Recommenders' Originals: The Welfare Effects of the Dual Role of Platforms as Producers and Recommender Systems[*]

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Abstract

We study a model of strategic interaction between producers and a monopolist platform that employs a recommendation system. We characterize the consumer welfare implications of the platform's entry into the production market. Upon entry, the platform biases recommendations to steer consumers towards its own goods, which leads to equilibrium investment adjustments by the producers and lower consumer welfare when the platform's market size is large. Furthermore, we find that a policy separating recommendation and production or imposing unbiased recommendations is not always welfare improving. Our results highlight the ability of platforms to foreclose competition through the use of biased recommender systems.

Keywords: Recommender System; Biased Intermediation; Upstream Entry; Bayesian Persuasion.

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1. Introduction

An increasing number of online platforms deploy recommender systems to assist consumers with purchase decisions by providing information on available goods, which determinedly impacts consumer choice. These systems facilitate information acquisition on product quality by consumers in environments where there are thousands or even millions of alternatives available. Existing experimental literature supplies causal evidence of these systems' immense power in steering demand, with market shares being significantly affected even by recommendation systems that supply simple information to consumers (Salganik et al. 2006). Moreover, anecdotal evidence reflects the huge influence the information provided by these systems have on consumption choices individuals make: recommendations are said to account for 75% of consumed content on Netflix and 35% of page views on Amazon (MacKenzie et al. 2013).

However, online platforms increasingly not only deploy recommender systems, but also develop and make available their own goods alongside other firms', with unclear implications to consumer welfare. Major platforms and technological leaders in the development and deployment of recommender systems – such as Amazon, Netflix and Spotify – all now develop their own goods that are then made available on their platforms: Amazon produces more than 22,000 goods that are available on the firm's platform (Davis 2020), Netflix hosts more than 2,300 "Netflix Originals" titles (Netflix 2021), and Spotify is now investing in developing its own audio content (Binder 2020).

One possible consequence of this dual role of the platforms as both a recommender system and a producer is that the platforms may systematically bias their search and recommendation systems towards their own goods. Indeed, not only is there a substantial amount of popular press coverage suggesting this,[1] there are also a number of recent legislative initiatives that appear motivated by potential abuse of this dual role, both in trying to prevent platforms in this dual role from biasing their recommendation systems in favor of their own products or in proposing the separation of the roles of recommender and pro-

[1]For instance, Creswell (2018) discusses Amazon's bias towards its own goods via recommendation and search. Grind et al. (2019) discusses how Google manipulates its search results to steer consumers. According to Carr (2013), upon release of *House of Cards*, Netflix recommended that consumers watch it regardless of their past behavior. Pandora has stated in court that it manipulates its recommendations based on the ownership of the sound recordings.

ducer.[2] While the goal of regulators is to increase consumer welfare in such markets, it is unclear whether these regulatory initiatives will ultimately harm or hurt consumers once the equilibrium effects of this recommendation bias are taken into account.

In this paper we study the welfare consequences of a platform acting as both a producer and a recommender and consider the specific role played by the deployment of a recommender system. We set up a stylized model of a pay-for-access platform where producers make investment decisions about the quality of their goods and revenue is split according to each goods' market share. Our main focus is in contrasting resulting consumer welfare, investments, and market shares across three different scenarios: the *no platform production* case, where only a good by an independent firm is available; the *platform dual role* case, where the platform can both produce a good and design recommendations, and both the platform's good and the independent firm's are available; and the *unbiased recommendations* case, where we modify the dual role case by imposing an exogenous policy that requires that recommendation be unbiased, or truthful and neutral.

Unlike other papers that study the consequences of platform steering (e.g. Hagiu and Jullien (2011); de Corniere and Taylor (2019); Teh and Wright (2020)), we model the platform's recommendation as providing information on product quality to consumers as opposed to directly influencing the search order or choosing the consumed product for a fraction of consumers. Producers have access to stochastic investment technology that affects the likelihood that goods turn out to be of high versus low quality. Consumers' prior beliefs on product quality stem from the observed investments, and update their beliefs on each product's quality based on the recommendation policy of the platform. This allows us to build credibility of recommendation directly into our model, where the platform's ability to steer the behavior of rational and Bayesian consumers is naturally limited and depends on the design of its recommendations.

In our model, the revenue generated by the platform is based on pay-for-access and producers are compensated according to their (expected) consumption share. We believe this captures the fundamental elements that platforms in this dual role face (e.g. Spotify,

[2] An example of tackling possible biases in recommendations is the European Commission's legislative proposal called "Digital Markets Act" (European Commission 2020), whereas the recent bill H.R. 3825 - "Ending Platform Monopolies Act" proposed to the House of Representatives of the United States aims to terminate situations of this dual role altogether (U.S. House. 117th Congress, 1st Session 2021).

Netflix), and constitutes one of the primary drivers in motivating the platforms to bias recommendations towards their own goods. Additionally, as a reduced-form proxy for the extent to which the independent firm is reliant on the platform for revenues, we allow the independent firm to have access to alternative sources of revenue, and characterize their impact on equilibrium investment decisions and consumer welfare. For instance, movie producers can garner revenues from movie theaters or sales of DVDs, and independent producers on e-commerce platforms can earn revenues from brick-and-mortar stores. We show that the degree to which the independent firm depends on the platform as its main source of revenue is decisive for whether the platform's dual role has a positive or a negative effect on consumer welfare.

We first consider the extent to which the platform's entry into the upstream production market influences investment levels and overall consumer welfare. We show that, despite increasing competition, the platform's entry results in lower quality investments and lower welfare when the independent firm is heavily dependent on the platform. However, we find that if the alternative sources of revenue are sufficiently large, the platform's entry increases consumer welfare.

The resulting differences in consumer welfare are driven by two opposing forces on changes in investment levels that result from the platform's entry. On the one hand, compared to when the independent firm is the sole producer, the dual role of the platform leads the independent firm to get a smaller share of the total platform revenue and, therefore, the independent firm only receives a fraction of its marginal impact on total platform revenue – opposite to the case where it is the sole producer. On the other hand, additional investment by the independent firm increases not only the total platform revenue but also the independent firm's market share, which expands the marginal return to investment relative to the sole producer case. These two opposing forces generate a threshold effect: for investment levels below a given threshold, the independent firm's marginal return to investment is weaker in the dual role case than in the no platform production setting, but it is stronger above that threshold. This directly leads to a threshold result for the investment levels of the independent firm in terms of its reliance on the platform as its main source of revenue: When the independent firm overly relies on revenue obtained from the platform, the platform's dual role effectively depresses its incentives to invest in quality, resulting in lower consumer welfare; if instead it has access to other sources of revenue that are significant enough, the independent firm invests more strongly than when it is the sole producer, driving up consumer welfare.

Another important consequence of the platform's dual role is the possibility of vertical foreclosure. This manifests itself in several ways. When the alternative revenue sources are small, the platform may find it profitable to become the product-quality leader. Then, due to to the ability to bias recommendations towards its own products, it completely drives demand away from its competition, capturing the entire demand on the platform. Although this is a sharp prediction, it echoes recent trends in video streaming markets, where platforms' original content quality – as indicated by awards received – has notably risen while their own content has simultaneously dominated platform viewership. When the independent firm's revenue sources are large enough compared to the platform's revenue potential, the platform becomes a product-quality follower. Even then, the platform can still partially foreclose the independent firm by biasing recommendations in favor of its own goods, enabling it to achieve a higher market share and profit than otherwise.

We then explore a natural policy remedy: ensuring that the platform cannot simultaneously provide recommendation services and produce goods; or, equivalently, a policy that prevents the platform from biasing recommendations towards its own goods. Although it would be reasonable to expect an unambiguous improvement in consumer welfare, we find that, this policy can actually harm consumers under certain conditions. There are two observations that lead to this result. The first is that, imposing unbiased recommendations results in a lower marginal gain in market share from increasing investment for both the independent firm and the platform. The second is that total platform revenue is now more responsive to platform investment, but less responsive to firm investment. Combined, these two observations again lead to a threshold result in terms of the how much the independent firm relies on the platform relative to alternative sources of revenue. When other sources of revenue are meager, unbiased recommendations are consumer welfare improving; but, if these are large enough, imposing unbiased recommendations lowers welfare when compared to the platform-optimal biased recommendations.

Our results illustrate how platforms entering the upstream production market benefit from biasing recommendations. However, the resulting distortion from this entry does not necessarily harm consumers, as it may spur other producers to invest more aggressively in product quality to counter not only increased product competition, but especially recommendation bias. An important element to consider is how dependent the other producers are on revenues from the platform. Only when this dependence is significant will policies targeting bias in recommender systems or separating recommendation and production altogether have a positive effect on consumer welfare. This suggests caution when considering policy interventions – the bias in recommender system may be inducing independent firms to produce higher quality goods than what they otherwise would. Indeed, our results provide a rationale for the stipulations of the *Ending Platform Monopolies Act* that ends the dual role only for dominant, "gatekeeper" firms. In such cases the welfare effect for consumers is likely to be positive, whereas for smaller platforms it will have an ambiguous or lesser effect.

Related Work

Our paper lies in the intersection of three different literatures: biased intermediation, recommender systems and, more broadly, vertical integration and foreclosure.

The most relevant literature that our paper fits into is the nascent biased intermediation literature and, more generally, biased information provision. This literature emerged from the traditional intermediation and two-sided market (Rubinstein and Wolinsky 1987; Rochet and Tirole 2003) and focuses on the incentives of an intermediary to bias consumers' consumption decisions. However, while the majority of the literature focuses on the consequences of an intermediary manipulating the search process of a user, we instead model the intermediary as providing information to consumers. The intermediary in our model, the recommender, is thus an information designer as in the Bayesian persuasion literature (Kamenica and Gentzkow 2011; Bergemann and Morris 2019). This has two main advantages. The first is that it provides a more accurate model of how recommender systems function, where recommendations are used to provide imperfectly informed consumers with information about goods on the platform whose true consumption values are only learned from experience. The second is that it builds in restrictions on the credibility of the recommendations allowing for us to study the possibilities and investment consequences of bias even with sophisticated consumers.

Within this literature, the papers closest to ours are Bourreau and Gaudin (2018), de Corniere and Taylor (2019) and Hagiu and Jullien (2011). Bourreau and Gaudin (2018) study the incentives of a pay-for-access platform to bias their recommendation in order to reduce the market power of the upstream content providers. They also consider that the payouts between the producers and the platforms are split via royalty fees that depend on consumer's consumption choices. However, they focus on perfectly horizontal preferences with fixed good location, whereas our model considers the effect that platform recommendation bias has on quality investments. de Corniere and Taylor (2019) study a model of biased intermediation where the recommendation is sold through an auction while Hagiu and Jullien (2011) examine a setting where consumers perform costly and sequential search and the intermediary directs the consumers to a seller; in both cases, uniformed consumers naively follow the recommendation, without any credibility constraint. In contrast, our model imposes discipline on recommendation so that the recommender has to be credible as consumers are assumed to be rational and Bayesian. Additionally, in our model recommendation depends on investment levels, and both are endogenously determined. Other related papers – where investment decisions are absent – focus on price competition among sellers on the platform (Armstrong et al. 2009), advertising and search (Hagiu and Jullien 2014; Burguet et al. 2015; de Cornière 2016) and commission and price setting (Inderst and Ottaviani 2012a; 2012b, Teh and Wright 2020).

Naturally, this paper contributes to the literature on recommender systems which analyzes the economic consequences of recommendation on consumer choice, pricing and sales. The most relevant paper to ours is Bergemann and Ozmen (2006), which analyzes model with horizontally differentiated products where a platform with a recommender system competes with a fringe of distribution channels without such system. In this paper, the recommender's information advantage is modeled as deriving observing past users' experience in a two-period model and consumers are able to obtain a recommendation at no cost. Opposite to our model, the emphasis in this paper is on the optimal pricing by the recommender and investment decisions are absent as all firms are intermediaries selling the same products. Other, less related works are Che and Hörner (2017), Fleder and Hosanagar (2009), and Hosanagar et al. (2008). Che and Hörner (2017) characterizes the optimal information provision by a welfare maximizing recommender that learns a product's quality through consumer feedback. Fleder and Hosanagar (2009) discuss the role that recommender systems can play in diversifying sales due to their personalized nature, but do not endogenize production or consider incentives to bias recommendation. Hosanagar et al. (2008) examines how a recommender would trade-off between optimizing for profit and maintaining reputation amongst consumers, but do not consider good investment or platform production.

Finally, our paper broadly contributes to a classic literature in industrial organization that studies vertical integration, upstream entry and investment (Grossman and Hart 1986; Williamson 1971; Perry 1989), and vertical foreclosure (Hart et al. 1990; Ordover et al. 1990). We are most interested in the dual role of platforms as producers – upstream entry – and information providers, which has not received as much attention in the literature. Two papers that look at related problems are Asker and Bar-Isaac (2020) – studying the role of vertical information restraints in a retail market that involves search frictions with a focus on understanding minimum advertising price restrictions – and Janssen and Shelegia (2015), who introduces a vertical industry structure into a consumer search model where consumers are uninformed about wholesale prices. These papers are complementary to ours, but, to our knowledge, we are the first to study the integration of recommendation and production. In particular, we analyze how this integration can lead to a novel form of vertical foreclosure: shifting market share from the non-integrated producers to the integrated producers by biasing the information that is revealed to rational, Bayesian consumers.

The remainder of the paper is structured as follows: Section 2 provides the setup for the model. The impact of the platform's dual role on equilibrium investment decisions and consumer welfare consequences is analyzed in Section 3. In Section 4, we explore the value of recommendation and characterize the equilibrium welfare consequences of a policy that imposes unbiased recommendations. We discuss the robustness of the results to the different assumptions in Section 5, before concluding with some final remarks in Section 6. Proofs are omitted from the main text and can be found in Appendix A.

2. Model Setup

Production. There are two firms, the independent firm F and the platform P. We consider two cases: one in which only F, the independent firm, makes production decisions, and another where both F and P make production decisions. In the case where both F and P make production decisions, we suppose that the independent firm's investment q_F is observable by the platform before deciding its investment. We argue that this timing assumption is realistic as platforms are usually second-movers in production decisions. However, as we discuss in Section 5, our conclusions do not rely on this: a setting where production decisions are simultaneous yields the same qualitative results.

We denote by J the set of firms making production decisions. Each firm $j \in J$ produces a single good x_j, which is either of high quality, $x_j = 1$, or low quality, $x_j = 0$. The realized quality of the goods ultimately produced (x_j) is stochastic and depends on the firms' investments. Each firm initially makes investment decisions $q_j \in [0,1]$ which determine the probability that the realized quality of the good is high, that is, $q_j = \mathbb{P}(x_j = 1)$. This need not be taken as pure vertical differentiation: high quality can be interpreted as idiosyncratic to a given consumer and q_j then refers to the probability that a given consumer will enjoy the product and deem it high quality. For simplicity, we assume that firms face a quadratic cost to this investment in (stochastic) quality: $C_j = q_j^2$.

Good Distribution. We focus on a subscription-based pricing model, which is ubiquitous in many markets where recommender systems are widely deployed – such as media streaming or news platforms. Firm P serves as a platform for consumers in the market to access the goods produced. It sets a single price τ, a subscription fee, that consumers need to pay in order to gain access to the platform. Once on the platform, consumers can choose which of the available goods to consume without incurring additional cost.

Consumers. All consumers prefer high-quality goods to low-quality goods, but vary in their willingness-to-pay. Consumer i's utility from joining the platform ($e_i = 1$), consuming good x and paying access fee τ is given by $u(x,\theta_i,\tau) = \theta_i x - \tau$, where θ_i denotes consumer

i's willingness-to-pay for high quality goods; not joining the platform ($e_i = 0$) gives the consumer zero utility. Consumers' willingness-to-pay θ_i is uniformly distributed on $[0, \bar{\theta}]$, and its distribution function is denoted by G. Consumers maximize expected utility and we assume they are well-informed and are able to observe firms' investments prior to deciding whether to access the platform and which good to consume. Finally, we denote by M_P the measure of consumers that access the produced goods exclusively through the platform; for simplicity we denote a given consumer as $i \in [0, M_P]$.

Recommendation Policy. We model platform recommendations as providing consumers with information on the realized product qualities. We define a recommendation policy ρ as a mapping from the set of possible states, the realized product qualities $\{0,1\}^J$, to distributions over an arbitrary message space $\mathscr{M}$. The platform then acts as an information designer who chooses to a recommendation policy before the quality of goods x_P and x_F is realized. Upon observing the realized message, consumers update their beliefs on the quality of the goods and choose the one that maximizes their expected utility.

Although allowing the platform to commit to a recommendation policy is ultimately a simplifying modeling device, commitment is a common and arguably well-grounded assumption in the literature in economics and computer science studying strategic interactions between recommender systems and Bayesian consumers (Che and Hörner 2017; Kremer et al. 2014; Mansour et al. 2015): Not only can it be justified by the need for credibility in the context of repeated interactions, but also by the fact that existing recommender systems are stable deployed algorithms which imply commitment to a predefined recommendation strategy.

We focus on the role of recommendations as being utilized purely for steering subject to the constraint of rational, Bayesian consumers. For that purpose, we will assume that consumers' decision whether to enter the platform occurs prior to the choice of a recommendation policy by the platform. This timing is not devoid of justification: consumers' decision to join the platform or not is arguably more stable when compared to the more frequent adjustment of recommendation systems, taking as given (and make use of the information from) the pool of consumers on the platform.

Revenue Sources Outside the Platform. We suppose that firm P only gets revenue from the platform itself, as is common for private-label goods – "recommender's originals" such as Netflix's, Spotify's, Hulu's, where their good is only available on their own platform. Contrastingly, we allow the independent producer, F, to obtain additional revenue streams off the platform, R_F, depending implicitly on its investment in quality. We interpret these additional revenue as the reliance of the independent firm on the platform revenues. This can be seen as a reduced-form proxy for revenues from offline alternatives to the online platform. For instance, in the case of Spotify, this could be the revenue achieved from concerts or album purchases; for Netflix, it could be the revenue achieved from movie theaters. In order to study how equilibrium and consumer welfare change as the strength of the outside option for the producing firms increases we parameterize $R_F = r_F \cdot q_F$ with $r_F > 0$. We interpret the parameter r_F as the size or relevance of this alternative market in which firm F operates.[3] We discuss the robustness of our results to the existence of alternative revenue sources for the independent firm in Section 5.

Revenue on the Platform. The platform revenue R_P will depend on the recommendation policy, pricing and quality investments of both firms. We suppose that it is split between the platform and the independent firm according to their expected consumption share on the platform, which we denote as α_P and α_F. This split rule can be interpreted as the reduced form of a linear contract agreed to by the platform and the independent producer where the independent producer gets a royalty fee for each consumer that consumes her good. This type of contractual relationship is common on pay for access platforms – e.g. Spotify pays musicians a royalty in accordance with the number of times their song is played on the platform, and on YouTube Premium the membership fees are distributed based on how many members watch a producer's content. We take this split rule as an exogenous industry benchmark and study its consequences.

[3] If consumers preferences in this unrelated market are also quasilinear and their willingness-to-pay is uniformly distributed on $[0,\hat{\theta}]$, then were firm F a monopolist in such market optimally setting a uniform price given the chosen investment level, one would have that the generated revenue would be $r_F \cdot q_F$, with $r_F = M_F \cdot \hat{\theta}/4$.

The overall expected payoffs for each firm is therefore given by:

$$\pi_P = \alpha_P \cdot R_P - C_P$$
$$\pi_F = \alpha_F \cdot R_P + R_F - C_F,$$

where the dependence on investment levels, recommendation policy, and access fee is implicit.

Timing. In line with the setup defined above, the timing of events in the model is summarized as follows:

1. Production decisions are made.
2. The platform determines access fee τ and consumers decide whether to join the platform or not, resulting in revenue R_P.
3. The platform commits to a recommendation policy.
4. True good qualities realize.
5. The platform makes recommendations.
6. Consumers decide which good to consume conditional on investment probabilities and platform recommendation.
7. The independent firm and the platform split the platform revenue according to their consumption share, and the independent firm accrues outside revenue R_F.

Other variations on the timing are discussed in Section 5.

3. Consequences of the Platform's Dual Role

In this section we study the consequences of the platform's dual role. We contrast the case where only the independent firm's good is available on the platform to the equilibrium in the case where the platform can itself choose to produce a good and steer consumers via its recommender system.

3.1. No Platform Production

We first consider the case where the independent firm is the sole producer in the market. The timing is the same, but the platform does not make production decisions. As there is only one good available on the platform and the platform does not observe product quality before consumers make the decision to join the platform, there is no scope for recommendation policy to impact consumers' valuation of paying to access the platform.

We assume that pricing is still profit maximizing.[4] The expected value of subscribing to the platform for a consumer of type θ is then $\mathbb{E}u(x,\theta,\tau) = \theta\mathbb{E}[x] - \tau$, where in the case we are analyzing we have the expected quality of the consumed good is $\mathbb{E}[x] = \mathbb{E}[x_F] = q_F$. A consumer of type θ then subscribes to the platform whenever $\mathbb{E}u(x_F,\theta,\tau) \geq 0$,[5] and therefore

$$e_i = \mathbf{1}_{\theta_i \geq \tau/\mathbb{E}[x_F]}.$$

The platform's pricing problem is then

$$\tau \in \arg\max_{t\geq 0} M_p \cdot t \cdot \int_0^{\bar{\theta}} e_i \, dG(\theta) = \arg\max_{t\geq 0} t \cdot \left(1 - G\left(\frac{t}{q_F}\right)\right)$$

Given the uniform distribution assumption, the pricing problem is equivalent to

$$\tau \in \arg\max_{t\geq 0} t \cdot \left(1 - \frac{t}{\bar{\theta} q_F}\right)$$

with solution $\tau = \frac{1}{2}\bar{\theta} q_F$. This implies that $R_P = \frac{M_P \cdot \bar{\theta}}{4} q_F$.

We define $r_P := \frac{M_P \cdot \bar{\theta}}{4}$, so that $R_P = r_P \cdot q_F$. The parameter r_P represents the total potential revenue that can be accrued on the platform. Both r_P and r_F can be taken as reduced form measures of market size and relative comparison between the two provides us with a notion of the relative dependence of the independent firm on the platform. The impli-

[4]Although the platform has no incentive to set profit maximizing prices in the current setup, as it effectively accrues no revenue, it can be seen – and indeed it is – the limit case of a related setup where the platform gets a fixed share s of the overall revenue, where this share is arbitrarily small. This analysis of this exact case yields the same qualitative results.

[5]Although the tie-breaking rule favors subscribing, this is not consequential for investment decisions as types are continuously distributed.

cations of the platform's dual role will crucially depend on how large the platform market size is relative to alternative markets available to the independent firm.

The firm's production decision problem is then given by

$$\begin{aligned} &\max_{q_F \in [0,1]} \alpha_F \cdot R_P + R_F - C_F \\ &= \max_{q_F \in [0,1]} r_P \cdot q_F + r_F \cdot q_F - q_F^2 \end{aligned}$$

and therefore the firm's optimal production decision in the "no-platform-production" (NP) case is

$$q_F^{NP} = \min\left\{\frac{r_P + r_F}{2}, 1\right\}.$$

Finally, we note that consumer welfare is linear in expected quality of the good consumed,[6] given that

$$W^{NP} = \mathbb{E}[e_i \cdot u(x_F, \theta, \tau)] = \int_{\frac{\bar{\theta}}{2}}^{\bar{\theta}} \theta q_F - \tau \, dG(\theta) = \frac{3}{8}\bar{\theta}^2 q_F^{NP}.$$

3.2. Platform's Dual Role

We now characterize the equilibrium investment levels of the case where the platform can also make production decisions. Given that now more than one good is available on the platform, recommendations play a role in determining how much consumers value having a platform subscription.

A subgame-perfect equilibrium is a tuple (ρ, τ, q_P, q_F) where the platform P chooses a recommendation policy ρ, an access fee τ, and an investment level q_P, and the independent firm F chooses investment level q_F in order to maximize their respective profits, and each consumer $i \in [0, M_P]$ makes a decision on whether to join the platform (e_i) and which product to consume (x_i) so as to maximize their expected utility.

[6]If one considers a similar market structure underlying the alternative revenue sources for the independent firm (see Footnote 3), this linearity of consumer welfare in expected quality of the independent firm's good extends also to this alternative independent market.

As is standard, we solve for equilibrium via backward induction. We recall the (inverse) timing of events:

9. The independent firm and the platform split the platform revenue according to their consumption share and the independent firm accrues outside revenue R_F.

8. Each consumer i selects the good x_i with the highest expected utility conditional on recommendation and investment probabilities:
$x_i \in \arg\max_{x_j \in \{x_P, x_F\}} \mathbb{E}[u(x_j, \theta_i, \tau) \mid \rho, m]$ given the recommendation policy ρ and the realized recommendation, breaking ties in favor of the platform.

7. The platform's recommendations realize:
$m \sim \rho(x_P, x_F)$, where $\rho : \{0,1\}^2 \to \Delta(\mathcal{M})$ and $m \in \mathcal{M}$.

6. Product qualities realize:
$x_j \sim \mathbb{P}(x_j = 1) = q_j$ and $\mathbb{P}(x_j = 0) = 1 - q_j$, with $j = P, F$.

5. The platform commits to a recommendation policy ρ:
$\rho \in \arg\max_{r:\{0,1\}^2 \to \Delta(\mathcal{M})} \alpha_P \cdot R_P - C_P$ given R_P, q_P and where the platform's market share is given by $\alpha_P = \mathbb{E}\left[\mathbf{1}_{x_P = x_i} \mid e_i = 1\right]$.

4. Each consumer i decides whether to join the platform ($e_i = 1$) or not ($e_i = 0$):
$e_i \in \arg\max_{e \in \{0,1\}} e \cdot \mathbb{E}[u(x_i, \theta_i, \tau) \mid \rho]$.

3. The platform determines access fee τ, resulting in revenue R_P:
$\tau \in \arg\max_{t \geq 0} t \cdot M_P \cdot \mathbb{E}_\theta[e_i]$.

2. The platform determines its investment level, q_P:
$q_P \in \arg\max_{q'_P \in [0,1]} \alpha_P \cdot R_P - C_P$.

1. The independent firm determines its investment level, q_F:
$q_F \in \arg\max_{q'_F \in [0,1]} \alpha_F \cdot R_P + R_F - C_F$.

Optimal Recommendation Policy

The first step is to solve for the optimal recommendation policy. The platform faces a standard Bayesian persuasion problem (Kamenica and Gentzkow 2011), choosing a conditional signal distribution to maximize its profits. As the consumer has two actions – choosing the either the platform's product of the independent firm's – it is without loss to consider recommendation policies such with at most two messages, $\{F,P\}$, where we interpret $\rho(x_P,x_F)=P$ $(=F)$ as recommending the consumer to choose the platform's (resp. firm's) product. The only constraint is one of credibility: the consumers cannot be left worse off by following the recommendation than if they were not to follow it. The problem can then be written as

$$\max_{\rho:\{0,1\}^2\to\Delta(\{F,P\})} \alpha_P\cdot R_P - C_P$$

subject to credibility constraints

$$\mathbb{E}[u(x_P,\theta_i,\tau)\mid\rho(x_P,x_F)=P]\geq\mathbb{E}[u(x_F,\theta_i,\tau)\mid\rho(x_P,x_F)=P]$$
$$\mathbb{E}[u(x_F,\theta_i,\tau)\mid\rho(x_P,x_F)=F]\geq\mathbb{E}[u(x_P,\theta_i,\tau)\mid\rho(x_P,x_F)=F]$$

Leaving the details to the Appendix, we state the result:

Proposition 1. The optimal recommendation policy by the platform is such that

(i) if $q_P\geq q_F$, the platform always recommends its good;

(ii) if $0=q_P<q_F$ or $q_P<q_F=1$ the platform sends unbiased recommendation and breaks indifference in favor of its good;

(iii) if $0<q_P<q_F<1$, then P recommends its own good whenever it has weakly higher quality than the independent firm's, $\mathbb{P}\left(\rho(x_P,x_F)=P\mid x_P\geq x_F\right)=1$, and also with non-zero probability when this is not the case, $\mathbb{P}\left(\rho(x_P,x_F)=P\mid x_P<x_F\right)=\frac{q_P}{1-q_P}\frac{1-q_F}{q_F}<1$.

Proposition 1 specifies the optimal recommendation policy for the platform. The intuition for the recommendation policy is as follows. When $q_P\geq q_F$, that is, when the platform invests at least as much as the independent firm in good quality, then the platform has no incentive to provide any information. Without additional information, consumers believe that the platform's good is more likely to be of high quality than the independent firm's and so will always choose it. When $q_P<q_F$, that is, when the independent firm invests more than the platform, then the platform commits to truthfully recommending the best option (breaking ties in its favor) whenever its product is of weakly higher quality. However, the platform will sometimes *bias* its recommendations and recommend its product even when

the independent firm's good is a strictly better option for the consumer. As recommendations need to be credible in the consumer's eyes, there is a natural credibility bound to how much the platform can bias its recommendations. This makes it so that the platform can only recommend its own good with probability $\frac{q_P}{1-q_P}\frac{1-q_F}{q_F}$ if, in fact, the independent firm's product is strictly better for the consumer.

It immediately follows from Proposition 1 that

Corollary 1. The expected market share of the platform α_P is given by $\min\{1, 1-(q_F - q_P)\}$ and that of the independent firm is $\alpha_F = 1 - \alpha_P = \max\{0, q_F - q_P\}$. Moreover, the expected good quality is given by $\mathbb{E}[x_m \mid \rho] = \max\{q_P, q_F\}$.

Corollary 1 highlights how the optimal recommendation policy heavily favors the platform's own goods and how, whenever the independent firm invests more than the platform, the recommendation policy results in consumer welfare only depending on the investment level of the independent firm. In order to be recommended and have its good subsequently consumed on the platform, the firm not only needs to initially invest more than the platform, but it also needs its realized quality to be higher than that of the platform's good. Even then, the platform can still induce Bayesian consumers to sometimes choose its good.

In the case when the independent firm invests more than the platform, the platform's recommendation is disciplined only by the credibility constraints. The platform's recommendation is designed to bias recommendations toward the platform's good, but just enough to render the consumer indifferent between following the recommendation and not following it. This leaves the consumer indifferent between following the recommendation and defaulting to their prior, consuming the independent firm's good. As a result – and despite the increase in number of goods on the platform – consumer welfare depends exclusively on the quality of the independent firm's product. An implication of this is that, when the platform marginally increases q_P, it leads to an increase in the probability that the consumer gets a biased recommendation; and not, as one would expect, that the consumer's expected utility increases.

Optimal Access Fee

The pricing problem faced by the platform is such that

$$\tau \in \arg\max_{t\in\mathbb{R}} M_P \cdot t \cdot \int_0^{\bar{\theta}} e_i dG(\theta)$$

where $e_i \in \{0,1\}$ describes consumer i's decision of whether or not to join the platform, given the optimal recommendation policy, that is,

$$e_i := \mathbf{1}_{\mathbb{E}[u(x_m,\theta_i,\tau)|\rho]\geq 0}.$$

The next proposition shows that the optimal access fee is similar to the no-platform-production case:

Proposition 2. The optimal access fee is given by $\tau = \frac{1}{2}\bar{\theta}\max\{q_P, q_F\}$, resulting in a total revenue collected by the platform of $R_P = r_P \max\{q_P, q_F\}$. Moreover, the resulting consumer welfare is given by $\mathbb{E}[e_i \cdot u(x_m, \theta_i, \tau) \mid \rho] = \frac{3}{8}\bar{\theta}^2 \max\{q_P, q_F\}$.

Proposition 2 provides the optimal access fee, total revenue, and consumer welfare given production decisions. Each of these quantities directly follows from the expected quality of the goods that consumers experience on the platform, which is characterized in Corollary 1, together with the fact that the optimal recommendation policy is independent from the consumer's type θ_i and the access fee.

One implication of the above result is that, whenever $q_F \geq q_P$, the optimal access fee under the dual role is identical to the access fee charged in the no-platform-production case, where only the independent firm is producing. This partly is a result of the timing of recommendation in the model which was set up to isolate the role of credibility and gives no explicit incentive for the platform's recommender system to optimally trade off revenue per consumer and overall platform demand. Nevertheless, the induced bias implicitly affects the platform demand by reducing the expected good quality; and, hence, the price consumers are willing to pay to join the platform. Furthermore, while the access fee and welfare are identical in the case when $q_F \geq q_P$, the independent firm's expected product quality q_F is endogenous and determined in equilibrium. This implies that the platform's entry influences consumer welfare on the platform only through the endogenous response of the independent firm's investment decisions to the ability of the platform to bias its recommendations.

Production Decisions

Finally, we characterize the optimal investment decisions of the firms. We assume that the independent firm chooses quality investment first and the platform second. The motivation for this assumption is that platforms are often seen as second-movers in terms of production decisions, being able to benefit from the information obtained from having other firms' goods available.

The platform's production problem is given by

$$\max_{q_P \in [0,1]} \alpha_P \cdot R_P - C_P$$

As $\alpha_P = \min\{1, 1-(q_F - q_P)\}$ and $R_P = r_P \max\{q_P, q_F\}$, we have that the objective function is continuous and piecewise strictly concave in q_P, with

$$\pi_P(q_P, q_F) = \alpha_P \cdot R_P - C_P = \begin{cases} r_P \cdot (1-(q_F - q_P)) \cdot q_F - {q_P}^2 & \text{if } q_P < q_F \quad (1) \\ r_P \cdot q_P - {q_P}^2 & \text{if otherwise} \quad (2) \end{cases}$$

Proposition 3. The equilibrium investment levels for the platform are given by:

$$q_P(q_F) = \begin{cases} \frac{r_P}{2} q_F & \text{if } q_F \geq \tilde{q}_F \text{ and } r_P < 2 \\ \min\left\{1, \frac{r_P}{2}\right\} & \text{if } q_F < \tilde{q}_F \text{ and } r_P < 2, \text{ or } r_P \geq 2 \end{cases}$$

where $\tilde{q}_F \equiv \frac{r_P}{4 - r_P}$.

Proposition 3 immediately follows from two observations. The first is that if $r_P \geq 2$, then the maximizer of both (1) and (2) is $q_P = 1$. The second is that if $r_P < 2$, then the maximizer of (2), $\frac{r_P}{2} < 1$, is always weakly larger than the maximizer of (1), $\frac{r_P}{2} q_F < q_F$, and so the platform will choose to invest at $\frac{r_P}{2}$ when $\pi_P(\frac{r_P}{2} q_F, q_F) \leq \pi_P(\frac{r_P}{2}, q_F)$ and $\frac{r_P}{2} \geq q_F$, which is equivalent to $q_F \leq \tilde{q}_F$. Furthermore, we break indifference in favor of the second-arm, when $q_F = \tilde{q}_F$. The tie-breaking will be immaterial in characterizing the equilibrium investment levels, and so is without loss for the overall conclusions.

The solution to the platform's production decision has a very natural interpretation: If the independent firm's investment in quality is too low, then the platform is better off by investing as if it were the only producer on the platform; and, indeed, it is going to recommend only its own goods. If instead the independent firm's investment is high enough, then the platform invests below what it would were its product the only one on the platform – as a single good monopoly case – saving in investment costs at the expense of the independent firm. It can still enjoy some positive market share and get a part of the revenue R_P as it will bias recommendations towards its own goods when its realized quality is weakly higher than the firm – and, sometimes, even when it is not.

The independent firm's production problem is then to choose q_F in order to maximize $\pi_F(q_F) = \alpha_F \cdot R_P + R_F - C_F$, given $q_P(q_F)$. By backward induction, the independent firm's payoffs can be written as follows:

$$\pi_F(q_F) = \begin{cases} (q_F - q_P(q_F)) \cdot r_P \cdot q_F + r_F \cdot q_F - {q_F}^2 & \text{if } r_P < 2 \text{ and } q_F \geq \tilde{q}_F = \frac{r_P}{4-r_P} \quad (3) \\ r_F \cdot q_F - {q_F}^2 & \text{if otherwise} \quad (4) \end{cases}$$

Proposition 4. The equilibrium investment level for the independent firm is given by

$$q_F^{DR} = \begin{cases} \min\left\{1, \frac{r_F}{2}\right\} & \text{if } r_F \leq \underline{r_F} \text{ and } r_P < 2\text{, or if } r_P \geq 2 \\ \tilde{q}_F & \text{if } \underline{r_F} \leq r_F < \overline{r_F} \text{ and } r_P < 2 \\ \min\left\{1, \frac{r_F}{2(1-r_P)+{r_P}^2}\right\} & \text{if } \overline{r_F} \leq r_F \text{ and } r_P < 2 \end{cases}$$

where $\tilde{q}_F \equiv \frac{r_P}{4-r_P}$, $\underline{r_F} \equiv \frac{r_P}{4-r_P}\left(2 - \sqrt{2r_P(2-r_P)}\right)$, $\overline{r_F} \equiv \frac{r_P}{4-r_P}\left(2(1-r_P)+{r_P}^2\right)$. Except when $\underline{r_F} = r_F$, the investment levels are uniquely determined.

The solution to the independent firm's production decision has a clear interpretation. If $r_P \geq 2$, the platform will always set $q_P = 1$ and recommends only its good, regardless of the firm's investment level, thereby excluding the independent firm from considering platform revenue. When instead $r_P < 2$, then there are three cases to consider, which depend on $\underline{r_F}$ and $\overline{r_F}$, both strictly increasing in r_P and implicitly defining conditions on r_F relative to r_P. In the first case, where r_F is small enough relative to r_P, we have that the independent firm's investment decisions only depend on the relative strength of the outside markets since the platform's ability to bias recommendations is sufficiently strong to foreclose the independent firm entirely from the platform. In the second case, where r_F attains intermediate values relative to r_P, the independent firm invests in quality just enough to leave the platform indifferent between foreclosing the independent firm and investing in lower (expected) quality, allowing the independent firm some consumption share. In this case, the investment that the independent firm would make in the absence of platform revenue would be considerably lower and fighting for higher consumption share on the platform is still not worthwhile. However, the independent firm strictly benefits from getting enough of the platform demand and investing more than it would when considering only the outside revenue. Finally, in the last case, where r_F is large relative to r_P, it is now worthwhile for the independent firm to invest in even higher quality, simultaneously allowing it to compete for a larger share of the platform demand as well as leading to higher revenue from platform subscriptions.

3.3. Welfare Consequences of the Dual Role

We now study the implications of the dual role on consumer welfare. Our primary question of interest is whether the increased competition in the production market through the entry of platform increases or decreases consumer welfare. We now state the main result comparing welfare between the two cases:

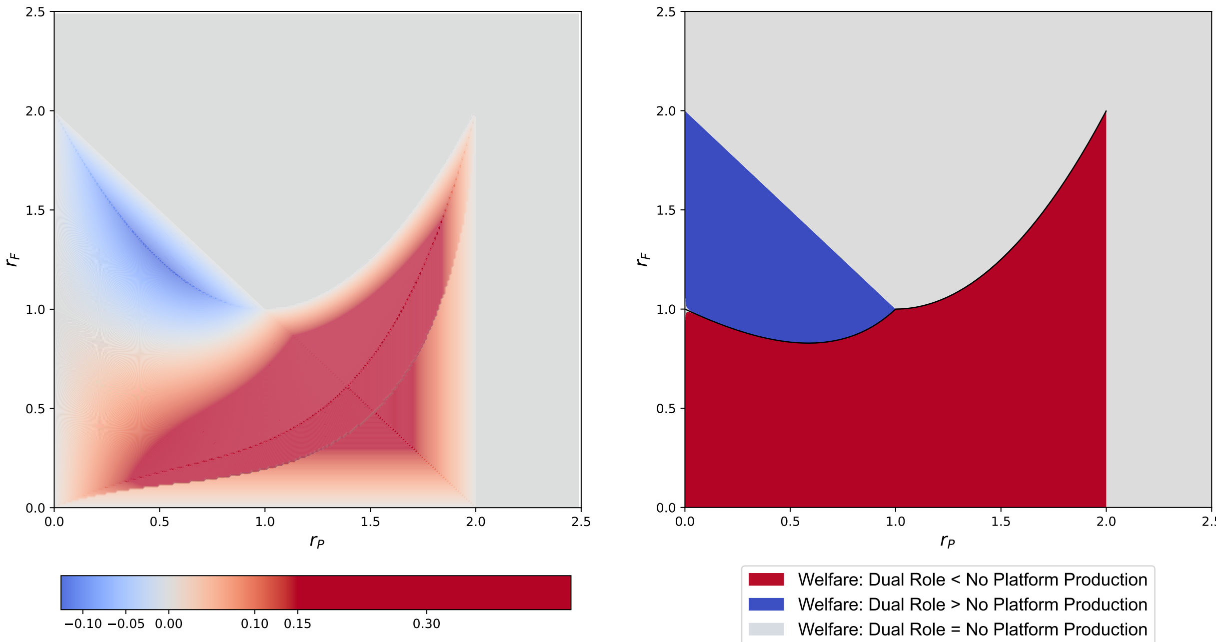
Proposition 5. Consumer welfare is weakly higher under the dual role than under the no platform production case if and only if $r_F \geq \frac{2(1-r_P)+r_P^2}{\max\{1,2-r_P\}}$ or $r_P \geq 2$.
It is strictly higher if and only if $2 - r_P > r_F > \frac{2(1-r_P)+r_P^2}{2-r_P}$.

Proposition 5 shows that, despite the increased competition in the upstream market, the platform's dual role results in lower quality investments and lower welfare when the independent firm's alternative market relevance is small compared to the platform's – cf. Figures 1 and 2.[7] This shows that when the platform steers a substantial fraction of the demand utilizing recommendation, platform upstream competition decreases consumer

[7]While Proposition 5 only focuses on consumer welfare on the platform, if one further assumes identical consumer preferences in the revenue sources outside of the platform, then the conclusion from Proposition 5 that for the dual role can either improve or harm consumer welfare extends to including these sources as well, although the thresholds would differ. Moreover, if the dual role strictly improves on on-platform consumer welfare, it also improves on off-platform consumer welfare. The main difference would be that if $r_P \geq 2$, the platform invests such that $q_P = 1$, leaving on-platform consumer welfare unchanged, but as the independent firm is foreclosed, it will invest strictly less than in the no-platform-production case, with negative welfare consequences for off-platform consumers.

Figure 1. **Average Consumer Welfare: Dual Role – No Platform Production**

(a) (b)

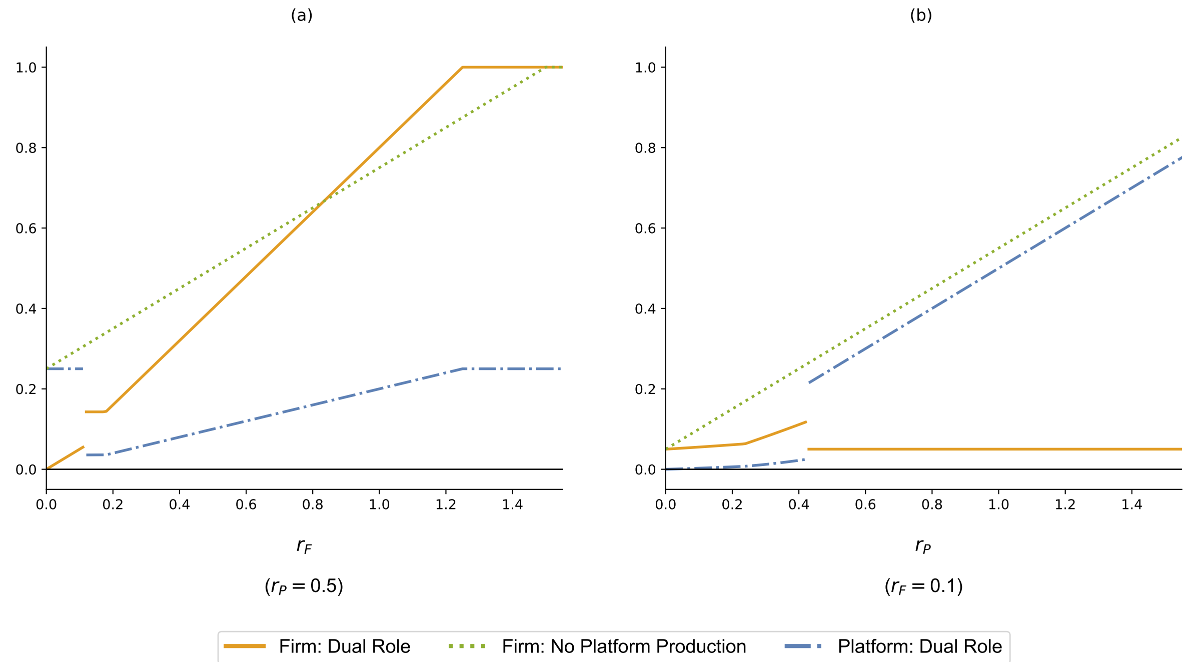


Notes: This figure displays the difference in expected good quality, which corresponds to average consumer welfare on the platform, between the no platform production and dual role cases. Panel (a) shows a heatmap of the differences between welfare for varying r_F and r_P and panel (b) shows for which values of r_F and r_P the different cases differ in resulting welfare.

welfare. It not only adversely impacts consumer welfare, but also strictly depresses the industry's total profits since, if the independent firm is the sole producer, its profits attain the industry's maximum. Therefore, the increased competition leads to an overall, unambiguous, decrease in total surplus. However, as the size of the alternative market grows relative to the size of the platform's potential revenues, eventually the platform's dual role is welfare improving.

The model holds another significant implication: Once the platform relevance becomes significant relative to other revenue sources, the platform becomes the product quality leader and uses recommendations to perform vertical foreclosure. As illustrated in Figure 2b, in equilibrium the platform may benefit from completely disregarding the independent firm, producing as if it were a monopolist. This occurs when the independent firm's alternative revenue sources are not strong enough relative to platform potential revenue to induce it to compete for market share with the platform as a producer. The outcome of this interaction is then a form of vertical foreclosure by means of the platform's use of biased

Figure 2. **Equilibrium Investment Levels**



Notes: This figure displays the investment levels across the no platform production and dual role cases. Panel (a) shows how investment levels change as we increase the alternative revenue sources for a fixed level of platform potential revenue. Panel (b) shows how investment levels change as we increase the platform potential revenue for a fixed level of alternative revenue sources.

recommendations, which establishes the platform as the quality leader by precluding the independent firm's access to the platform's demand. This necessarily has a negative effect on consumer welfare as the expected good quality on the platform is lower than it would be when compared to a case where only the independent firm's good is available.

This prediction echoes anecdotal evidence on streaming platforms. First, the already mentioned concerns that platforms bias their recommendation systems towards their own goods to the detriment of goods produced by other firms manifests itself in our model through the biased recommendations the platform uses to steer consumers towards its own goods. Second, data on viewer and subscriber patterns on streaming platforms indicates that there is a positive correlation between number of subscribers, platform original content's share of the total platform viewership, and ranking of platform's original content.[8] Even though the model's prediction is sharp and reality is necessarily more complex and nuanced, the evidence is consistent with the main intuition from the model.

[8]See, for the case of Netflix, e.g. "Netflix Original Series Viewing Climbs, but Licensed Content Remains Majority of Total U.S. Streams" (Spangler 2019) and "Netflix Subscriber Numbers Soar, Showing the Sky Is Not Falling" (Vena 2019).

Nevertheless, the need to compete for market share on the platform can still drive the independent firm to stronger quality investments as the platform's audience loses its overwhelming relevance within the industry, possibly due to the emergence of alternative platforms. When the independent firm has a base incentive to support sufficiently high quality investments – when the alternative revenue sources are significant enough relative to the platform's – it is worthwhile for the firm to invest even more and compete for market share on the platform. In this case, the platform becomes a quality follower relative to the independent firm, making use of recommendations to appropriate a substantial fraction of the market share that the independent firm's production decisions attract.

4. Unbiased Recommendations

In this section we consider a natural policy remedy that imposes that the platform needs to provide unbiased – truthful and neutral – recommendations. Truthfulness requires that the platform always recommends a good when it is of strictly higher quality than the other, while neutrality requires that the platform always breaks ties uniformly. Another interpretation of the unbiased recommendation case is as a separation (or divestiture) between the platform's production and recommendation activities. Therefore, this also corresponds to a benchmark of two producers, independent from the platform.

While it would be natural to expect that such a policy is unambiguously beneficial for consumers, we find that when the platform potential revenue is large relative to the firm's alternative revenue sources such a policy may in fact harm consumers. When the firm's alternative revenue is low then unbiased recommendation levels competition conditions between the platform and the independent firm. In contrast, when the firm's alternative revenue is high, biased recommendations may spur the firm to invest more strongly in quality than it would otherwise under unbiased recommendations to the point that it overcomes the negative effect of biased recommendations on consumer welfare.

4.1. Equilibrium Characterization

The model remains the same, up to imposing unbiased recommendations: The recommender system now recommends whichever good realizes the highest quality, with uniform tie-breaking. This implies that the expected good quality that consumers end up getting is

$$q^U := q_P \cdot q_F + q_P \cdot (1-q_F) + (1-q_P) \cdot q_F = q_P + (1-q_P) \cdot q_F$$

The solution to the optimal access fee is analogous to the one from before, leading also to a similar expression for platform revenue R_P. In fact, the revenue maximizing access fee is the same up to replacing $\max\{q_P, q_F\}$ with the new expression for expected good quality q^U. Thus, the optimal access fee and resulting revenue are given by $\tau = \frac{1}{2}\bar{\theta} \cdot q^U$ and $R_P = r_P \cdot q^U$.

Expected market shares are given by $\alpha_P = 1 - \alpha_F = \frac{1}{2}(1-(q_F - q_P))$, resembling the form of market share under biased recommendations with two differences. On the one hand, market shares are always strictly positive for any strictly positive quality investment. This immediately implies that the independent firm is now able to capture a share of the market, even when it invests less than the platform, as imposing unbiased recommendations precludes the use of this policy instrument by the platform to induce vertical foreclosure. On the other hand, the incentives for the firm to compete for market share are dampened: the marginal change in the firm's market share from increasing its investment is halved when compared to the biased recommendation case with positive market share.

The platform's production problem is given by the same expression up to the changes in R_P and α_P:

$$\pi_P(q_P, q_F) = \alpha_P R_P - C_P = \frac{1}{2}(1-(q_F - q_P)) \cdot r_P \cdot (q_F + (1-q_F)q_P) - {q_P}^2 \tag{5}$$

We note that the platform has a unique best response to the independent firm's investment level;

Lemma 1. The platform's optimal investment, $q_P^U(q_F) := \arg\max_{q_P \in [0,1]} \pi_P(q_P, q_F)$ is unique and continuous in q_F.

The firm's production problem is now given by

$$\pi_F(q_P, q_F) = \alpha_F R_P + R_F - C_F = \frac{1}{2}(1-(q_P - q_F)) \cdot r_P \cdot (q_F + (1-q_F)q_P) + r_F \cdot q_F - {q_F}^2$$

with $q_P = q_P^U(q_F)$.

It results that this problem has a unique maximizer and therefore we obtain a unique equilibrium:

Proposition 6. Equilibrium investment levels with unbiased recommendations are uniquely defined.

Unfortunately, the solution for the independent firm investment levels has no closed-form solution; hence, we evaluate the effect of such policy by numerical computation.

4.2. Comparison to Unbiased Recommendation Equilibrium

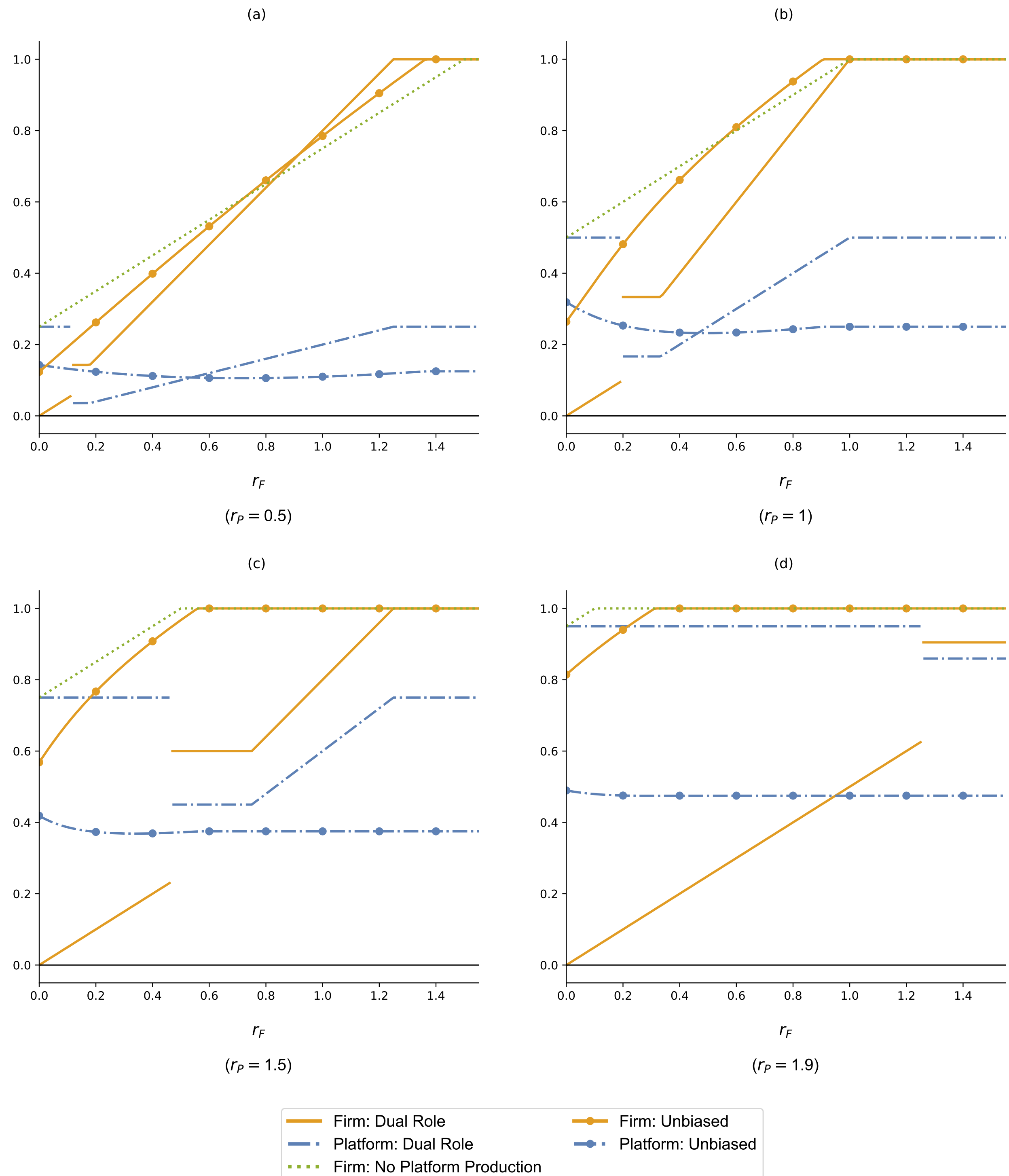
Investment Levels

We now directly compare the equilibrium investment levels in the different cases. Figure 3 depicts the equilibrium investment levels as we vary the significance of the firm's alternative revenue, r_F, for different representative values of platform market sizes, r_P. The figure shows that imposing unbiased recommendations has an ambiguous effect on firm equilibrium investment levels.

We first focus on the independent firm. Similarly to before, the independent firm invests less in the unbiased case compared to the dual role when r_F is high and r_P is low (see Figure 3b). There are two channels that depress the incentives for the independent firm to invest. First, we note that the marginal gain on market share is halved under unbiased recommendations compared to the dual role. Second, we have that the marginal increase in overall platform revenue as a result of increasing independent firm investment is r_P in the dual role case, but, under unbiased recommendations, the marginal effect on total revenue is only $r_P(1-q_P)$.

However, there are also two forces that act in the opposite direction and encourage the independent firm to increase investment. The first is that the platform's reaction to the independent firm's quality investment is softer as it can no longer make use of biasing recommendations in its favor. The other is that even though the marginal effect of investment on market share is lower, unbiased recommendation still leads to an overall higher level of market share for the independent firm.

Figure 3. **Equilibrium Investment Levels including Unbiased Recommendation**



Notes: This figure displays the investment levels across the unbiased, no platform production, and dual role cases. Each figure plots the changes in investment levels as we vary the strength of the alternative revenue sources for representative values of platform potential revenue.

When r_F is high enough and r_P is low enough, the mechanisms that depress incentives are stronger and drive the independent firm to invest less under unbiased recommendations compared to biased recommendations. As r_P increases, the channels that drive the independent firm to invest more become stronger than those that depress investment. Thus, when r_P is sufficiently high, the forces that lead to higher investment dominate the investment-depressing channels, leading to overall higher investment levels in the unbiased case.

We now investigate the effect that unbiased recommendation has on the platform's production decision, which can similarly be seen in Figure 3. We highlight three main results.

First, when the platform potential revenue is high relative to the firm's alternative markets, we previously noted that the platform is able to use recommendation to effectively become a monopolist. When recommendations have to be unbiased, the resulting competition leads to a decrease in the platform's equilibrium investments. Although it is reasonable to expect that the fact that the platform is now unable to capture the whole market would lead to more aggressive investment by the platform, this is not the case. As the independent firm has higher returns to investments than the platform – due to its alternative revenue sources – it results that it will always obtain at least half of the market share under unbiased recommendations. This leads to competition resulting in lower investment by the platform.

Second, unbiased recommendations depress platform investment when the independent firm's alternative revenue is large enough. When the platform can bias recommendations, it has a stronger incentive to keep up with the independent firm's investments as r_F increases. In contrast, under unbiased recommendations, this effect turns negative as the alternative revenue sources grow more and more significant. In this case, as happens for the independent firm, unbiased recommendations actually dampen competition incentives, making it less worthwhile for the platform to produce higher quality goods given the halved effect on the market share and virtually no marginal change in total revenue when q_F is close to 1.

Finally, if the platform's potential revenue is high enough and the firm's alternative markets are not too significant, the firm's investment under unbiased recommendations is lower than the platform's when it can bias recommendations. As it is possible to observe in Figures 3c and 3d, when r_P is high enough and r_F is low, in order to capture full platform demand in the dual role case, the platform invests more in expected quality than it does in the unbiased recommendations case. Moreover, the platform's equilibrium investment levels are then consistently higher under the dual role, than it is when imposing unbiased recommendations.

The two main findings regarding to investment levels are then the following:

Remark 1.

1. When the platform's market size is small and the firm's alternative market size is large, imposing unbiased recommendations leads to lower investments by the independent firm.

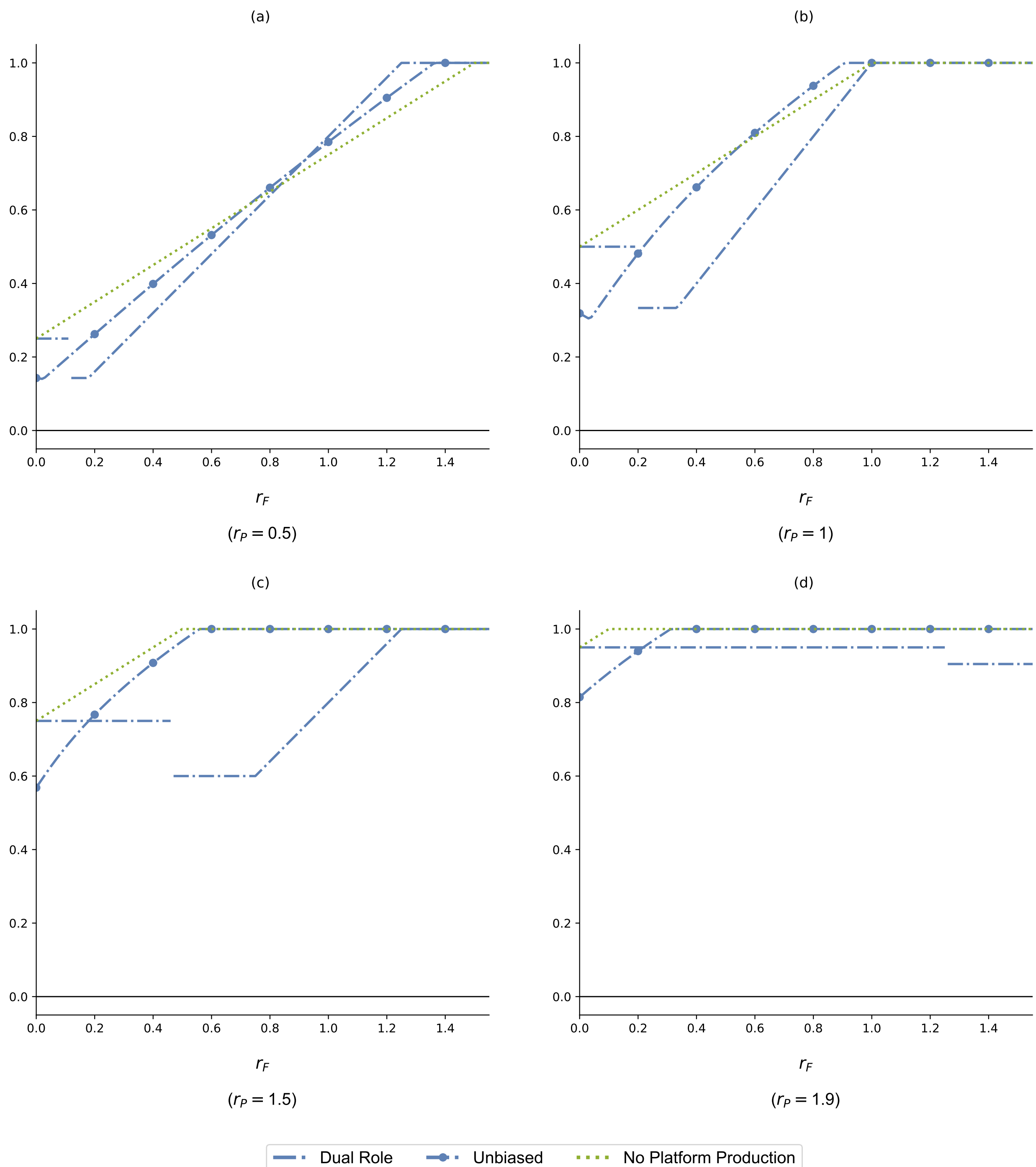
2. When the platform's market size is large relative to the firm's alternative market size or when the latter is large enough, imposing unbiased recommendations leads to lower investments by the platform.

Consumer Welfare

The analysis of the resulting differences in consumer welfare between the two regimes does not follow immediately from assessing the platform's and the independent firm's investment levels separately since the expected market shares further differ as a result of the change in recommendation policy. In both these regimes consumer welfare depends in the exact same manner on expected good quality and so our results here have direct parallels to the previously discussed changes in investment levels. There are two channels through which this policy affects welfare. The first is that, fixing investment levels and prices, unbiased recommendations have an unambiguously positive effect on consumer welfare, owing to consumers being better informed about each good's realized quality. This leads to differences in expected market shares for the producers, and, as a result, the second channel comes from responses in equilibrium investment levels.

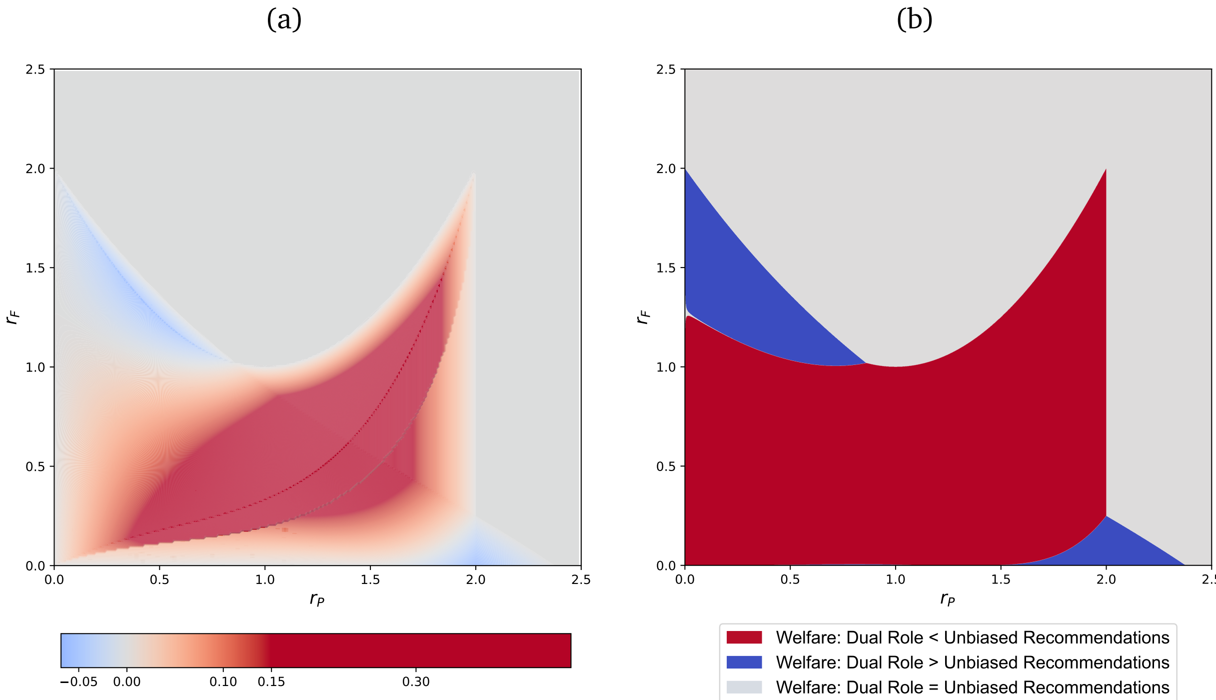
Interestingly, imposing unbiased recommendations can lower consumer welfare both when the platform market size relative to the size of the firm's alternative market is large

Figure 4. **Average Consumer Welfare: Unbiased, Dual Role, No Platform Production**



Notes: This figure displays the average consumer welfare values across the unbiased, sole producer, and dual role cases. Each figure plots the changes in welfare as we vary the strength of the alternative revenue sources for representative values of platform potential revenue.

Figure 5. **Average Consumer Welfare: Unbiased – Dual Role**



Notes: This figure displays the difference in expected good quality, which corresponds to average consumer welfare on the platform, between the dual role and unbiased recommendations cases. Panel (a) shows a heatmap of the differences between welfare for varying r_F and r_P and panel (b) shows for which values of r_F and r_P the different cases differ in resulting welfare.

and when it is small – cf. Figure 5. Immediately, remark 1 implies that when r_P is low and r_F is high, both the independent firm and the platform are investing less in quality under the new policy than when the platform is able to bias the recommendations. By itself, this need not imply that welfare is lower, as de-biasing recommendations leads to a higher informational value of recommendations for consumers, which could potentially outweigh the lower investments. When looking at panel (a) of Figure 4, we can observe this is not always the case: When the platform's market size is small and the firm's alternative market size is large enough, imposing unbiased recommendation leads to a welfare loss.

There is also a second case where unbiased recommendations can be welfare depressing: When the platform's market size is large relative to the firm's alternative market. In this case, in order for the platform to completely foreclose the independent firm utilizing biased recommendations would require it to undertake higher investments in quality than both the platform and the independent firm do with unbiased recommendations. This results in the platform increasing its investment in order to shut out the independent firm when it can take advantage of designing the recommendation policy to its favor, and this increased investment can be strictly beneficial for consumers. Therefore, it is exactly the ability to engage in anti-competitive practices enabled by the ability to bias recommendations that leads to a higher consumer welfare with biased recommendations in this case.

These cases are clearly identifiable in Figure 5, resulting in the main observation of this section:

Remark 2. Imposing unbiased recommendations depresses consumer welfare when either the platform's market size is low and the independent firm's alternative market size is large, or vice-versa.

Although Remark 2 highlights the striking result that preventing platforms from biasing their recommender systems may be harmful for consumers, Figure 5a shows that the welfare gains may be very significant when the platform's and the firm's alternative markets' potential revenue are comparable. Then, when considering the consequences of such a policy, it becomes crucial to understand not only the industry's structure, but also its returns.

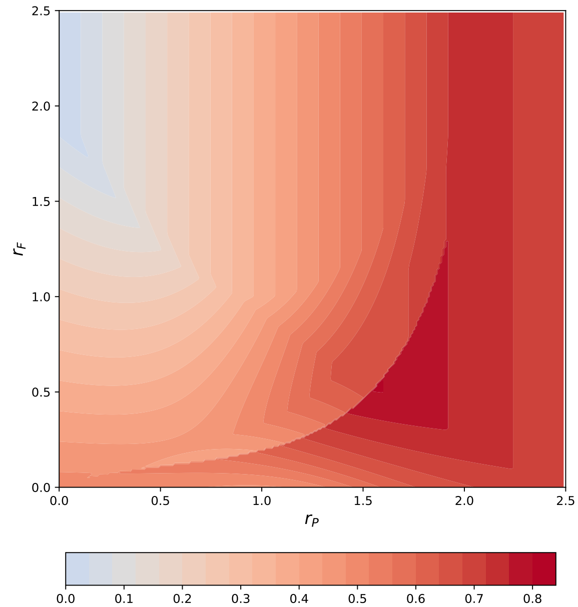
Decomposing the Foreclosure Effects

Finally, we decompose the extent to which the ability for the platform to bias recommendation allows it to shift market share to itself from the independent firm. We characterize the overall difference in market share between the dual role and unbiased case and identify to which extent of is due to biased recommendations received by consumers and to the equilibrium adjustment in investment levels.

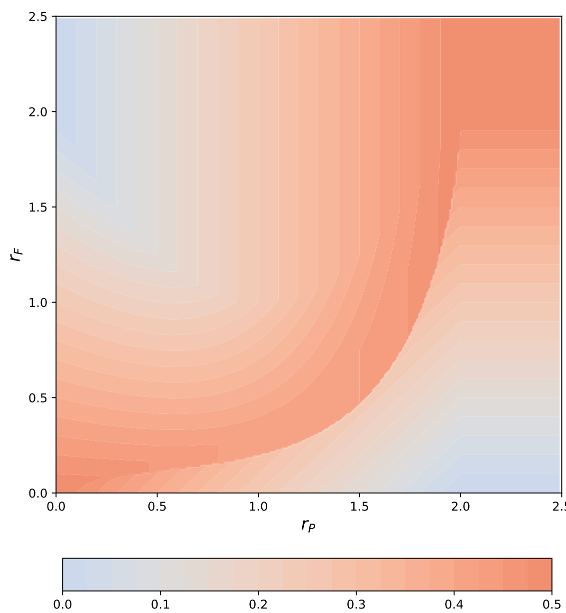
Figure 6a displays the overall differences in market share between the two regimes. As expected, overall the unbiased recommendation regime leads to a larger market share for the independent firm across all parameter values. Figure 6b compares the difference in market shares as a result of biased recommendation alone by fixing the equilibrium levels at the unbiased equilibrium investment levels and varying the recommendation policy between the two cases. Figure 6c imposes that the recommendation policy is always unbiased and compares the resulting difference in market shares across the dual role and unbiased equilibrium investment levels.

Figure 6. **Difference in Market Share for Independent Firm**

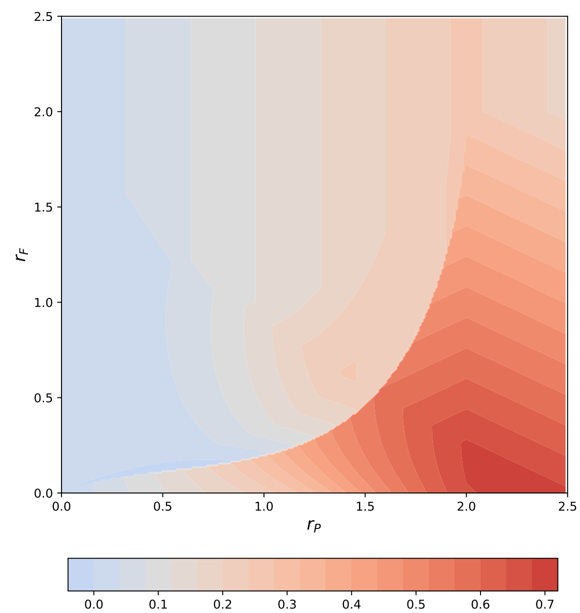
(a) **Difference in Market Share: Unbiased – Dual Role**



(b) **Difference in Market Share: Unbiased w/ Dual Role Investments – Dual Role**



(c) **Difference in Market Share: Unbiased - Unbiased w/ Dual Role Investments**



Notes: This figure displays the differences in market share between the unbiased and dual role cases for the independent firm. Panel (a) displays the overall difference in market share in equilibrium between the unbiased and dual role case. Panel (b) displays the difference in market share for the independent firm between the unbiased recommendation regime with investment levels fixed at the dual role levels and the equilibrium in the dual role. Panel (c) displays the difference in market share between the equilibrium in the unbiased recommendation regime and unbiased recommendation with investment levels fixed at the equilibrium values for the dual role.

These figures suggest that the influence of both is non-trivial, especially when r_F is small. On the one hand, the effect of unbiased recommendation itself, and not necessarily the resulting equilibrium adjustments, appears to play a bigger role when the firm was already obtaining positive market share under biased recommendations, besides the case where it was already producing at maximum quality. On the other hand, equilibrium adjustments in quality lead to extremely significant changes in market share when the firm's alternative revenue sources are meager, as under unbiased recommendations it can do always at least as well as the platform, increasing market share from zero to over 50%. This underscores the extent to which the ability of platforms to bias recommendation can undeservedly shift substantial market share from independent firms' goods to the platform's goods. The clearly identifiable discontinuity is given by $r_F = \underline{r_F}$ (as given in Proposition 4), which determines the threshold at which the independent firm starts enjoying strictly positive market share in the dual role case.

5. Additional Discussion and Robustness Exercises

In this section we provide additional discussion about the assumptions in the model as well as several robustness exercises in order to show that the qualitative conclusions from our analysis are robust to different modeling assumptions.

Heterogeneous Costs: The model that we consider crucially relies on the ability of the independent firm to access outside revenue sources as this provides it with some advantage relative to the platform. An alternative modeling assumption that provides the independent firm with an advantage relative to the platform is that the independent firm has a more efficient production process and thus has a lower marginal cost to invest in quality. This is a natural assumption as independent producers are likely to have mature production processes for their goods, whereas the platforms are usually new entrants and unlikely to have as efficient production processes.

In Appendix B we consider a setup where there is no outside revenue for the independent producer ($R_F = 0$), and, instead, there is a cost advantage, leading to potentially heterogeneous cost structures: The platform's production cost will still be $C_P(q_P) = q_P^2$, but the independent firm's is now $C_F(q_F) = c_F \cdot q_F^2$, with $c_F \in (0,1)$. Keeping the remaining elements of the setup in the baseline model, we show that the results on the welfare comparison of the dual role case with both the no-platform-production and the unbiased recommendations cases are robust to this alternative specification.

In particular, the dual role of the platform as both a recommender and a producer retains an ambiguous effect on consumer welfare in comparison to the other two situations: it will *strictly* improve consumer welfare when the independent producer's cost advantage is neither too significant nor too negligible and the potential market size of the platform — as given by r_P — is not too large.

Simultaneous Investment Timing: We show that our main conclusions are robust to the assumption on the timing of investments. The baseline model that we consider has investment decisions decided in a Stackelberg manner with the independent firm moving first followed by the platform. While this timing is most natural, we further consider the case in which investments are simultaneous rather than sequential, keeping everything else in the model the same.

In Appendix C we characterize the equilibria in the dual role and unbiased case under this timing. This modification of the timing implies that there might be multiple equilibria in the dual role case for a given range of parameters r_P, r_F. In spite of this, the resulting welfare comparisons are remarkably consistent with the Stackelberg timing. Specifically, we obtain conclusions that are analogous to Proposition 5 and Remark 2: the platform's dual role may induce either higher or lower consumer welfare relative to both the no-platform-production and the unbiased recommendation benchmarks. The welfare comparisons are summarised in Figure 7 in Appendix C, and show that nearly the same parameter regions induce the no platform production case to be welfare improving relative to the dual role case as well as the unbiased recommendation case to be welfare improving relative to the dual role case.

Information Disclosure Timing: We model the information disclosure problem of the platform as a Bayesian persuasion problem (Kamenica and Gentzkow 2011). An alternative modeling assumption is that the platform could determine its recommendations after quality realizations. In this case the problem would be a cheap talk problem (Crawford and Sobel 1982). While this could be an interesting avenue in other setups, in the context of our model, this would result in no information being conveyed in equilibrium, with only "babbling" equilibria persisting.[9]

Pricing: We consider a model of subscription-based pricing in order to restrict attention to the interplay between product quality and recommendation without introducing the additional complexity due to item pricing and issues of price competition. Many of the prominent online platforms which rely on recommender systems, such as media streaming platforms and news websites, follow a subscription-based model and, to our knowledge, platforms such as Spotify and YouTube have similar revenue splitting rules between independent producers and themselves.[10] In contrast, the insights of our model are not directly applicable to e-commerce platforms, such as Amazon or Wayfair, due to this modeling specification.

6. Conclusion

In this paper we study a stylized model of strategic interaction between a platform that deploys a recommender system and producers of the goods distributed on this platform. Using this model we explore the welfare consequences of the entry of the platform into the production market. Opposite to the common intuition that increased competition in good production is welfare improving, we find that the ability by the platform to deploy a recommender system enables it to steer demand towards its own goods which leads to lower consumer welfare in equilibrium as a result of the platform's entry. When the primary revenue sources for the independent producers are from the platform, the bias in recommendation leads to depressed incentives to invest both for the independent producers and the platform itself.

The policy implications from our model are clear – the increasing trend of online platforms to produce their own goods should be viewed with caution by regulators. A unique element of these platforms is their deployment of recommender systems, which provide utility for consumers by providing them with information on which goods on the platform

[9]Note that if the platform's message were able to persuade the consumer to choose its good given knowledge of the realized qualities, then it would do so regardless of the realized qualities. This mechanism renders equilibrium messages uninformative.

[10]While it does not directly map to the procedure on a platform such as Netflix, one can interpret the contractual agreements between the independent film distributors and Netflix as being determined by the expected consumption share on the platform.

they should consume. However, as our model points out, the clear evidence of bias in both search and recommendation can lead to negative equilibrium effects on the quality of the goods that get produced and threatens the ability of independent producers to thrive when they are dependent on the platform as their primary revenue source.

A natural policy remedy is to require that platforms have unbiased recommendations or, equivalently, force a separation between recommendation and production. Surprisingly, we find that the equilibrium effects of biased recommendation lead to this policy not being unambiguously welfare-improving for consumers. In the case in which the platform is the primary revenue source for the independent producers, we find that this policy does improve welfare for consumers: unbiased information disclosure directly generates positive consumer welfare gains. In contrast, when the alternative revenue sources for the independent producers are large relative to the platform potential revenue, biased recommendations induce higher investment levels and lead to higher consumer welfare when compared to unbiased recommendations.

As a result, if independent producers are primarily dependent on the platform for revenue then policies enforcing the separation between recommendation and production will be welfare-improving. But if independent producers have access to large alternative revenue sources relative to the platform's potential revenue, then these policies targeting the integration of recommendation and production may have adverse effects on consumer welfare.

Finally, there are several aspects of the integration between recommendation and production that warrant further study. The first is a better understanding of the interaction between the information accumulated about consumer preferences due to intermediation and dynamic production decisions. This is particularly amplified in the case of recommender systems since, in order to develop a good recommendation system, the intermediary needs to collect fine-grained information about consumer preferences. For instance, Netflix and Amazon are primarily relying on "data-driven" approaches to production decisions using the data they get to power their recommendation systems. Moreover, consumer choices in these markets may have a path-dependence as illustrated by Aridor et al. (2020), and so, understanding the dynamic consequences of the integration of production and recommendation seems a fruitful and important direction for future work. As the role of recommender systems in online platforms increases and platforms increasingly integrate production and recommendation, examining their effects on competition, investment, and consumer welfare of all these considerations becomes increasingly more important for better policy design for the digital economy.

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Appendices

The appendix contains proofs that are omitted from the main text.

A. Omitted Proofs

A.1. Proof of Proposition 1

We assume, as is customary in the information design literature (Bergemann and Morris 2019), that the recommender is able to select its preferred equilibrium. Noting that

$$\begin{aligned}\arg\max_{x_j\in\{x_P,x_F\}} \mathbb{E}[u(x_j,\theta,\tau)\mid\rho(x_P,x_F)=m] &= \arg\max_{x_j\in\{x_P,x_F\}} \theta\mathbb{E}[x_j\mid\rho(x_P,x_F)=m]-\tau\\ &= \arg\max_{x_j\in\{x_P,x_F\}} \mathbb{E}[x_j\mid\rho(x_P,x_F)=m]\end{aligned}$$

we have that the event $\{x_P\in\arg\max_{x_j\in\{x_P,x_F\}}\mathbb{E}[u(x_j,\theta,\tau)\mid\rho(x_P,x_F)=m]\}$ is independent from θ for any recommendation policy ρ and so

$$\alpha_P=\mathbb{P}\left(x_P\in\arg\max_{x_j\in\{x_P,x_F\}}\mathbb{E}[x_j\mid\rho(x_P,x_F)=m]\right).$$

As the recommendation policy is determined after revenue R_P is collected and q_P is chosen, the problem of designing a recommendation policy that maximizes the platform's payoffs collapses to maximizing the platform's market share subject to consumer credibility constraints:

$$\begin{aligned}&\arg\max_{\rho:\{0,1\}^2\to\Delta(\mathcal{M})}\alpha_P\cdot R_P-C_P \qquad\text{(RP)}\\ &=\arg\max_{\rho:\{0,1\}^2\to\Delta(\mathcal{M})}\mathbb{P}\left(x_P\in\arg\max_{x_j\in\{x_P,x_F\}}\mathbb{E}[x_j\mid\rho(x_P,x_F)=m]\right).\end{aligned}$$

Given that there are only two relevant actions that the recommendation policy induces x_P,x_F, the problem is equivalent to having (stochastic) direct recommendations, that is, to having $\rho:\{0,1\}^2\to\Delta\{P,F\}$. We can then recast the optimal recommendation policy from the optimization problem given in (RP) to:

$$\max_{\rho:\{0,1\}^2\to\Delta(\{P,F\})} \sum_{a,b\in\{0,1\}} \mathbb{P}\left(\rho(x_P,x_F)=P \mid x_P=a,\, x_F=b\right)\mathbb{P}(x_P=a,\, x_F=b)$$

subject to credibility constraints

$$\mathbb{E}[x_P \mid \rho(x_P,x_F)=P] \geq \mathbb{E}[x_F \mid \rho(x_P,x_F)=P] \tag{1}$$

$$\mathbb{E}[x_F \mid \rho(x_P,x_F)=F] \geq \mathbb{E}[x_P \mid \rho(x_P,x_F)=F] \tag{2}$$

Given independence of x_P and x_F, the objective function becomes $q_P q_F \mathbb{P}\left(\rho(1,1)=P\right) + q_P(1-q_F)\mathbb{P}\left(\rho(1,0)=P\right) + (1-q_P)q_F\mathbb{P}\left(\rho(0,1)=P\right) + (1-q_P)(1-q_F)\mathbb{P}\left(\rho(0,0)=P\right)$, which is linear and increasing in $\mathbb{P}\left(\rho(a,b)=P\right)$, $a,b\in\{0,1\}$.
Note that the unconstrained optimum is setting $\mathbb{P}\left(\rho(x_P,x_F)=P\right)=1$ regardless of the quality realizations, implying that the platform always recommends its own goods. This is indeed the solution to the optimal recommendation policy problem whenever $q_P \geq q_F$ as, in this case, the unconstrained optimum is feasible as, without further information, the consumers will always consume the platform's good.

The solution to the case where $0=q_P<q_F$ is similarly straightforward, as recommendations are ineffective and thus the only policy that complies with obedience is to send consumers unbiased recommendations to choose the independent firm's good whenever it is of high quality, and break indifference in favor of the platform's good when $x_F=0$. Similarly, when $q_P<q_F=1$, it should be straightforward that the optimal recommendation policy is to send consumers unbiased recommendations, but breaking indifference in favor of the platform's good. For the case where $0<q_P<q_F<1$, as the constraints do not depend on $\mathbb{P}\left(\rho(j,j)=P\right)$, $j=0,1$, we can set $\mathbb{P}\left(\rho(j,j)=P\right)=1$ noting that the objective function is strictly increasing in $\mathbb{P}\left(\rho(j,j)=P\right)$ given that $q_P>0$ and $q_F<1$. When $q_P<q_F$, the constraint (2), is redundant as $\mathbb{P}(x_P=1,x_F=0)-\mathbb{P}(x_P=0,x_F=1)=q_P(1-q_F)-(1-q_P)q_F<0$. Rearranging the the terms in the constraint (1), we have $0\leq\mathbb{P}\left(\rho(x_P=0,x_F=1)=P\right)\leq \frac{q_P(1-q_F)}{q_F(1-q_P)}\mathbb{P}\left(\rho(x_P=1,x_F=0)=P\right)\leq 1$. Again by monotonicity of the objective function in $\mathbb{P}\left(\rho(x_P,x_F)=P\right)$, the optimal policy is given by setting $\mathbb{P}\left(\rho(x_P=1,x_F=0)=P\right)=1$ and $\mathbb{P}\left(\rho(x_P=0,x_F=1)=P\right)=\frac{q_P}{1-q_P}\frac{1-q_F}{q_F}$.

A.2. Proof of Proposition 2

Since the optimal recommendation policy is independent of the access fee and the consumer's type, $\mathbb{E}[u(x_i,\theta_i,\tau)\mid\rho]=\theta_i\mathbb{E}[x_m\mid\rho]-\tau$. As, from Corollary 1, $\mathbb{E}[x_m\mid\rho]=\max\{q_P,q_F\}$, we obtain that $e_i=\mathbf{1}_{\theta_i\geq\tau/\max\{q_P,q_F\}}$. Then, the problem simplifies to

$$\tau\in\arg\max_{t\geq 0} t\cdot\left(1-\frac{t}{\bar{\theta}\max\{q_P,q_F\}}\right)$$

which implies that $\tau=\frac{1}{2}\bar{\theta}\max\{q_P,q_F\}$, $R_P=r_P\max\{q_P,q_F\}$, where r_P is defined as before, and $\mathbb{E}[e_i u(x_m,\theta_i,\tau)\mid\rho]=\frac{3}{8}\bar{\theta}^2\max\{q_P,q_F\}$.

A.3. Proof of Proposition 4

Note that $\pi_F(q_F)$ is also a piecewise strictly concave function, but it is not continuous. Immediately, if $r_P\geq 2$, we have that the independent firm sets quality at $\frac{r_F}{2}$. We now consider the case where $r_P<2$. Let $\pi^{(1)}(q_F):=r_F\cdot q_F-{q_F}^2$ and $\pi^{(2)}(q_F):=(q_F-q_P(q_F))\cdot r_P\cdot q_F+r_F\cdot q_F-{q_F}^2$. The maximizer of $\pi_F^{(1)}$ is $\min\left\{1,\frac{r_F}{2}\right\}$, while that of $\pi_F^{(2)}$ is $\min\left\{1,\frac{r_F}{2(1-r_P)+{r_P}^2}\right\}$. We have split the exogenous parameters into different cases and find the maximum under each of these cases.

1. When $\tilde{q}_F\geq\frac{r_F}{2}$, then the maximizer can only be that of $\pi_F^{(2)}$. This follows by strict concavity of $\pi_F^{(1)}$ which then leads to the fact that $\frac{d}{dq_F}\pi_F^{(1)}(q_F)\mid_{q_F=\tilde{q}_F}>0$. As such, $\max_{q_F\in[\tilde{q}_F,1]}\pi_F^{(2)}(q_F)\geq\pi_F^{(2)}(\tilde{q}_F)>\pi_F^{(1)}(\tilde{q}_F)$. Finally, when $\tilde{q}_F\geq\frac{r_F}{2}$ we also have that $\frac{d}{dq_F}\pi_F^{(2)}(q_F)\mid_{q_F=\tilde{q}_F}\geq 0$, which implies that $\arg\max_{q_F\in[0,1]}\pi_F^{(2)}(q_F)=\min\left\{1,\frac{r_F}{2(1-r_P)+{r_P}^2}\right\}$.

2. When $\frac{r_F}{2}\geq\tilde{q}_F\geq\frac{r_F}{2(1-r_P)+{r_P}^2}$, then simple but cumbersome algebraic manipulations show that $\max_{q_F\in[0,\tilde{q}_F]}\pi^{(1)}(q_F)<\max_{q_F\in[\tilde{q}_F,1]}\pi^{(2)}(q_F)$ whenever this is the case and therefore $\arg\max_{q_F\in[0,1]}\pi_F^{(2)}(q_F)=\min\left\{1,\frac{r_F}{2(1-r_P)+{r_P}^2}\right\}$.

   From the conditions in this and the above case, we have that $\min\left\{1,\frac{r_F}{2(1-r_P)+{r_P}^2}\right\}$ is a maximizer whenever (i) $\tilde{q}_F\geq\frac{r_F}{2}$ or (ii) $\frac{r_F}{2}\geq\tilde{q}_F\geq\frac{r_F}{2(1-r_P)+{r_P}^2}$, which, given $r_P<2$, leads to the condition that $\frac{r_F}{2}\geq\tilde{q}_F\frac{2(1-r_P)+{r_P}^2}{2}$.

3. Finally, when $\frac{r_F}{2(1-r_P)+{r_P}^2}<\tilde{q}_F$, there are two candidates for maximizers: the discontinuity point, $\tilde{q}_F$, which corresponds to the unique (corner) solution to $\arg\max_{q_F\in[\tilde{q}_F,1]}\pi^{(2)}(q_F)$,

and $\frac{r_F}{2} = \arg\max_{q_F\in[0,\tilde{q}_F]} \pi^{(1)}(q_F)$. The discontinuity point is a maximizer whenever, together with the above inequalities,

$$\begin{aligned}
&\pi_F(\tilde{q}_F) \geq \pi_F\left(\frac{r_F}{2}\right)\\
\iff &\left(r_P\frac{2-r_P}{2}-1\right)(\tilde{q}_F)^2 + r_F\cdot\tilde{q}_F \geq \frac{{r_F}^2}{4}\\
\iff &\frac{r_F}{2} \in \left[\tilde{q}_F\left(1-\sqrt{r_P\frac{2-r_P}{2}}\right), \tilde{q}_F\left(1+\sqrt{r_P\frac{2-r_P}{2}}\right)\right]
\end{aligned}$$

As $\tilde{q}_F\left(1+\sqrt{r_P\frac{2-r_P}{2}}\right) \geq \frac{r_F}{2(1-r_P)+{r_P}^2}$ whenever $r_P < 2$, we have that the discontinuity point is a maximizer whenever $\frac{r_F}{2} \in \left\{\tilde{q}_F\left(1-\sqrt{r_P\frac{2-r_P}{2}}\right), \tilde{q}_F\frac{2(1-r_P)+{r_P}^2}{2}\right)$ and $\frac{r_F}{2}$ is a maximizer when $\frac{r_F}{2} \leq \tilde{q}_F\left(1-\sqrt{r_P\frac{2-r_P}{2}}\right)$.

A.4. Proof of Proposition 5

As welfare in both cases is given by $K\cdot\max\{q_P^{DR}, q_F^{DR}\}$ and $K\cdot q_F^{NP}$ for the same positive constant K, it suffices to compare the resulting quality investments in both cases. If $r_P \geq 2$, then $q_P^{DR} = q_F^{NP} = 1$, attaining the same welfare. We proceed by analyzing the case where $r_P < 2$. Note that

$$\max\left\{q_P^{DR}, q_F^{DR}\right\} = \begin{cases} \min\left\{1, \frac{r_F}{2(1-r_P)+{r_P}^2}\right\} & \text{if } \frac{2(1-r_P)+{r_P}^2}{2}\tilde{q}_F \leq \frac{r_F}{2} \\ \tilde{q}_F & \text{if } \tilde{q}_F\left(1-\sqrt{r_P\frac{2-r_P}{2}}\right) \leq \frac{r_F}{2} < \frac{2(1-r_P)+{r_P}^2}{2}\tilde{q}_F \\ \frac{r_P}{2} & \text{if } \frac{r_F}{2} \leq \tilde{q}_F\left(1-\sqrt{r_P\frac{2-r_P}{2}}\right) \end{cases}$$

As $q_P^{DR} \leq \frac{r_P}{2} < \frac{r_P+r_F}{2} \leq q_F^{NP}$, if $\max\{q_P^{DR}, q_F^{DR}\} = q_P^{DR}$, welfare is lower in the dual role case.

Suppose that $\max\{q_P^{DR}, q_F^{DR}\} = \tilde{q}_F \geq \frac{r_P+r_F}{2} = q_F^{NP} \iff \tilde{q}_F - \frac{r_P}{2} \geq \frac{r_F}{2}$. As $\max\{q_P^{DR}, q_F^{DR}\} = \tilde{q}_F$ implies that $\tilde{q}_F\frac{2\left(1-\sqrt{r_P\frac{2-r_P}{2}}\right)}{2} \leq \frac{r_F}{2}$. However, $\tilde{q}_F\frac{2\left(1-\sqrt{r_P\frac{2-r_P}{2}}\right)}{2} > \tilde{q}_F - \frac{r_P}{2}\ \forall r_P < 2$, which then leads to a contradiction.

We then have the case where $\max\{q_P^{DR}, q_F^{DR}\} = \min\left\{1, \frac{r_F}{2(1-r_P)+{r_P}^2}\right\}$. Note that $\frac{r_F}{2(1-r_P)+{r_P}^2} \geq \frac{r_P+r_F}{2} \implies r_F \geq \frac{2(1-r_P)+{r_P}^2}{2-r_P}$. Moreover, as $\max\{q_P^{DR}, q_F^{DR}\} = \frac{r_F}{2(1-r_P)+{r_P}^2} \implies r_F \geq \left(2(1-r_P)+{r_P}^2\right)\frac{r_P}{4-r_P}$ and $\frac{1}{2-r_P} \geq \frac{r_P}{4-r_P}$, we have that only if $r_F \geq \frac{2(1-r_P)+{r_P}^2}{2-r_P}$ do we have $q_F^{DR} \geq q_F^{NP}$ and that if $r_F \geq \frac{2(1-r_P)+{r_P}^2}{2-r_P}$ and if $q_F^{NP} = \min\{1, \frac{r_P+r_F}{2}\} = \frac{r_P+r_F}{2}$ then $q_F^{DR} \geq q_F^{NP}$.

Finally, note that $\frac{r_P+r_F}{2} \geq q_F^{NP} = 1 > \frac{r_F}{2(1-r_P)+r_P{}^2}$ implies that $\frac{2(1-r_P)+r_P{}^2}{2-r_P} > r_F$, which is necessary and sufficient for this case. To see this note that $\max\{q_P^{DR}, q_F^{DR}\} = \frac{r_F}{2(1-r_P)+r_P{}^2}$ implies $r_F \geq \left(2(1-r_P)+r_P{}^2\right)\frac{r_P}{4-r_P}$ and as $\frac{1}{2-r_P} \leq \frac{r_P}{4-r_P}$ when $r_P < 2$, this imposes no further constraint.

Consequently, $r_F \geq \frac{2(1-r_P)+r_P{}^2}{\max\{1,2-r_P\}}$ is a necessary and sufficient for $q_F^{NP} \leq \max\{q_P^{DR}, q_F^{DR}\}$. Moreover, $q_F^{NP} < \max\{q_P^{DR}, q_F^{DR}\}$ if and only if $r_F > \frac{2(1-r_P)+r_P{}^2}{2-r_P}$ and $1 \geq \frac{r_P+r_F}{2}$.

A.5. Proof of Lemma 1

If $r_P \geq \frac{2}{1-q_F}$, then $\pi_P(q_P, q_F)$ is convex and strictly increasing in q_P, which immediately implies that the platform optimally sets $q_P = 1$. If $\frac{2}{1-q_F} > r_P \geq \frac{4}{3(1-q_F)+q_F{}^2}$, then $\pi_P(q_P, q_F)$ is strictly concave but $\frac{\partial}{\partial q_P}\pi_P(q_P, q_F)\,|_{q_P=1} \geq 0$ and still implies that the platform optimally sets $q_P = 1$. Finally, if $\frac{4}{3(1-q_F)+q_F{}^2} > r_P$, then $\pi_P(q_P, q_F)$ is strictly concave and the platform sets investments optimally at $q_P = \hat{q}_P(q_F) := \frac{r_P}{2}\frac{1-q_F(1-q_F)}{2-r_P(1-q_F)}$. As $\forall q_F \in [0,1]$ and $\forall r_P > 0$, π_P is either strictly increasing or strictly concave in q_P, it is strictly quasiconcave in q_P. Moreover, as π_P is continuous in (q_P, q_F), then we have that $q_P(q_F)$ is continuous, by Berge's theorem of the maximum. Hence, the platform's optimal investment, as a function of the firm's investment, is given by

$$q_P(q_F) = \begin{cases} 1 & \text{if } \frac{4}{3(1-q_F)+q_F{}^2} > r_P \\ \hat{q}_P(q_F) & \text{if otherwise} \end{cases}$$

and is a continuous function of q_F.

A.6. Proof of Proposition 6

Recall that the condition under which $q_P(q_F) = 1$ is $\frac{4}{3(1-q_F)+q_F{}^2} > r_P$. Note that $\frac{4}{3(1-q_F)+q_F{}^2} > r_P \iff \frac{4}{r_P} - 3 + 3q_F - q_F{}^2 > 0 \iff q_F \geq \frac{1}{2}\left(3 - \sqrt{\frac{16-3r_P}{r_P}}\right) \equiv \hat{q}_F$. Clearly, $\hat{q}_F \geq 1 \iff r_P \geq 4$, which implies that if $r_P \geq 4$, then $q_P(q_F) = 1\ \forall q_F$, in which case $q_F^U := \arg\max_{q_F \in [0,1]} \pi_F(1, q_F) = \min\left\{1, \frac{r_F + r_P/2}{2}\right\}$.

If $r_P < 4$, then $\hat{q}_F < 1$. We define:

$$\pi_F^{(1)}(q_F) = \pi_F(1, q_F)$$
$$\pi_F^{(2)}(q_F) = \pi_F(\hat{q}_P(q_F), q_F)$$

where $\pi_F(q_P(q_F), q_F) = \pi_F^{(1)}(q_F)$ if $q_F \leq \hat{q}_F$ and $\pi_F(q_P(q_F), q_F) = \pi_F^{(2)}(q_F)$ if otherwise. Note that

1. $\pi_F^{(1)}$ is strictly concave
2. When $r_P < 4$, it is also the case that $\frac{d}{dq_F}\pi_F^{(1)}(q_F) > 0 \; \forall q_F \in [0, \hat{q}_F]$.
3. Straightforward computations show that $\frac{d}{dq_F}\pi_F^{(2)}(q_F)\,|_{q_F=\hat{q}_F} > 0$
4. $\frac{d^2}{(dq_F)^2}\pi_F^{(2)}(q_F) < 0 \; \forall q_F \in [0,1]$ when $r_P < 4$.

(1) - (3) directly imply that $\arg\max_{q_F \in [0,1]} \pi_F(q_P(q_F), q_F) = \arg\max_{q_F \in [\hat{q}_F, 1]} \pi_F^{(2)}(q_F)$.
(4) implies that $\arg\max_{q_F \in [\hat{q}_F, 1]} \pi_F^{(2)}(q_F)$ is a singleton.
The direct implication of these two results is that $\arg\max_{q_F \in [\hat{q}_F, 1]} \pi_F^{(2)}(q_F) = \arg\max_{q_F \in [0,1]} \pi_F^{(2)}(q_F) = \arg\max_{q_F \in [0,1]} \pi_F(q_P(q_F), q_F)$ is uniquely defined.

B. Model with Heterogeneous Costs

In this appendix, we consider the a setup where there is no outside revenue for the independent producer ($R_F = 0$), and, instead, there is a cost advantage, leading to potentially heterogeneous cost structures: the platform's production cost will still be $C_P(q_P) = q_P^2$, but the independent firm's is now $C_F(q_F) = c_F \cdot q_F^2$, with $c_F \in (0,1)$. Keeping the remaining elements of the setup in the main text, we show that the results on the comparison of the dual role case with both the no-platform-production and the unbiased recommendations cases are robust to this alternative specification.

B.1. Dual Role: Equilibrium, Welfare Comparison

Keeping the same timeline as in the main text, this change in the setup affects only the investment decisions. In the no-platform-production benchmark, the independent firm solves

$$\max_{q_F \in [0,1]} r_P \cdot q_F - c_F \cdot q_F^2$$

which results in

$$q_F^{NP} = \min\left\{\frac{r_P}{2 \cdot c_F}, 1\right\}.$$

Under the platform's dual role, Proposition 3 continues to hold as before. However, given the cost-advantage specification, the independent firm's payoff is now given by

$$\pi_F(q_F) = \begin{cases} (q_F - q_P(q_F)) \cdot r_P \cdot q_F - c_F \cdot q_F{}^2 & \text{if } r_P < 2 \text{ and } q_F \geq \tilde{q}_F = \frac{r_P}{4 - r_P}, \quad (6) \\ 0 & \text{if otherwise.} \quad (7) \end{cases}$$

Then, the firm's equilibrium investment is

$$q_F^{DR} = \begin{cases} 1 & \text{if } 0 < c_F \leq \frac{1}{2} r_P (2 - r_P), \\ 0 & \text{if otherwise.} \end{cases}$$

The difference in consumer welfare between the dual role case and the no-platform-production benchmark is proportional to $\max\{q_F^{DR}, q_R^{DR}\} - q_F^{NP}$, as consumer welfare is linear in expected quality of the good consumed (given the recommendations). Consequently, this implies that welfare is the same whenever $r_P \geq 2$ and strictly higher under the dual role than under absent of platform production when $\frac{1}{2} r_P < c_F \leq \frac{1}{2} r_P (2 - r_P)$.

B.2. Unbiased Recommendation: Equilibrium, Welfare Comparison

We turn to the case of allowing for platform production but imposing unbiased recommendations. Here again we will have uniquely defined equilibrium investments as a function of the exogenous parameters r_P and c_F. The platform's investment problem is the same as in the main text, maximizing the profits as given in 5. It is straightforward to verify that the solution to the platform's problem yields a best response given by

$$q_P(q_F) = \begin{cases} 1 & \text{if } r_P \geq \frac{4}{3} \text{ and } q_F \leq \frac{1}{2}\left(3 - \sqrt{16/r_P - 3}\right), \\ \frac{r_P}{2}\frac{1-q_F(1-q_F)}{2-r_P(1-q_F)} & \text{if otherwise.} \end{cases}$$

The independent firm's payoffs are given by

$$\pi_F(q_F) = \frac{1}{2}(1-(q_P(q_F)-q_F))\cdot r_P \cdot (q_F + (1-q_F)q_P(q_F)) - c_F \cdot {q_F}^2$$

It is easy to see that if we substitute $q_P(q_F) = 1$, then the firm's profit function simplifies to

$$\frac{1}{2}q_F \cdot r_P - c_F \cdot {q_F}^2$$

being maximized at $q_F = \min\left\{1\,,\, \frac{r_P}{4\cdot c_F}\right\}$.

Given that, $\forall c_F \in (0,1)$ and $r_P \in \left[\frac{4}{3}, 4\right)$, $\frac{r_P}{4\cdot c_F} > \frac{1}{2}\left(3 - \sqrt{16/r_P - 3}\right)$, then $q_P^U = 1$ if and only if $r_P \geq 4$, in which case $q_F^U = 1$. Moreover, as $\frac{d\pi_F(q_F)}{dq_F}\big|_{q_F=1} = \frac{r_P}{4}\left(6 - 2r_P + \frac{3}{8}r_P^2\right) - 2c_F$, then equilibrium investments (q_F^U, q_P^U) are both strictly smaller than 1 if and only if $c_F > \frac{r_P}{8}\left(6 - 2r_P + \frac{3}{8}r_P^2\right)$. This also imposes a constraint on the size of the platform, as $1 > \frac{r_P}{8}\left(6 - 2r_P + \frac{3}{8}r_P^2\right)$. Let $\bar{r}_P \in (0,4)$ be the solution to $1 = \frac{r_P}{8}\left(6 - 2r_P + \frac{3}{8}r_P^2\right)\}$, which turns out is uniquely defined (with $\bar{r}_P \approx 2.38$). Then $c_F > \frac{r_P}{8}\left(6 - 2r_P + \frac{3}{8}r_P^2\right)$ requires $r_P < \bar{r}_P$. In contrast, when $c_F \leq \frac{r_P}{8}\left(6 - 2r_P + \frac{3}{8}r_P^2\right)$, we again have $q_F^U = 1$, with $q_P^U < 1$ if and only if $r_P < 4$.

Here too, the dual role can yield greater welfare than imposing unbiased recommendation policies. If $1 = \max\{q_P^{DR}, q_F^{DR}\} > q_P^U + (1-q_P^U)q_F^U$, then this is trivially the case, occurring for intermediate values of the cost advantage of the independent firm (fixing $r_P < \bar{r}_P$): $\frac{1}{2}r_P(2-r_P) \geq c_F > \frac{r_P}{8}\left(6 - 2r_P + \frac{3}{8}r_P^2\right)$. In this case, the platform's threat of biasing recommendations induces larger investments by the independent firm to the point of strictly exceeding the investments that would have occurred under unbiased recommendations, to the benefit of consumers.

However, it can also be the case that $1 > \max\{q_P^{DR}, q_F^{DR}\} = q_P^{DR} > q_P^U + (1-q_P^U)q_F^U$ for any fixed $\bar{r}_P$ in so far as the cost advantage of the independent firm is small enough (i.e. c_F

is close enough to 1).[11] Note that this implies that, in the dual role case, even when the threat of biased recommendations leads to foreclosure of the independent firm and the platform alone is producing, it can still lead to a higher consumer welfare than when unbiased recommendations are imposed.

B.3. Discussion

Providing the independent firm with a cost advantage works similarly to it having alternative revenue sources available. When the cost advantage is (not) large enough, the firm will commit to a larger (resp. lower) investment in face of the platform's dual role than when the platform is not involved in production, leading to higher (lower) consumer welfare. The reason for why this is the case is exactly the same: while having to split the revenue under the dual role depresses the independent firm's marginal incentives to invest, higher investment levels now increase both the total revenue as well as the share of the total revenue that is accrued by the independent firm.

However – and again similarly to what occurs in the benchmark model –, this is not the whole story. The (threat of) bias arising from the optimal information design policy by the platform can also contribute to stronger investment incentives. If biasing recommendations negatively affects the value of the platform to consumers (relative to unbiased recommendations), it can induce the independent producer to investment more in order to expand its market share. We can then observe that only when the firm's cost advantage is large (analogously to having significant sources of outside revenue) letting the platform set up the recommendation system to its own advantage improves consumer welfare relative to having unbiased recommendations.

A final note on this variation and how it differs relative to the benchmark setup. The cost structure and the cost advantage specification result in a "bang-bang" solution in the dual-role case, in that either the independent firm expects to be foreclosed from the platform — its only source of revenue — and therefore does not even invest, or the threat of bias induces the firm to invest as much as possible to counter it. This then effectively results in there being no bias in equilibrium recommendation policies, as the consumers know

[11] The derivation of the exact expression for the lower bound on c_F is tedious and provides no significant additional insight.

that, if the independent firm's good is available, it is a high quality good for sure. Then, Bayes plausibility requires the recommendation to guarantee at least as good quality in expectation, the platform has no leeway to bias recommendations (in contrast to what occurs in our benchmark setup), implying that the consumers will only be told to choose the platform's good instead if and when it is at least as good as the available alternative. Therefore, the *threat* of bias in recommendations alone is enough to drive up the firm's investment incentives.

C. Model with Simultaneous Investment

In this appendix we show that our main conclusions are robust to our assumption on the timing of investments. In particular, we consider the case in which investments are simultaneous rather than sequential, keeping everything else the same case as in the main text.

C.1. Dual Role Equilibrium Characterization

Naturally, the only changes that occur are for the independent producer in the dual role and in the unbiased recommendations cases, as they no longer take as given the platform's sequential reaction to their investment choices. Hence, in the dual role we still have that the platform's best response to the producer's chosen quality is given by

$$q_P(q_F) = \begin{cases} \frac{r_P}{2} q_F & \text{if } q_F \geq \tilde{q}_F \text{ and } r_P < 2 \\ \min\left\{1, \frac{r_P}{2}\right\} & \text{if } q_F < \tilde{q}_F \text{ and } r_P < 2, \text{ or } r_P \geq 2. \end{cases}$$

Differently from the baseline, the independent firm's profit function is now given by

$$\pi_F(q_F, q_P) := \max\{0, q_F - q_P\} r_P q_F + r_F q_F - q_F^2.$$

Proposition 7. For any $r_P, r_F > 0$, there is an equilibrium in the dual role with simultaneous investments. There are r_P, r_F such that consumer welfare is strictly higher under the dual role than under the no-platform-production case.

The proof for Proposition 7 provides a complete characterization of the equilibria. In general, a result similar to our baseline model follows, that is, consumer welfare is weakly higher under the dual role than under the no-platform-production case if and only if r_F is large enough relative to r_P. However, given potential multiplicity of equilibria when $1 > r_P > r_F > 0$, the characterization holds only when the equilibrium selection across the parameter space is monotone in $\max\{q_P, q_F\}$. There are multiple of such selection rules, for instance, selecting the equilibrium that attains the highest (or the smallest) $\max\{q_P, q_F\}$ whenever multiple equilibria exist.

Proof. We characterize all equilibria by studying different cases of the parameter space.

Case 1: $r_P \geq 2$ and $r_F > 0$.
In this case, the platform will choose $q_P = 1$ regardless of the firm's choice of investment, leading a unique equilibrium where $q_P = 1$ and $q_F = \min\{1, r_F/2\}$.

Case 2: $2 > r_P \geq 1$ and $r_F \geq r_P$.
Note that $r_P \geq 1 \Longrightarrow \pi_F$ is convex on $[q_P, 1]$. Moreover, π_F is strictly concave on $[0, q_P]$.

Any equilibrium has either $q_P = \frac{r_P}{2}$ or $q_P = \frac{r_P}{2} q_F < q_F$. Then, if $q_P = \frac{r_P}{2}$, we have that

$$0 \leq \frac{\partial}{\partial q_F} \pi_F(q_F, q_P)\Big|_{q_F = \frac{r_P}{2}^-} = -r_P + r_F < -r_P + r_F + \frac{r_P^2}{2} = \frac{\partial}{\partial q_F} \pi_F(q_F, q_P)\Big|_{q_F = \frac{r_P}{2}^+}.$$

This implies that $\arg\max_{q_F \in [0,1]} \pi_F(q_F, q_P) = \arg\max_{q_F \in [q_P, 1]} \pi_F(q_F, q_P) = 1$, where the last equality follows by convexity of π_F on $[q_P, 1]$. As $q_F = 1 \geq \frac{r_P}{4 - r_P}$ and $q_P = \frac{r_P}{2} q_F = \frac{r_P}{2}$, we have that $(q_P, q_F) = \left(\frac{r_P}{2}, 1\right)$ is an equilibrium.

To see that, in this case, this is the unique equilibrium, suppose that we have an equilibrium where $q_F < 1$. Then we must have that $q_P = \frac{r_P}{2} q_F$. But then $q_P < q_F$ and, by convexity of π_F on $[q_P, 1]$, $q_F \in \{q_P, 1\}$. By assumption $q_F < 1$ and if instead $q_F = q_P$, then $q_P = \frac{r_P}{2} q_P = 0 = q_F$, which contradicts the fact that $\frac{\partial}{\partial q_F} \pi_F(q_F, q_P)\Big|_{q_F = q_P = 0} > 0$.

Case 3: $2 > r_P > 1$ and $r_P > r_F > 0$.
As $r_P \geq 1$, π_F remains convex on $[q_P, 1]$, but $r_P > r_F$ implies that there is a unique interior maximum on $[0, q_P]$ whenever $q_P = \frac{r_P}{2}$ due to π_F being strictly concave on this region and

$$0 > -r_P + r_F = \frac{\partial}{\partial q_F} \pi_F(q_F, q_P)\Big|_{q_F = \frac{r_P}{2}^-}.$$

The associated maximizer is $\frac{r_F}{2}$, that is, the investment that the independent firm when foreclosed.

Thus, if, at an equilibrium, $q_P = \frac{r_P}{2} q_F \leq q_F$, we must have that $q_F = 1$. If not, as by convexity of π_F on $[q_P, 1]$, $\arg\max_{q_F \in [q_P,1]} \pi_F(q_F, q_P) \in \{q_P, 1\}$, we would again have $q_F = q_P = \frac{r_P}{2} q_F = 0$, a contradiction. Then, as $1 \geq \frac{r_P}{4-r_P}$, it suffices to check that $\pi_F\left(\frac{r_F}{2}, \frac{r_P}{2}\right) \leq \pi_F\left(1, \frac{r_P}{2}\right)$, which holds whenever $r_F \geq 2 - \sqrt{2r_P}\sqrt{2-r_P}$.

Now suppose that, at an equilibrium, $q_F = \frac{r_F}{2} < q_P \implies q_P = \frac{r_P}{2} \implies \frac{r_F}{2} \leq \frac{r_P}{4-r_P}$. Furthermore, when $2 > r_P \geq 1$ and $r_P > r_F$, some algebra shows that

$$2 - \sqrt{2r_P}\sqrt{2-r_P} \leq 2\frac{r_P}{4-r_P}.$$

Then, given $2 > r_P > 1$ and $r_P > r_F > 0$,

(1) if $r_F < 2 - \sqrt{2r_P}\sqrt{2-r_P}$, there is a unique equilibrium with $(q_P, q_F) = \left(\frac{r_P}{2}, \frac{r_F}{2}\right)$;

(2) if $2 - \sqrt{2r_P}\sqrt{2-r_P} \leq r_F \leq 2\frac{r_P}{4-r_P}$, there are two equilibria, where $(q_P, q_F) \in \left\{\left(\frac{r_P}{2}, 1\right), \left(\frac{r_P}{2}, \frac{r_F}{2}\right)\right\}$;

(3) if $2\frac{r_P}{4-r_P} < r_F$, there is a unique equilibrium, where $(q_P, q_F) = \left(\frac{r_P}{2}, 1\right)$.

Case 4: $r_P = 1 > r_F > 0$.
Note that $\forall q_P < q_F$, $\frac{\partial}{\partial q_F}\pi_F(q_F, q_P) = -q_P + r_F$. Then, not only do we have the same equilibria from Case 3,[12] we have one additional equilibrium, where $q_P = r_F = \frac{r_P}{2} q_F \implies q_F = 2r_F$, whenever $2r_F \geq \frac{r_P}{4-r_P} \iff r_F \geq \frac{1}{6}$.

Case 5: $1 > r_P > 0$ and $r_F \geq r_P$.
In this case we have that π_F is strictly concave on $[0, q_P]$ and on $[q_P, 1]$. At an equilibrium where $q_P = \frac{r_P}{2}$, as $r_P \leq r_F$, we have that

$$0 \leq \frac{\partial}{\partial q_F}\pi_F(q_F, q_P)\Big|_{q_F = \frac{r_P}{2}^-} = -r_P + r_F < -r_P + r_F + \frac{r_P^2}{2} = \frac{\partial}{\partial q_F}\pi_F(q_F, q_P)\Big|_{q_F = \frac{r_P}{2}^+}.$$

This implies that

$$\arg\max_{q_F \in [0,1]} \pi_F(q_F, q_P) = \arg\max_{q_F \in [q_P,1]} \pi_F(q_F, q_P) = \min\left\{1, \frac{r_F - r_P q_P}{2(1-r_P)}\right\}.$$

[12] The only difference is that instead of having that $\arg\max_{q_F \in [q_P,1]} \pi_F(q_F, q_P) \in \{q_P, 1\}$, we have $\arg\max_{q_F \in [q_P,1]} \pi_F(q_F, q_P) \cap \{q_P, 1\} \neq \emptyset$.

Then, given $q_P = \frac{r_P}{2}$, as

$$\min\left\{1, \frac{r_F - r_P q_P}{2(1-r_P)}\right\} = 1 \Longleftrightarrow r_F \geq \max\left\{r_P, \frac{(2-r_P)^2}{2}\right\},$$

and

$$\frac{(2-r_P)^2}{2} > r_F \geq r_P \Longrightarrow \frac{r_F - r_P q_P}{2(1-r_P)} \geq \frac{r_P}{4-r_P},$$

there is an equilibrium with $q_P = \frac{r_P}{2}$ if and only if $r_F \geq \max\left\{r_P, \frac{(2-r_P)^2}{2}\right\}$; in which case the equilibrium is given by $(q_P, q_F) = \left(\frac{r_P}{2}, 1\right)$.

Noting that

$$\frac{\partial}{\partial q_F}\pi_F(q_F, q_P)\Big|_{q_F = q_P^-} = r_F - 2q_P < r_P q_P + r_F - 2q_P = \frac{\partial}{\partial q_F}\pi_F(q_F, q_P)\Big|_{q_F = q_P^+},$$

if at an equilibrium $q_P = \frac{r_P}{2} q_F$, then we further have that $r_F - 2q_P = r_F - r_P q_F \geq 0$, which again delivers

$$\arg\max_{q_F \in [0,1]} \pi_F(q_F, q_P) = \arg\max_{q_F \in [q_P, 1]} \pi_F(q_F, q_P) = \min\left\{1, \frac{r_F - r_P q_P}{2(1-r_P)}\right\}.$$

Replacing $q_P = \frac{r_P}{2} q_F$ and solving for q_F yields $q_F = \min\left\{1, \frac{4}{(2-r_P)^2}\frac{r_F}{2}\right\}$, and when $1 > r_P > 0$ and $r_F \geq r_P$, $q_F > \frac{r_P}{4-r_P}$. Moreover, $r_F \geq \frac{(2-r_P)^2}{2} \Longleftrightarrow q_F = 1$.

Therefore, we have shown there is a unique equilibrium, where $(q_P, q_F) = \left(\frac{r_P}{2}, 1\right)$ if $r_F \geq \max\left\{r_P, \frac{(2-r_P)^2}{2}\right\}$ and $(q_P, q_F) = \left(\frac{r_P}{2}\frac{4}{(2-r_P)^2}\frac{r_F}{2}, \frac{4}{(2-r_P)^2}\frac{r_F}{2}\right)$ if $\frac{(2-r_P)^2}{2} > r_F \geq r_P$.

Case 6: $1 > r_P > 0$ and $r_P > r_F > 0$.
As before, given that $1 > r_P$, π_F is strictly concave on $[0, q_P]$ and on $[q_P, 1]$. Then, in any equilibrium, $q_P \in \{\frac{r_P}{2}, \frac{r_P}{2} q_F\}$ and $q_F \in \left\{\frac{r_F}{2}, \min\left\{1, \frac{r_F - r_P q_P}{2(1-r_P)}\right\}\right\}$.

Immediately we see that there is no equilibrium where $(q_P, q_F) = \left(\frac{r_P}{2} q_F, \frac{r_F}{2}\right)$, seeing that if $q_P < q_F$, then q_F corresponds to the maximizer of π_F on $[q_P, 1]$, which is given by $\min\left\{1, \frac{r_F - r_P q_P}{2(1-r_P)}\right\}$, and this quantity is always strictly larger than $\frac{r_F}{2}$.

Case 6.1: There is an equilibrium where $(q_P, q_F) = \left(\frac{r_P}{2}, 1\right)$ if and only if (i) $\pi_F\left(\frac{r_F}{2}, \frac{r_P}{2}\right) \leq \pi_F\left(1, \frac{r_P}{2}\right) \Longleftrightarrow 2 - \sqrt{2r_P}\sqrt{2-r_P} \leq r_F$, and (ii) $\frac{\partial}{\partial q_F}\pi_F(q_F, q_P)|_{q_F = 1, q_P = r_P/2} \geq 0 \Longleftrightarrow \frac{(2-r_P)^2}{2} \leq r_F$. Note that if $q_F = 1$, then the platform best-responds by choosing $q_P = \frac{r_P}{2}$ as their investment level. Consequently, such an equilibrium exists whenever

$$1 > r_P > r_F \geq \max\left\{2 - \sqrt{2r_P}\sqrt{2-r_P}, \frac{(2-r_P)^2}{2}\right\}.$$

Case 6.2: An equilibrium in which $(q_P, q_F) = \left(\frac{r_P}{2}q_F, \min\left\{1, \frac{r_F - r_P q_P}{2(1-r_P)}\right\}\right) \neq \left(\frac{r_P}{2}, 1\right)$ implies $(q_P, q_F) = \left(\frac{r_P}{2}\frac{4}{(2-r_P)^2}\frac{r_F}{2}, \frac{4}{(2-r_P)^2}\frac{r_F}{2}\right)$. Note that, if $\frac{r_P}{2}\frac{4}{(2-r_P)^2}\frac{r_F}{2} \leq \frac{r_F}{2} \iff r_P \leq \frac{(2-r_P)^2}{2}$, we have that π_F is maximized at $q_F > \frac{r_F}{2}$. Then, there is such an equilibrium if

(i) $r_P \leq \dfrac{(2-r_P)^2}{2}$ or $\pi_F\left(\dfrac{r_F}{2}, \dfrac{r_P}{2}\dfrac{4}{(2-r_P)^2}\dfrac{r_F}{2}\right) \leq \pi_F\left(\dfrac{4}{(2-r_P)^2}\dfrac{r_F}{2}, \dfrac{r_P}{2}\dfrac{4}{(2-r_P)^2}\dfrac{r_F}{2}\right)$

(ii) $q_F = \frac{4}{(2-r_P)^2}\frac{r_F}{2} < 1 \iff \min\left\{r_P, \frac{(2-r_P)^2}{2}\right\} > r_F$, and

(iii) $\pi_P\left(\dfrac{r_P}{2}, \dfrac{4}{(2-r_P)^2}\dfrac{r_F}{2}\right) \leq \pi_P\left(\dfrac{r_P}{2}\dfrac{4}{(2-r_P)^2}\dfrac{r_F}{2}, \dfrac{4}{(2-r_P)^2}\dfrac{r_F}{2}\right) \iff r_F \geq 2\dfrac{r_P}{4-r_P}\dfrac{(2-r_P)^2}{4}$.

Combining these, we find

$$\min\left\{r_P, \frac{(2-r_P)^2}{2}\right\} > r_F \geq \frac{r_P}{4-r_P}\frac{(2-r_P)^2}{2} \qquad \text{and} \qquad \frac{(2-r_P)^2}{2} \geq 2\frac{r_P}{4-r_P}.$$

Case 6.3: Finally, the last possible equilibrium to consider is one such that $(q_P, q_F) = \left(\frac{r_P}{2}, \frac{r_F}{2}\right)$. If $\min\left\{1, \max\left\{0, \frac{r_F - r_P^2/2}{2(1-r_P)}\right\}\right\} \leq q_P = \frac{r_P}{2}$, then $\arg\max_{q_F \in [0,1]} \pi_F(q_F, q_P) = \frac{r_F}{2}$. So equilibrium conditions are given by

(i) $\pi_P\left(\dfrac{r_P}{2}, \dfrac{r_F}{2}\right) \leq \pi_P\left(\dfrac{r_P}{2}\dfrac{r_F}{2}, \dfrac{r_F}{2}\right) \iff r_F \leq 2\dfrac{r_P}{4-r_P}$, and

(ii) $\dfrac{r_F - r_P^2/2}{2(1-r_P)} \leq \dfrac{r_P}{2}$ or
$\dfrac{r_F - r_P^2/2}{2(1-r_P)} > \dfrac{r_P}{2}$ and $\pi_F\left(\dfrac{r_F}{2}, \dfrac{r_P}{2}\right) \geq \pi_F\left(\min\left\{1, \dfrac{r_F - r_P^2/2}{2(1-r_P)}\right\}, \dfrac{r_P}{2}\right)$.

Simplifying the above, we find the conditions supporting this equilibrium to be

$$\min\left\{2\frac{r_P}{4-r_P}, 2 - \sqrt{2r_P}\sqrt{2-r_P}\right\} \geq r_F > 0.$$

We now verify that there is always an equilibrium where $1 > r_P > r_F$. First, note that Cases 6.1 and 6.3 have disjoint conditions, as

$$\min\left\{2\frac{r_P}{4-r_P}, 2-\sqrt{2r_P}\sqrt{2-r_P}\right\} < \max\left\{2-\sqrt{2r_P}\sqrt{2-r_P}, \frac{(2-r_P)^2}{2}\right\}.$$

If $\frac{(2-r_P)^2}{2} \geq 2\frac{r_P}{4-r_P}$, then

$$\frac{(2-r_P)^2}{2} = \max\left\{2-\sqrt{2r_P}\sqrt{2-r_P}, \frac{(2-r_P)^2}{2}\right\}$$

and

$$2\frac{r_P}{4-r_P} = \min\left\{2\frac{r_P}{4-r_P}, 2-\sqrt{2r_P}\sqrt{2-r_P}\right\}.$$

Consequently, the conditions for either Case 6.1, 6.2, or 6.3 are satisfied, as

$$(0, r_P) = \left(0, 2\frac{r_P}{4-r_P}\right) \cup \left(2\frac{r_P}{4-r_P} \cdot \frac{1}{2}\frac{(2-r_P)^2}{2}, \frac{(2-r_P)^2}{2}\right) \cup \left[\frac{(2-r_P)^2}{2}, r_P\right).$$

If $\frac{(2-r_P)^2}{2} \leq 2\frac{r_P}{4-r_P}$,

$$2-\sqrt{2r_P}\sqrt{2-r_P} = \max\left\{2-\sqrt{2r_P}\sqrt{2-r_P}, \frac{(2-r_P)^2}{2}\right\} = \min\left\{2\frac{r_P}{4-r_P}, 2-\sqrt{2r_P}\sqrt{2-r_P}\right\},$$

and therefore,

$$(0, r_P) = \left(0, 2-\sqrt{2r_P}\sqrt{2-r_P}\right) \cup \left[2-\sqrt{2r_P}\sqrt{2-r_P}, r_P\right),$$

implying that the conditions for either Case 6.1 or 6.3 are satisfied.

□

C.2. Welfare Comparison – Dual Role and No Platform Production

We now directly compare the resulting consumer welfare in the dual role case with simultaneous investment decisions to the no platform production case. Recall that in the no platform production case, consumer welfare is given by $q_F^{NP} = \frac{r_P + r_F}{2}$, whereas in the dual role case, consumer welfare is given by $\max\{q_P^{DR}, q_F^{DR}\}$.

In Case 1, consumer welfare is maximal under both the dual role and the no-platform-production scenarios. In Cases 2, 3, and 4, i.e. $2 > r_P \geq 1$, consumer welfare is (strictly) higher under the dual role in some equilibrium if an only if $2 - \sqrt{2r_P}\sqrt{2-r_P} \leq r_F$ (and $r_F < 2 - r_P$). If, moreover $2\frac{r_P}{4-r_P} < r_F$ ($< 2 - r_P$) it is (strictly) so in any equilibrium. In Case 5, consumers are (strictly) better off under the dual role when $\max\left\{r_P, \frac{(2-r_P)^2}{4-r_P}\right\} \leq r_F$ ($< 2 - r_P$). In Case 6.1, i.e. $1 > r_P > r_F \geq \max\left\{2 - \sqrt{2r_P}\sqrt{2-r_P}, \frac{(2-r_P)^2}{2}\right\}$, the dual role is always strictly beneficial to consumers. Case 6.2 is (strictly) consumer-welfare-improving whenever its conditions hold and $\frac{(2-r_P)^2}{4-r_P} \leq r_F$ ($< 2 - r_P$), where this lower-bound on r_F is binding. Finally, Case 6.3 – $\min\left\{2\frac{r_P}{4-r_P}, 2 - \sqrt{2r_P}\sqrt{2-r_P}\right\} \geq r_F > 0$ – has the dual role being always strictly detrimental to consumers.

These comparisons are displayed graphically in Figure 7a and Figure 7b. Due to the multiplicity of equilibria, we have to consider some equilibrium selection criteria in order to be able to compare the cases. We compare the two extreme selection cases and find that there are no significant qualitative differences. In Figures 7a and 7b we consistently select the equilibrium investment levels in the dual role case which induce minimal and maximal welfare, respectively.

C.3. Unbiased Recommendation

Now we examine the case of simultaneous investments with unbiased recommendations.

Equilibrium Characterization

The payoff functions for the platform and the independent firm are similar to the main text:

$$\pi_P(q_P, q_F) := r_P \frac{1}{2}(1 - (q_F - q_P))(q_F + (1 - q_F)q_P) - q_P^2;$$
$$\pi_F(q_F, q_P) := r_P \frac{1}{2}(1 - (q_P - q_F))(q_F + (1 - q_F)q_P) + r_F q_F - q_F^2.$$

As $\frac{\partial^2}{(\partial q_F)^2}\pi_F(q_F, q_P) = -2 + (1 - q_P)r_P$ and $\frac{\partial^2}{(\partial q_P)^2}\pi_P(q_P, q_F) = -2 + (1 - q_F)r_P$, and as

$$\frac{\partial}{\partial q_F}\pi_F(q_F, q_P)|_{q_F=0}\frac{\partial}{\partial q_P}\pi_P(q_P, q_F)|_{q_P=0} > 0,$$

we know that their best-responses are uniquely defined:

$$q_P^*(q_F) := \arg\max_{q_P \in [0,1]} \pi_P(q_P, q_F) = \begin{cases} 1 & , \text{ if } q_F \leq \frac{r_P - 2}{r_P} \\ \min\left\{1, \frac{r_P}{2} \frac{1-q_F(1-q_F)}{2-r_P(1-q_F)}\right\} & , \text{ if } q_F > \frac{r_P-2}{r_P} \end{cases}$$

$$q_F^*(q_P) := \arg\max_{q_F \in [0,1]} \pi_F(q_F, q_P) = \begin{cases} 1 & , \text{ if } q_P \leq \frac{r_P - 2}{r_P} \\ \min\left\{1, r_F \frac{1}{2-r_P(1-q_P)} + \frac{r_P}{2} \frac{1-q_P(1-q_P)}{2-r_P(1-q_P)}\right\} & , \text{ if } q_P > \frac{r_P-2}{r_P} \end{cases}.$$

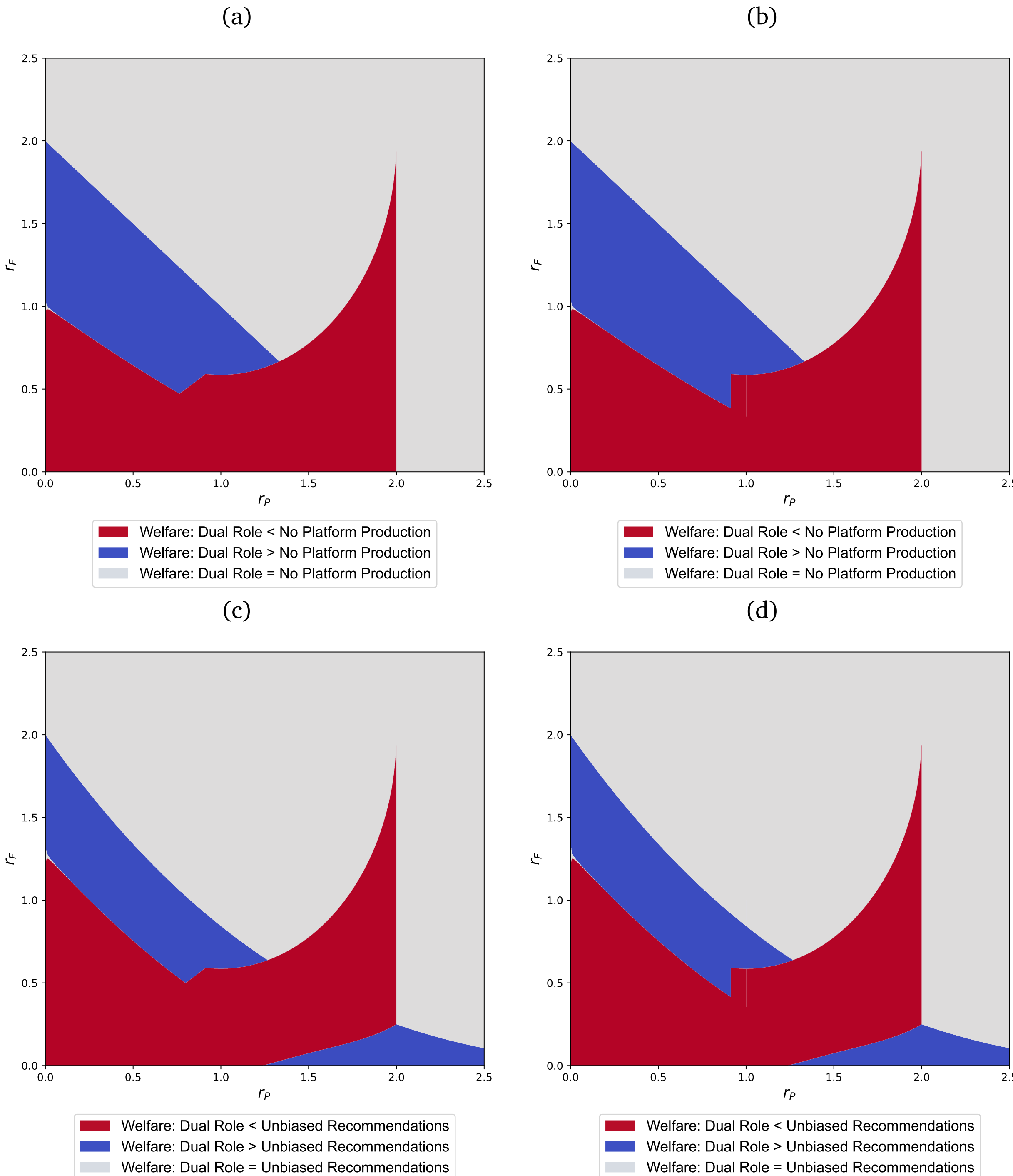
Moreover, algebraic manipulations show that $-2+(1-q_P^*(q_F))r_P, -2+(1-q_F^*(q_P))r_P \leq 0$ for any $q_F, q_P \in [0,1]$, which implies that, at any equilibrium we have $q_P, q_F \geq \frac{r_P-2}{r_P}$ (trivially satisfied if $r_P \leq 2$).

For any $q_F > \frac{r_P-2}{r_P}$, $\frac{\partial^2}{(\partial q_F)^2} q_P^*(q_F) < 0$. For simplicity, we restrict ourselves to the case where $r_F \leq 3$ as $\forall r_F > 3$ we already know that consumer welfare is maximum under the dual role. Under such condition, we also have that $q_P > \frac{r_P-2}{r_P}$, $\frac{\partial^2}{(\partial q_P)^2} q_F^*(q_P) < 0$. Then, we can further verify algebraically that $q_P^*\left(\min_{1 \geq q_P \geq (r_P-2)/r_P} q_F^*(q_P)\right) \leq \arg\min_{1 \geq q_P \geq (r_P-2)/r_P} q_F^*(q_P)$, which delivers the uniqueness of an equilibrium.

Welfare Comparisons

We display the welfare comparisons between the dual role and unbiased recommendation case in Figures 7c and 7d. Since we only characterize the unique best-response functions, we compute the equilibrium for parameter values numerically. Similarly to the previous case, we plot the comparison between the equilibrium selection that induces minimal and maximal welfare in the dual role case in Figure 7c and 7d respectively. We find comparable results to the welfare comparisons in the sequential investment case.

Figure 7. **Average Welfare Comparisons under Simultaneous Case.**



Notes: This figure displays the difference in expected good quality, which corresponds to average consumer welfare on the platform, across the no platform production, dual role, and unbiased recommendation cases. Panels (a) and (b) compare welfare between the dual role and no platform production cases. Panels (c) and (d) compare welfare between the dual role and unbiased recommendation cases. Panels (a) and (c) display the comparisons where we select the equilibria in the dual role case with minimal welfare across the possible equilibria. Panels (b) and (d) display the comparisons where we select the equilibria in the dual role case with maximal welfare across the possible equilibria.