Platform Recommendation and Sequential Contracting*

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A content platform sequentially contracts with artists and later controls their exposure via algorithmic recommendations. We identify a time-inconsistency problem: once an early artist is locked into a royalty contract, the platform has an incentive to sign later artists at lower rates and favor them in recommendations. Anticipating this, early artists demand compensation entirely through fixed payments, driving equilibrium royalty rates to zero. When fixed payments are relatively costly, royalties become positive but unequal, distorting recommendations. The platform may mitigate these inefficiencies by designing the sequence of artists to contract with or committing to uniform royalty rates.

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1 Introduction

Music streaming platforms, such as Spotify and Apple Music, shape consumer listening behavior through curated playlists and algorithmic recommendations. Spotify owns and curates 24 of the 25 most-followed playlists, and inclusion in a top playlist, such as "Discover Weekly," can generate millions of additional streams (Aguiar and Waldfogel, 2021). These recommendations directly affect stream counts, and, in turn, artist compensation under per-stream royalty contracts.

Although recommendations affect artists' success, they are difficult to specify contractually. Recommendation outcomes depend on complex and opaque algorithms that react to user behavior and the evolving pool of content on the platform. As new artists and content enter the platform, these algorithms continually adjust, making it impractical to specify recommendations in advance.

The inability to contract on recommendations creates a dynamic incentive distortion problem for the platform when artists sign their agreements sequentially. Because each agreement affects the platform's future incentives, an artist who joins early must accept terms without knowing how her work will be promoted after later artists arrive. When later artists are offered different royalty rates, the platform's incentive shifts toward recommending the artists who are cheaper to promote, potentially reducing the exposure of higher-royalty artists and undermining the effectiveness of royalty-based contracts.

This tendency for the platform to promote cheaper content has been documented by both industry statements and recent empirical evidence. Spotify acknowledges that "commercial considerations, such as the cost of content or whether we can monetize it, may influence our recommendations."[1] Universal Music Group's CEO, Lucian Grainge, has voiced similar concerns: "consumers are often guided by algorithms to generic music that...is less expensive for the platform to license."[2] Recent empirical evidence finds that Spotify promotes lower-cost independent music, thereby shifting royalty payments away from major labels (Aguiar et al., 2024).

In this paper, we study the interaction between the non-contractibility of recommen-

[1]See Spotify (2026).
[2]See Aswad (2023).

dations and sequential contracting. In our model, a platform contracts sequentially with artists using two standard instruments: fixed payments and per-stream royalty rates.[3] We assume that the platform's contract with the first artist is fixed once it is signed. In other words, this contract cannot depend on what the platform signs with the second artist. Once both contracts are signed, the platform chooses its recommendation mix to maximize its profit.

Our main result is to show that the platform's commitment problem, which arises because of the non-contractibility of recommendations, eliminates the effectiveness of the royalty-based contract entirely. We show that, when contracting with the second artist, the platform's optimal strategy is to set her royalty rate to zero and rely exclusively on fixed payments. The zero royalty rate makes recommending the second artist costless at the margin, allowing the platform to reduce its overall royalty obligations by shifting its recommendations away from the first artist. Anticipating this future undercutting, the platform recognizes that setting any positive royalty rate for the first artist would create a rate differential that induces a recommendation bias and reduces total revenue. The platform therefore finds it optimal to set the royalty rate to zero for the first artist as well.

Consequently, in equilibrium, both royalty rates collapse to zero, and artists are compensated entirely through fixed payments. The platform's inability to commit to its future recommendations thus causes the royalty-based compensation to unravel completely. This result stands in contrast to a benchmark in which the platform can commit to both contracts simultaneously. With commitment, the platform can sustain any common royalty rate, yielding a continuum of efficient contract structures. The loss of commitment eliminates this flexibility.

We extend this result in several directions. First, we show that the unraveling result continues to hold for any number of artists. Second, we study the case where fixed payments are costly for the platform because they tie up cash. In this case, royalties become positive. But the commitment problem keeps them low and unequal: the later-

[3] In practice, streaming contracts combine per-stream royalties with other instruments that are less directly tied to realized streams, such as non-recoupable payments, equity stakes, advances, and minimum revenue guarantees (see, e.g., Jones, 2015; Ingham, 2018). We abstract from the specific features of these instruments and represent them in reduced form as fixed payments. The general trade-off between these instruments has been a concern in the industry: independent labels worried that major labels might trade lower per-stream rates for higher advances; see Dredge (2014).

signed artist receives a strictly lower rate, which biases recommendations toward that artist. The platform can reduce these inefficiencies by its choice of contracting order.

Our analysis implies that the platform may benefit from committing to a uniform royalty rate across artists, thereby limiting future undercutting. Such a commitment eliminates the undercutting incentive, allowing the platform to make unbiased recommendations while substituting royalties for potentially costly fixed payments. Apple Music publicly states that "while other services pay some independent labels a substantially lower rate than they pay major labels, we pay the same headline rate to all labels."[4] In our model, this policy reduces the inefficiency arising from time inconsistency.[5]

Our paper relates to three strands of literature. First, it relates to studies of opportunism in multilateral vertical contracting (e.g., Hart and Tirole, 1990; O'Brien and Shaffer, 1992; McAfee and Schwartz, 1994); see Rey and Tirole (2007) for an overview. In this literature, an upstream supplier contracts with competing downstream firms. After one firm is contractually committed, the supplier may offer a later firm a lower marginal input price in exchange for a higher fixed fee. This undercutting harms the earlier firm by reducing its rival's marginal cost and inducing more aggressive downstream competition.

We complement this work by studying opportunism in the allocation of recommendations. The two settings differ in the role of the marginal contractual term. In vertical contracting, a marginal input price changes a downstream firm's marginal cost and therefore how aggressively it competes. In our model, the gap in royalty rates changes the mix of artists the platform prefers to recommend. The welfare implications also differ. Opportunistic discounts in vertical contracting tend to lower downstream prices, expand output, and benefit consumers. In our model, the distortion is in the allocation of attention: unequal royalty rates move recommendations away from the value-maximizing allocation, tending to harm consumers. Contracting order and uniform-rate commitments are therefore important in our setting because they reduce or eliminate this gap.[6]

[4]See Apple Music for Artists (2021).

[5]This result does not imply that all platforms should adopt uniform rates. Such a commitment is not costless. It restricts contractual flexibility, because platforms may benefit from tailoring royalty rates to artists and labels with different demand conditions, outside options, or bargaining power. The policy is therefore more attractive when the gain from limiting future undercutting outweighs the cost of reduced contractual flexibility (for a related discussion, see McAfee and Schwartz, 1994).

[6]In vertical contracting, McAfee and Schwartz (1994) argue that MFN clauses need not restore commitment under two-part tariffs. Subsequent work reexamines this issue and shows that nondiscrimination may restore commitment in related formulations (see, e.g., Marx and Shaffer, 2004; DeGraba, 1996). Other

More broadly, our paper is related to the literature on contracting with externalities (see, e.g., Segal (1999)). A closely related example is the durable good monopolist problem (Coase, 1972), formalized by Stokey (1981), Bulow (1982), and Gul et al. (1986).[7] A monopolist, after selling to high-value buyers, has an incentive to cut prices to serve the lower-value buyers who remain. Anticipating this, high-value buyers delay their purchases, undermining the monopolist's ability to maintain high prices. Our model shares a similar unraveling outcome, but the underlying mechanism differs. There is no selection of heterogeneous buyers over time. The platform's problem arises from its retained control over recommendations. The platform lowers later royalty rates not to sell more units but to shift attention away from earlier artists and reduce its royalty obligations. The distortion is therefore a misallocation of attention across artists that tends to harm consumers, rather than an expansion of output that, as in the durable-good monopoly problem, tends to benefit buyers.

Finally, our paper relates to work on intermediation and platform recommendations. This literature studies how intermediaries steer consumers to obtain more favorable terms from suppliers, such as lower input prices, lower royalty rates, or higher commissions (see, e.g., Armstrong and Zhou, 2011; Hagiu and Jullien, 2011; Inderst and Ottaviani, 2012; Teh and Wright, 2022; Bourreau and Gaudin, 2022).[8] We study a distinct implication of exposure control. Rather than serving as an instrument for extracting surplus from suppliers, the platform's control over recommendations creates a commitment problem when contracts are signed sequentially.

2 Model

A music streaming platform interacts with two artists, $i = 1, 2$. The game has two stages, a contracting stage and a recommendation stage.

responses include resale price maintenance and exclusivity; see, for example, DeGraba and Postlewaite (1992), Segal and Whinston (2003), Rey and Vergé (2004), and Gilo and Yehezkel (2020).

[7] Subsequent work studies the robustness of the Coase conjecture to production constraints, durability, differentiation, buyer arrival, outside options, and mechanism design; see, for example, Kahn (1986), Sobel (1991), McAfee and Wiseman (2008), Fuchs and Skrzypacz (2010), Board and Pycia (2014), Nava and Schiraldi (2019), Doval and Skreta (2022, 2024), and Brzustowski et al. (2023).

[8] Related work on retail shelf space also studies how firms allocate scarce consumer attention (e.g., Corstjens and Doyle, 1981; Shaffer, 1991; Martínez-de Albéniz and Roels, 2011).

The contracting stage begins with the platform offering a contract to artist 1. This contract specifies a *fixed payment* F_1 and a per-stream *royalty rate* p_1. Artist 1 accepts this contract if her payoff is greater than the outside option $\bar{u} > 0$. After contracting with artist 1, the platform offers a separate contract (F_2, p_2) to artist 2, who faces the same decision based on her outside option, also $\bar{u}$. Both F_i and p_i are non-negative due to artists' limited liability.

Once both contracts are signed, the game proceeds to the recommendation stage. In this stage, the platform chooses the proportion of its playlist allocated to artist 1, denoted by q_1, with the remainder $1 - q_1$ allocated to artist 2. We assume that a representative consumer follows this recommendation, so the recommendation shares are also the consumption shares. This consumption generates revenue $R(q_1)$ for the platform. The revenue function R is strictly concave and maximized at $q_1 = \frac{1}{2}$.

The platform's profit Π is the revenue from the recommendation stage minus the payments to artists:

$$\Pi = R(q_1) - (F_1 + p_1 q_1 + F_2 + p_2(1 - q_1)).$$

The payoff for artist i is the sum of her fixed payment, F_i, and her royalties, which are $p_1 q_1$ for artist 1 and $p_2(1 - q_1)$ for artist 2.

All information is public, and the solution concept is subgame-perfect equilibrium. We focus on the case where both artists accept their contracts.

Remark. Several assumptions simplify the analysis without affecting the main insights. First, we present the model with two artists. We consider any finite number of artists later. Second, defining recommendations as shares (q_1 and $1 - q_1$) models a scenario of direct substitution, which captures the competition for listener attention: featuring one artist more means featuring another less. Third, $R(q_1)$ is a reduced-form representation of how the recommendation mix affects platform revenue. We require only that revenue fall when the platform shifts the recommendation mix away from the consumer's preferred mix. This can hold whether the consumer follows the recommendation only or also searches on her own. Lastly, we assume symmetry for expositional clarity. The model can accommodate asymmetric artists who differ in popularity or in their outside options.

3 Analysis

We analyze the model in three steps. First, we derive the platform's optimal recommendation. Second, we analyze a benchmark in which the platform can commit to the terms of both artists' contracts. Finally, we solve for the equilibrium in our main model of sequential contracting and compare it with the benchmark.

3.1 Optimal Recommendation

We first consider the recommendation stage. In this stage, both artists' contracts, (F_1, p_1) and (F_2, p_2), have been signed and cannot be changed. Taking these terms as given, the platform chooses the recommendation, q_1, to maximize its profit:

$$\max_{q_1} \quad R(q_1) - \big(F_1 + p_1 q_1 + F_2 + p_2(1 - q_1)\big).$$

The fixed payments, F_1 and F_2, do not affect the choice of q_1. The royalty rates, p_1 and p_2, are the marginal costs of recommending each artist. Any difference between these two rates biases the platform's recommendation. We assume an interior solution. The optimal recommendation satisfies the following first-order condition:

$$R'(q_1) = p_1 - p_2. \tag{1}$$

To see the intuition, suppose $p_1 > p_2$, so artist 2 is cheaper to recommend. To reduce its total royalty payments, the platform shifts its recommendation toward artist 2 and away from its revenue-maximizing mix, $\frac{1}{2}$. It continues until the marginal loss in revenue $(R'(q_1))$ equals the marginal net saving in royalty payments $(p_1 - p_2)$.

The following lemma summarizes the properties of the optimal recommendation.

Lemma 1. *The optimal recommendation $q_1(p_1, p_2)$ satisfies*

(*i*) $q_1(p_1, p_2) = \frac{1}{2}$ *if and only if* $p_1 = p_2$*;*

(*ii*) $q_1(p_1, p_2)$ *is strictly decreasing in* p_1 *and strictly increasing in* p_2.

Part (i) of this lemma shows that the platform will recommend the unbiased mix if and only if the artists' royalty rates are identical. When the marginal cost of recommending each artist is the same, the platform has no incentive to give up revenue by biasing the recommendation. Part (ii) shows that when the royalty rates differ, the platform shifts its recommendation away from the more expensive artist and toward the cheaper one.[9]

The optimal recommendation creates a contractual externality between artists: the terms set for one artist influence the recommendation for the other. The contracts therefore cannot be considered independently in the contracting stage. We first study this contractual externality in a benchmark in which the platform can commit to the terms of both artists' contracts. We then turn to sequential contracting.

3.2 Benchmark: Contracting with Commitment

As a benchmark, suppose the platform can commit to both artists' contracts at the beginning of the game. The platform then chooses both contracts, (F_1, p_1) and (F_2, p_2), simultaneously to maximize its profit:

$$\max_{F_1,p_1,F_2,p_2} \quad R(q_1) - \big(F_1 + p_1 q_1 + F_2 + p_2(1 - q_1)\big),$$

subject to the artists' participation constraints ($F_1 + p_1 q_1 \geqslant \bar{u}$ and $F_2 + p_2(1 - q_1) \geqslant \bar{u}$) and limited liability constraints ($F_1, F_2, p_1, p_2 \geqslant 0$), and the anticipation that the future recommendation will be optimal ($q_1 = q_1(p_1, p_2)$).

With commitment, the platform can maximize revenue and minimize payments to the artists simultaneously. Revenue is maximized when the recommendation is unbiased. By Lemma 1, this requires equal royalty rates, $p_1 = p_2 = p$. Payments are minimized when the artists' participation constraints bind, so the fixed payment $F_i = \bar{u} - \frac{p}{2}$.

Any common royalty rate $p \in [0, 2\bar{u}]$, with the fixed payment adjusted accordingly, is therefore optimal. At one endpoint, $p = 0$ and $F_i = \bar{u}$, so compensation is entirely through fixed payments. At the other endpoint, $p = 2\bar{u}$ and $F_i = 0$, so compensation is entirely through royalties. Thus, the commitment benchmark has a continuum of optimal

[9] A general version of this lemma for N asymmetric artists is Lemma A.1 in the appendix.

contract structures and allows the platform to choose how compensation is split between fixed payments and royalties.

3.3 Contracting without Commitment

We now solve for the equilibrium in our main model, in which the platform cannot commit and must contract with artists sequentially. By backward induction, we begin with the contract for artist 2 and then turn to the contract for artist 1.

3.3.1 The Contract with Artist 2

When the platform contracts with artist 2, artist 1's contract, (F_1, p_1), has been signed and cannot be changed. The platform's problem is then to choose a contract (F_2, p_2) for artist 2 to maximize its profit:

$$\max_{F_2, p_2} R(q_1) - (F_1 + p_1 q_1 + F_2 + p_2(1 - q_1)),$$

subject to artist 2's participation constraint ($F_2 + p_2(1 - q_1) \geqslant \bar{u}$) and limited liability constraint ($F_2, p_2 \geqslant 0$), and the anticipation that the future recommendation will be optimal ($q_1 = q_1(p_1, p_2)$).

The platform's main decision is to choose the royalty rate p_2. Once p_2 is chosen, F_2 is determined because the participation constraint must bind. Otherwise, the platform can decrease F_2 or p_2 and increase its profit. Consequently, the platform's problem reduces to choosing p_2 to maximize $R(q_1(p_1, p_2)) - (F_1 + p_1 q_1(p_1, p_2) + \bar{u})$.

The royalty payment to artist 1, $p_1 q_1$, is the only remaining cost the platform can reduce. This creates an incentive to undercut artist 1. The platform can lower artist 2's royalty rate (p_2) to make her cheaper to recommend. By Lemma 1, this shifts the recommendation away from artist 1 and reduces the royalty payment $p_1 q_1$. One might guess that the platform would not lower p_2 too much, as a large recommendation bias would significantly harm its revenue. This intuition, however, is incomplete.

We find that as long as artist 2's royalty rate is positive ($p_2 > 0$), the marginal gain from undercutting artist 1 is always strictly greater than the marginal loss in revenue. The reason is as follows. When the platform decreases p_2, it creates a marginal saving on

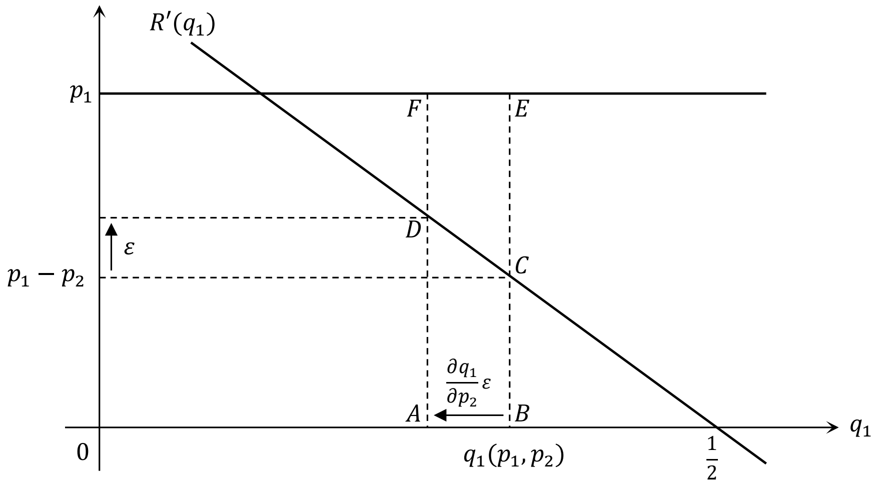

Figure 1: The Incentive to Undercut: Royalty Savings versus Revenue Loss

royalties paid to artist 1, $p_1 \frac{\partial q_1}{\partial p_2}$. At the same time, it incurs a marginal loss in revenue from the increased recommendation bias, $R'(q_1)\frac{\partial q_1}{\partial p_2}$. Using the result from the recommendation stage that $R'(q_1) = p_1 - p_2$, this marginal loss in revenue is $(p_1 - p_2)\frac{\partial q_1}{\partial p_2}$. Therefore, the loss is always strictly smaller than the saving whenever $p_2 > 0$.

Figure 1 illustrates this comparison. A marginal decrease in p_2 by ε saves the platform royalties on artist 1 equal to the area of the large rectangle ABEF. The corresponding loss in revenue is the area of the smaller ABCD. Because the height of the saving rectangle is p_1 while the height of the loss rectangle is only $p_1 - p_2$, the saving is always greater than the loss.

The platform therefore lowers p_2 until it reaches zero, at which point the marginal loss finally equals the marginal saving.

Proposition 1. *For any contract with artist 1, the platform's optimal royalty rate for artist 2 is* $p_2 = 0$.

Our result highlights a time-inconsistency problem for the platform. When choosing artist 2's contract, the platform views recommending artist 2 as free at the margin, because her total payment is fixed at $\bar{u}$ through the adjustable fixed payment. Therefore, the platform wishes it could commit to recommending artist 2 heavily, as this allows it to reduce the royalties that will be paid to artist 1. However, if the platform sets $p_2 > 0$, its future self at the recommendation stage will be reluctant to recommend artist 2 that much, because doing so would incur a marginal royalty cost p_2. By setting $p_2 = 0$, the platform ensures that recommending artist 2 remains free at the margin for its future self.

This removes its future reluctance and aligns its incentives across the two stages.

3.3.2 The Contract with Artist 1

We now consider the contract with artist 1. The platform chooses (F_1, p_1) to maximize its profit:

$$\max_{F_1, p_1} R(q_1) - (F_1 + p_1 q_1 + \bar{u}),$$

subject to artist 1's participation constraint $(F_1 + p_1 q_1 \geqslant \bar{u})$ and limited liability constraint $(F_1, p_1 \geqslant 0)$, the anticipation that the future contract for artist 2 will be optimal $(F_2 = \bar{u}$ and $p_2 = 0)$, and the anticipation that the future recommendation will be optimal $(q_1 = q_1(p_1, p_2))$. Because the participation constraint for artist 1 also binds, the platform's problem reduces to choosing p_1 to maximize the revenue $R(q_1(p_1, 0))$.

Revenue is maximized when the recommendation is unbiased, $q_1 = \frac{1}{2}$. By Lemma 1, an unbiased recommendation requires equal royalty rates, $p_1 = p_2$. By Proposition 1, the platform anticipates setting $p_2 = 0$. The platform must therefore set $p_1 = 0$. Any $p_1 > 0$ would bias the recommendation and reduce the platform's profit.

Theorem 1. *Under sequential contracting, the unique equilibrium involves zero royalty rates for both artists* $(p_1^* = p_2^* = 0)$. *Compensation is delivered entirely through fixed payments* $(F_1^* = F_2^* = \bar{u})$.

This result contrasts with the commitment benchmark. With commitment, the platform can choose any combination of fixed payments and royalties. Without commitment, the platform's incentive to undercut artist 1 causes royalty-based compensation to unravel, and fixed payments become the only form of compensation in equilibrium. The loss of commitment eliminates the platform's contractual flexibility, even without other frictions.

4 Extensions

We now extend the model in three directions. First, we allow the platform to contract with any finite number of artists and show that the main results are robust. Second, we introduce a friction, costly fixed payments, to show how the commitment problem creates inefficiency. Finally, we show that the platform can reduce this inefficiency by designing the sequence of artists to contract with.

4.1 Multiple Artists

We now extend the model to a setting with $N \geqslant 2$ artists. With commitment, the platform can achieve an efficient, unbiased recommendation by setting any common royalty rate for all N artists, so a continuum of contract structures is again optimal.

This flexibility is lost under sequential contracting. The reasoning from our main analysis extends directly. Start with the final contract offered to artist N. At this stage, the contracts for artists $1, \ldots, N-1$ have been signed and cannot be changed. The platform has an incentive to undercut this group of artists. By setting a low royalty rate, p_N, the platform makes artist N cheaper to recommend. This biases the recommendation away from the first $N-1$ artists and reduces the royalties paid to them. As in the main analysis, the marginal gain from undercutting is always greater than the marginal revenue loss, so the platform sets $p_N = 0$.

This undercutting incentive cascades backwards through the contracting sequence: the platform sets $p_k = 0$ to reduce payments to artists $1, \ldots, k-1$. Finally, when choosing the contract for artist 1, the platform anticipates that all future royalty rates will be zero. Because the artists' total payments are fixed, the platform maximizes its profit by maximizing revenue, so it sets $p_1 = 0$ as well.

Proposition 2. *With $N \geqslant 2$ artists and sequential contracting, the unique equilibrium involves zero royalty rates for all artists ($p_1^* = \cdots = p_N^* = 0$).*

The unraveling therefore does not depend on the two-artist setting. It follows from the interaction between recommendation and sequential contracting.

4.2 Costly Fixed Payments

Although sequential contracting yields a unique zero-royalty outcome, this outcome is still efficient in our frictionless baseline. We now allow fixed payments to be costly,[10] and

[10] Fixed payments may be costly for several reasons: they require cash, may involve transfers of ownership when paid in equity, or cannot scale with realized demand (Wang and Wright, 2017). We represent these frictions in reduced form.

show how the commitment problem creates inefficiency. Specifically, a fixed payment F_i costs the platform $(1+r)F_i$, where $r > 0$, while royalties carry no additional cost.

With commitment, the platform can use its contractual flexibility to shift compensation away from costly fixed payments and toward royalties. The optimal choice is to set high, equal royalty rates at $p_1 = p_2 = 2\bar{u}$, which eliminates fixed payments. This choice attains the profit upper bound: the platform avoids the cost of fixed payments, and equal royalty rates keep the recommendation unbiased and maximize revenue.

Without commitment, this efficient royalty-based compensation cannot be sustained. If the platform sets a high royalty rate for artist 1, it still has an incentive to undercut artist 1 when contracting with artist 2. Anticipating this, the platform also avoids setting a high rate for artist 1, because doing so would create a large rate differential, bias the recommendation, and reduce revenue. Consequently, the time-inconsistency problem prevents the platform from sustaining the royalty rates needed to eliminate fixed payments.

Proposition 3. *When fixed payments are costly, the equilibrium royalty rates satisfy $0 < p_2^* < p_1^* < 2\bar{u}$. Consequently, the platform bears the cost of positive fixed payments and loses revenue from a biased recommendation.*

Proposition 3 shows that the platform is left with a second-best outcome. It cannot fully eliminate costly fixed payments, because the undercutting incentive prevents it from raising royalty rates high enough. At the same time, this incentive leads to unequal royalty rates in equilibrium, which bias the recommendation and reduce revenue.

Interpreting $R(q_1)$ as consumer value allows us to study the welfare implications. In the frictionless baseline, the unraveling of royalties does not generate a welfare loss relative to the commitment benchmark: the recommendation remains unbiased at $q_1^* = 1/2$, and the shift from royalties to fixed payments only changes the form of compensation. Welfare losses arise once fixed payments are costly. In this case, sequential contracting leads to unequal royalty rates, $p_1^* > p_2^*$, which biases the recommendation and lowers consumer value. Moreover, the cost of fixed payments can also be a social loss, but only to the extent that it reflects real resource costs rather than pure transfers.

These inefficiencies point to a natural commitment device. In the model, a credible commitment to uniform royalty rates ($p_1 = p_2$) would eliminate the incentive to undercut.

The platform could then set both royalty rates at the efficient level of $2\bar{u}$, eliminating fixed payments and their associated costs. Equal royalty rates would also remove the recommendation distortion and maximize platform revenue. Thus, when such a commitment is feasible and not too costly, uniform royalty rates can restore the efficient outcome. This result offers a possible formal rationale for Apple Music's policy of paying a uniform headline rate, discussed in the Introduction.

4.3 Endogenous Order of Contracting

Our analysis has so far assumed a fixed contracting order. We now allow the platform to choose which artist to contract with first. We show that this choice does not matter in the frictionless baseline but affects the platform's profit when fixed payments are costly.

We relax the assumption of symmetric artists and allow them to differ in popularity, so the consumer's preferred mix, which also maximizes the platform's revenue, can favor one artist over the other. The platform must now decide whether to contract first with the more popular artist or the less popular one.

First, consider the baseline model in which fixed payments are costless. The equilibrium outcome is the same under either order: both artists receive zero-royalty contracts, and the final recommendation is efficient. The platform's profit is therefore identical regardless of which artist it contracts with first.

The contracting order matters once fixed payments are costly. To obtain a sharp result, we consider a quadratic revenue function $R(q_1) = \bar{R} - [q_1 - (1-\theta)]^2$. Here $\bar{R}$ is the revenue when the recommendation matches the consumer's preferred mix, and θ is the consumer's preferred share of the artist contracted second. While the platform's incentive to undercut the first artist remains, its profit now depends on the popularity of the artist contracted second.

A more popular second artist allows the platform to rely more on royalties in the second contract. When the second artist is more popular, the platform anticipates recommending her more heavily. A higher royalty rate, p_2, then shifts more of her compensation away from costly fixed payments and toward royalties. The platform therefore has a stronger incentive to raise p_2.

A higher royalty rate for the second artist has two positive effects on the platform's profit. First, it directly reduces the fixed payment and its associated costs. Second, it narrows the difference between the two artists' royalty rates, which reduces the recommendation bias and raises revenue. The platform's profit is therefore higher when the second artist is more popular.

Corollary 1. *Suppose fixed payments are costly and revenue takes the quadratic form above. The platform's profit is higher if it contracts with the less popular artist first and the more popular artist second.*

The contracting order is therefore a partial substitute for commitment. A firm that cannot commit to the terms of future contracts can still mitigate its time-inconsistency problem by choosing the sequence in which it contracts.

5 Conclusion

We study a platform that contracts sequentially with artists and later recommends their work. The platform's control over non-contractible recommendations creates a time-inconsistency problem. The platform has an incentive to undercut earlier artists by offering lower royalty rates to later artists. This allows the platform to bias its recommendations and reduce the royalties paid to earlier artists.

We show that this undercutting incentive causes royalty-based compensation to unravel. In a frictionless baseline, the unique equilibrium involves zero royalties for all artists, and artists are compensated entirely through fixed payments. This unraveling creates inefficiency when fixed payments are costly. The platform bears the cost of fixed payments and loses revenue from biased recommendations.

The inefficiency can be reduced in two ways. A credible commitment to uniform royalty rates, when feasible, eliminates the undercutting incentive and restores efficiency. This offers a possible rationale for the uniform royalty rates that platforms such as Apple Music have adopted. When commitment is infeasible, the platform can still reduce inefficiency by choosing its contracting order.

Appendix

We provide details for the three extensions.

A Multiple Artists

Consider N artists. Denote the recommendation by $\mathbf{q} := (q_1, \ldots, q_N)$. We assume that $R(\mathbf{q})$ is continuously differentiable and strictly concave. Let $\mathbf{q}^{FB} = (q_1^{FB}, \ldots, q_N^{FB})$ denote the consumer's preferred recommendation, which uniquely maximizes $R(\mathbf{q})$. We assume $q_i^{FB} > 0$ for all i and $\sum_{i=1}^{N} q_i^{FB} = 1$.

Optimal Recommendation. In the recommendation stage, the platform chooses $\mathbf{q}$, subject to $\sum q_i = 1$, to maximize its profit $R(\mathbf{q}) - \sum(F_i + p_i q_i)$. The Lagrangian is

$$\mathcal{L} = R(\mathbf{q}) - \sum(F_i + p_i q_i) - \lambda \left(1 - \sum q_i\right).$$

The first-order conditions are

$$R_1(\mathbf{q}) - p_1 + \lambda = 0, \quad \ldots, \quad R_N(\mathbf{q}) - p_N + \lambda = 0, \quad \sum_{j=1}^{N} q_j - 1 = 0,$$

where $R_j(\mathbf{q}) = \frac{\partial R(\mathbf{q})}{\partial q_j}$. Thus,

$$R_i(\mathbf{q}) - p_i = -\lambda \quad \text{for } i = 1, \ldots, N, \qquad \sum q_i = 1,$$

or $R_i - R_j = p_i - p_j$ for all $i \neq j$.

The optimal recommendation creates an externality among artists. Let $\mathbf{q}(\mathbf{p})$ denote the optimal recommendation, where $\mathbf{p} := (p_1, \ldots, p_N)$. We assume an interior solution.

Lemma A.1. *The optimal recommendation $\mathbf{q}(\mathbf{p})$ has the following properties:*

(*i*) $\mathbf{q}(\mathbf{p}) = \mathbf{q}^{FB}$ *if and only if* $p_1 = \cdots = p_N$;

(*ii*) $q_i(\mathbf{p})$ *is strictly decreasing in* p_i *and* $\sum_{j \neq i} q_j(\mathbf{p}) = 1 - q_i(\mathbf{p})$ *is strictly increasing in* p_i.

Proof. For (i), first suppose $p_1 = \cdots = p_N = p$. Because $\sum q_i = 1$, the total royalty payments satisfy $\sum p_i q_i = p$. The platform therefore chooses $\mathbf{q}$ to maximize $R(\mathbf{q})$, which gives $\mathbf{q}(\mathbf{p}) = \mathbf{q}^{FB}$. Second, suppose $\mathbf{q}(\mathbf{p}) = \mathbf{q}^{FB}$. Because $\mathbf{q}^{FB}$ maximizes $R(\mathbf{q})$ subject to $\sum q_i = 1$, we have $R_i(\mathbf{q}^{FB}) = R_j(\mathbf{q}^{FB})$ for all i and j. The first-order conditions then imply $p_i = p_j$ for all i and j.

For part (ii), fix an artist i and consider two royalty rate vectors $\mathbf{p}$ and $\mathbf{p}'$ that differ only in artist i's rate with $p_i' > p_i$. Let $\mathbf{q} = \mathbf{q}(\mathbf{p})$ and $\mathbf{q}' = \mathbf{q}(\mathbf{p}')$. Then we have

$$R(\mathbf{q}) - \mathbf{p} \cdot \mathbf{q} \geqslant R(\mathbf{q}') - \mathbf{p} \cdot \mathbf{q}' \quad \text{and} \quad R(\mathbf{q}') - \mathbf{p}' \cdot \mathbf{q}' \geqslant R(\mathbf{q}) - \mathbf{p}' \cdot \mathbf{q}.$$

Adding them gives $(p_i' - p_i)(q_i - q_i') \geqslant 0$. Because $p_i' > p_i$, we have $q_i \geqslant q_i'$. The inequality must be strict. Otherwise, the above two inequalities would bind, and strict concavity would imply $\mathbf{q} = \mathbf{q}'$. But the same recommendation cannot satisfy the first-order conditions under both $\mathbf{p}$ and $\mathbf{p}'$ when only p_i differs. Therefore, $q_i > q_i'$, which proves that $q_i(\mathbf{p})$ is strictly decreasing in p_i. Because $\sum_{k=1}^{N} q_k = 1$, $\sum_{j \neq i} q_j(\mathbf{p}) = 1 - q_i(\mathbf{p})$ is strictly increasing in p_i. $\square$

Benchmark: Contracting with Commitment. If the platform can commit to all contracts simultaneously, it chooses $\mathbf{p}$ to maximize revenue and makes participation constraints binding. By Lemma A.1(i), revenue is maximized when $p_1 = \cdots = p_N$. As in the two-artist case, there are multiple efficient contracts.

Contracting without Commitment. Without commitment, the platform contracts with artists sequentially from $i = 1$ to N.

Proof of Proposition 2. The proof proceeds by backward induction.

Step 1. Given contracts for artists $1, \ldots, N-1$, the platform chooses (F_N, p_N) to maximize its profit. As the participation constraint for artist N binds, the platform's problem is to choose p_N to maximize

$$\Pi_N = R(\mathbf{q}(\mathbf{p})) - \sum_{i=1}^{N-1} (F_i + p_i q_i(\mathbf{p})) - \bar{u}$$

Differentiating w.r.t. p_N gives $\frac{d\Pi_N}{dp_N} = \sum_{i=1}^{N} R_i \frac{\partial q_i}{\partial p_N} - \sum_{i=1}^{N-1} p_i \frac{\partial q_i}{\partial p_N}$. Using the recommendation stage's first-order condition, $R_i = p_i - p_N + R_N$, this simplifies to $R_N \sum_{i=1}^{N} \frac{\partial q_i}{\partial p_N} - p_N \sum_{i=1}^{N-1} \frac{\partial q_i}{\partial p_N}$. Because $\sum q_i = 1 \implies \sum \frac{\partial q_i}{\partial p_N} = 0$, this derivative becomes $-p_N \sum_{i=1}^{N-1} \frac{\partial q_i}{\partial p_N}$.

Because $\sum_{i=1}^{N-1} \frac{\partial q_i}{\partial p_N} = -\frac{\partial q_N}{\partial p_N} > 0$ by Lemma A.1(ii), we have $\frac{d\Pi_N}{dp_N} < 0$ whenever $p_N > 0$. Therefore $p_N^* = 0$.

Step 2. For artist $l \in \{2, \cdots, N-1\}$, assume the platform will set $p_k^* = 0$ for all $k > l$. When contracting with artist l, a similar derivation shows the derivative w.r.t. p_l simplifies to $\frac{d\Pi_l}{dp_l} = -p_l \sum_{i \neq l} \frac{\partial q_i}{\partial p_l}$. Because $\sum_{i \neq l} \frac{\partial q_i}{\partial p_l} = -\frac{\partial q_l}{\partial p_l} > 0$ by Lemma A.1(ii), we have $\frac{d\Pi_l}{dp_l} < 0$ whenever $p_l > 0$. Therefore $p_l^* = 0$.

Step 3. The platform anticipates $p_2^* = \cdots = p_N^* = 0$. Its problem reduces to choosing p_1 to maximize $R(q_1(p_1, 0, \ldots, 0), \ldots, q_N(p_1, 0, \ldots, 0))$. By Lemma A.1(i), revenue is maximized when all rates are equal, so we have $p_1^* = 0$. □

B Costly Fixed Payments

We now characterize the equilibrium when fixed payments are costly, $r > 0$. We assume $R'' < 0$ and $R''' \geqslant 0$,[11] and focus on an interior recommendation $q_1^* \in (0, 1)$. Because the recommendation depends only on the gap $p_1 - p_2$, we write $q_1(p_1 - p_2)$ with derivative q_1' and second derivative q_1''. Differentiating the first-order condition $R'(q_1) = p_1 - p_2$ then gives $q_1' < 0$, and $R''' \geqslant 0$ gives $q_1'' \geqslant 0$. We also assume $\bar{u}$ is large enough that the equilibrium fixed payments are positive, $F_i^* = \bar{u} - p_i^* q_i^* > 0$, and that $p_1^* < 2\bar{u}$, where p_i^* and q_i^* are artist i's equilibrium royalty rate and recommendation. Because these do not depend on $\bar{u}$ (as shown below), a finite threshold for $\bar{u}$ suffices.

Optimal contract for artist 2. Given (F_1, p_1), the platform chooses (F_2, p_2) to maximize profit. With the participation constraint binding, the problem is to choose p_2 to maximize $R(q_1) - (F_1 + p_1 q_1 + \bar{u}) - r[F_1 + \bar{u} - p_2(1 - q_1)]$. The first-order condition is

$$-(R' - p_1)q_1' + r\left(1 - q_1 + p_2 q_1'\right) = 0. \tag{B.1}$$

Lemma B.1. *When fixed payments are costly, the optimal royalty rate for artist 2 $p_2(p_1)$ satisfies $p_2(p_1) > 0$, and $\frac{\partial p_2}{\partial p_1} \in (0, 1)$.*

Proof. At $p_2 = 0$, the first-order derivative of the platform's profit is $r(1 - q_1) > 0$, so $p_2 > 0$. With $R' = p_1 - p_2$, the first-order condition (B.1) simplifies to $p_2 q_1' + \frac{r}{1+r}(1 - q_1) = 0$. The

[11] Revenue functions like the quadratic $R(q_1) = \bar{R} - (q_1 - \frac{1}{2})^2$ satisfy these two conditions.

second-order condition holds because $(1+2r)q_1' - (1+r)p_2 q_1'' < 0$. Differentiating the first-order condition w.r.t. p_1 yields $\frac{\partial p_2}{\partial p_1} = \frac{(1+r)p_2 q_1'' - r q_1'}{(1+r)p_2 q_1'' - (1+2r)q_1'}$. Given $p_2 > 0$, $q_1' < 0$, and $q_1'' \geqslant 0$, the numerator is strictly positive and strictly smaller than the positive denominator, hence $\frac{\partial p_2}{\partial p_1} \in (0,1)$. □

Optimal contract for artist 1. The platform chooses p_1 to maximize its total profit, anticipating $p_2(p_1)$. The first-order condition is

$$R' q_1' \left(1 - \frac{\partial p_2}{\partial p_1}\right) + \frac{r}{1+r}\left(q_1 + \frac{\partial p_2}{\partial p_1}(1-q_1)\right) = 0. \tag{B.2}$$

This balances the marginal revenue loss from increased recommendation bias against the marginal savings in the cost of fixed payments from shifting compensation to royalties.

Proof of Proposition 3. We prove that $0 < p_2^* < p_1^* < 2\bar{u}$. Lemma B.1 shows $p_2^* > 0$. To show $p_1^* > p_2^*$, suppose for contradiction that $p_1^* \leqslant p_2^*$. This implies $q_1(p_1^*, p_2^*) \geqslant 1/2$ and thus $R'(q_1^*) \leqslant 0$. Because $q_1' < 0$ and $1 - \frac{\partial p_2}{\partial p_1} > 0$, the first term on the left-hand side of (B.2), $R' q_1'(1 - \frac{\partial p_2}{\partial p_1})$, is non-negative. The second term is strictly positive. The platform's profit is therefore strictly increasing in p_1 whenever $p_1 \leqslant p_2$, a contradiction. Finally, (B.2) pins down p_1^* independently of $\bar{u}$, so $p_1^* < 2\bar{u}$ for $\bar{u}$ sufficiently large, as we have assumed. □

C Endogenous Order of Contracting

We use the quadratic revenue function $R(q_1) = \bar{R} - [q_1 - (1-\theta)]^2$, where $\theta \in (0,1)$ represents the popularity of the second artist contracted. We assume costly fixed payments, an interior recommendation, and a large enough $\bar{u}$.

The platform's equilibrium profit can be written as

$$\Pi(\theta) = \bar{R} - 2(1+r)\bar{u} + \frac{r^2(1+2r)}{(1+r)^2} + \frac{r^2\theta^2}{1+2r}.$$

Proof of Corollary 1. Because $\frac{d\Pi}{d\theta} = \frac{2r^2\theta}{1+2r} > 0$, the platform's profit is strictly increasing in the popularity of the second artist. The platform therefore contracts with the less popular artist first and the more popular artist second. □

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