once the marginal cost is sufficiently high, the platform's incentive is reversed and it now prefers to set a governance design that maximizes transaction volume, so that its design instead becomes distorted towards intensifying seller competition. This distortion can lead to an insufficient gross transactional value generated for buyers, depending on the correlation between the change in V and the change in M in response to a change in the platform's governance design.

With per-transaction fees, the platform's profit increases with total transaction volume, and thus it sets its governance design to maximize the volume. This overemphasis on transaction volume means that the platform can potentially fail to balance the dual roles of governance (i.e., influencing V and M) in a welfare-maximizing manner. For a design decision whereby the correlation between V and M is always negative (e.g., the variety choice in Example 1), there is no distortion because both volume-maximization and welfare-maximization call for the highest V and the lowest M. However, when the correlation between V and M is not always negative (e.g., the recommendation design in Example 2), we find that the profit-maximizing design can be distorted towards intensifying on-platform seller competition and insufficient gross transactional value (compared with the welfare benchmark).

We then consider the case in which the platform charges sellers participation fees, e.g., listing fees that some online marketplaces charge sellers. With pure participation fees, the platform profit becomes proportional to the joint industry (the platform and sellers) profit, and its governance design is distorted towards relaxing on-platform seller competition to maximize this joint profit. A similar intuition applies when the platform charges seller two-part tariffs (i.e., when both transaction-based fees and participation fees are feasible). Finally, we also consider alternative forms of revenue models, such as external advertising income or buyer participation fees in the form of subscription charges or device sales, and show that the result from the case of per-transaction fees is applicable in these cases.

Our results thus motivate the following taxonomy for platform fee instruments (or business models in general). On one hand, there are *seller-aligned* fee instruments (e.g., proportional fees when seller marginal costs are low, seller participation fees, and two-part tariffs), in which the platform prefers governance designs that relax seller competition so as to increase seller surplus. For instance, in Example 1, a platform with seller-aligned fee instruments tends to admit and show too few sellers (relative to the welfare benchmark). On the other hand, there are *volume-aligned* fee instruments (e.g., per-transaction fees, proportional fees when seller marginal costs are high, buyer participation fees, and external advertising revenue), in which the platform prefers governance designs that intensify seller competition and increase transaction volume. In Example 2, a platform with volume-aligned fee instruments tends to overemphasize the price dimension in its recommendation design.

The results have two main implications. First, they highlight the fact that welfare results on platform models can be sensitive to different modelling assumptions on the fee instruments available. Therefore, it is important to be cautious when using theoretical results obtained under certain fee instruments to make predictions about real-world markets if, in practice, different fee instruments are used. Second, our framework echoes the recent regulatory discussion that emphasizes the need to understand how different "business models" or monetizing methods of digital platforms can lead to different antitrust implications.[3] To this end, the taxonomy outlined in the previous paragraph provides a simple way to relate a platform's fee instrument (i.e., its monetization method) with potential welfare distortions in the class of governance design decisions that can be captured by the current framework.

The rest of the paper proceeds as follows. Section 1.1 surveys the relevant literature. Section 2 lays out a general framework that nests various models of on-platform competition and governance. Section 3 and Section 4 analyze the general framework under a variety of platform fee instruments. Section 5 applies the insights obtained to discuss specific models of platform governance. Section 6 explores several extensions of our framework: allowing for endogenous choice of fee instruments, examining what happens when governance design is costly, and considering a consumer surplus benchmark rather than a total welfare benchmark. Section 7 concludes. All omitted proofs and derivations are relegated to the Appendix.

1.1 Relation to the literature

Most of the existing literature on multi-sided platforms has focused on pricing aspects (Caillaud and Jullien, 2003; Rochet and Tirole, 2003, 2006; Armstrong, 2006; Armstrong and Wright,

[3]For instance, Caffarra, Etro, Latham, and Scott Morton (2020) point out that "one major source of differentiation we need to take on board is distinctions in the business models the various ecosystems operate, and how these different strategies for monetising the surplus created by their platforms influence their incentives." The importance of business models has also been highlighted in the existing works on media platforms, e.g., Anderson and Coate (2005), Peitz and Valleti (2008), Calvano and Polo (2020).

2007; Weyl, 2010; Jullien and Pavan, 2019; Tan and Zhou, 2021; Liu, Teh, Wright, and Zhou, 2021). This study contributes to recent efforts that expand the formal study of multi-sided platforms beyond pricing into the domain of platform governance. Among the platform governance design decisions investigated in the strategy and economics literature are: platform openness and innovation (Boudreau, 2010; Parker and Van Alstyne, 2017), intellectual property sharing (Niculescu, Wu, and Xu, 2018), introduction of platform first-party content (Hagiu and Spulber, 2013), and delegation of control rights (Hagiu and Wright, 2015a; 2015b; 2018). Most of these studies focus on how governance choices can generate additional surplus on platforms by encouraging innovations by third-party developers or coordinating end-user behavior. They do not focus on the role of governance in influencing on-platform price competition between sellers.

The focus on on-platform seller competition is also at the heart of Nocke, Peitz, and Stahl (2007), Hagiu (2009), Belleflamme and Peitz (2019), and Anderson and Bedre-Defolie (2020). In these papers, platform pricing (in particular, the seller-side participation fee component) endogenously determines the number of participating sellers through the free entry condition of sellers. As such, product variety on the platform is directly tied to platform pricing rather than being a separate governance decision. These papers show that in equilibrium, different levels of seller competition are induced by platforms' pricing, depending on various exogenous factors such as platform ownership, strength of the cross-network effect, and buyers' preference for product variety. In contrast to this line of literature, this paper takes a different modelling approach by treating platform governance design (in this case, variety provision) and platform pricing as two distinct decisions.[4] This approach offers two benefits. First, it allows us to explore how the types of fee instruments employed by the platform shape its governance design choices, and how its choices differ from the welfare-maximizing solution. Second, it extends the insights from this literature to other design decisions that may not be directly tied to the free entry condition, e.g., search interface design and information provision.

A key theme in our framework is the connection between value generation and the extent of seller competition in governance design. This is closely related to the work of Karle and Peitz (2017) and de Cornière (2016) which look at the degree of targeted advertising implementable on a monopoly search engine (which can be interpreted as a platform design choice). In the model of de Cornière (2016), the platform charges sellers a lump-sum advertising fee and benefits from lowering the accuracy of targeting. Doing so induces buyers to search through fewer products in equilibrium, which deteriorates product match and relaxes competition between sellers. Karle and Peitz (2017) consider a similar context but with loss-averse buyers. They show that an industry-profit-maximizing platform can use imprecise targeting to relax seller competition through manipulating the formation of buyers' consideration sets and reference points. Using our terminologies, these two setups can be categorized as having seller-aligned fees, whereby the platform is predicted to choose the design that is associated with less seller competition (i.e., less targeting). Our framework complements these two studies by extending

[4] Despite the difference in modelling approaches, some of our results, when applied to Example 1, coincide with those obtained by Nocke et al. (2007) and Anderson and Bedre-Defolie (2020). One key reason is that when the platform charges sellers lump-sum fees in Example 1, we recover the relationship between equilibrium product variety and platform pricing, as in these papers. We discuss these connections in Sections 4.3 and 4.4.

their insights to other types of fee instruments whereby the platform may want to implement excessive targeting.

Concurrent with this paper, Choi and Jeon (2021) analyze platforms' incentives to adopt technological innovations that trade off between buyer surplus and advertiser surplus, e.g., privacy policies. Even though they look at environments that do not involve seller competition, their high-level insights are consistent with ours. They show that the platform adopts innovations that are (weakly) biased in favor of buyers when the non-negative pricing constraint on the buyer side does not bind (which corresponds to pure buyer participation fees and two-part tariffs in our framework), and that the opposite is true when the constraint binds (correspond to pure seller participation fee in our framework). Etro (2021) analyzes competition between a device-funded platform and an ad-funded platform, à la Apple's iOS and Google's Android ecosystems. He examines how the adoption of these two different business models shapes each platform's incentive in their decisions regarding investments in the platform's inherent quality and introduction of the platform's first-party apps. This paper differs in that we focus on a different class of platform design decisions, that we focus on a monopoly platform, and that we consider a wider range of possible fee instruments.

In interpreting our framework, we also have in mind decisions regarding search interface design, information provision, and quality control. Here we provide a non-exhaustive survey of recent work along these lines.

☐ **Search design and information provision.** Hagiu and Jullien (2011) and White (2013) consider a platform that can garble the buyer search process to divert buyers towards sellers that generate higher revenue for the platform. In doing so, the platform trades off between earning a higher margin per buyer versus less buyer participation. However, such search diversion has no impact on the price competition among sellers. Casner (2020) analyzes a platform's incentive to increase buyer search cost in a search environment based on the random sequential search model of Wolinsky (1986). He independently obtains one of the same findings as ours — a platform with a proportional fee has an incentive to obfuscate search to sustain seller markups. Casner's analysis focuses on an exogenously fixed proportional fee on sellers, whereas our framework considers other fee instruments under which the platform may have no incentive to obfuscate search. Our framework is also readily applicable to other nonrandom search environments, in particular, a price-directed search environment (e.g., Armstrong and Zhou, 2011; Armstrong, 2017; Choi, Dai, and Kim, 2018), whereby the platform's incentive to obfuscate search can be reversed.

☐ **Quality control.** Jeon and Rochet (2010) analyze how the quality standard decisions of an academic journal depend on whether it operates as an "open access" journal (charging readers nothing) or a standard subscription-based journal. They show that the resulting quality standard is too high relative to welfare benchmarks if the journal charges readers for access, while the standard is too low if the journal is open access. Bouvard and Levy (2018) consider a certification intermediary that can invest in the capability of its certification technology in detecting low-quality firms. In contrast to these works, however, we consider a marketplace setting in which a platform intermediates trades between buyers and multiple competing price-setting sellers. We show that the incentive to manipulate on-platform competition provides another explanation for why platforms may set quality controls that are either too restrictive or too permissive.

Finally, our emphasis on the role of different platform fee instruments (in particular, transaction-based fees) relates to work by Shy and Wang (2011), Johnson (2017), and Wang and Wright (2017), among others. These studies compare constant per-transaction fees against proportional fees, and they show the superiority of the latter in mitigating the double marginalization problem or in facilitating price discrimination across product categories. These studies (and this paper) do not address the question of the optimal instrument to use; this can reflect other considerations, such as technological limitations (e.g., the inability to monitor the price and/or quantity of transactions) or coordination issues (participation-based fees may be less profitable when platforms face a chicken-and-egg problem to launch). For this line of inquiry, see Hagiu and Wright (2019).

2 Model setup

The environment consists of a continuum of unit-demand buyers, multiple sellers (a finite number or a continuum), and a platform that enables transactions between buyers and sellers. We first present a general framework that is meant to encompass several models of platform governance. Several of the assumptions in this framework can be relaxed, as we discuss in Section 2.1. We then illustrate the framework using three specific micro-foundations in Section 2.2.

Governance design. The platform chooses and announces a governance design, which is parameterized as a continuous variable $a \in \Theta$.[5] Here, $\Theta \subseteq \mathbb{R}$ is a compact set indicating the designs implementable by the platform. To fix ideas, we can think of a as a stylized representation of a platform's choices regarding the effective number of sellers on the platform, quality control level, search interface, or information design.

The choice of a affects (i) the gross transactional value $V(a)$ that each buyer obtains from visiting the platform and purchasing items from the sellers, and (ii) the intensity of on-platform seller competition, which is parameterized as the markup $M(a)$ that sellers earn (to be made precise below). Both $V(a)$ and $M(a)$ are continuous functions for all $a \in \Theta$. To highlight our main points in a simple fashion, we assume that the platform faces zero fixed and marginal costs, and both costs are independent of a.

Without loss of generality, we define a such that a higher a corresponds to a higher markup (less seller competition), so that $M(a)$ is an increasing function. We allow $V(a)$ to be non-monotone in general, but in various parts of the paper it is useful to take note of two special cases:[6]

- V and M are always negatively correlated: $V(a)$ is monotonically decreasing.
- V and M are always positively correlated: $V(a)$ is monotonically increasing.

[5] The analysis easily extends to the case where a is a discrete or multi-dimensional variable. See the discussion in Section 2.1.

[6] Our formulation based on value and markup is reminscent of the (U, R) -framework in de Cornière and Taylor (2019). The main difference is that their framework describes how individual firms strategically compete with each other (e.g., price competition or quality competition; whereas our formulation focuses on how exogenous parameters regarding the market condition affect the equilibrium outcome of the price competition.

Seller pricing. For each design a chosen by the platform, sellers engage in price competition to attract buyers. Sellers have a constant marginal cost $c > 0$. Suppose we ignore any platform fees for the moment. Without imposing any specific micro-foundation, we posit that the seller competition results in a symmetric equilibrium price p that is a function of design:

$$p(a) = c + M\left(a\right). \tag{1}$$

Hence, $M\left(a\right) \geq 0$ is exactly the equilibrium markup that sellers earn. With an arbitrary form of $M\left(a\right)$, the equilibrium price equation (1) is consistent with those arising from various micro-foundations with unit-demand buyers, e.g. the circular city model of Salop (1979), the discrete choice model of Perloff and Salop (1985), the spokes model of Chen and Riordan (2007), the sequential search model of Wolinsky (1986) and Anderson and Renault (1999), and the price-directed search model of Choi et al. (2018), among others. The reduced-form formulation allows us to concisely capture the effect of platform governance on how seller competition unfolds.

Buyers and volume of transactions. Buyers need to pay an intrinsic cost, $d \geq 0$, to visit the platform. We assume that the market is conditionally ex-post covered; that is, every buyer purchases one product conditional on visiting the platform.[7] The net surplus a buyer obtains from visiting the platform (and eventually purchasing a product) is $V(a) - p$, while the buyer's surplus from the outside option is normalized to zero. There is heterogeneity in d so that only buyers with $d \leq V\left(a\right) - p(a)$ would participate on the platform. Given this, the total number of transactions (or aggregate demand) faced by the platform is the mass of participating buyers, denoted as

$$Q\left(V\left(a\right) - p(a)\right) = \Pr\left(d \leq V\left(a\right) - p(a)\right), \tag{2}$$

where Q is strictly increasing, continuously differentiable, and weakly log-concave.

Platform fees. The platform levies a fee on sellers for each transaction, which can be a linear per-transaction fee τ or a proportional fee r (also known as a revenue sharing contract).[8] For notational brevity, we assume that the platform does not charge any transaction fee to buyers, which is without loss of generality due to the tax neutrality principle (Weyl and Farbinger, 2013).[9]

Under a per-transaction fee, the fee τ is essentially an additional marginal cost to sellers, so that the equilibrium price equation in (1) becomes

$$p(a) = c + \tau + M\left(a\right).$$

Under a proportional fee, for each unit of sales revenue generated, a seller receives its share

[7] A similar demand formulation has been adopted by Edelman and Wright (2015) and Anderson and Bedre-Defolie (2020), among others. This approach allows the framework to be compatible with micro-foundations that have ex-post covered markets — most notably spatial competition models — while still allowing for elastic aggregate demand.

[8] The possibility of participation-based fees is examined in Sections 4.3 - 4.5.

[9] In the marketplace environments we study, the standard principle of tax-neutrality - whereby sellers take into account the buyer-side fees when they set prices - implies that aggregate demand does not depend directly on the decomposition of platform fees between buyer fees and seller fees. Even if such neutrality does not hold, in many of the platform examples we have in mind, buyers do not face any fees, suggesting that our focus on seller fees, is in any case a realistic assumption.

$1-r$ while the platform keeps the remaining share $r \in [0,1]$. For any given r, each seller's sales margin can be written as $(1-r)\left(p - \frac{c}{1-r}\right)$. Ignoring the multiplicative factor, the seller sales margin is $p - \frac{c}{1-r} < p - c$, reflecting that a seller keeps only a share of its revenue but bears all of its costs of production, so that the seller acts as if its "effective" marginal cost is $\frac{c}{1-r}$. Hence, the equilibrium price equation in (1) becomes

$$p(a) = \frac{c}{1-r} + M(a).$$

Timing: (i) Given the particular fee instrument, the platform sets its fee level and its governance design simultaneously. (ii) Buyers and sellers decide whether to enter the platform. (iii) The on-platform interaction between buyers and sellers unfolds according to the specified micro-foundation.

2.1 Discussion of modelling features

The assumption of governance design being a continuous variable simplifies the exposition, but it is not a necessary ingredient to derive the main insights. In practice, platforms may make discrete or even multi-dimensional governance design choices, e.g., deciding whether to ban certain behaviors or choosing a set of rules to govern interactions between buyers and sellers. In Section A of the Online Appendix, we extend the model to the case in which each design choice a is a vector from a finite set Θ (possibly multi-dimensional). By exploiting the correspondence between the finite design choices and the outcomes (captured through the pair $(V(a), M(a))$), we show that the main results continue to hold with weak inequalities.[10]

It is useful to think of our framework as focusing on design decisions on the platform's user interface, how information is provided to buyers, and the number and variety of sellers, where these do not involve substantial costs in their implementation. In Section 6.2, we allow for costly design decisions by assuming that the platform's fixed cost $K = K(V(a)) \geq 0$ is increasing in $V(a)$, i.e., a design that is associated with a higher gross transactional value is more costly. For example, to implement a stricter quality control regime, a platform may need to invest in its capability to screen sellers for uncertain quality.

Finally, the assumption that transactional value $V(a)$ is the same for every buyer shuts down the well-known Spence (1975) distortion. A Spence distortion arises from the fact that a monopolist focuses on the valuation of marginal users in its choice of product quality (or other product attributes), while the social planner focuses on the valuation of average users. Shutting down the Spence distortion allows us to isolate the new forms of distortion that arise in our platform setting.

2.2 Micro-foundations

In this subsection, we provide three simple micro-foundations that fit the general framework presented above, whereby each example corresponds to a different aspect of platform governance design. To keep the exposition brief, we focus on showing how each example maps onto the

[10] The only exceptions are Propositions 2 and 4, in which we need to impose tighter thresholds on c to obtain each of the stated cases.

general framework, and relegate the detailed derivations to Section B of the Online Appendix. We will return to these examples when we discuss the implications of our analysis.

Example 1 *Entry regulation and variety choice by platform (Perloff and Salop, 1985)*

There is a continuum of unit-demand buyers and multiple ex-ante symmetric and N horizontally differentiated sellers in the market. The platform chooses the number of sellers admitted to the platform, $N-a$, where $a \in \{0, ..., N-2\}$ is the number of sellers that are not admitted.[11] Thus, the model is effectively equivalent to oligopolistic price competition with $N-a \geq 2$ sellers. After observing a, each buyer chooses whether to incur her joining cost d to join the platform and learns her match values and the prices of the available products. Let x_i denote the random match value of a product i, which is identically and independently realized across buyers and products for $i = 1, ..., N$. Let F be the common cumulative distribution function (cdf) for all x_i with log-concave density function f. For each seller i, the effective demand is $\int_{-\infty}^{\infty} (1 - F(x - p + p_i))\, dF(x)^{N-a-1}$, where p_i is the price by seller i and p is the symmetric equilibrium price.

The standard derivation shows that the equilibrium price is

$$p(a) = c + M(a) \equiv c + \frac{1}{(N-a)\int_{-\infty}^{\infty} f(x)\, dF^{N-a-1}(x)},$$

It follows from Anderson, de Palma, and Nesterov (1995) that $M(a)$ is strictly increasing in a, reflecting that a lower number of sellers decreases demand elasticity. A buyer joins the platform if the expected gain outweighs the joining cost, i.e., $V(a) - p > d$, where $V(a) = \mathbf{E}\left(\max_{i=1,...,N-a}\{x_i\}\right)$ is decreasing in a. Notice that $V(a)$ and $M(a)$ are negatively correlated: admitting fewer sellers reduces product variety but increases the seller markup.[12]

Example 2 *Information design by the platform (based on Lewis and Sappington, 1994)*

Consider the standard linear Hotelling model with two sellers. Buyers observe both prices p_1 and p_2, but they are initially uncertain about their match values. Before purchasing, buyers observe all prices and a private signal s of their mismatch costs $x_1 \in [0,1]$ for seller 1 and $x_2 = 1 - x_1$ for seller 2, and then decide which seller to purchase from. The platform commits to a "truth-or-noise" signal structure parameterized by $a \in [0,1]$ that is implemented through its recommendation algorithm. With probability a the signal s is informative and equals the true value x_1, and with probability $1-a$ the signal is an uninformative random draw from a uniform distribution over $[0,1]$.

Upon receipt of a signal s, a buyer is unable to distinguish between truth or noise and has to form her posterior expectation on the mismatch costs via Bayesian updating: $\mathbf{E}(x_1|s) =$

[11] Provided that all N sellers are willing to join the platform (which holds if the sellers face no fixed costs or participation fees), a mathematically equivalent interpretation is that the platform chooses the number of leads to show each buyer. Choosing more leads allows more sellers to enter each buyer's "consideration set", so that it is effectively equivalent to admitting more sellers to the platform. We will ignore the integer constraint on a when using this example in the main text, but our main results easily allows for discrete a.

[12] See also Huang and Xie (2021) for a similar model in which products are homogenous and the platform influences the size of consideration set a through non-uniform sampling.

$as + (1-a)\mathbf{E}(x_1)$, where $\mathbf{E}(x_1) = 1/2$ is the prior expectation. A buyer receiving signal s is indifferent between the two sellers if $p_1 + t\mathbf{E}(x_1|s) = p_2 + t(1 - \mathbf{E}(x_1|s))$, and the demand for seller 1 can be derived as $\frac{1}{2} + \frac{p_2 - p_1}{2ta}$. We can show that the symmetric equilibrium price is

$$p(a) = c + M(a) \equiv c + ta.$$

Meanwhile, a buyer joins the platform if the expected gain outweighs the joining cost, i.e., $V(a) - p > d$, where $V(a) = V_0 + (a-2)\frac{t}{4}$.

Value and markup are positively correlated in this setting: a fully informative signal structure ($a = 1$) has the highest $M(a)$ and $V(a)$ because it maximizes the perceived product differentiation and buyers always purchase their preferred product; an uninformative signal structure ($a = 0$) has the lowest $M(a)$ and $V(a)$ because in equilibrium sellers compete away all of their margin, while buyers purchase their preferred product only with probability 1/2.[13] As such, variable a can be interpreted as the weight the recommendation algorithm assigns to the product match dimension (relative to the price dimension).

Example 3 *Quality control by the platform (based on Eliaz and Spiegler, 2011).*

There is a continuum of unit-demand buyers and a continuum of sellers. Each seller i has quality $q_i \in [0,1]$, which is randomly distributed. When a buyer is matched with a seller of type q_i, with probability q_i the seller's product is suitable and provides utility value x_i where $x_i > 0$ is a buyer-product match component; with probability $1 - q_i$ the product is defective and provides zero utility. The values of x_i are i.i.d drawn across buyers and product, with distribution function F and log-concave density f. Upon visiting the platform, buyers search randomly and sequentially with perfect recall with a search cost $s > 0$ each time they sample a seller. By sampling seller i, a buyer learns the product price p_i, the match value x_i, and whether product i is suitable, but the buyer never observes the seller type q_i.

The platform imposes a minimum quality standard. Only sellers with quality $q_i \geq 1 - a$ are allowed to sell on the platform, where $a \in [\underline{a}, \bar{a}] \subseteq [0,1]$ represents how relaxed the quality standard is.[14] Buyers search only within the pool of sellers with $q_i \geq 1 - a$, and they infer from a that the average quality of the seller pool is $\mathbf{E}(q_i | q_i \geq 1 - a)$. Define a buyer's search reservation value $V(a)$ implicitly as

$$\int_V^\infty (x - V)\, dF(x) = \frac{s}{\mathbf{E}(q_i | q_i \geq 1 - a)}. \tag{3}$$

Notably, the "effective search cost" faced by buyers (the right-hand side of (3)) is increasing in a, so that $V(a)$ is decreasing in a. Eliaz and Spiegler show that the demand faced by a seller i

[13] Armstrong and Zhou (2020) consider a more general information design problem and derive the exact "buyer-optimal" and "seller-optimal" information design, and show that the trade-off between intensifying seller competition and ensuring that buyers purchase their preferred product applies more generally.

[14] This can be done by screening out low-quality sellers, or by a commitment to remove problematic listings. In practice, how strictly the platform's ranking algorithm penalizes listings with poor reviews will have a similar effect.

with price p_i is proportional to $1 - F(V(a) - p + p_i)$. The symmetric equilibrium price is

$$p(a) = c + M(a) \equiv c + \frac{1 - F(V(a))}{f(V(a))},$$

where $M(a)$ is increasing in a.[15] The standard derivation shows that if a buyer ever visits the platform she eventually purchases one of the products, so that she visits the platform if and only if $V(a) - p > d$. Notice that $V(a)$ and $M(a)$ are negatively correlated: a more relaxed quality standard is equivalent to a higher search cost, which worsens the match value from search but increases the seller markup.[16]

3 Baseline analysis: exogenous platform fees

Given that $M(a)$ is an increasing function, we can reformulate the platform's problem as choosing the level of seller markup $m \in M(\Theta)$ directly, whereby each m is associated with gross transactional value $v(m) \equiv V\left(M^{-1}(m)\right)$. We will use this reformulation throughout the rest of the paper to simplify the notations. In addition, it is useful to denote the smallest and largest elements of $M(\Theta)$ as $\underline{m}$ and $\bar{m}$, respectively.

To develop some initial intuition, in this section we slightly deviate from the setup in Section 2 by assuming that the fee levels τ and r are exogenously fixed. By doing so we shut down any distortion introduced by fee-setting decisions of the platform, which allows us to highlight the distortions directly caused by the platform's choice of governance design. Moreover, this baseline analysis is relevant when fee levels are determined through some unmodeled institutional constraints (e.g., binding fee caps) or bargaining processes.[17] We first consider the case of per-transaction fees (Section 3.1), and then the case of proportional fees (Section 3.2).[18]

3.1 Per-transaction fees

When the platform charges a per-transaction fee $\tau > 0$ to sellers, the equilibrium price that arises from seller competition is $p_\tau(m) = c + \tau + m$. Consider a profit-maximizing platform, with profit function

$$\Pi(m) = \tau Q(v(m) - p_\tau(m)).$$

We denote $m^p \equiv \arg\max_m \Pi$, where the superscript refers to profit-maximization. Using $dp_\tau(m)/dm = 1$, the derivative of profit is

$$\frac{d\Pi}{dm} = \left(\frac{dv}{dm} - 1\right)\tau Q'. \tag{4}$$

[15] The log-concavity of f implies increasing hazard rate $f/1 - F$, which implies the stated property.

[16] The feature of a higher search cost increasing seller markups (or relaxing competition) is common to more general random sequential search models, as shown by Wolinsky (1986) and Anderson and Renault (1999).

[17] For example, Parker and Van Alstyne (2017) consider the Nash bargaining solution with equal bargaining power between the platform and third-party sellers/developers, which gives $r = 0.50$.

[18] In this section, we do not consider lump-sum participation fees. If such fees are exogenously fixed, then they are independent of the design choice and do not affect the analysis below as long as sellers are willing to participate.

The profit is maximized at m that maximizes the volume of transactions, i.e.,

$$m^p = \arg\max \{v(m) - m\}.$$

If value and markup are always negatively correlated ($dv/dm \leq 0$), then it is the most profitable to decrease m until $m^p = \underline{m}$ because doing so increases the transactional value and decreases the price, both of which increase the volume of transactions. More generally, however, if value and markup are positively correlated over some range of m, then a trade-off arises: if the platform attempts to increase the transactional value $v(m)$, this would come with an "implicit cost" of increasing the seller markup and the price.

To identify the source of distortion in the profit-maximizing governance choice, we consider the welfare-maximization benchmark for comparison.[19] Note that welfare maximization is equivalent to a pure value-creation benchmark (Boudreau and Hagiu, 2009; Scott Morton et al., 2019); i.e., maximizing the total amount of economic value generated from user interactions on the platform. Total welfare is defined as the sum of joint industry profit (the platform and sellers) and buyer surplus:

$$W(m) = (p_\tau(m) - c)Q\left(v(m) - p_\tau(m)\right) + \int_{-\infty}^{v(m)-p_\tau(m)} Q(t)\, dt,$$

where the buyer surplus is obtained by integrating the aggregate demand from $Q = 0$ up to the marginal demand.[20] Define $m^w \equiv \arg\max_m W$, where the superscript refers to welfare-maximization.[21]

The derivative of the welfare function is

$$\frac{dW}{dm} = \left(\frac{dv}{dm} - 1\right)\left((p_\tau - c)\, Q' + Q\right) + Q. \tag{5}$$

Similar to the profit maximization problem, if value and markup are always negatively correlated ($dv/dm \leq 0$) then

$$\frac{dW}{dm} < \left(\frac{dv}{dm} - 1\right) Q + Q \leq 0,$$

so that it is welfare-maximizing to set $m^w = \underline{m}$.

If, instead, value and markup are positively correlated over some range of m, the trade-off between value generation and the implicit cost of a higher seller markup also arises in welfare maximization. An important distinction between (4) and (5) is the additional term $Q > 0$, reflecting that the implicit cost of a higher seller markup is smaller in the welfare maximization problem. This is because the loss in transaction volume (or output) due to a higher markup is partially offset by the corresponding gain in seller surplus (which increases if price increases).

[19] We consider the consumer surplus benchmark in Section 6.3.

[20] This specific reduced-form buyer surplus representation relies on our assumption that the buyer's outside option is normalized to zero. Our results would remain valid even if the outside option is some non-zero constant; we only require that it is not a function of the governance design.

[21] This benchmark is welfare-maximizing only in a partial sense given that the platform fees are assumed to be fixed. In Section 4, where we endogenize the platform fee-setting decision, we consider the second-best welfare benchmark whereby there is a social planner that controls the governance design but does not control the fee decision of the platform.

In this case, the welfare-maximizing design calls for a higher m and $v(m)$ compared with the profit-maximizing design.

Proposition 1 *(Exogenous per-transaction fees) Suppose the platform charges an exogenous per-transaction fee* τ*, then* $m^p \leq m^w$ *and* $v(m^p) \leq v(m^w)$*, with the inequalities strict if* m^p *or* m^w *is an interior solution.*

Proposition 1 suggests that the profit-maximizing governance design is associated with seller markups that are too low and insufficient value generation. Notably, this holds even though there is no explicit cost associated with value generation. To illustrate the implications of Proposition 1, we return to the first two examples in Section 2.2.

In the variety decision of Example 1, value and markup are always negatively correlated. As such, $m^p = m^w = \underline{m}$, meaning that both profit maximization and welfare maximization lead to the maximum amount of variety, N (i.e., $a = 0$). There is no distortion in this case.

In the information design decision of Example 2, value and markup are always positively correlated. A more informative design (higher a) involves a trade-off between generating more value and the implicit cost of increasing seller markup. Assuming that $V_0 = 10$, $c = 4$, $\tau = 1$, $t = 1$, and $Q(t)$ is the CDF of uniform distribution with domain $[0, V_0/2]$, then we can solve the profit-maximizing and welfare-maximizing information designs as $a = 0$ and $a = 0.4$, respectively. The profit-maximizing design is insufficiently informative and leads to excessive product mismatch.

3.2 Proportional fees

With a proportional fee $r > 0$, the equilibrium price that arises from seller competition is

$$p_r(m) = \frac{c}{1-r} + m. \tag{6}$$

With slight abuse of notation, we continue to denote the platform's profit and total welfare as

$$\begin{aligned} \Pi(m) &= r p_r(m) Q\left(v(m) - p_r(m)\right) \\ W(m) &= \left(p_r(m) - c\right) Q\left(v(m) - p_r(m)\right) + \int_{-\infty}^{v(m)-p_r(m)} Q(t)\, dt. \end{aligned}$$

After substituting for (6), the platform's profit is

$$\frac{1}{r}\Pi(m) = \underbrace{mQ\left(v(m) - p_r(m)\right)}_{\text{proportional to seller surplus}} + \frac{c}{1-r}\underbrace{Q\left(v(m) - p_r(m)\right)}_{\text{volume of transactions}}. \tag{7}$$

Equation (7) essentially decomposes the platform's profit into two components. The first component in (7) is proportional to the volume of transactions. The second component is proportional to seller surplus $(1-r)\, mQ\left(v(m) - p_r(m)\right)$. The platform's profit is fully aligned with the seller surplus if the first component of (7) is absent. Hence, (7) can be loosely interpreted as a weighted sum between seller surplus and the volume of transactions, in which the relative weight depends on $\frac{c}{1-r}$. This weighted-sum interpretation suggests that the direction of distortion in platform governance depends on the level of seller marginal cost.

More formally, using $dp_r(m)/dm = 1$, the derivative of the profit function can be written as

$$\frac{d\Pi}{dm} = \left(\frac{dv}{dm} - 1\right) rp_r Q' + rQ. \tag{8}$$

Similar to (4), the platform has an incentive to expand the transaction volume, as captured by the first component in (8). However, with proportional fees, the platform's margin increases with the price and the seller markup. There is an additional incentive to maintain the markup level, as captured by the second component in (8). Meanwhile, the derivative of the welfare function is

$$\frac{dW}{dm} = \left(\frac{dv}{dm} - 1\right) \left((p_r - c)\, Q' + Q\right) + Q, \tag{9}$$

which similarly takes into account the governance design's effect on (i) transaction volume (the first component) and (ii) seller markup (the second component). The key difference between profit maximization and welfare maximization is in how relative weights are assigned between the two considerations.

Proposition 2 *(Exogenous proportional fee) Suppose the platform charges an exogenous proportional fee r and $W(m)$ is unimodal,*[22] *then:*

- *If $c < \frac{Q(v(m^p)-p_r(m^p))}{Q'(v(m^p)-p_r(m^p))}$, then $m^p \geq m^w$, with the inequality strict if m^p or m^w is an interior solution.*
- *If $c = \frac{Q(v(m^p)-p_r(m^p))}{Q'(v(m^p)-p_r(m^p))}$, then $m^p = m^w$.*
- *If $c > \frac{Q(v(m^p)-p_r(m^p))}{Q'(v(m^p)-p_r(m^p))}$, then $m^p \leq m^w$, with the inequality strict if m^p or m^w is an interior solution.*

In Proposition 2, the condition $c < \frac{Q}{Q'}$ is more likely to hold if c is small or if Q is relatively inelastic (formally, $\frac{Q}{Q'}$ is the inverse semi-elasticity of the aggregate demand). Intuitively, a lower c or a less elastic aggregate demand shifts the platform's objective function towards seller surplus, so that the profit-maximizing design is associated with a seller markup that is higher than the welfare benchmark. Conversely, a higher c or a more elastic aggregate demand shifts the platform's objective function towards the volume of transactions, so that its design is associated with a seller markup that is lower than the welfare benchmark.

To sharpen the results and intuitions, suppose value and markup are always negatively correlated ($dv/dm \leq 0$). In this case, we can prove from (9) that $m^w = \underline{m}$. Meanwhile, from (8), if $c \geq \frac{Q}{Q'}$ so that $p_r > c > \frac{Q}{Q'}$, then

$$\frac{d\Pi}{dm} < \left(\frac{dv}{dm} - 1\right) rQ + rQ \leq 0,$$

meaning that $m^p = \underline{m}$ and there is no distortion in this case. Therefore, a strict distortion $m^p > m^w$ and $v(m^p) < v(m^w)$ occurs only if $c < Q'/Q$. These observations reflect that (i)

[22] A function $H(z)$ is unimodal if for some value $\bar{z}$, it is monotonically increasing for $z \leq \bar{z}$ and monotonically decreasing for $z \geq \bar{z}$. Lemma 1 in the Appendix shows that sufficient conditions for $W(m)$ to be unimodal are (i) $v\,(m)$ is monotone decreasing, or (ii) $v\,(m)$ is concave, which is satisfied in Examples 1-3.

the profit-maximizing platform prefers to maintain the markup and price level, and (ii) as c increases, the price level becomes high enough so that the platform has a weaker incentive to maintain high markups, in which case the distortion disappears.[23] Figure 1.1 illustrates the result with the variety choice of Example 1 assuming $N = 10$ and F follows the standard normal distribution. The profit-maximizing platform chooses strictly fewer varieties than the welfare benchmark when $c < 4.6$. As c increases, the distortion becomes smaller and eventually vanishes.

Next, suppose value and markup are always positively correlated ($dv/dm \geq 0$). Consider $c \to 0$, so that the platform's profit function approximates seller surplus. The platform faces no trade-off in this case because it can keep increasing m to increase both $v(m)$ and m, as long as the resulting price is not above the price that maximizes joint industry profit. In contrast, there is a trade-off from the welfare perspective because increasing $v(m)$ comes at the implicit cost of a higher price set by sellers. Consequently, $m^w \leq m^p$ and $v(m^w) \leq v(m^p)$. As c increases, the platform profit and the seller surplus begin to diverge, as can be seen from (7). The divergence reflects that under proportional fees, the platform internalizes the sellers' revenue but does not internalize the sellers' marginal cost. When c is high enough, the logic of Proposition 1 applies, whereby the profit-maximizing governance design is instead skewed towards maximizing the volume of transactions, with $m^w \geq m^p$ and $v(m^w) \geq v(m^p)$. Figure 1.2 illustrates the result with the information design choice of Example 2, showing that the profit-maximizing design is excessively informative for $c < 4.1$ and insufficiently informative for $c > 4.1$.

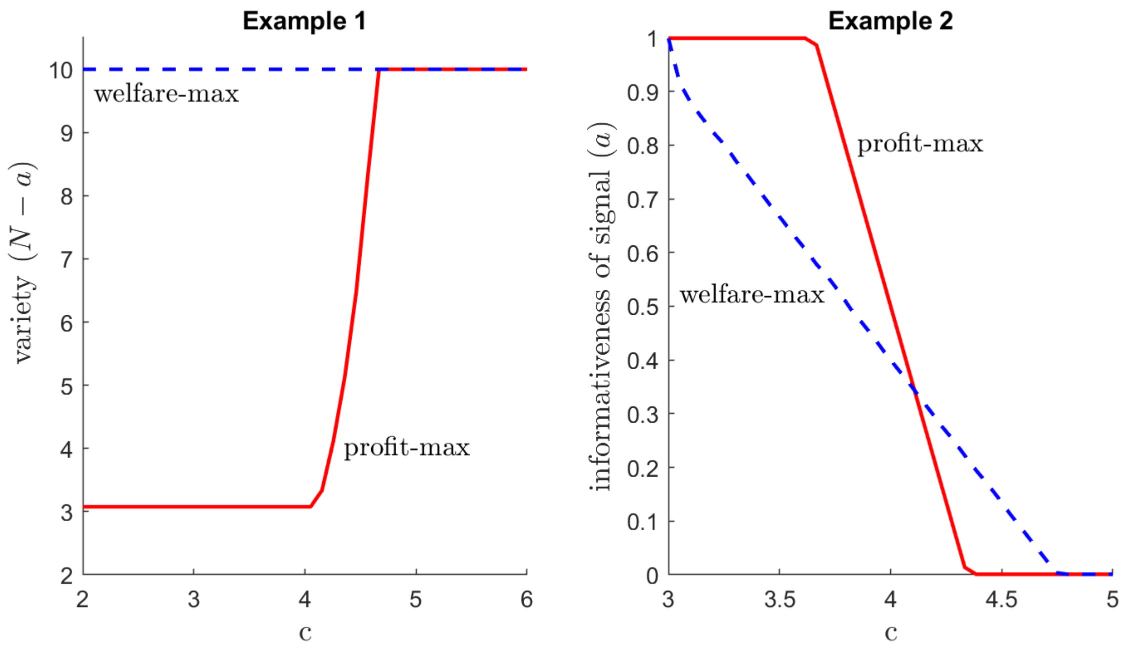

Figure 1: Governance design with exogenous proportional fee $r = 0.2$: (1) Variety choice in Example 1, with $F \sim Normal(10, 1)$ and $N = 10$; (2) Information design of Example 2, with $V_0 = 10$ and $t = 1$. In both examples, we assume $Q(t)$ is the uniform cdf with domain $[0, 5]$.

Finally, note that the conditions in Proposition 2 are stated in terms of endogenous variables whereby m^p depends on c. Lemma 2 in the Appendix shows that if $v(m)$ is weakly concave or

[23] It can be formally shown that m^p is monotone decreasing in c (see Lemma 2 in the Appendix).

decreasing (which is satisfied in Examples 1-3), then there exists a unique threshold $\bar{c}$ such that $c \leq \bar{c}$ implies $m^p \geq m^w$, while $c \geq \bar{c}$ implies $m^p \leq m^w$. Moreover, in cases in which $W(m)$ is not unimodal, we construct exogenous thresholds $\bar{c}_l$ and $\bar{c}_h$, where $\bar{c}_h \geq \bar{c}_l > 0$, such that $c < \bar{c}_l$ implies $m^p \geq m^w$ while $c > \bar{c}_h$ implies $m^p \leq m^w$ (see Section A of the Online Appendix).

4 Analysis: endogenous platform fees

We now consider the general analysis with endogenous fee levels. Throughout this section, we adopt a "second-best" welfare benchmark, in which there is a social planner that fixes the governance design before the platform sets its fee. The planner is constrained by the fee-setting response of the profit-maximizing platform. One interpretation is that the planner regulates only the platform's governance while leaving its fees unregulated.

4.1 Per-transaction fees

When the platform sets per-transaction fee τ, its profit function is $\tau Q\left(v\left(m\right) - m - c - \tau\right)$. For each given m the profit-maximizing fee $\tilde{\tau} = \tilde{\tau}\left(m\right)$ is implicitly defined by the standard first-order condition

$$\tilde{\tau} = \frac{Q\left(v\left(m\right) - m - c - \tilde{\tau}\right)}{Q'\left(v\left(m\right) - m - c - \tilde{\tau}\right)}. \tag{10}$$

Denote $p_{\tilde{\tau}}(m) = c + \tilde{\tau}\left(m\right) + m$. Given this, we can write down the platform's profit function as an indirect function of m:

$$\tilde{\Pi}\left(m\right) = \tilde{\tau}\left(m\right) Q\left(v\left(m\right) - p_{\tilde{\tau}}(m)\right).$$

By the envelope theorem, we can ignore the indirect effect of m on $\tilde{\tau}$ so that $m^p \equiv \arg\max \tilde{\Pi} = \arg\max\left\{v\left(m\right) - m\right\}$. Compared with the baseline case with a fixed transaction fee, maximizing $v - m$ has a twofold effect here. First, it allows the platform to raise the number of transactions Q; second, it allows the platform to reoptimize by increasing its fee, which leads to an even higher profit. The latter point can be seen from (10). Q being log-concave implies that $\tilde{\tau}$ is increasing in $v\left(m\right) - m$ but with an incomplete pass-through, i.e., $\frac{d\tilde{\tau}}{d(v-m)} \in (0, 1)$.

The welfare function is

$$\tilde{W}\left(m\right) = \left(p_{\tilde{\tau}}(m) - c\right) Q\left(v\left(m\right) - p_{\tilde{\tau}}(m)\right) + \int_{-\infty}^{v(m)-p_{\tilde{\tau}}(m)} Q\left(t\right) dt. \tag{11}$$

We denote $m^{sb} \equiv \arg\max \tilde{W}\left(m\right)$, where the superscript refers to second-best. Compared with the welfare benchmark in Section 3, here the planner's design choice needs to consider how the platform adjusts its fee:

$$\frac{d\tilde{W}}{dm} = \left(\frac{dv}{dm} - 1 - \frac{d\tilde{\tau}}{dm}\right)\left(\left(p_{\tilde{\tau}} - c\right) Q' + Q\right) + \left(1 + \frac{d\tilde{\tau}}{dm}\right) Q,$$

where we have used $\frac{dp_{\tilde{\tau}}}{dm} = 1 + \frac{d\tilde{\tau}}{dm}$. In the special case where value and markup are always negatively correlated, then the incomplete pass-through property of $\tilde{\tau}$ implies $\frac{dv}{dm} - 1 - \frac{d\tilde{\tau}}{dm} \leq 0$, so that $\frac{d\tilde{W}}{dm} \leq \left(\frac{dv}{dm} - 1 - \frac{d\tilde{\tau}}{dm}\right) Q + \left(1 + \frac{d\tilde{\tau}}{dm}\right) Q \leq 0$. In this case, similar to the analysis of the exogenous fees, $m^{sb} = m^p = \underline{m}$ and there is no distortion. More generally, the following result shows that Proposition 1 continues to hold when we endogenize the fee levels.

Proposition 3 *(Endogenous per-transaction fees) Suppose the social planner can control the platform's governance design, but cannot control the per-transaction fee τ set by the platform. Then $m^p \leq m^{sb}$ and $v(m^p) \leq v(m^{sb})$, with the inequalities strict if m^p or m^{sb} is an interior solution.*

The key step in the analysis comes from the fact that $\frac{d\tilde{\tau}}{d(v-m)} \in (0,1)$, so that the profit-maximizing governance design m^p also maximizes the transaction volume $Q\left(v\left(m\right) - p_{\tilde{\tau}}(m)\right)$. Proposition 3 then follows from the same logic that establishes Proposition 1: the platform focuses on maximizing volume and fails to internalize seller surplus. It is unwilling to set a design that corresponds to a high seller markup, even when doing so increases the transactional value generated.

4.2 Proportional fees

Suppose the platform sets the proportional fee $r \in [0,1]$ so that its profit function is given by $r\left(m + \frac{c}{1-r}\right) Q\left(v\left(m\right) - m - \frac{c}{1-r}\right)$. For each given m, setting $r = 0$ and $r = 1$ are obviously sub-optimal because they result in zero profit for the platform. Therefore, the platform necessarily sets some $\tilde{r}\left(m\right) \in (0,1)$ implicitly pinned down by first-order condition

$$\tilde{r} = \frac{Q\left(v\left(m\right) - m - \frac{c}{1-\tilde{r}}\right)}{Q'\left(v\left(m\right) - m - \frac{c}{1-\tilde{r}}\right)} \left(\frac{\left(1-\tilde{r}\right)^2}{c} + \frac{\tilde{r}}{m + \frac{c}{1-\tilde{r}}}\right). \tag{12}$$

We can verify that the right-hand side of (12) is decreasing in $\tilde{r}$, so that (12) has a unique solution. Denote $p_{\tilde{r}}(m) = c + m + \frac{c}{1-\tilde{r}(m)}$. Given this, the platform's profit function becomes

$$\tilde{\Pi}\left(m\right) = \tilde{r}\left(m\right) p_{\tilde{r}}(m) Q\left(v\left(m\right) - p_{\tilde{r}}(m)\right). \tag{13}$$

By the envelope theorem, we can ignore the indirect effect of m on $\tilde{r}$, so that

$$\frac{d\tilde{\Pi}\left(m\right)}{dm} = \left(\frac{dv}{dm} - 1\right) \tilde{r} p_{\tilde{r}} Q' + \tilde{r} Q, \tag{14}$$

which is the same as (8) except that the endogeneity of the fee restricts the possible range of $p_{\tilde{r}}$. Indeed, if we rewrite (12) using the definition of $p_{\tilde{r}}$, we get

$$\begin{aligned} p_{\tilde{r}} &= \frac{Q\left(v\left(m\right) - p_{\tilde{r}}\right)}{Q'\left(v\left(m\right) - p_{\tilde{r}}\right)} \left(1 + \frac{p_{\tilde{r}} c}{(p_{\tilde{r}} - m - c)(p_{\tilde{r}} - m)}\right) \\ &> \frac{Q\left(v\left(m\right) - p_{\tilde{r}}\right)}{Q'\left(v\left(m\right) - p_{\tilde{r}}\right)}. \end{aligned} \tag{15}$$

Therefore, in the special case where value and markup are always negatively correlated ($dv/dm \leq 0$), then (14) implies $\frac{d\tilde{\Pi}(m)}{dm} \leq -\tilde{r} p_{\tilde{r}} Q' + \tilde{r} Q < 0$, so that $m^p = \underline{m}$. Intuitively, when the platform sets its fee level, it no longer needs to raise the transaction price through increasing the seller markup. There is no downside from lowering m so that the lowest m maximizes profit (which is in contrast to the case with exogenous r). However, if value and markup are positively correlated over some range of m, the trade-off between value generation and the implicit cost of a higher seller markup persists and the lowest m is not necessarily profit-maximizing.

Comparing m^p and m^{sb}, the following result extends Proposition 2 to endogenous fees.

Proposition 4 *(Endogenous proportional fee) Suppose the social planner can control the platform's governance design, but cannot control the proportional fee set by the platform. Suppose $W(m)$ is unimodal, and denote*

$$\Psi(m) \equiv \frac{\left(\frac{p_{\tilde{r}}}{\tilde{r}}\right)\frac{d\tilde{r}}{dm}}{\frac{dp_{\tilde{r}}}{dm} - \frac{dv}{dm}}.$$

- *If $c < \frac{Q(v(m^p)-p_{\tilde{r}}(m^p))}{Q'(v(m^p)-p_{\tilde{r}}(m^p))}(1+\Psi(m^p))$, then $m^p \geq m^{sb}$, with the inequality strict if m^p or m^{sb} is an interior solution.*
- *If $c = \frac{Q(v(m^p)-p_{\tilde{r}}(m^p))}{Q'(v(m^p)-p_{\tilde{r}}(m^p))}(1+\Psi(m^p))$, then $m^p = m^{sb}$.*
- *If $c > \frac{Q(v(m^p)-p_{\tilde{r}}(m^p))}{Q'(v(m^p)-p_{\tilde{r}}(m^p))}(1+\Psi(m^p))$, then $m^p \leq m^{sb}$, with the inequality strict if m^p or m^{sb} is an interior solution.*

To sharpen the results, it is again useful to consider a few special cases. If value and markup are always negatively correlated ($dv/dm \leq 0$), applying the implicit function theorem to (15) shows that that $\frac{dv}{dm} - \frac{dp_{\tilde{r}}}{dm} < 0$. Consequently, the derivative of the welfare function is

$$\begin{aligned} \frac{d\tilde{W}}{dm} &= \left(\frac{dv}{dm} - \frac{dp_{\tilde{r}}}{dm}\right)\left((p_{\tilde{r}} - c)\,Q' + Q\right) + \frac{dp_{\tilde{r}}}{dm}Q \\ &\leq \left(\frac{dv}{dm} - \frac{dp_{\tilde{r}}}{dm}\right)Q + \frac{dp_{\tilde{r}}}{dm}Q < 0, \end{aligned} \tag{16}$$

implying $m^{sb} = \underline{m} = m^p$. Returning to Example 1, this implies that the profit-maximizing design and welfare-maximizing design both result in the highest level of variety at $N = 10$ ($a = 0$) and there is no distortion, as depicted in Figure 2.1.

In the cases of $dv/dm \geq 0$ or, more generally, non-monotone $v(m)$, Proposition 4 reflects a similar intuition as Proposition 2. As an illustration, Figure 2.2 shows that the profit-maximizing design is excessively informative for $c < 0.7$, and insufficiently informative for $c > 0.7$. However, the key difference in Proposition 4 is the additional coefficient $\Psi(m^p)$, which has the same sign as $\frac{d\tilde{r}}{dm}$. The additional coefficient reflects the endogenous fee response of the platform in the second-best problem.[24] In the proof of Proposition 4, we show that $\frac{d\tilde{r}}{dm} \leq 0$, and so $\Psi(m^p) \leq 0$. Therefore, the range of parameter values for which $m^p \geq m^{sb}$ becomes smaller when the proportional fee is endogenized.

4.3 Lump-sum seller fees

In some contexts, a platform may find it hard to implement transaction-based fees due to the difficulties in monitoring transactions. Suppose instead that the platform charges each seller a

[24]For the knife-edge case of $\frac{d\tilde{r}}{dm} = 0$, we get $\Psi(m^p) = 0$ so that Proposition 4 recovers Proposition 2 as a special case.

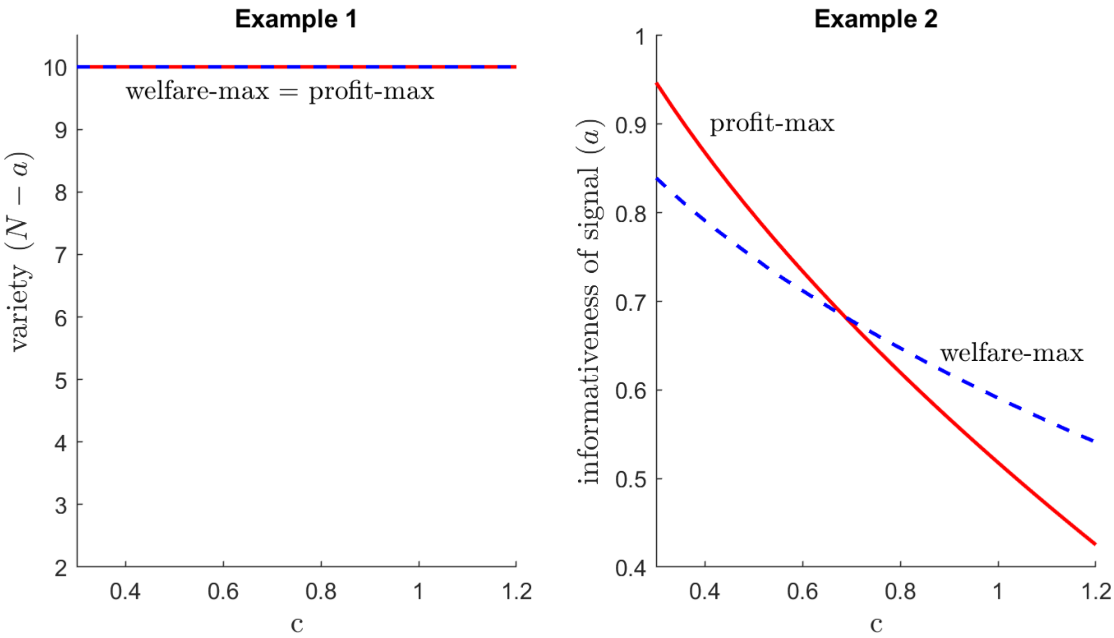

Figure 2: Governance design with endogenous proportional fees: (1) Variety choice in Example 1, and (2) Information design of Example 2. We assume $V_0 = 20$, $t = 8$, and $Q(t)$ is the uniform cdf with domain $[0, V_0/2]$.

lump-sum fee T_S. The fee T_S can be interpreted as a participation fee, a per-item listing fee, or any transaction-independent fee that sellers have to incur to reliably make sales on the platform (e.g., advertising fees, as considered by de Cornière (2016)).

It is easy to see that the platform does best by choosing a governance design that maximizes total seller surplus and then sets T_S to fully extract it (given that sellers are ex-ante homogenous at the participation stage). Its profit is

$$\begin{aligned}\tilde{\Pi}(m) &= (p-c)Q(v(m)-p) \\ &= mQ(v(m)-m-c),\end{aligned} \tag{17}$$

while welfare is $\tilde{W}(m) = \tilde{\Pi}(m) + \int_{-\infty}^{v(m)-m-c} Q(t)\,dt$. Similar to the logic of Proposition 2 (with small c), the profit-maximizing platform's choice of governance design induces a lower level of seller competition than the level the planner desires.

Proposition 5 *(Lump-sum seller fees) Suppose the social planner can control the platform's governance design, but cannot control the lump-sum seller fee set by the platform. Then, $m^p \geq m^{sb}$, with the inequality strict if m^p or m^{sb} is an interior solution.*

Proposition 5 is closely related to the analysis of Nocke et al. (2007) that examines the platform's variety choice, as in our Example 1. In their model, for each given listing fee, the number of participating sellers is endogenously determined by the free entry condition (rather than being a separate design choice). Sellers have heterogenous fixed costs for operating, so that the platform does not fully extract the total seller surplus. Despite the modelling differences, Nocke et al. show that a monopoly platform under-provides variety (the platform's size, in their terminology), which is consistent with Proposition 5 given that fewer varieties corresponds to a higher m.[25]

If we focus on Example 1 (or more generally, other models where the platform chooses the number of participating sellers as the design decision), notice that the design choice is inherently related to the level of lump-sum seller fee whenever there is free entry. To see this, suppose that the desired design involves admitting N^* sellers and the platform optimally charges each seller $T_S = \pi(N^*)$, i.e., the profit of each seller when there are N^* competing sellers. Given the fee level, notice that in the equilibrium exactly N^* sellers are willing to participate because $\pi(N^*+1) < \pi(N^*) = T_S$. Thus, the lump-sum fee exactly implements the desired number of sellers, so that the design decision is a redundant variable in this special case. This explains the similarity with the result by Nocke et al. (2007). Nonetheless, for other design applications such as our Examples 2-3, this property of exact implementability does not hold, and so separating the design decisions with the fee-setting decisions remains a useful approach for analysis in general.

4.4 Two-part tariffs

Suppose the platform charges sellers a two-part tariff consisting of a participation fee T_S and a combination of per-transaction fees and proportional fees. The latter component means that the platform charges sellers a total of $rp + \tau$ for each facilitated transaction that is priced at p. We rule out the possibility of the platform providing a *net* transactional subsidy, i.e., we require $rp + \tau \geq 0$ (this does not rule out $r < 0$ and $\tau < 0$). Net transactional subsidies are rare in practice, and they are difficult to implement because each seller can potentially fabricate transactions by fraudulently purchasing from itself to exploit the subsidy scheme.[26]

The platform sets T_S to fully extract the total seller surplus, and its profit function equals the joint industry profit, as in (17). However, with a two-part tariff the platform can influence the price level through its variable fee component because $p = m + \frac{\tau+c}{1-r}$. To state the result, define $p^*(m)$ as the monopoly price that maximizes the joint industry profit, i.e., it solves $p^* = c + \frac{Q(v(m)-p^*)}{Q'(v(m)-p^*)}$, and denote the value-maximizing design as

$$m^* = \arg\max_{m \in M(\Theta)} v(m).$$

Proposition 6 *(Two-part tariff) Suppose the social planner can control the platform's governance design, but cannot control the two-part tariff set by the platform. Suppose m^* is unique,*[27] *then:*

- *If $c \leq p^*(m^*) - m^*$, then $m^p = m^{sb} = m^*$.*
- *If $c > p^*(m^*) - m^*$ and $v(m)$ is unimodal, then $m^p \geq m^{sb}$, with the inequality strict if*

[25] Nocke et al. also allow for platform costs to depend on the number of sellers on the platform. We consider this extension in Section 6.2 and show that Proposition 5 continues to hold, provided that value and markup are negatively correlated (which includes Example 1).

[26] Allowing the platform to charge $rp+\tau$ does not affect the analysis in Section 4.1. because the platform would optimally set $\tau = 0$ and r given by (12). To see this, we can use the relation $p = m + \frac{c+\tau}{1-r}$ to subsitute away r in the platform's fee-setting problem. Then, the platform's margin becomes $p(1 - \frac{c+\tau}{p-m}) + \tau$, which is decreasing in τ for any given p. See also the discussion at the end of Section 6.1.

[27] This assumption is satisfied in all three examples presented in Section 2.2.

m^p or m^w is an interior solution.

Absent any constraint, the platform optimally sets its governance design at $m^p = m^*$ to maximize $v(m)$, and then adjusts τ and r accordingly to implement the corresponding monopoly price $p^*(m^*)$. The optimal monopoly price $p^*(m^*)$ is implementable without a net subsidy as long as the platform's monopoly markup is lower than the seller markup, i.e., $m^* \leq p^*(m^*) - c$. In addition, Q being log-concave implies that p^* is increasing in v but with an incomplete pass-through, so that $v(m) - p^*(m)$ and transaction volume are both maximized at m^*. It follows that $m^{sb} = m^* = m^p$ in this case.

However, when $m^* > p^*(m^*) - c$,[28] the optimal monopoly price $p^*(m^*)$ is no longer implementable due to the constraint of no net subsidy. Intuitively, the price set by sellers is determined by the extent of competition, as captured by m. When the competition is weak, the resulting price $m + c$ is higher than the platform's target monopoly price $p^*(m)$, and so any attempt to induce $p^*(m)$ would violate the constraint of no net subsidy. In other words, if m and c are sufficiently large such that the constraint binds, the platform's profit function becomes the same as if it charged only participation fees. This is reminiscent of a result by Karle, Peitz, and Reisinger (2020), whereby the platform's optimal fee instrument involves a lower transaction-based fee when seller marginal cost increases. In this case, the profit-maximizing governance design is skewed towards maximizing seller surplus, as in Proposition 5.

If we apply Proposition 6 to Example 1, then it says that the platform (weakly) under-provides varieties under a two-part tariff. Anderson and Bedre-Defolie (2020) independently derived a similar result with a more general demand specification, but their result involves a mechanism that slightly differs from ours. In their model, the platform's fixed cost increases with the number of sellers on the platform. The platform does not extract the entire buyer surplus, meaning that it does not fully internalize the benefit from a higher variety so that it "under-invests" in varieties. In Section D, we allow for costly governance designs and show that the mechanism pointed out by Anderson and Bedre-Defolie reinforces the mechanism in Proposition 6, provided that value and markup are always negatively correlated (e.g., Example 1).

4.5 Other revenue models

Apart from the fee instruments analyzed above, platforms may use other forms of revenue models such as revenues from advertisements or buyer participation fees in the form of subscription charges or device sales. We briefly discuss how these revenue models can be mapped onto our existing analysis.

☐ **External advertising revenues.** Suppose the platform generates revenues through displaying external ads, which are viewed as a nuisance by buyers. For simplicity, we assume the platform charges no other fees, so $p(m) = m + c$. Let T_A be the amount of ads the platform carries. The net surplus that a buyer obtains from visiting the platform is $v(m) - p(m) - T_A$. Following Casadeus-Masanell and Zhu (2010), we assume that (i) the revenue rate for each unit of ad, $R = R(Q)$, is an increasing and concave function of the aggregate demand faced by the

[28] It is easy to check that $p^*(m^*)$ is increasing in c with gradient less than 1, and so there exists a unique cost threshold such that c being smaller than the threshold is equivalent to $c \leq p^*(m^*) - m^*$.

platform; and (ii) the revenue rate is determined by a competitive advertising sector that earns zero profit. The platform's profit is

$$\tilde{\Pi}(T_A, m) = T_A R \left(Q(v(m) - p(m) - T_A)\right).$$

By the envelope theorem, the platform chooses its design to maximize aggregate demand, so $m^p = \arg\max \{v(m) - m\}$. Given that the advertising sector earns zero profit, and thus it does not enter the welfare function, we can apply the same analysis as in Section 4.1 to yield the same result as in Proposition 3.[29]

☐ **Buyer participation fees.** In practice, many online marketplaces focus on levying fees on the seller side. An important reason for this is that buyers are often uncertain about whether they want to buy a product on the platform, and so they first need to inform themselves about the characteristics of the available products on the platform. Thus, charging buyers participation fees may deter many buyers. Alternatively, buyer participation fees may be infeasible if the platform cannot monitor participation decisions by buyers.

Nonetheless, in contexts in which buyer participation fees are feasible, we can amend the framework by supposing that the platform charges buyers a lump-sum participation fee T_B. Following the unit-demand assumption, the aggregate demand function Q quantifies the number of participating buyers. The platform's profit is

$$\tilde{\Pi}(T_B, m) = T_B Q(v(m) - p(m) - T_B).$$

If the platform charges no other fees, then $p(m) = m + c$ so that Proposition 3 applies.

Finally, we can also consider a platform that mixes buyer participation fees with seller participation fees and transaction-based fees. The analysis is similar to the case of two-part tariff in Section 4.4, except that the platform now has an extra instrument to implement any desired "effective price level", $p + T_B$. This allows it to circumvent the constraint of no net transactional subsidy. Hence, whenever the condition $c > p^*(m^*) - m^*$ in Proposition 6 holds, the platform's optimal buyer participation fee is necessarily negative so as to implement the optimal monopoly price $p^*(m^*)$. In this case, if negative buyer participation fee (which can be difficult to implement in practice due to moral hazard) is feasible, the platform's optimal design is $m^p = m^{sb} = m^*$ so that there is no distortion. Otherwise, $m^p \geq m^{sb}$, as in Proposition 6.

4.6 Summary

Our analysis highlights the fact that the platform's incentives in its governance design choices are strongly tied to (i) the fee instrument employed and (ii) the market characteristics in terms of the seller marginal cost and the elasticity of the aggregate demand.

To summarize the main insights, in Table 1 we categorize each of the analyzed fee instruments according to the direction of the welfare distortion in platform governance designs. For *volume-aligned* fee instruments, the profit-maximizing governance design maximizes the vol-

[29] Etro (2021) considers an ad-funded platform that competes with a device-funded platform, and assumes that T_A is fixed. These differences partly explain why his result on the misalignment between the ad-funded platform's incentive and consumers' interests is slightly different from ours (see also Section 6.3 below).

ume of transactions. It is skewed towards intensifying seller competition and generating low transactional value. For *seller-aligned* fee instruments, the profit-maximizing governance design is skewed towards increasing the seller surplus, and hence tends to induce too little seller competition.

Fee instrument:	Per-transaction fees / Proportional fees (high c) / Advertising revenues / Buyer participation fees	Seller participation fees / Proportional fees (low c) / Two-part tariffs
Platform's incentive in setting governance design:	Volume-aligned: to *intensify* on-platform competition ($m^p \leq m^{sb}$)	Seller-aligned: to *relax* on-platform competition ($m^p \geq m^{sb}$)

Table 1: Summary

5 Discussion and stylized facts

We apply the insights developed in Sections 3 and 4 to several platform governance design decisions.

☐ **Variety choice by the platform.** In Example 1, admitting more sellers increases product variety and decreases the seller markup. Both effects increase total welfare and aggregate demand. With volume-aligned fee instruments, both welfare maximization and profit maximization call for the highest possible number of sellers, N. In contrast, with seller-aligned fee instruments, decreasing the markup reduces platform's revenue. Therefore, if the markup-decreasing effect of admitting more sellers dominates, the platform will admit strictly fewer than N sellers.

To illustrate the implications, consider the example of video game platforms, e.g., Sony PS4, Microsoft Xbox One, and Nintendo. These platforms price their game consoles to buyers at approximately cost, generating most of the revenue through charging game developers/publishers a two-part tariff consisting of developer kit fees (i.e., participation fees) and a fixed per-game licensing payment (i.e., constant per-transaction fees). Proposition 6 suggests that these platforms tend to restrict the number of competing video game titles too much in order to sustain the profits of major game developers. Consistent with this prediction, Sony, Microsoft, and Nintendo indeed restrict access to a selected set of game developers and exclude many others, as documented by Evans et al. (2008).

☐ **Information design by the platform.** Buyers typically rely on online platforms to obtain product information and determine the match with their preferences. The platform can choose how it wants to disclose information to buyers, such as how detailed the product information is, how it wants to aggregate customer reviews, and the extent to which buyers can filter the information displayed. Example 2 provides a stylized model to capture this, highlighting a fundamental trade-off between improving the product match and raising seller markups (or relaxing seller competition) when more product match information is disclosed.

The model in Example 2 can also be interpreted as a platform choosing its recommendation algorithm. An algorithm that emphasizes the price dimension more intensifies seller competition, and so it is analogous to disclosing less product match information. Likewise, an algorithm that emphasizes facilitating product match (i.e. by taking into account product differentiation) would be analogous to disclosing more product information.[30] Dinerstein et al. (2018) find evidence consistent with this trade-off in the context of eBay's search interface redesign. In May 2011, eBay switched its search algorithm from the so-called best-match algorithm (which emphasizes product match more, especially when there is a high degree of differentiation between products) to a two-stage algorithm that emphasizes the price dimension more but requires sellers and the platform to accurately classify product listings. However, eBay reverted to the best-match algorithm a year later. Dinerstein et al. explained this design reversion by pointing out that the best-match algorithm is easier for sellers to use; in particular, sellers who are less professional in classifying their listings. The current paper shows that eBay is better off with a best-match algorithm than the two-stage algorithm given that it sets proportional fees, which suggests another explanation for the design reversion.

☐ **Quality control by the platform.** In online markets, the prevalence of an information asymmetry between buyers and sellers means that platforms need to carefully regulate the quality of the listed sellers. In the quality control model of Example 3, a search pool with a higher expected quality is analogous to a lower effective search cost for buyers. This reflects that each buyer searches less and consequently incurs a lower total expected search cost before reaching a positive-valued match. Raising the quality standard improves the expected product match and reduces the seller markup.[31] If the markup-reducing effect dominates, with seller-aligned fee instruments a platform's choice of quality standard will be strictly less than the welfare benchmark.

Consider the example of PC game distribution platforms such as Steam. With extensive online user reviews available, prospective buyers can learn performance of each game if they carefully go through the review system. Steam charges game developers a fixed 30% proportional fee for each transaction on the platform, while developers typically have a marginal cost that is close to zero. Our results suggest that the platform does not have a strong incentive to set very strict quality control. A relaxed quality control regime allows game developers to maintain higher prices, which the platform can extract through its proportional fees. Reportedly, Steam has shown reluctance to impose simple low-cost measures that could significantly increase the average quality of product pool on offer.[32]

Even though our analysis has focused on the role of a high quality standard in facilitating search (which intensifies seller competition and reduces the seller markup), in some contexts

[30] A similar trade-off also arises in the model of platform recommendations of Johnson, Rhodes, and Wildenbeest (2020).

[31] Consistent with our formulation, Hui et al. (2019) provide empirical evidence showing that a more stringent quality certification policy on eBay has increased the extent of on-platform seller competition while at the same time increasing the average quality of the seller pool.

[32] Given that Steam is the leading PC game distribution platform, independent developers tend to release their new titles on the platform before releasing them somewhere else. As such, consumers often do not have reliable information on these from outside the platform, especially on small and niche titles. While there are external review websites such as Metacritic, these typical focus on highly popular or established titles. See, e.g., https://www.rockpapershotgun.com/steam-curation-user-reviews-fixes, accessed on 17 June 2020.

a high quality standard can plausibly generate countervailing effects that instead relax seller competition. For instance, if the number of sellers is finite, excluding low-quality sellers reduces the total number of sellers akin to entry restriction, which instead relaxes seller competition. In such cases, the overall effect of a higher quality standard on seller competition depends on whether the search-facilitating effect or the entry-restriction effect dominates.

□ **On-platform search friction.** Online platforms often make design decisions that influence the ease of buyer search on the platform (i.e., the search cost incurred by buyers to browse and inspect products). When platforms can costlessly manipulate buyers' search cost, the question is: would a platform profit from obfuscating search, that is, not minimizing buyers' search cost?

A natural starting point to analyze search cost manipulations is Wolinsky's (1986) random search model. In Wolinsky's model, lowering search cost improves the expected product match and intensifies seller competition because the demand faced by each seller becomes more elastic. Value and the seller markup are negatively correlated in this context. Welfare maximization calls for the lowest possible search cost. As for the profit-maximizing platform, the results in Sections 3 and 4 imply that the platform has no incentive to obfuscate search if its fee instrument is volume-aligned, consistent with the conventional wisdom (Dinerstein et al., 2018) that platforms want to limit search frictions and provide buyers with transparent and low prices. However, the results also imply that a platform would want to obfuscate search if its fee instrument is instead seller-aligned, consistent with Hagiu and Jullien's (2011) point that platforms do not always want to eliminate search frictions.[33] Thus, our framework offers a reconciliation between Hagiu and Jullien's (2011) point and the conventional wisdom by showing that the platform's incentive to reduce search frictions can go in either direction depending on the fee instrument employed by the platform.

Departing from Wolinsky's (1986) random search model, another interesting setting to analyze search cost manipulations is to allow buyer search to be price-directed; e.g., the model of Choi et al. (2018).[34] In a price-directed search setting, buyers can observe prices before sampling for product match values. This feature is particularly relevant in the context of price-comparison websites, in which buyers first look at a list of product-price offers before clicking on offers they want to spend time investigating.

Following our terminology, value and markup are positively correlated in a price-directed search setting: lowering search cost improves the expected product match and, somewhat counter-intuitively, relaxes seller competition. To understand the latter point, note that a higher search cost means that buyers become less likely to visit another seller after having visited the first seller. This makes it worthwhile for each seller to set a low price and attract buyers to visit it first (recall that buyers' search sequence is influenced by the prices they observe). Due to this mechanism, a lower search cost essentially makes demand less price-elastic in a

[33]In the current paper the exact mechanism for this result differs from those in Hagiu and Jullien (2011). In our setup, search diversion or obfuscation relaxes seller competition, increases seller pricing, and increases revenue for the intermediary (through a proportional fee) from each buyer. Hagiu and Jullien shut down this channel by assuming that sellers are either (i) independent or (ii) interdependent but unable to adjust their prices in response to any diversion. In their model, the intermediary obtains revenue for each store visits by buyers, and search diversion increases the number of store visit for each buyer that goes to the intermediary.

[34]See also Armstrong and Zhou (2011) and Armstrong (2017).

price-directed search environment, as opposed to the random search environment of Wolinsky (1986).

Given that lowering search costs relaxes competition, the welfare-maximizing search quality optimally balances between improving the product match and avoiding high seller markups. A profit-maximizing platform with volume-aligned fee instruments prefers an even lower seller markup than the social planner and its design tends to correspond to search costs that are too high, whereas a platform with seller-aligned fee instruments tends to choose a design that corresponds to search costs that are too low. The results suggest that price-comparison websites, which typically charge sellers a listing fee for displaying their offers on the platforms, have a strong incentive to present information in a way to facilitate search on the platforms.

6 Extensions

This section examines several extensions of our framework. To keep the exposition brief, we focus on presenting the main insights in this section and relegate further details and formal proofs to Sections C to E in the Online Appendix.

6.1 Endogeneity of fee instrument

In Section 4, the fee instrument used by the platform is taken as given. There are a few reasons for this approach.

First, by comparing exogenously imposed instruments, we show that different modelling assumptions on the platform's fee instruments can generate substantially different welfare results.

Second, the choice of fee instruments may reflect institutional considerations not captured in the current framework. For example, if there are technological limitations such that the platform cannot reliably monitor transactions, then any transaction-based fee component may not be feasible.[35] On the other hand, a participation-based fee component may give rise to the possibility of a chicken-and-egg coordination problem that leads to a no-participation outcome. Another possible reason is that sellers may face liquidity constraints that would limit the ability to set up-front participation fees. Finally, in richer environments, the choice of fee instrument may take into account asymmetric information or moral hazard problems. For this line of inquiry, see, e.g., Foros, Hagen, and Kind (2009), Hagiu and Wright (2019), and Section 6.1.2 of Karle et al. (2020).

Relatedly, institutional considerations may change over time which could induce a change in business models. For example, improvement in the technology of monitoring transactions would facilitate the use of transaction fees. In some cases, the use of certain fee instruments in practice may not necessarily be optimal. Market participants in a particular industry may be accustomed to it or they may simply be copying the revenue models of the market leaders,

[35]A relevant example is price-comparison websites in housing or rental markets, in which deals are typically conducted outside the platform and are difficult to monitor. Instead of transaction-based fees, these platforms typically charge sellers an up-front listing fee. Notable examples include rental market websites such as Rightmove and Zoopla in the United Kingdom, or Immobilienscout24 and Immowelt in Germany (Karle et al., 2020).

e.g., HomeAway vs. Airbnb.[36] The current framework can then be used to understand the implications of such changes of business models.

Nonetheless, if we endogenize the platform's choice of fee instrument in our framework (which abstracts from these additional considerations), then for each given m, the two-part tariff is optimal. This allows the platform to obtain the highest possible profit. This maximal profit is equivalent to a (multiproduct) monopolist's profit, as has been noted by Anderson and Bedre-Defolie (2020). The platform (i) uses the lump-sum fee to fully extract all seller surplus, (ii) sets transaction-based fees to implement the optimal monopoly price $p^*(m^*)$, and (iii) chooses design m^* to achieve the maximum transactional value $v(m^*)$.

However, in our model the profit equivalence disappears when the constraint of no net subsidy (on transactions) binds. To restore the equivalence, we could allow the platform to subsidize buyer participation directly (i.e., negative buyer participation fee, as in Section 4.5). Provided that we interpret Q as the mass of participating buyers, the per-participation subsidy would be mathematically equivalent to a negative τ. Then, for any m, the platform can always feasibly induce $p^*(m)$ without subsidizing transactions.

Remark 1 *(Endogenous fee instrument choice) For any given design, the platform's profit-maximizing fee instrument is a two-part tariff with a subsidy on buyer participation.*

Once we endogenize the choice of fee instruments, it becomes natural to consider a "stronger" second-best benchmark whereby the regulator may not only intervene in platform design but also limit the use of certain fee instruments (but the exact fee levels are still chosen by the platform itself). In Section C of the Online Appendix, we compare this stronger second-best design benchmark, m^{sb+}, and the profit-maximizing design (without any intervention), m^{p+}, and obtain the following result:

Proposition 7 *(Intervention with endogenous fee instruments) Suppose the social planner can intervene in the governance design and the choice of fee instruments. The second-best intervention requires (i) that the platform charges a lump-sum listing fee, and (ii) a design choice of* $m^{sb+} \leq m^{p+}$*, with the inequality strict if* m^{p+} *or* m^{sb+} *is an interior solution.*

Part (i) of the proposition is straightforward because pure listing fees eliminate the pricing distortions that result from transaction-based fees (given that the platform would attempt to use such components to induce the monopoly price level). Part (ii) follows from the fact that m^{p+} maximizes $v(m)$, while m^{sb+} also considers how design affects the final price level.[37]

In cases in which the lump-sum fee component of the two-part tariff is infeasible, then we must focus on pure transaction-based fees as in Shy and Wang (2011) and Johnson (2017). In our framework, for each given m, it can be shown that the platform's profit is higher with proportional fees compared with per-transaction fees. The proof follows from the more general

[36] See, e.g., https://www.wsj.com/articles/expedia-to-buy-vacation-rental-site-homeaway-for-3-9-billion-1446672445, accessed on 1 May 2021.

[37] The welfare optimality of the listing fee relies on seller participation being inelastic in the current framework. If seller participation is elastic, listing fees could lead to a downward distortion in seller participation. Still, provided that seller participation is not too elastic relative to Q, the loss from the participation distortion would be dominated by the gain from the smaller price distortion, so that pure listing fees remain welfare optimal.

result of Johnson (2017), whereby proportional fees mitigate double marginalization. To see this, notice that if we transform the platform's decision in Sections 4.1 and 4.2 as choosing the final price levels directly, then for each given m, the platform's profit is $\Pi_\tau = \max_p(p - c - m)Q(v(m) - p)$ under per-transaction fees, and $\Pi_r = \max_p(p - c - \frac{mc}{p-m})Q(v(m) - p)$ under proportional fees. We know that $p - m \geq c$, and so a standard monotone comparative statics argument shows that $\Pi_r > \Pi_\tau$. Likewise, the second-best intervention involves requiring the platform to charge proportional fees, again to best mitigate double marginalization. Hence, Proposition 4 is applicable in this case.

Finally, in cases in which subsidizing the buyers is infeasible, the profit-maximizing fee instrument in Remark 1 reduces to the two-part tariff described in Section 4.4, so that Proposition 6 applies.

6.2 Costly governance design

In this section, we briefly discuss how our results in Section 4 can be extended to the case in which the governance design affects the platform's costs. Suppose that the platform's fixed cost $K = K(v(m))$ is increasing and convex in its argument. For simplicity, we focus on the case of monotone $v(m)$.

For all instruments analyzed in Section 4, we know that the platform does not extract the entire total welfare. This implies that it does not internalize the entire benefit from a higher transactional value, while at the same time it bears the entire cost related to changes in governance design. This cost consideration creates an additional distortion that shifts the profit-maximizing governance design towards a lower v relative to the welfare benchmark. In Section D of the Online Appendix, we prove the following result:

Proposition 8 *(Costly governance design). Suppose value and markup are always negatively correlated; then Propositions 3 and 4 (with large enough c) continue to hold. Suppose value and markup are always positively correlated; then Propositions 4 (with small enough c), 5, and 6 continue to hold.*

When value and markup are always negatively correlated (e.g., Example 1), all else being equal, the cost consideration induces the platform to choose design $m^p \geq m^{sb}$. Recall from Table 1 that absent any design costs, we have $m^p \geq m^{sb}$ when the platform uses seller-aligned fee instruments, meaning that the cost consideration reinforces the existing distortion. When the platform uses volume-aligned fee instruments, the cost consideration acts in the opposite direction of the distortion identified in Table 1, thus mitigating (and possibly overturning) the existing distortion.

Following the same logic as above, the reverse is true when value and markup are always positively correlated (e.g., Example 2). All else being equal, the cost consideration makes $m^p \leq m^{sb}$ more likely, thus reinforcing the existing distortion in the case of volume-aligned fee instruments and mitigating the existing distortion in the case of seller-aligned fee instruments.

6.3 Consumer surplus benchmark

Sometimes antitrust authorities focus on a consumer welfare (rather than a total welfare) standard. One such standard is to focus on the buyer surplus $\widetilde{BS} = \int_{-\infty}^{v(m)-p(m)} Q(t)\,dt$. Similar to the second-best welfare benchmark, we let m^{bs} be the design that maximizes $\widetilde{BS}$, subject to the endogenous fee responses of the platform.

Note that $\widetilde{BS}$ is increasing with the aggregate transaction volume, so m^{bs} also maximizes the transaction volume. Given the intuition and categorization in Table 1, it is natural to expect that the profit-maximizing design involves no distortions in the case of volume-aligned fee instruments, but involves insufficient seller competition in the case of seller-aligned fee instruments. In Section E of the Online Appendix, we prove the following Corollary that corresponds to the propositions in Section 4:

Corollary 1 *Comparing profit-maximizing and consumer surplus-maximizing designs:*

- *If the platform uses per-transaction fees, advertising revenues, or buyer participation fees then* $m^p = m^{bs}$.
- *If the platform uses proportional fees (for all c), seller participation fees, or two-part tariffs, then* $m^p \geq m^{bs}$.

With the buyer surplus benchmark, the only possible direction of distortion is $m^p > m^{bs}$. The sole concern is that the platform's design induces excessive seller markup (insufficient competition). This is in contrast to the total welfare benchmark, in which the opposite concern of insufficient markup is possible: the platform (with volume-aligned fee instruments) may focus on decreasing seller markup at the expense of value generation and seller surplus. Corollary 1 highlights the observation that focusing on the buyer surplus standard in regulating platforms' behaviors sometimes leads to a conclusion that differs from the case of the total welfare standard.

In two-sided markets, another possible consumer welfare standard is the joint seller and buyer surplus, $\widetilde{JS} = \tilde{W} - \tilde{\Pi}$. If the platform's fee instruments are such that seller surplus is not fully extracted (i.e., those that do not involve any seller participation fees), we would obtain results that are similar to the total welfare benchmark. To see the intuition, suppose that the profit-maximizing design satisfies the first-order condition so $\frac{d\tilde{\Pi}(m)}{dm}|_{m=m^p} = 0$. Then, $\frac{d\widetilde{JS}}{dm}|_{m=m^p} = \frac{d\tilde{W}}{dm}|_{m=m^p}$, so that any distortion in the joint surplus would have the same sign as the distortion in the total welfare. Suppose, instead, the platform's fee instruments involve seller participation fees such that seller surplus is fully extracted. This implies $\widetilde{JS} = \widetilde{BS}$ so that the joint surplus benchmark is equivalent to the buyer surplus benchmark and Corollary 1 applies. However, in a more general setting where sellers are heterogeneous and the platform cannot price discriminate using its participation fees, the platform does not fully extract the seller surplus so that $\widetilde{JS} \neq \widetilde{BS}$. In that case, the result moves closer to the case of the total welfare benchmark as the amount of unextracted seller surplus increases.

7 Conclusion

An important distinction between a platform (marketplace) business and a traditional retailer is that the platform hosts groups of sellers that make independent pricing decisions, whereas the retailer sells and prices all of its products directly. As such, a platform's governance design decisions affect not just the gross surplus generated from on-platform transactions but also how the seller competition unfolds. The current paper investigates what drives differences between the profit-maximizing and the socially optimal governance design.

As summarized in Table 1, the sign of welfare distortion in platform governance crucially depends on the fee instrument employed. Given that prices enter transaction volume and seller surplus in opposite directions, each platform business can be seen as positioning itself on a continuum of business models. At one end, there is a pure volume-aligned model in which the platform prefers governance designs that induce more intense seller competition than the socially optimal design. At the other end, there is a pure seller-aligned model in which the platform prefers governance designs that induce less intense seller competition than the socially optimal design.

To extend our framework, an obvious direction is to investigate how competition between platforms affects their choice of governance design. Suppose there are two rival platforms and each seller can join both platforms while each buyer can join only one. This leads to a competitive bottleneck equilibrium similar to that analyzed by Armstrong and Wright (2007). Inter-platform competition implies a transaction volume that is more elastic (with respect to the net utility offered to buyers) than the case of a monopoly platform, which induces the platforms to adjust their governance design towards inducing more on-platform competition, so as to achieve a more competitive price on their respective platforms. Following this intuition, for each given fee instrument, we expect that the introduction of inter-platform competition shifts platform businesses to be more volume-aligned and designs to correspond to more intense seller competition.[38]

This paper focuses on the case in which the platform operates purely as a marketplace. One issue that has come to the forefront in recent policy discussions is that platforms sometimes play the dual role of "umpire and player"(Caffarra et al., 2020): operating marketplaces while at the same time offering their own products on these marketplaces. Considering such vertically integrated platforms creates other design issues that the current framework does not capture. For example, the platform may engage in abusive design decisions such as preferencing its own product in ranking algorithms or imitating third-parties' innovative products, both of which hurt rival sellers (de Cornière and Taylor, 2019; Hagiu, Teh, and Wright, 2020; Chen and Tsai, 2021). The current paper shows that distortions can arise even without any vertical integration. An important direction for future studies is to consider incorporating these additional features.

[38]This is consistent with the findings of Karle et al.'s (2020) model, who show that introducing platform competition can sometimes result in equilibria in which multiple sellers participate and compete on the same platform, while a monopoly platform induces a single seller to participate.

8 Appendix: Proofs

8.1 Proposition 1

For all $m < m^p$, we have

$$\begin{aligned} W(m) &\leq \Pi(m^p) + mQ\left(v\left(m^p\right) - p_\tau(m^p)\right) + \int_{-\infty}^{v(m^p)-p_\tau(m^p)} Q(t)\,dt \\ &< \Pi(m^p) + m^p Q\left(v\left(m^p\right) - p_\tau(m^p)\right) + \int_{-\infty}^{v(m^p)-p_\tau(m^p)} Q(t)\,dt \\ &= W\left(m^p\right), \end{aligned}$$

where the first inequality follows from the definition of $m^p \equiv \arg\max\{v(m) - p_\tau(m)\}$, while the second inequality follows from $m < m^p$. Therefore, $m^w \geq m^p$, and it follows that $v(m^w) \geq v(m^p)$ as otherwise m^w cannot be welfare maximizing. To complete the proof, we need to rule out the existence of an interior m^p that simultaneously satisfies first order conditions (FOCs) $\frac{dW}{dm} = 0$ and $\frac{d\Pi}{dm} = 0$. From (4), we know $\frac{d\Pi}{dm}|_{m=m^p} = 0$ implies $\frac{dv}{dm}|_{m=m^p} = 1$. Substituting this into (5), we get $\frac{dW}{dm}|_{m=m^p} = Q > 0$, so there is no interior solution satisfying both FOCs simultaneously.

8.2 Proposition 2

Suppose $\frac{dv}{dm}|_{m=m^p} \geq 1$, then from (8) this implies $\frac{d\Pi}{dm}|_{m=m^p} > 0$, so that $m^p = \bar{m}$. Moreover, from (9), $\frac{dW}{dm}|_{m=m^p} > 0$, and so unimodality of W implies $m^w = m^p = \bar{m}$.

Suppose instead $\frac{dv}{dm}|_{m=m^p} < 1$. Rearrange (9) as

$$\begin{aligned} \frac{dW}{dm} &= \left(\frac{dv}{dm} - 1\right) p_r(m) Q' + Q + \left(\frac{dv}{dm} - 1\right)(Q - cQ') \\ &= \frac{1}{r}\frac{d\Pi}{dm} + \left(\frac{Q}{Q'} - c\right)\left(\frac{dv}{dm} - 1\right) Q'. \end{aligned}$$

Then:

- When $c = \frac{Q(v(m^p)-p_r(m^p))}{Q'(v(m^p)-p_r(m^p))}$, then $\frac{dW}{dm}|_{m=m^p} = \frac{1}{r}\frac{d\Pi}{dm}|_{m=m^p}$, so $m^w = m^p$.
- When $c < \frac{Q(v(m^p)-p_r(m^p))}{Q'(v(m^p)-p_r(m^p))}$, then $\frac{dW}{dm}|_{m=m^p} < \frac{1}{r}\frac{d\Pi}{dm}|_{m=m^p}$. If $\frac{d\Pi}{dm}|_{m=m^p} = 0$, then m^p is interior and unimodality of W implies $\frac{dW}{dm} < 0$ for all $m \geq m^p$. If $\frac{d\Pi}{dm}|_{m=m^p} < 0$, then $m^w = m^p = \underline{m}$. If $\frac{d\Pi}{dm}|_{m=m^p} > 0$, then $m^p = \bar{m}$, then $m^w \leq m^p$ holds trivially. Combining all three cases, we conclude that $m^w \leq m^p$, with the inequality strict if either m^p or m^w is interior.
- When $c > \frac{Q(v(m^p)-p_r(m^p))}{Q'(v(m^p)-p_r(m^p))}$, then $\frac{dW}{dm}|_{m=m^p} < \frac{1}{r}\frac{d\Pi}{dm}|_{m=m^p}$. The same analysis as above shows $m^w \geq m^p$, with inequality strict if either m^p or m^w is interior.

Finally, we prove the following claims stated in the main text:

Lemma 1 *If $v(m)$ is monotone decreasing or weakly concave, then W defined in Section 3.2 is unimodal.*

Proof. If $v(m)$ is monotone decreasing, then it is clear from (9) that $\frac{dW}{dm} < 0$, so unimodality is trivial. Consider weakly concave $v(m)$, i.e. $\frac{dv}{dm}$ is decreasing. Consider the range of small m such that $\frac{dv}{dm} \geq 1$. Then (9) implies $\frac{dW}{dm} > 0$. Consider the range of larger m such that $\frac{dv}{dm} < 1$ and rewrite (9) as

$$\frac{1}{Q}\frac{dW}{dm} = \left(\frac{dv}{dm} - 1\right)\left((p_r(m) - c)\frac{Q'}{Q} + 1\right) + 1. \tag{18}$$

When m increases, $\frac{dv}{dm} - 1$ becomes more negative. We also know $(p(m) - c)\frac{Q'}{Q}$ is increasing in m (using log-concavity and $\frac{dv}{dm} < 1$), so that the first term in (18) is decreasing in overall. It follows that if there exists some $\bar{m}$ such that $\frac{dW}{dm}|_{m=\bar{m}} = 0$, then $\frac{dW}{dm} < 0$ for all $m > \bar{m}$, which proves the unimodality. ■

Lemma 2 *m^p is monotone decreasing in c.*

Proof. From (8), whenever m^p is interior it is implicitly pinned down by FOC:

$$\left(\frac{dv}{dm}-1\right)\left(m+\frac{c}{1-r}\right)+\frac{Q(v\left(m\right)-m-\frac{c}{1-r})}{Q'(v\left(m\right)-m-\frac{c}{1-r})}=0. \tag{19}$$

For the FOC to hold, m^p must be such that $\frac{dv}{dm}|_{m=m^p}<1$. Moreover, interiority ensures that (19) is locally decreasing in m when evaluated at $m=m^p$. By the implicit function theorem, the sign of $\frac{dm^p}{dc}$ is the same as the sign of the derivative of the left hand side of (19) with respect to c, which is strictly negative because Q is log-concave (i.e., Q/Q' is increasing in its argument). ■

Lemma 3 *Suppose $v(m)$ is monotone decreasing or weakly concave. There exists a cutoff $\bar{c}$ such that $c<\bar{c}$ implies $m^p\geq m^w$ and $c>\bar{c}$ implies $m^p\leq m^w$.*

Proof. Suppose $\frac{dv}{dm}|_{m=m^p}>0$, then it suffices to show that $v\left(m^p\right)-p_r(m)=v\left(m^p\right)-m^p-\frac{c}{1-r}$ is monotone decreasing in c so that the lemma follows from Proposition 2. If m^p is a corner solution then $v\left(m^p\right)-m^p-\frac{c}{1-r}$ is obviously decreasing in c. If m^p is interior, we use notation $\psi\equiv v\left(m\right)-m-\frac{c}{1-r}$ to rewrite (19) as

$$\left(\frac{dv}{dm}|_{m=m^p}-1\right)\left(v\left(m^p\right)-\psi\right)+\frac{Q(\psi)}{Q'(\psi)}=0,$$

where $\frac{dv}{dm}|_{m=m^p}\in(0,1)$. We want to show ψ is decreasing in c. By the implicit function theorem,

$$\frac{d\psi}{dc}=\left(\frac{\left(\frac{dv}{dm}-1\right)\frac{dv}{dm}+\frac{d^2v}{dm^2}\left(v\left(m^p\right)-\psi\right)}{\left(\frac{dv}{dm}-1\right)-\frac{dQ/Q'}{d\psi}}\right)\frac{dm^p}{dc}<0,$$

where everything is evaluated at $m=m^p$. The denominator is negative given $\frac{dv}{dm}|_{m=m^p}\in(0,1)$, while the numerator is positive given $v(m)$ is weakly concave and m^p is decreasing (Lemma 2).

Suppose instead $\frac{dv}{dm}|_{m=m^p}\leq 0$ (which includes the case of $v(m)$ being monotone decreasing), then from the main text we know $m^w=\underline{m}$, so $m^p\geq m^w$ for all c and the lemma is trivially satisfied. ■

8.3 Proposition 3

Given the incomplete pass-through property $\frac{d\tilde{\tau}}{d(v-m)}\in(0,1)$, we know $v\left(m\right)-p_{\tilde{\tau}}(m)=v-c-\tilde{\tau}\left(m\right)-m$ is increasing in m if and only if $v(m)-m$ is increasing in m. Given $m^p=\arg\max\left\{v\left(m\right)-m\right\}$, it follows that $v\left(m\right)-p_{\tilde{\tau}}(m)$ is maximized at m^p. Proposition 3 then follows from the same proof as Proposition 1.

8.4 Proposition 4

We first establish the following properties of $p_{\tilde{\tau}}(m)$ given in (15).

Lemma 4 *At each given m:*

- *If $\frac{dv}{dm}\geq 0$ then $\frac{dp_{\tilde{\tau}}}{dm}>0$.*
- *If $\frac{dv}{dm}\leq 1$ then $\frac{dp_{\tilde{\tau}}}{dm}<1$.*
- *If $\frac{dv}{dm}\leq 0$ or $\frac{dv}{dm}\leq 1-\frac{Q}{p_{\tilde{\tau}}Q'}$, then $\frac{dv}{dm}<\frac{dp_{\tilde{\tau}}}{dm}$.*
- *If $\frac{dv}{dm}\leq\frac{dp_{\tilde{\tau}}}{dm}$, then $\frac{dp_{\tilde{\tau}}}{dm}<1$ and $\frac{d\tilde{\tau}}{dm}<0$.*

Proof. Implicit differentiation on (15) shows

$$\frac{dp_{\tilde{\tau}}}{dm}=\frac{\left(1+\frac{p_{\tilde{\tau}}c}{(p_{\tilde{\tau}}-m-c)(p_{\tilde{\tau}}-m)}\right)\frac{dQ/Q'}{dx}\frac{dv}{dm}+\left(1-\frac{Q}{p_{\tilde{\tau}}Q'}\right)\frac{p_{\tilde{\tau}}(2p_{\tilde{\tau}}-2m-c)}{(p_{\tilde{\tau}}-m-c)(p_{\tilde{\tau}}-m)}}{\frac{Q}{p_{\tilde{\tau}}Q'}+\left(1+\frac{p_{\tilde{\tau}}c}{(p_{\tilde{\tau}}-m-c)(p_{\tilde{\tau}}-m)}\right)\frac{dQ/Q'}{dx}+\left(1-\frac{Q}{p_{\tilde{\tau}}Q'}\right)\frac{p_{\tilde{\tau}}(2p_{\tilde{\tau}}-2m-c)}{(p_{\tilde{\tau}}-m-c)(p_{\tilde{\tau}}-m)}},$$

where $\frac{dQ/Q'}{dx} = \frac{d}{dx}\left(\frac{Q(x)}{Q'(x)}\right)|_{x=v(m)-p_{\tilde{r}}(m)} \geq 0$ by the log-concavity of Q and where we have used that $1 - \frac{Q}{Q'}\frac{c}{(p_{\tilde{r}}-m-c)(p_{\tilde{r}}-m)} = \frac{Q}{p_{\tilde{r}}Q'} > 0$ (from (15)) to simplify the denominator. Clearly, $\frac{dv}{dm} > 0$ implies $\frac{dp_{\tilde{r}}}{dm} > 0$; $\frac{dv}{dm} \leq 1$ implies $\frac{dp_{\tilde{r}}}{dm} < 1$. Next

$$\frac{dv}{dm} - \frac{dp_{\tilde{r}}}{dm} = \frac{\frac{dv}{dm}\frac{Q}{p_{\tilde{r}}Q'} - \left(1-\frac{dv}{dm}\right)\left(1-\frac{Q}{p_{\tilde{r}}Q'}\right)\frac{p_{\tilde{r}}(2p_{\tilde{r}}-2m-c)}{(p_{\tilde{r}}-m-c)(p_{\tilde{r}}-m)}}{\frac{Q}{p_{\tilde{r}}Q'} + \left(1+\frac{p_{\tilde{r}}c}{(p_{\tilde{r}}-m-c)(p_{\tilde{r}}-m)}\right)\frac{dQ/Q'}{dx} + \left(1-\frac{Q}{p_{\tilde{r}}Q'}\right)\frac{p_{\tilde{r}}(2p_{\tilde{r}}-2m-c)}{(p_{\tilde{r}}-m-c)(p_{\tilde{r}}-m)}}. \tag{20}$$

If $\frac{dv}{dm} \leq 0$, then the numerator of (20) is obviously negative given (15) implies $1 - \frac{Q}{p_{\tilde{r}}Q'} > 0$. Meanwhile, if $\frac{dv}{dm} \leq 1 - \frac{Q}{p_{\tilde{r}}Q'}$, the numerator of (20) is

$$\begin{aligned} &\leq \frac{dv}{dm}\frac{Q}{p_{\tilde{r}}Q'} - \frac{Q}{p_{\tilde{r}}Q'}\left(1-\frac{Q}{p_{\tilde{r}}Q'}\right)\frac{p_{\tilde{r}}\,(2p_{\tilde{r}}-2m-c)}{(p_{\tilde{r}}-m-c)(p_{\tilde{r}}-m)} \\ &< \frac{dv}{dm}\frac{Q}{p_{\tilde{r}}Q'} - \frac{Q}{p_{\tilde{r}}Q'}\left(1-\frac{Q}{p_{\tilde{r}}Q'}\right) \leq 0. \end{aligned}$$

Finally, to prove the last part of the claim we prove its contrapositive statement, i.e. $\frac{dp_{\tilde{r}}}{dm} \geq 1$ implies $\frac{dv}{dm} > \frac{dp_{\tilde{r}}}{dm}$. First, notice $\frac{dp_{\tilde{r}}}{dm} \geq 1$ implies $\frac{dv}{dm} > 1$ by the second part of Lemma 4 that has been proven above. From (20), the numerator is then greater than $\frac{Q}{p_{\tilde{r}}Q'} > 0$, implying $\frac{dv}{dm} > \frac{dp_{\tilde{r}}}{dm}$ which proves the contrapositive statement. Finally, $\frac{dp_{\tilde{r}}}{dm} < 1$ implies $\tilde{r}(m) = 1 - \frac{c}{p_{\tilde{r}}-m}$ is decreasing in m. ■

To prove Proposition 4, rewrite the welfare function as

$$\tilde{W}(m) = \frac{1}{\tilde{r}(m)}\tilde{\Pi}(m) + \int_{-\infty}^{v(m)-p_{\tilde{r}}(m)} Q(t)dt - cQ\left(v(m) - p_{\tilde{r}}(m)\right),$$

and so

$$\begin{aligned} \frac{d\tilde{W}}{dm} &= \frac{1}{\tilde{r}}\frac{d\tilde{\Pi}}{dm} - \frac{1}{\tilde{r}^2}\tilde{\Pi}\frac{d\tilde{r}}{dm} + \left(\frac{dv}{dm} - \frac{dp_{\tilde{r}}}{dm}\right)\left(\frac{Q}{Q'} - c\right)Q' \\ &= \frac{1}{\tilde{r}}\frac{d\tilde{\Pi}}{dm} - \frac{p_{\tilde{r}}}{\tilde{r}}Q\frac{d\tilde{r}}{dm} + \left(\frac{dv}{dm} - \frac{dp_{\tilde{r}}}{dm}\right)\left(\frac{Q}{Q'} - c\right)Q' \\ &= \frac{1}{\tilde{r}}\frac{d\tilde{\Pi}}{dm} + \left(\frac{Q}{Q'}(1+\Psi(m)) - c\right)\left(\frac{dv}{dm} - \frac{dp_{\tilde{r}}}{dm}\right)Q'. \end{aligned}$$

Case 1: Suppose m^p is interior. From (14), $\frac{d\Pi}{dm}|_{m=m^p} = 0$ is equivalent to

$$\frac{dv}{dm}|_{m=m^p} = 1 - \frac{Q}{p_{\tilde{r}}Q'}|_{m=m^p}. \tag{21}$$

By Lemma 4, (21) implies $\frac{dv}{dm} < \frac{dp_{\tilde{r}}}{dm}$ and $\frac{d\tilde{r}}{dm} > 0$. Hence, $\frac{d\tilde{W}}{dm}|_{m=m^p}$ has the opposite sign of $\frac{Q}{Q'}(1+\Psi(m))|_{m=m^p} - c$. Then, unimodality of $W(m)$ implies Proposition 4.

Case 2: Suppose $m^p = \underline{m}$, so obviously $m^{sb} \geq m^p$. It remains to rule out the possibility that $m^{sb} > m^p$ when $c < \frac{Q}{Q'}(1+\Psi(m))|_{m=m^p}$. Notice $m^p = \underline{m}$ implies $\frac{d\Pi}{dm}|_{m=m^p} < 0$, or

$$\frac{dv}{dm}|_{m=m^p} < 1 - \frac{Q}{p_{\tilde{r}}Q'}|_{m=m^p}. \tag{22}$$

By Lemma 4, (22) implies $\frac{dv}{dm} < \frac{dp_{\tilde{r}}}{dm}$ and $\frac{d\tilde{r}}{dm} > 0$. So, if $c \leq \frac{Q}{Q'}(1+\Psi(m))|_{m=m^p}$, then $\frac{d\tilde{W}}{dm}|_{m=m^p} < 0$. Unimodality of $W(m)$ implies $m^{sb} = \underline{m}$ as required.

Case 3: Suppose $m^p = \bar{m}$, so obviously $m^{sb} \leq m^p$. It remains to rule out the possibility that $m^{sb} < m^p$ when $c > \frac{Q}{Q'}(1+\Psi(m))|_{m=m^p}$. From the main text (14), we know that $\frac{dv}{dm}|_{m=m^p} \leq 0$ implies $m^p = \underline{m}$. Therefore, for $m^p = \bar{m}$ to hold, we must have $\frac{dv}{dm}|_{m=m^p} > 0$. There are two subcases to consider. If $(\frac{dv}{dm} - \frac{dp_{\tilde{r}}}{dm})|_{m=m^p} \geq 0$, then (16) immediately implies $m^{sb} = \bar{m}$ regardless of c. If $(\frac{dv}{dm} - \frac{dp_{\tilde{r}}}{dm})|_{m=m^p} < 0$, then $c > \frac{Q}{Q'}(1+\Psi(m))|_{m=m^p}$ implies $\frac{d\tilde{W}}{dm}|_{m=m^p} > 0$ and unimodality of $W(m)$ implies $m^{sb} = \bar{m}$ as required.

8.5 Proposition 5

From $\tilde{\Pi}(m) = mQ(v(m) - m - c)$, for all $m > m^p$ we have $v(m) - m < v(m^p) - m^p$. This is because otherwise if there is some $m' > m^p$ such that $v(m') - m' \geq v(m^p) - m^p$, then $\tilde{\Pi}(m') > \tilde{\Pi}(m^p)$, which contradicts the definition of m^p being a profit maximizer. Next, from the welfare function

$$\tilde{W}(m) = \tilde{\Pi}(m) + \int_{-\infty}^{v(m)-m-c} Q(t)dt, \tag{23}$$

it follows that $\tilde{W}(m) < \tilde{W}(m^p)$ for all $m > m^p$. Hence, we conclude $m^{sb} \leq m^p$. To complete the proof, we know

$$\frac{d\tilde{\Pi}}{dm} = Q + \left(\frac{dv}{dm} - 1\right)Q',$$

so that $\frac{d\tilde{\Pi}}{dm}|_{m=m^p} = 0$ implies $\frac{dv}{dm}|_{m=m^p} < 1$. Substituting this into the derivative of (23) to get $\frac{d\tilde{W}(m)}{dm}|_{m=m^p} < 0$.

8.6 Proposition 6

For each given m, the platform can induce the joint monopoly price $p^*(m)$ by setting r and τ such that $\frac{rc+\tau}{1-r} = p^*(m) - c - m$, or equivalently, $rp^*(m) + \tau = p^*(m) - c - m$. Such fees imply that the price resulting from seller competition is $p = m + \frac{c+\tau}{1-r} = m + c + \frac{rc+\tau}{1-r} = p^*(m)$. It is optimal to induce $p^*(m)$ as long as the no-subsidy constraint is satisfied, which holds if and only if $p^*(m) - c - m \geq 0$. When $p^*(m) - c - m < 0$, quasi-concavity of the profit function $(p-c)Q(v(m)-p)$ with respect to p implies that the no-subsidy constraint in binding, so that the optimal induced price is $m+c$. Combining both cases, for each given m we denote the profit-maximizing induced price as

$$\tilde{p}(m) = \max\{m + c, p^*(m)\}.$$

Case 1. If $c \leq p^*(m^*) - m^*$, then $p^*(m^*)$ is implementable. By the envelope theorem, $\tilde{\Pi}(m) = (\tilde{p}(m) - c)Q(v(m) - \tilde{p}(m))$ is maximized at $m^p = m^*$. Moreover, log-concavity of Q implies that $v(m) - p^*(m)$ is maximized when $m^* \equiv \arg\max_m v(m)$. Therefore, $v(m) - \tilde{p}(m) \leq v(m) - p^*(m) \leq v(m^*) - p^*(m^*)$, meaning that $\tilde{W}(m) = \tilde{\Pi}(m) + \int_{-\infty}^{v(m)-\tilde{p}(m)} Q(t)dt$ is maximized at $m^{sb} = m^*$.

Case 2. Suppose $c > p^*(m^*) - m^*$, then we know $p^*(m^*)$ is no longer implementable. To proceed, define $\hat{m} \geq m^*$ as the largest solution to $\hat{m} + c = p^*(\hat{m})$ (and define $\hat{m} = \bar{m}$ if a solution does not exist). Unimodality of $v(m)$ implies $v(m)$ and $p^*(m)$ are monotonically decreasing for all $m > m^*$, which implies $\tilde{p}(m) = m + c$ for all $m \in [m^*, \hat{m}]$ and $\tilde{p}(m) = p^*(m)$ for all $m > \hat{m}$. The envelope theorem and unimodality of $v(m)$ implies all $m > \hat{m}$ deliver a lower profit than $m = \hat{m}$. Hence, we conclude $m^p \leq \hat{m}$, or $\tilde{p}(m^p) = c + m^p$. To prove $m^p \geq m^{sb}$, suppose to the contrary that $m^p < m^{sb}$. If $v(m^p) - m^p - c > v(m^{sb}) - \tilde{p}(m^{sb})$ then

$$\tilde{W}\left(m^{sb}\right) < \tilde{\Pi}\left(m^{sb}\right) + \int_{-\infty}^{v(m^p)-m^p-c} Q(t)dt \leq \tilde{W}(m^p),$$

contradicting the definition of m^{sb}. If $v(m^p) - m^p - c \leq v(m^{sb}) - \tilde{p}(m^{sb})$ then

$$\begin{aligned}
\tilde{\Pi}\left(m^{sb}\right) &= (\tilde{p}(m^{sb}) - c)Q\left(v\left(m^{sb}\right) - \tilde{p}(m^{sb})\right) \\
&\geq (\tilde{p}(m^{sb}) - c)Q(v(m^p) - m^p - c) \\
&> m^p Q(v(m^p) - m^p - c) = \tilde{\Pi}(m^p),
\end{aligned}$$

where the last inequality is due to $\tilde{p}(m^{sb}) - c \geq m^{sb} > m^p$. This contradicts the definition of m^p. We conclude $m^p \geq m^{sb}$.

To complete the proof, we need to rule out the existence of an interior m^p that simultaneously satisfies $\frac{d\tilde{W}}{dm} = 0$ and $\frac{d\tilde{\Pi}}{dm} = 0$. We know $\frac{dtildePi(m)}{dm}|_{m=m^p} = 0$ implies $\left(\frac{dv}{dm} - 1\right)|_{m=m^p} < 0$, and

$$\frac{d\tilde{W}}{dm}|_{m=m^p} = \frac{d\tilde{\Pi}(m)}{dm}|_{m=m^p} + Q\left(\frac{dv}{dm} - 1\right)|_{m=m^p},$$

so that $\frac{d\tilde{\Pi}}{dm}|_{m=m^p} = 0$ implies $\frac{d\tilde{W}}{dm}|_{m=m^p} > 0$.

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Online appendix: Platform governance

Tat-How Teh*

This Online Appendix contains omitted details from the main paper and the details of extensions in Section 6.

A Discrete governance

In this section, we consider the case in which the design choice a is not a continuous variable. In what follows, we replicate the results in Sections 3 - 4. Let $\Theta \subseteq \mathbb{R}^n$ be a finite subset of n-dimensional real vector space. Each design choice is denoted as a vector $a \in \Theta$ and corresponds to a given level of gross transaction value $V(a)$ and markup $M(a)$.

Given that the choice set is finite, we can equivalently reformulate the design problem as directly choosing a pair of markup level and transaction value $(M(a), V(a))$, or $(m, v(m))$, as in the analysis in the main text. In cases in which a given $M(a)$ corresponds to multiple possible levels of $V(a)$, we can select the highest $V(a)$ among them without loss of generality.

Given the reformulation, we note that the proofs of Proposition 1, 3, 5, and 6 in the main text do not rely on a being a continuous variable, except when establishing the strict inequalities (in which we have explicitly used the first-order conditions). Therefore, these results carry over immediately with weak inequalities. As for Propositions 2 and 4, the following propositions deliver similar insights:

Proposition A.1 *(Exogenous proportional fee) Suppose the platform charges an exogenous proportional fee r. There exist thresholds $\bar{c}^l$ and $\bar{c}^h$, where $0 < \bar{c}^l \leq \bar{c}^h$, such that:*

- *If $c < \bar{c}^l$, then $m^p \geq m^w$.*
- *If $c > \bar{c}^h$, then $m^p \leq m^w$.*

Proof. From

$$\begin{aligned}\Pi(m) &= r\left(\frac{c}{1-r}+m\right)Q\left(v(m)-m-\frac{c}{1-r}\right)\\ W(m) &= \left(\frac{c}{1-r}+m-c\right)Q\left(v(m)-m-\frac{c}{1-r}\right)+\int_{-\infty}^{v(m)-m-\frac{c}{1-r}}Q(t)\,dt,\end{aligned}$$

we make the following two observations: (i) $v(m)-m < v(m^p)-m^p$ for all $m > m^p$; and (ii) $v(m)-m < v(m^w)-m^w$ for all $m > m^w$. Otherwise, m^p and m^w cannot be maximizers. Consider the following function:

$$\psi(x) \equiv -cQ(x) + \int_{-\infty}^{x} Q(t)\,dt, \tag{A.1}$$

the derivative of which is $\frac{\partial \psi}{\partial x} = \left(\frac{Q(x)}{Q'(x)} - c\right)Q'(x)$. Rewrite the welfare function as

$$W(m) = \frac{1}{r}\Pi(m) + \psi\left(v(m) - m - \frac{c}{1-r}\right).$$

Let $m^h \equiv \arg\max_m \{v(m) - m\}$ and $m^l \equiv \arg\min_m \{v(m) - m\}$, both of which are well defined by the compactness of the domain and the continuity of $v(m) - m$. Let $\bar{c}^i$, $i \in \{l, h\}$ be the solution to

$$\frac{Q(v(m^i) - m^i - \frac{\bar{c}^i}{1-r})}{Q'(v(m^i) - m^i - \frac{\bar{c}^i}{1-r})} = \bar{c}^i.$$

*School of Management and Economics and Shenzhen Finance Institute, The Chinese University of Hong Kong, Shenzhen, China, e-mail: tehtathow@gmail.com

The existence and uniqueness of $\bar{c}^i$ follows from the intermediate value theorem and log-concavity of Q.

Suppose $c < \bar{c}^l$. This implies $\frac{\partial \psi}{\partial x} > 0$ for all $x \geq v(m^l) - m^l - \frac{c}{1-r}$, i.e., $\psi\left(v\left(m\right) - m - \frac{c}{1-r}\right)$ is increasing for all possible m. Given that we know $v\left(m\right) - m < v\left(m^p\right) - m^p$ for all $m > m^p$, it follows that

$$W\left(m\right) < \frac{1}{r}\Pi(m) + \psi\left(v\left(m^p\right) - m^p - \frac{c}{1-r}\right) \leq W\left(m^p\right)$$

for all $m > m^p$, implying $m^w \leq m^p$.

Suppose $c > \bar{c}^h$. This implies $\frac{\partial \psi}{\partial x} < 0$ for all $x \leq v(m^h) - m^h - \frac{c}{1-r}$, i.e. $\psi\left(v\left(m\right) - m - \frac{c}{1-r}\right)$ is decreasing for all possible m. Given that we know $v\left(m\right) - m < v\left(m^w\right) - m^w$ for all $m > m^w$, it follows that

$$\begin{aligned}\Pi(m) &= rW\left(m\right) - r\psi\left(v\left(m\right) - m - \frac{c}{1-r}\right)\\ &< rW\left(m^w\right) - r\psi\left(v\left(m^w\right) - m^w - \frac{c}{1-r}\right) = \Pi(m^w),\end{aligned}$$

implying $m^p \leq m^w$. ∎

Proposition A.2 *(Endogenous proportional fee) Suppose the social planner can control the platform's governance design, but cannot control the proportional fee set by the platform. There exist thresholds $\tilde{c}^l$ and $\tilde{c}^h$, where $0 < \tilde{c}^l \leq \tilde{c}^h$, such that:*

- *If $c < \tilde{c}^l$, then $m^p \geq m^{sb}$.*
- *If $c > \tilde{c}^h$, then $m^p \leq m^{sb}$.*

Proof. We first make the following two observations regarding m^{sb}:

Claim 1: For all $m > m^{sb}$, we have $\tilde{r}\left(m\right) < \tilde{r}\left(m^{sb}\right)$. By contradiction, suppose there is some $m' > m^{sb}$ such that $\tilde{r}\left(m'\right) \geq \tilde{r}\left(m^{sb}\right)$. Using these two inequalities, (12) implies $v\left(m'\right) - p_{\tilde{r}}(m') \geq v\left(m^{sb}\right) - p_{\tilde{r}}(m^{sb})$. From the welfare function, this implies

$$\begin{aligned}\tilde{W}(m') &\geq \left(\frac{c}{1-\tilde{r}(m')} + m' - c\right) Q\left(v\left(m^{sb}\right) - p_{\tilde{r}}(m^{sb})\right) + \int_{-\infty}^{v\left(m^{sb}\right) - p_{\tilde{r}}(m^{sb})} Q\left(t\right) dt\\ &> \tilde{W}(m^{sb}),\end{aligned}$$

a contradiction, which proves the claim.

Claim 2: For all $m > m^{sb}$, we have $v\left(m\right) - p_{\tilde{r}}(m) < v\left(m^{sb}\right) - p_{\tilde{r}}(m^{sb})$. By contradiction, suppose there is some $m' > m^{sb}$ such that $v\left(m'\right) - p_{\tilde{r}}(m') \geq v\left(m^{sb}\right) - p_{\tilde{r}}(m^{sb})$. Then, (15) implies $p_{\tilde{r}}\left(m'\right) > p_{\tilde{r}}(m^{sb})$. From the welfare function, this implies $W(m') > W(m^{sb})$, a contradiction, which proves the claim.

To prove the proposition suppose $c > \tilde{c}^h$, where

$$\tilde{c}^h \equiv \frac{Q(v(m^h) - m^h)}{Q'(v(m^h) - m^h)} \tag{A.2}$$

and $m^h \equiv \arg\max_m \{v(m) - m\}$. In this case, $\psi\left(x\right)$, as defined in (A.1), is decreasing for all $x \leq$

$v(m^h) - m^h$. For all $m > m^{sb}$, we have

$$\begin{aligned}
\tilde{\Pi}(m) &= \tilde{r}(m)\tilde{W}(m) - \tilde{r}(m)\psi(v(m) - p_{\tilde{r}}(m)) \\
&< \tilde{r}\left(m^{sb}\right)\tilde{W}(m) - \tilde{r}\left(m^{sb}\right)\psi(v(m) - p_{\tilde{r}}(m)) \\
&< \tilde{r}\left(m^{sb}\right)\tilde{W}(m) - \tilde{r}\left(m^{sb}\right)\psi\left(v\left(m^{sb}\right) - p_{\tilde{r}}(m^{sb})\right) \\
&< \tilde{r}\left(m^{sb}\right)\tilde{W}(m) - \tilde{r}\left(m^{sb}\right)\psi\left(v(m^h) - m^h\right) \\
&= \tilde{\Pi}(m^w).
\end{aligned}$$

where the first inequality is due to Claim 1, the second inequality is due to Claim 2, and the last inequality is due to $v\left(m^{sb}\right) - p_{\tilde{r}}(m^{sb}) = v\left(m^{sb}\right) - m^{sb} - \frac{c}{1-r} \leq v(m^h) - m^h$ (by Claim 2 and the definition of m^h). We conclude that $m^p \leq m^{sb}$.

To establish the existence of the lower threshold $\tilde{c}^l$, it suffices to consider the case of $c \to 0$. When $c \to 0$, we first note that $\psi(x)$, as defined in (A.1), is increasing for all x. Moreover, $c \to 0$ implies (12) $\tilde{r}(m) \to 1$ and $\tilde{\Pi}(m) \to mQ(v(m) - m)$, which implies that $v(m) - m < v(m^p) - m^p$ for all $m > m^p$ (otherwise m^p is not a maximizer). So,

$$\begin{aligned}
\tilde{W}(m) &\to \tilde{\Pi}(m) + \psi\left(v(m) - m - \frac{c}{1-r}\right) \\
&\leq \tilde{\Pi}(m) + \psi\left(v(m^p) - m^p - \frac{c}{1-r}\right) \leq W(m^p)
\end{aligned}$$

for all $m > m^p$, implying $m^{sb} \leq m^p$. ■

B Derivations of Examples 1-3

This section provides the derivations of the examples in Section 2. In what follows, we do not specify the exact fee instrument used by the platform. Instead, we focus on deriving how the platform's governance design influences the buyer-seller interactions in each of the examples.

B.1 Example 1: Variety choice by the platform

Example 1 can be summarized with the following timing: (i) The platform announces the number of sellers $N - a$ that it will admit; (ii) Sellers and buyers decide whether to enter the platform; (iii) Sellers set their prices; (iii) $N - a$ sellers are admitted, and the buyer observes the prices and match values of these sellers and purchases accordingly. We focus on symmetric pure strategy Nash equilibrium in which all sellers set the same price p (for any $N - a$ chosen by the platform).

Let Q be the number of participating buyers, which is exogenous from individual sellers' point of view. To derive seller pricing, consider a deviating seller i who sets price $p_i \neq p$. For each seller, the effective demand is

$$\begin{aligned}
&\Pr\left(x_i - p_i \geq \max_{j \neq i}\{x_j - p\}\right) \\
= &\int_{-\infty}^{\infty}(1 - F(x - p + p_i))\, dF(x)^{N-a-1}.
\end{aligned}$$

The demand for seller i's product is

$$Q_i(p_i) = Q \times \int_{-\infty}^{\infty}(1 - F(x - p + p_i))\, dF(x)^{N-a-1}.$$

From the profit function $(p_i - c) Q_i(p_i)$, we can derive the symmetric equilibrium price as

$$p = c + M(a) \equiv c + \frac{1}{(N-a)\int_{-\infty}^{\infty} f(x)\, dF^{N-a-1}(x)}.$$

B.2 Example 2: Information design by the platform

Example 2 can be summarized with the following timing: (i) The platform announces the information structure parameterized by $a \in [0,1]$; (ii) Sellers and buyers decide whether to enter the platform; (iii) Sellers set their prices; (iii) Each buyer observes the realized signal and prices and purchases accordingly.

Let $\bar{s}$ be the signal received by the buyer who is indifferent between seller 1 and 2, i.e., $p_1 + t\mathbf{E}(x_1|\bar{s}) = p_2 + t\mathbf{E}(x_2|\bar{s})$, or $\bar{s} = \frac{1}{2} + \frac{p_2 - p_1}{ta}$. Given s is drawn from uniform distribution over $[0,1]$, seller 1's demand is $\Pr(s < \bar{s}) = \frac{1}{2} + \frac{p_2 - p_1}{ta}$. Therefore, the price competition is the same as Example 1, except that the transportation cost parameter is replaced by ta. It follows that $p = c + ta$. To ensure that the market is fully covered, we assume $V_0 - t\mathbf{E}(x_1|s = 1/2) - p > 0$ for all a, or $V_0 > c + \frac{3t}{2}$.

From a buyer's ex-ante perspective, with probability a the signal is informative and the buyer gets the preferred product, with expected mismatch cost $t/4$; With probability $1-a$ the signal is uninformative so that the buyer effectively gets a randomly chosen product, with expected mismatch cost $t/2$; Hence, the ex-ante expected mismatch cost is $\frac{t(2-a)}{4}$, as stated in the main text.

B.3 Example 3: Quality control by the platform

Example 3 can be summarized with the following timing: (i) The platform announces a; (ii) Buyers and sellers decide whether to enter the platform; (iii) Sellers with $q_i \geq 1-a$ set their prices, and buyers who have has entered the platform carry out sequential search. We focus on symmetric perfect Bayesian equilibria (PBE) in which all sellers set the same price p. As is standard in the search literature, buyers keep the same (passive) beliefs about the distribution of future prices on and off the equilibrium path.

The following derivation follows from Eliaz and Spiegler (2011). We first derive buyers' search strategy for each given a set by the platform. Define the reservation value $V(a)$ as the solution to

$$\mathbf{E}(q_i|q_i \geq 1-a) \int_V^{\bar{\epsilon}} (\epsilon - V)\, dF(\epsilon) = s. \tag{B.1}$$

The left-hand side of (B.1) represents the incremental expected benefit from one more search, while the right-hand side represents the incremental search cost. There is, at most, one solution to (B.1), since the left-hand side is strictly decreasing in v.

It is well known in the consumer search literature (Wolinsky, 1986; Anderson and Renault, 1999) that buyers' optimal search rule in this environment is stationary and described by the standard cutoff rule. When searching, each buyer employs the following strategy: (i) she stops and buys form seller i if the product is not defective and $\epsilon_i - p_i \geq V(a) - p$; and (ii) she continues to search the next seller otherwise. Following the standard result, the buyer's expected surplus from initiating a search is $V(a) - p$. Then, a buyer with intrinsic participation cost d enters the platform if and only if $d < p - V(a)$. Provided that search cost is not too large, there is a symmetric price equilibrium in which a strictly positive measure of buyers join the platform.

Compared with a standard search model, notice from (3) that a search pool with a higher expected quality $\mathbf{E}(q_i|q_i \geq 1-a)$ is analogous to a lower effective search cost for buyers. This reflects that each buyer searches less and consequently incurs a lower total expected search cost of $s/\mathbf{E}(q_i|q_i \geq 1-a)$ before reaching a non-defective match. Given that $\mathbf{E}(q_i|q_i > 1-a)$ decreases with a, a more relaxed quality standard set by the platform is analogous to increasing the effective search cost of buyers. Thus, it follows that $V(a)$ is a decreasing function of a.

From the buyer search rule above, the derivation of demand is straightforward. The mass of buyers initiating search is $Q(V(a)-p)$, which is exogenous from each firm's point of view. Conditional on these buyers, the demand of a deviating firm i with type q_i follows the standard search model and is given by

$$q_i\left(1-F\left(V\left(a\right)-p+p_i\right)\right)\sum_{z=0}^{\infty}F\left(V\left(a\right)\right)^z=\left(\frac{1-F\left(V\left(a\right)-p+p_i\right)}{1-F\left(V\left(a\right)\right)}\right)q_i.$$

The log-concavity assumption on $1-F$ ensures that the usual first-order condition determines a unique optimal price. The symmetric equilibrium price is given by $p=c+\frac{1-F(V(a))}{f(V(a))}$.

C Endogeneity of fee instrument

We prove Proposition 7 stated in the main text. Recall that the platform's optimal fee instrument is a two-part tariff with a subsidy on buyer participation. It optimally sets its governance design at $m^{p+}=m^*$ to maximize $v\left(m\right)$ and then adjusts the transaction-based fee components and the buyer-side participation subsidies accordingly to achieve the maximal monopoly profit, which we denote as $\Pi^*\equiv(p^*\left(m^*\right)-c)Q\left(v\left(m^*\right)-p^*\left(m^*\right)\right)$.

Meanwhile, the social planner optimally restricts the platform to charge sellers a pure lump-sum participation fee. Notice that allowing the platform to impose participation fees on both sellers and buyers is ineffective, because the platform would set a positive buyer participation fee in an attempt to replicate Π^*, which results in deadweight losses. The welfare function under the restriction of seller participation fees is

$$\tilde{W}\left(m\right)=mQ\left(v\left(m\right)-m-c\right)+\int_{-\infty}^{v(m)-m-c}Q\left(t\right)dt.$$

For all $m>m^*$, we have

$$\begin{aligned}\tilde{W}\left(m\right) &\leq mQ\left(v\left(m^*\right)-m-c\right)+\int_{-\infty}^{v(m^*)-m-c}Q\left(t\right)dt\\ &< m^*Q\left(v\left(m^*\right)-m^*-c\right)+\int_{-\infty}^{v(m^*)-m^*-c}Q\left(t\right)dt\\ &= \tilde{W}\left(m^*\right),\end{aligned}$$

which implies $m^{sb+}\leq m^*=m^{p+}$.

D Costly governance

The analysis in this section corresponds to Section 6.2 of the main text. We focus on extending the results in Section 4 to the case in which the platform's fixed cost is an increasing and convex function $K=K(v(m))\geq 0$. Denote $k\geq 0$ as the derivative of K with respect to its argument, where k is increasing by the convexity assumption.

Proposition D.1 *(Endogenous per-transaction fees) If value and markup are always positively correlated, then Proposition 3 continues to hold.*

Proof. If we rewrite the profit function in terms of price, we have

$$\tilde{\Pi}\left(m\right)=(p_{\tilde{\tau}}(m)-c-m)Q\left(v\left(m\right)-p_{\tilde{\tau}}(m)\right)-K(v(m)),$$

where $p_{\tilde{\tau}}(m)$ is implicitly defined by $p_{\tilde{\tau}}(m) = c + m + \frac{Q(v(m)-m-c-\tilde{\tau})}{Q'(v(m)-m-c-\tilde{\tau})}$. Recall that the log-concavity of Q implies that $v(m) - p_{\tilde{\tau}}(m)$ is increasing in m if and only if $v(m) - m$ is increasing in m.

We first claim that $v(m) - p_{\tilde{\tau}}(m) \leq v(m^p) - p_{\tilde{\tau}}(m^p)$ for all $m < m^p$. By contradiction, suppose there is some $m' < m^p$ such that $v(m') - p_{\tilde{\tau}}(m') > v(m^p) - p_{\tilde{\tau}}(m^p)$; then the definition of $p_{\tilde{\tau}}$ implies $p_{\tilde{\tau}}(m') - m' > p_{\tilde{\tau}}(m^p) - m^p$. Given that $v(m)$ is increasing, $K(v(m')) \leq K(v(m^p))$, and so

$$\begin{aligned} \tilde{\Pi}(m') &> (p_{\tilde{\tau}}(m^p) - c - m^p)Q(v(m^p) - p_{\tilde{\tau}}(m^p)) - K(v(m')) \\ &\geq \tilde{\Pi}(m^p), \end{aligned}$$

which contradicts the definition of m^p being a maximizer. Hence, the claim is proven.

From the welfare function,

$$\tilde{W}(m) = \tilde{\Pi}(m) + mQ(v(m) - p_{\tilde{\tau}}(m)) + \int_{-\infty}^{v(m)-p_{\tilde{\tau}}(m)} Q(t)\,dt.$$

the proven claim implies $\tilde{W}(m) < \tilde{W}(m^p)$ for all $m < m^p$, implying $m^{sb} \geq m^p$. The final step in ruling out the equality is the same as the corresponding step in the proof of Proposition 3, and hence omitted here. ■

Proposition D.2 *(Endogenous proportional fee) Suppose the social planner can control the platform's governance design, but cannot control the proportional fee set by the platform. Suppose welfare function (D.1) is unimodal, and denote*

$$\tilde{\Psi}(m) \equiv \frac{\left(\frac{p_{\tilde{r}}}{\tilde{r}} + \frac{K}{\tilde{r}^2}\right)\frac{d\tilde{r}}{dm}}{\frac{dp_{\tilde{r}}}{dm} - \frac{dv}{dm}}.$$

- *Suppose $c \leq \frac{Q(v(m^p)-p_{\tilde{r}}(m^p))}{Q'(v(m^p)-p_{\tilde{r}}(m^p))}(1+\tilde{\Psi}(m^p))$. If value and markup are always negatively correlated, then $m^p \geq m^{sb}$.*
- *Suppose $c \geq \frac{Q(v(m^p)-p_{\tilde{r}}(m^p))}{Q'(v(m^p)-p_{\tilde{r}}(m^p))}(1+\tilde{\Psi}(m^p))$. If value and markup are always positively correlated, then $m^p \leq m^{sb}$.*

Proof. Recall

$$\tilde{\Pi}(m) = \tilde{r}(m)\,p_{\tilde{r}}(m)Q(v(m) - p_{\tilde{r}}(m)) - K(v(m)),$$

where $p_{\tilde{r}}(m)$ is defined in (15). The welfare function is

$$\begin{aligned} \tilde{W}(m) &= (p_{\tilde{r}}(m) - c)Q(v(m) - p_{\tilde{r}}(m)) - K(v(m)) + \int_{-\infty}^{v(m)-p_{\tilde{r}}(m)} Q(t)dt \qquad \text{(D.1)} \\ &= \frac{\tilde{\Pi}(m) + K(v(m))}{\tilde{r}(m)} - K(v(m)) - cQ(v(m) - p_{\tilde{r}}(m)) + \int_{-\infty}^{v(m)-p_{\tilde{r}}(m)} Q(t)dt \end{aligned}$$

and

$$\frac{d\tilde{W}}{dm} = \frac{1}{\tilde{r}}\frac{d\tilde{\Pi}}{dm} + \left(\frac{1-\tilde{r}}{\tilde{r}}\right)k\frac{dv}{dm} + \left(\frac{Q}{Q'}(1+\tilde{\Psi}(m^p)) - c\right)\left(\frac{dv}{dm} - \frac{dp_{\tilde{r}}}{dm}\right)Q'.$$

Suppose $c \leq \frac{Q(v(m^p)-p_r(m^p))}{Q'(v(m^p)-p_r(m^p))}(1+\tilde{\Psi}(m^p))$ and $\frac{dv}{dm} \leq 0$ for all m. Lemma 4 implies $\frac{dv}{dm} - \frac{dp_{\tilde{r}}}{dm} \leq 0$. Hence, $\frac{d\tilde{W}}{dm}|_{m=m^p} \leq 0$ whenever $\frac{d\tilde{\Pi}}{dm}|_{m=m^p} = 0$ and $\frac{d\tilde{W}}{dm}|_{m=m^p} < 0$ whenever $\frac{d\tilde{\Pi}}{dm}|_{m=m^p} < 0$. The unimodality of $\tilde{W}(m)$ implies $m^{sb} \leq m^p$ as required.

Suppose $c \geq \frac{Q(v(m^p)-p_r(m^p))}{Q'(v(m^p)-p_r(m^p))}(1+\tilde{\Psi}(m^p))$ and $\frac{dv}{dm} \geq 0$ for all m. If $(\frac{dv}{dm} - \frac{dp_{\tilde{r}}}{dm})|_{m=m^p} \leq 0$, then we have $\frac{d\tilde{W}}{dm}|_{m=m^p} \geq 0$ whenever $\frac{d\tilde{\Pi}}{dm}|_{m=m^p} = 0$, and $\frac{d\tilde{W}}{dm}|_{m=m^p} > 0$ whenever $\frac{d\tilde{\Pi}}{dm}|_{m=m^p} > 0$. These imply

$m^{sb} \geq m^p$. Suppose instead that $(\frac{dv}{dm} - \frac{dp_{\tilde{r}}}{dm})|_{m=m^p} > 0$; then we get from (D.1):

$$\frac{d\tilde{W}}{dm}|_{m=m^p} = (p_{\tilde{r}}(m) - c)Q' \left(\frac{dv}{dm} - \frac{dp_{\tilde{r}}}{dm}\right)|_{m=m^p} + (Q-k)\frac{dv}{dm}|_{m=m^p} > 0,$$

and the unimodality of $\tilde{W}(m)$ implies $m^{sb} \geq m^p$. ■

Proposition D.3 *(lump-sum fees) If value and markup are always negatively correlated, then Proposition 5 continues to hold.*

Proof. The platform's profit is $\tilde{\Pi}(m) = mQ(v(m) - m - c) - K(v(m))$, while the welfare function is

$$\tilde{W}(m) = \tilde{\Pi}(m) + \int_{-\infty}^{v(m)-m-c} Q(t)dt.$$

We first claim that $v(m) - m \leq v(m^p) - m^p$ for all $m > m^p$. By contradiction, suppose there is some $m' > m^p$ such that $v(m') - m' > v(m^p) - m^p$. Given that $v(m)$ is decreasing, $K(v(m')) \leq K(v(m^p))$, and so $\tilde{\Pi}(m') > m^p Q(v(m^p) - m^p) - K(v(m')) \geq \tilde{\Pi}(m^p)$, which contradicts the definition of m^p being a maximizer thus proving the claim.

From the welfare function, the proven claim implies that $\tilde{W}(m) < \tilde{W}(m^p)$ for all $m > m^p$, and so we have $m^{sb} \leq m^p$, as required. The final step in ruling out the equality is the same as the corresponding step in the proof of Proposition 5, and hence omitted here. ■

Proposition D.4 *(Two-part tariff) If value and markup are always negatively correlated, then Proposition 6 continues to hold.*

Proof. Recall from the proof of Proposition 6 that we denote the profit-maximizing induced price as $\tilde{p}(m) = \max\{m + c, p^*(m)\}$ (the existence of the fixed cost does not affect the optimal pricing). Denote

$$\begin{aligned} m_k^* &\equiv \arg\max_m \tilde{\Pi}(m) \\ &= \arg\max_m \{(p^*(m) - c)Q(v(m) - p^*(m)) - K(v(m))\}. \end{aligned}$$

Similar to the proof of Proposition 6, we denote $\hat{m}$ as the solution to $\hat{m} + c = p^*(\hat{m})$. By construction, $\tilde{p}(m) = p^*(m)$ for all $m > \hat{m}$ given that $v(m)$ is decreasing for all m.

Case 1. If $c \leq p^*(m_k^*) - m_k^*$, then $p^*(m_k^*)$ is implementable. We know by the envelope theorem that $\tilde{\Pi}(m)$ is maximized at $m^p = m_k^*$. For all $m > m^p$, we know $\tilde{p}(m) = p^*(m)$ because $m^p = m_k^* > \hat{m}$. We first claim that $v(m) - p^*(m) \leq v(m^p) - p^*(m^p)$ for all $m > m^p$. By contradiction, suppose there is some $m' > m^p$ such that $v(m') - p^*(m') > v(m^p) - p^*(m^p)$; then the definition of p^* implies $p^*(m') > p^*(m^p)$. Therefore,

$$\begin{aligned} \tilde{\Pi}(m^p) &< (p^*(m') - c)Q(v(m') - p^*(m')) - K(v(m^p)) \\ &\leq \tilde{\Pi}(m'), \end{aligned}$$

where the second inequality is due to $K(v(m')) \leq K(v(m^p))$ given that $v(m)$ is decreasing. This contradicts the definition of m^p being a maximizer. Hence, the claim is proven. Then, from the welfare function, the proven claim implies $\tilde{W}(m) < \tilde{W}(m^p)$ for all $m > m^p$, and so we have $m^{sb} \leq m^p$.

Case 2. Suppose $c > p^*(m_k^*) - m_k^*$, then from the preceeding case we know that $p^*(m_k^*)$ is no longer implementable. Similar to the proof of Proposition 6, we know $m^p < \hat{m}$ and $\tilde{p}(m^p) = c + m^p$. We first claim that $v(m) - \tilde{p}(m) \leq v(m^p) - m^p - c$ for all $m > m^p$. By contradiction, suppose there is some

$m' > m^p$ such that $v(m') - \tilde{p}(m') > v(m^p) - m^p - c$. The definition of $\tilde{p}$ implies $\tilde{p}(m') \geq m' + c > m^p + c$. So,

$$\tilde{\Pi}(m') > (m^p - c)Q(v(m^p) - m^p) - K(v(m')) \geq \tilde{\Pi}(m^p),$$

which contradicts the definition of m^p being a maximizer. Hence, the claim is proven. Then, from the welfare function, the proven claim implies that $\tilde{W}(m) < \tilde{W}(m^p)$ for all $m > m^p$, and so we have $m^{sb} \leq m^p$. The final step in ruling out the equality is the same as the corresponding step in the proof of Proposition 6. ■

E Consumer surplus benchmark

For all given fee instruments, we know that $m^{bs} = \arg\max\{v(m) - p(m)\}$. Following the previous analysis, when the platform uses per-transaction fees (regardless of whether it is exogenous or endogenous), $m^p = \arg\max\{v(m) - p(m)\}$, so $m^p = m^{bs}$. Likewise, if the platform uses lump-sum fees, two-part tariffs, or exogenous proportional fees, from the expressions of the platform's profit function it is obvious that $m^p \geq m^{bs}$ because a higher m increases the platform's margin.

The only non-obvious case is when the platform uses endogenous proportional fees. Let $m^{bs} = \arg\max\{v(m) - p_{\tilde{r}}(m)\}$. If $m^p = \bar{m}$, then $m^p \geq m^{bs}$ trivially holds. If $m^p < \bar{m}$, then either it is an interior solution or $m^p = \underline{m}$. In both cases, from (8) we have $\frac{dv}{dm}|_{m=m^p} \leq 1 - \frac{Q}{p_{\tilde{r}}Q'}|_{m=m^p}$. Recall from Lemma 4 that $\frac{dv}{dm} - \frac{dp_{\tilde{r}}}{dm} < 0$ whenever $\frac{dv}{dm} \leq 1 - \frac{Q}{p_{\tilde{r}}Q'}$. Hence, we have $\left(\frac{dv}{dm} - \frac{dp_{\tilde{r}}}{dm}\right)|_{m=m^p} < 0$, implying $m^p \geq m^{bs}$.