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Resale Royalties for Digital Goods

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Abstract

In recent years, the resale market for digital goods has grown substantially, enabled by blockchain smart contracts that enable and enforce resale royalties. This paper explores the economic impact of these resale royalties on digital goods and examines whether firms should monetize digital products solely through secondary market royalties or use a combination of primary and secondary sales. Using a game-theoretic model, we analyze a monopolistic seller's optimal pricing and royalty strategies in a market where resale is either prohibited or allowed with royalties. Our findings suggest that enforcing resale royalties through blockchain smart contracts can increase profitability by capturing revenue from secondary sales. Additionally, we demonstrate that the decision to implement royalties depends on market conditions, including the depreciation rate of goods and the relative size of the secondary market. These insights contribute to economic theory and offer practical guidance for firms navigating the evolving digital goods market.

Keywords: web3, blockchain, smart contract, NFT, marketplace, platform

1. Introduction

Resale markets are common for durable physical goods—from books and cameras to watches and cars. Digital platforms such as ThriftBooks, MPB, Chrono24, Edmunds, and eBay intermediate resale by offering services that include shipping, verification of authenticity, and refurbishment. Separately, royalty arrangements are prevalent in certain sectors such as intellectual property, publishing, music, and technology licensing (Besen & Kirby, 1989; Crama et al., 2008; van Haaften-Schick & Whitaker, 2022). These arrangements enable the producer to receive compensation when their work or technology is utilized or sold by others. For example, musicians earn royalties from the streaming or sale of their music, and investors earn royalties when others apply their technology to new products (Kamien & Tauman, 1986).

This paper investigates the role of royalties in the resale markets for digital goods as a source of producer revenue. In the last few years, such markets have grown to billions of dollars in volume and royalties through the tokenization of digital goods on blockchain smart contracts that can cryptographically validate ownership and enforce resale royalties (Qadir & Parker, 2024).[1] Our research addresses key economic questions for firms launching digital products in this market: Should firms focus solely on monetizing through secondary market royalties? Or should they adopt a mixed approach incorporating both primary and secondary sales? What royalty rates should they set, and how should primary sales be priced? How do market conditions affect those decision variables?

In developing our model, we consider a monopolistic scenario where a single seller markets a good to buyers, each with a private valuation. The seller sets an initial price and a royalty fee for resales, which influences both primary and secondary market dynamics. Our analysis employs a game-theoretic approach with backward induction to model the strategic interplay of pricing, royalties, and market behavior. Buyers' purchasing behavior in the primary market is influenced by expected secondary market conditions, as exemplified in textbook purchase behavior (Chevalier & Goolsbee, 2009). We aim to understand how these

[1] See the trading volume of non-fungible tokens on statista.com. Accessed June 9, 2024.

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choice variables influence buyers' consumption and resale decisions and to optimize the seller's pricing and royalty strategies to enhance profitability and welfare (Calzolari & Pavan, 2006; Colombo & Filippini, 2016).

Historically, secondary markets have introduced strategic challenges for primary sellers who have to compete with secondary market sellers. For instance, used-book markets have been shown to lower publisher welfare while raising consumer surplus and profits for the used-book platform (Ghose et al., 2006). Digital goods have further complicated the enforcement of secondary sales controls. While digital platforms like Spotify or Amazon execute royalty payments to artists or authors, these royalties are only for subscription-based consumption or primary sales; the distribution of digital goods on such platforms is tightly controlled via digital rights management tools, and resale is non-existent.[2] The intangible nature of digital goods makes it difficult to track ownership and enforce resale restrictions, as digital goods can be easily copied and redistributed without proper authorization.

These challenges are particularly evident in the gaming industry, where digital goods are frequently resold in grey markets—uncontrolled, unmanaged secondary markets (Mohamed & Capel, 2023). This demand is driven by the desire to enhance the gameplay experience, access rare items, and participate in secondary economies within games. Thus, grey markets represent a substantial portion of player expenditure.[3] For firms, however, these markets often undermine primary sales since the firms do not have control over secondary sales.

Despite challenges in controlling unauthorized resale, recent advancements in Web3 technologies—including virtual currencies, tokenized assets, and smart contracts—are transforming how digital goods are managed and sold. Using smart contracts, such as ERC-721C, a producer of digital goods can set royalties that are cryptographically enforced in secondary market trading of its goods (LimitBreak, 2023). The introduction of enforced royalty mechanisms can potentially ameliorate the cannibalization of primary sales in the secondary market by allowing firms to monetize resale. Further, enforced resale royalties offer novel methods for monetizing digital goods (Hemenway Falk et al., 2022). For example, streaming services in the music industry have demonstrated a positive impact on overall music sales by compensating for the loss in sales with gains in streaming revenue (Aguiar & Waldfogel, 2017). When combined with scalable, efficient blockchain payments and endowment effects of digital ownership,[4] resale royalties have the potential to become a key monetization model in the digital economy, complementing traditional models like subscription and licensing.

We contribute to the literature by examining whether resale royalties are an optimal strategy for digital goods and, if so, how to set prices and royalties. While our theory can be generalized to non-digital goods, resale royalties can be enforced for digital goods by blockchains and smart contracts. By developing a game-theoretic model, we analyze the optimal pricing and royalty strategies under different resale conditions. In the current model, we consider two resale conditions—the enforcement of resale prohibitions and the implementation of royalty fees on secondary sales—and determine the optimal approach in each circumstance. We plan to further extend the model to additional conditions before the conference, including to more than two periods and multiple products. Our findings offer insights into the strategic decisions that a monopolist firm must make when selling digital goods in a market where secondary sales are possible to capitalize on this relatively new revenue stream.

2. The Model

Consider a monopolist firm that produces multiple units of an indivisible good and potential buyers that can consume the good over time. Primary buyers arrive at the market in period 1 and decide whether they will purchase the goods from the monopolist.

There are n_1 primary buyers with unit demand each of whom has private valuation v for the consumption of the good in period 1 and who purchases it directly from the monopolist. The private valuation v is an independently and identically distributed random variable drawn from a uniform cumulative distribution function $U(v)$ which is common knowledge. The respective probability density function is only positive in the support $[0, 1]$. These functions are common knowledge.

A primary buyer with valuation v that consumes the good in period 1, gets value ρv in period 2 from continuing consuming the product, where $\rho \in [0, 1]$. Parameter ρ is the rate at which the consumption value depreciates over time, between the two periods if the buyer consumes the good in both periods. A primary buyer that is not allocated the good in period 1, exits the

[2]See royalty policies on Spotify and Amazon.

[3]Grey markets for gaming are estimated to be over \$10 billion annually, which is around 30-40% of player spending. Accessed April 16, 2024.

[4]See, as an example of the implications of efficient, scalable blockchain payments and digital ownership, the recent resale of a Cryptopunk non-fungible token (NFT) for \$16 million. Accessed April 16, 2024.

market at the end of period 1 with zero payoff.

There are n_2 secondary buyers with unit demand that arrive at the market at the beginning of period 2, with private valuation v drawn from the same distribution $U(v)$ as the valuations of primary buyers.

We first assume that the monopolist can enforce the prohibition of resale by primary buyers in period 2. So, the monopolist is the exclusive seller of the good in period 2. We then relax this restrictive and unrealistic assumption. The monopolist cannot now enforce the prohibition of resale, but it can charge a royalty $r \geq 0$ over any resale that takes place in period 2. In such a case, primary buyers have the option to interrupt their consumption and resale the goods to the secondary buyers that arrive in period 2. Moreover, each time the primary buyers resell the good in period 2 they need to pay the monopolist a non-negative royalty.

The timing of our game is as follows:

1. At the beginning of period 1, the monopolist sets p_1^m, which charges the primary buyers and royalty fee r if the prohibition of resale in period 2 cannot be enforced. If instead, it can prohibit resale, it only chooses p_1^m. The n_1 primary buyers observe the offer and decide whether they will buy the good.

2. At the beginning of period 2, when resale is possible, the primary buyers that were allocated the good in the previous period decide whether they will sell the good at price $p_2^r - r$. The monopolist may also sell additional units of the good at that price. If resale is prohibited, the monopolist sets a price p_2^m. The secondary buyers decide whether they will buy the product.

The utility of a secondary buyer v from purchasing and consuming the good in period 2 is

$$V_S = v - p_2^j,$$

where $j = r, m$.

The utility of a primary buyer v who consumes the good in both periods is

$$V_P = v(1 + \rho) - p_1^m.$$

The utility of a primary buyer v who consumes the good in period 1 and resales it in period 2 is

$$V_P^r = v - p_1^m + (p_2^r - r)(1 - p_2^r).$$

When the prohibition of resale cannot be enforced, a primary buyer of valuation v who purchases the good in period 1 will resell it in period 2 only if $V_P^r > V_P$ or in other words if $\frac{p_2^r - r}{\rho}(1 - p_2^r) = \hat{v}(r, p_2^r; \rho) > v$. Primary buyers with valuations $v \geq \hat{v}(r, p_2^r; \rho)$ that get the good in period 1 will prefer to continue consuming the good in period 2 instead of reselling it.

The profit of the monopolist, when resale is prohibited, is

$$\Pi = p_1^m(1 + \rho - p_1^m)n_1 + p_2^m(1 - p_2^m)n_2.$$

With resale as a viable option, the monopolist's profit depends on the valuations of the primary buyers that get the good in period 1. If the good is allocated only to primary buyers with valuations $v \geq \hat{v}(r, p_2^r; \rho)$, there will be no resale in period 2 and the monopolist is the only one selling at that period, so its profit will be

$$\Pi = p_1^m(1 + \rho - p_1^m)n_1 + p_2^r(1 - p_2^r)n_2.$$

If instead, the good is also allocated to primary buyers with valuations $v < \hat{v}(r, p_2^r; \rho)$, then, resale takes place in period 2. Let $v^m \in (0, 1)$ be the marginal primary buyer that gets the good in period 1 with $\hat{v}(r, p_2^r; \rho) > v^m$. There are two possible cases. First, if $\hat{v}(r, p_2^r; \rho) \geq 1$, all primary buyers that allocated the good in period 1 resell it in period 2. The profit of the monopolist in this case is

$$\Pi = p_1^m(1 - p_1^m + (p_2^r - r)(1 - p_2^r))n_1 + r(1 - p_2^r)n_2.$$

Second, if $\hat{v}(r, p_2^r; \rho) \in (v^m, 1)$, primary buyers with valuations $v \in [\hat{v}(r, p_2^r; \rho), 1]$ prefer to keep consuming the good in period 2, while those with valuations $v \in [v^m, \hat{v}(r, p_2^r; \rho))$ resell it.

3. Analysis

Our objective is to understand when the monopolist will choose a strictly positive royalty and when it will not. There are two games discussed above, one that the prohibition of resale can be enforced and one that it cannot. For each of them, we compute the equilibrium strategies of the monopolist, the primary and secondary buyers using backward induction.

When the prohibition of resale can be enforced, the monopolist has to solve two maximization problems, one for each of the two periods. In period 2, it chooses the price p_2^m such that $p_2^m(1 - p_2^m)n_2$ is maximized. Secondary buyers with valuations equal to or above p_2^m purchase one unit of the good and buyers with lower valuations do not get the good.

Its optimal price in the second period is:

$$p_2^{m,*} = \frac{1}{2}.$$

In period 1, the monopolist chooses the price p_1^m such that $p_1^m(1+\rho-p_1^m)n_1$ is maximized. The respective optimal price is

$$p_1^{m,*}=\frac{1+\rho}{2}.$$

So, the profit of the monopolist without resale is:

$$\Pi^{nr}=\frac{(1+\rho)^2 n_1}{4}+\frac{n_2}{4}.$$

In the more realistic case that the prohibition of resale cannot be enforced, there are two different subgames that we can consider. Let's start by considering the case where $v^m \geq \hat{v}(r,p_2^r;\rho)$. In such a case, resale never occurs in equilibrium, even if it cannot be prohibited. For the marginal primary buyer v^m it is $v^m(1+\rho)=p_1^m$ which implies that $p_1^m \geq \frac{\hat{v}(r,p_2^r;\rho)}{1+\rho}$. So, the constrained maximization problem is defined as:

$$\max_{p_1^m,p_2^r}\{p_1^m(1+\rho-p_1^m)n_1+p_2^r(1-p_2^r)n_2\}$$
$$\text{s.t.}\quad p_1^m \geq \frac{\hat{v}(r,p_2^r;\rho)}{1+\rho}. \tag{1}$$

The other subgame is the one where at least some of the primary buyers that are allocated the good find it profitable to resell it in period 2. The equilibrium price p_2^r of the second period is determined by primary buyers who resell the good as well as the demand conditions shaped by the valuations of the secondary buyers. In setting this price, the primary buyers should also consider the royalty r charged to them by the monopolist in the case of resale. Amount r of the price of resale, p_2^r goes to the monopolist.

The following lemma applies:

Lemma 1. *When some primary buyers that are allocated the good in period 1 find it profitable to resell it at equilibrium price p_2^r in period 2, in the symmetric equilibrium, it should be $p_2^{r,*} \leq r+\frac{\rho n_2}{(1+\rho-p_1^m)n_1}$.*

A primary buyer of valuation v resells the good in period 2 only if $(p_2^r-r)(1-p_2^r)\geq \rho v$. This occurs with probability $\frac{(p_2^r-r)(1-p_2^r)}{\rho}$. So, the number of primary buyers that get the good in period 1 and resell it in period 2 is $\frac{(p_2^r-r)(1-p_2^r)}{\rho}(1-p_1^m)n_1$.

Primary buyers will never select a p_2^r such that $\frac{(p_2^r-r)(1-p_2^r)}{\rho}(1+\rho-p_1^m)n_1 > (1-p_2^r)n_2 \Rightarrow \frac{(p_2^r-r)}{\rho}(1+\rho-p_1^m)n_1 > n_2$. This is because when this condition holds competition between primary buyers in selling the good in period 2 is fierce, and all but one buyer do not derive any additional payoff from reselling the good in comparison to the value they get when they consume the good in period 2. Since demand for the good in period 2 is lower than the supply, each primary buyer that holds the good and wants to resell it will feel the competitive pressure from its competitor sellers in period 2. Each seller will have incentives to undercut the price they offer to secondary buyers to secure that their unit will be sold in equilibrium. In other words, the lack of demand increases competition between primary buyers which lowers the equilibrium price and reduces the benefits primary sellers can gain by reselling the good. To avoid this situation, primary buyers prefer to set a price p_2^r such that there is sufficient demand for all the goods that are resold in period 2. The primary buyers do not have any more incentives to compete with each other.

Following the same reasoning, if in addition to resale, the monopolist is willing to sell n units of the good in period 2, then the symmetric equilibrium $p_2^{r,*} \leq r+\frac{\rho n_2}{(1+\rho-p_1^m)n_1}-n$. As the number n increases, the symmetric equilibrium price declines and so does the royalty rate r the monopolist collects from reselling. This leads to the following lemma:

Lemma 2. *When at least some primary buyers that are allocated the good in period 1 find it profitable to resell it at equilibrium price p_2^r in period 2, the monopolist will set a strictly positive royalty rate over resale only if it does not sell directly to secondary buyers.*

This is a sufficient condition. Since competition of the primary buyers for selling the good in the secondary market dictates that they should select in equilibrium a price that equates the number of primary buyers that resell and the number of secondary buyers that want to buy at that given price, the monopolist is better off by not selling in the second period. It instead relies on its royalty rate in order to derive a positive share from the transactions in the secondary market.

If the monopolist was to sell some units of the good in period 2, it would have cannibalized the proceeds it could derive through the royalty rate r. More units available in period 2 would have led to a drop in equilibrium price p_2^r which in turn would have led to a lower royalty r collected from resale. In other words, charging a royalty for each resale is a substitutable strategy for the monopolist with selling directly in period 2 when competing with primary buyers.

So, the constrained maximization problem for each primary buyer when the royalty scheme is employed by the monopolist is defined as:

$$\max_{p_2^r} \{(p_2^r - r)(1-p_2^r)\}$$
$$\text{s.t.} \quad p_2^r \leq r + \frac{\rho n_2}{(1+\rho-p_1^m)n_1}.$$

The solution of this maximization program is:

$$p_2^{r,*} = \begin{cases} \frac{1+r}{2}, \text{if} \quad \frac{1-r}{2} \leq \frac{\rho n_2}{(1+\rho-p_1^m)n_1}, \\ = r + \frac{\rho n_2}{(1+\rho-p_1^m)n_1}, \text{otherwise.} \end{cases}$$

The maximization program of the monopolist is:

$$\max_{p_1^m, r} \left\{ p_1^m (1 - p_1^m + \frac{(1-r)^2}{4}) n_1 + r \frac{1-r}{2} n_2 \right\}$$
$$\text{s.t.} \quad \frac{1-r}{2} \leq \frac{\rho n_2}{(1+\rho-p_1^m)n_1}. \qquad (2)$$

The solutions of (1) and (2) define the equilibrium profits of the monopolist in each of the two subgames, the without resale and the one with resale where a royalty rate, r^* applies. So, to understand whether the monopolist will implement a royalty scheme we need to study whether and when the equilibrium profit under (2) surpasses the equilibrium profit under (1) with $r^*(n_1, n_2) > 0$.

We first solve (2) without considering the constraint and then we study whether the solution of the unconstrained maximization satisfies the constraint. The solution of (2) is presented in Figure 1 for given values of n_1 and n_2.

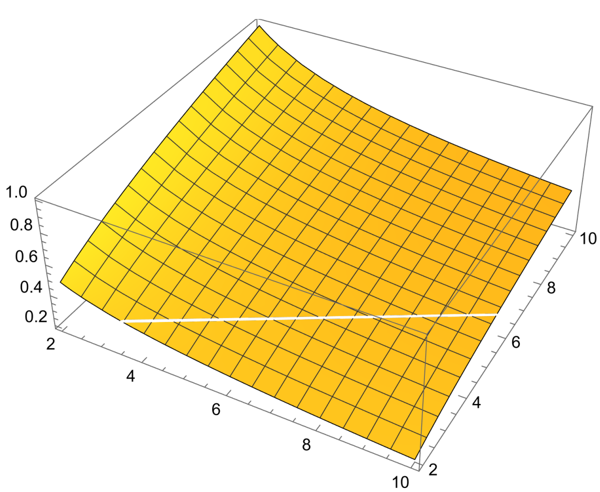


Figure 1: The optimal royalty rate from maximization problem (2) for a range 2-10 of values of n_1 and n_2.

The optimal royalty $r^*(n_1, n_2)$ takes higher values when the fraction $\frac{n_2}{n_1}$ is higher. The royalty strategy becomes a more attractive source of profitability for the monopolist when it expects that the market will expand in period 2 and therefore a significant amount of reselling transactions is expected. This is more likely to be the case for a new good that is introduced to the market in period 1 and it becomes very popular. As a result, many more users are entering the market and are interested in consuming it in period 2.

The resulting optimal price $p_1^{m,*}$ is defined as:

$$p_1^{m,*} = \frac{1}{2} + \frac{(1-r^*)^2}{8}.$$

The optimal price $p_1^{m,*}$ is strictly declining in r^*. The monopolist is willing to forgo some profits from the period 1 sales of the good to primary buyers if it expects a market expansion in period 2 due to the increased popularity of its good.

Moving to the maximization problem (1), we first note that the constraint depends on r^*. The threshold value $\hat{v}(r, p_2^r; \rho)$ is strictly declining in r. As the royalty rate increases, primary buyers are more inclined not to resell the good in period 2 and keep consuming it, instead. The same applies as ρ increases.

If ρ is sufficiently high such that $\rho(1+\rho) \geq \frac{1}{4}$, then the constraint in (1) is slack for every possible r^*. The monopolist finds it optimal to charge $p_1^{m,**} = \frac{1+\rho}{2}$ in period 1, $p_2^{r,**} = \frac{1}{2}$ and it will realize profit $\Pi^{nr}(n_1, n_2)$. This is equivalent with the case where the monopolist could enforce the prohibition of resale.

If, instead, $2\rho(1+\rho) < \frac{1}{2} - r^*(n_1, n_2)$, the constraint in maximization (1) is binding. The optimal strategies for the monopolist in this case are $p_2^{r,**} = \frac{1}{2}$ and $p_1^{m,**} = \frac{\frac{1}{2} - r^*}{2\rho}$. The profit of the monopolist in this case is

$$\Pi^{**}(n_1, n_2; \rho) = \frac{\frac{1}{2} - r^*(n_1, n_2)}{2\rho} \left(1 + \rho - \frac{\frac{1}{2} - r^*(n_1, n_2)}{2\rho}\right) n_1 + \frac{n_2}{4}.$$

The respective equilibrium profit of maximization (2) is:

$$\Pi^*(n_1, n_2) = \left(\frac{1}{2} + \frac{(1 - r^*(n_1, n_2))^2}{8}\right)^2 n_1 + r^*(n_1, n_2) \frac{1 - r^*(n_1, n_2)}{2} n_2.$$

The following propositions apply:

Proposition 1. *If ρ, n_1 and n_2 take values such that $2\rho(1+\rho) \geq \frac{1}{2} - r^*(n_1, n_2)$, there is no resale in period 2. The monopolist follows the same strategy as if it were able to enforce the prohibition of resale.*

In other words, it is $\Pi^{nr} > \Pi^*$. When the value from consumption of the good in period 2 is relatively high for the primary users and the number of secondary buyers, the monopolist finds it optimal to sell in period 1 only to primary buyers that have a strong interest in continuing to consume the good in period 2. As a result, the monopolist is the only active seller in period 2 and it does not have to compete with primary sellers. Figure 2 illustrates this. In the given range of parameters, as the number of buyers increases, the monopolist has stronger incentives to implement the no-resale equilibrium.

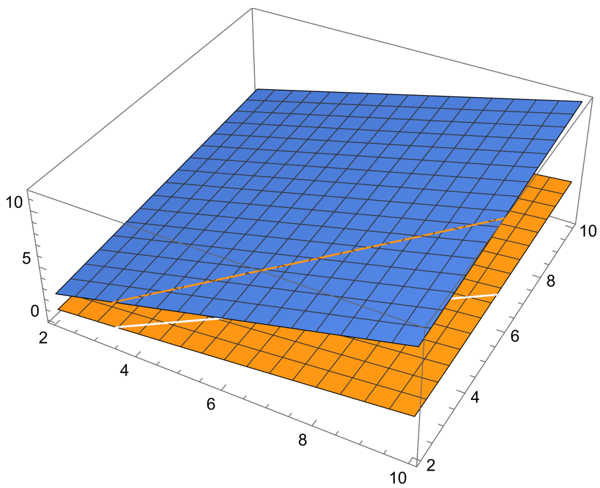
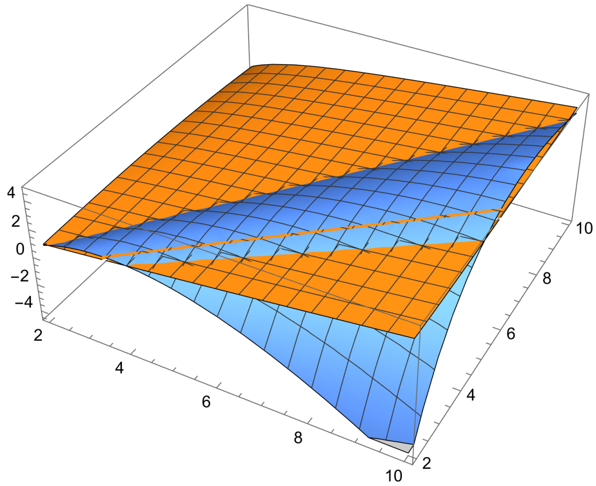


Figure 2: Π^{nr} (blue surface) and Π^* (orange surface) for a range 2-10 of values of n_1 and n_2 and for $\rho = 0.9$.

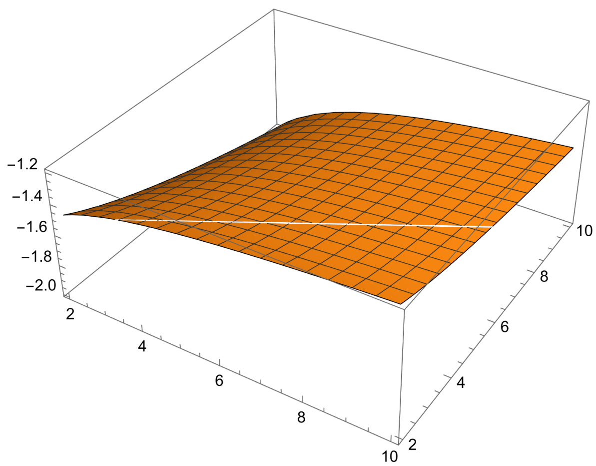
Proposition 2. *A positive royalty rate $r^*(n_1, n_2)$ emerges in equilibrium if and only if ρ, n_1 and n_2 take values such that $\Pi^*(n_1, n_2) > \Pi^{**}(n_1, n_2; \rho)$ and $2\rho(1+\rho) < \frac{1}{2} - r^*(n_1, n_2)$.*

An example of this situation is depicted in Figure 3. Following Proposition 2, we see that in equilibrium a positive royalty can be preferred by the monopolist especially when there is a sufficiently high difference between the number of primary and secondary buyers and when primary buyers do not have very strong incentives to continue consuming the good in period 2. This is because:

1. the monopolist in such a case can extract through the royalty rate a higher share of the reselling transaction value (since the period 2 consuming value of primary buyers is low),



(a) Π^{**} (blue surface) and Π^* (orange surface) in the n_1 - n_2 space.



(b) Function $2\rho(1+\rho) - \frac{1}{2} + r^*(n_1, n_2)$ in the n_1 - n_2 space.

Figure 3: The non-empty set of n_1 and n_2 values in the intersection of the two conditions for a positive equilibrium royalty rate when $\rho = 0.5$.

2. if the number of secondary buyers is relatively high with respect to primary buyers n_1, royalty can be a profitable strategy due to the high volume of resales that take place in period 2.

3. if the number of primary buyers is relatively high with respect to secondary buyers, n_2, the monopolist does not have strong incentives to sell directly to the secondary buyers in period 2 by itself.

4. Discussion and Conclusion

This study investigates the role of resale royalties in the digital goods market. Specifically, we focus on how resale royalties influence the profitability and strategic decisions of monopolistic sellers. We find that when resale is prohibited, the monopolist can maximize profit by setting optimal prices for both primary and secondary markets. However, in scenarios where resale is allowed and royalties can be enforced, royalties can increase profitability, particularly in markets with high secondary market demand. Our game-theoretic model demonstrates that resale royalties can effectively mitigate the negative impact of secondary sales on primary sales, provided the royalty rates are set optimally.

There are alternative modelling options that we could consider. One would be to introduce some uncertainty over the market conditions. For example, so far we consider that the number of primary buyers in period 1, n_1, and the number of secondary buyers in period 2, n_2 is known by the monopolist before it introduces its good in period 1. As a result, the monopolist can make an informed decision based on the exact demand conditions in each period. If these numbers of potential buyers were instead uncertain, then, n_1 and n_2 could be seen as random variables over which the monopolist forms some expectations, $E[n_1]$ and $E[n_2]$. Then, the analysis above is still valid where the actual number of buyers is replaced by the expected one.

We could also introduce some asymmetry over the uncertainty related to market demand. It could either be the case that the monopolist can assess market conditions more accurately than buyers or that buyers have a better understanding on how market is shaped. These modelling modifications will be investigated in the near future.

So far, we considered a royalty as a fixed amount of the equilibrium price in the secondary market. If instead we were to consider a percentage-based royalty of that price, we would have expected similar qualitative results. Primary buyers would tend to increase their resale price with a higher royalty. The monopolist would still impose a positive royalty only if it did not sell directly in the secondary market. Royalty would emerge under some conditions as an equilibrium strategy. The derivation of the exact conditions in this case is work in progress. These conditions even if they point towards similar strategies by the monopolist and the buyers, they will lead to different inequalities from the ones presented in the two propositions of the paper.

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