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Abstract

We study the seller's pricing strategy of one good (finite inventory) that can be sold in two bargaining periods (before a deadline) when she faces two strategic buyers with private valuations. In particular, we are interested in analyzing the effect of allowing a resale option between buyers when the seller has commitment to future prices. First, allowing the resale option may decrease the whole sequence of prices. This price reduction is justified in the high impact of the resale option on early demand elasticity; that is, early purchases are highly responsive to prices. Second, when the seller can commit to prices, setting higher future prices increases the sensitivity of early purchases to changes in current prices. This effect is not credible without commitment, where buyers anticipate the incentives to reduce prices in the future. Thus, the commitment to set prices in advance generates an extra increase in seller's profits when the resale option is allowed. Alternatively, we claim that there is a complementarity between commitment in the pricing policy and the resale option, improving the price discrimination strategy of the seller.

Keywords: resale, commitment, strategic buyers.

JEL Classification: L11, D4.

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1 Introduction

Suppose a monopolist with a finite number of units of a good to sell before a deadline. The good can be consumed only at that deadline. That is, before the deadline the good can be bought but it cannot be consumed and after it the non-traded units are valueless. For instance, consider sports' or concerts' tickets, airline tickets, hotels reservations, etc...Thus, through time, the monopolist proposes and commits to a sequence of prices to a finite number of strategic buyers with private information about their willingness to pay. The buyers decide whether to accept or not one of those prices, anticipating that waiting may imply that no good is available in the future. In this revenue management scenario with commitment to set prices in advance, we are interested in studying the impact of a resale option in prices, profits, consumer surplus, and welfare. We show that under some reasonable conditions, introducing the resale option induces the monopolist increases her profits by reducing prices. Additionally, we show that the resale option complements the commitment to set prices in advance.

The revenue management problem without the resale option has already been analyzed in many previous articles (we discuss about them below). In particular, Hörner & Samuelson (2011) is the first one in characterizing the optimal sequence of prices offered by a monopolist with and without commitment who faces strategic buyers. We use this model as our benchmark case and we study the important and realistic contractual option of resale with commitment.

In particular, we consider the simplified problem of a seller with one unit of an indivisible and costless good that can be trade in one of two periods. The seller faces two strategic buyers with private and heterogeneous valuations, and unit demand. In the first period the monopolist announces and commits to a sequence of prices and each buyer faces the following tradeoff: he can accept the current price or he can wait for a future (maybe lower) price with the risk that, if the rival buyer has accepted the current offer, he will end up empty-handed. If only one buyer accepts the current price, he receives the unit and pays the price announced. If both buyers are willing to buy, a random tie-breaking rule allocates the unit to one of them. Otherwise, the game moves to the next stage with the same logic. Since we allow for resale, when a buyer succeed in getting the good in the first period, he can make a take-it-or-leave-it price offer to the remaining buyer.

As Hörner & Samuelson (2011) shows, in the benchmark case the seller chooses a decreasing price sequence that balances a trade-off between price discriminating consumers and charging a high reserve price. When resale is allowed, consumers' buying decisions is affected by the following two effects. First, at a given price, their willingness to buy sooner increases since they can get some extra surplus out of the resale option. Everything else equal, this effects induces the monopolist to ask for a larger price. Second, the buyer in the model with resale is more sensitive to changes in prices. In the benchmark case, an increment in the price gives incentive to buyers to wait for a lower price. This effect is also present in the model with resale. However, in this case, an increment in the price also reduces the probability of reselling. In other words, the new demand has greater price-elasticity. Everything else equal, this second effect induces the monopolist to reduce the price in the first period.

We are interested in identifying the effects of allowing the resale option in prices and profits when the seller has commitment to set prices in advance. We find that the commitment case generates new relevant insights. First, the future price helps the seller to price discriminate. This help is driven by early consumers that resell in the future. Then, the resale effect when there are more early purchaser, which is case with commitment.

Second, we show that the demand for early purchases is more sensitive to changes in prices with resale. This sensitivity increases when the valuation of the marginal buyer is smaller. In the commitment case the marginal buyer is smaller than in the no commitment case, generating more incentives to reduce the price for early purchases.

Last, but not least, the seller chooses the future price in advance, then consumers are not speculating to future price reductions as they do in the no commitment case. Additionally, we find that for a given current price, the resale option motivate a higher future price, something that is not feasible in the no commitment case. When both prices change, the sequence can decrease or increase.

Concluding, the commitment case add some new insights on the effect of the resale option on the seller's pricing strategy and profits.

The organization of the paper is as follows. Section 1.1 shortly review the literature and our contribution to it. Section 2 describes the model. Sections 3 and 4 solve the no-resale and the resale cases. Section 5 present our main results by comparing the solutions of both cases. 6 discusses the relevance of our results by comparing the case with and without commitment to set future prices. Section 7 concludes.

1.1 Literature review

Hörner & Samuelson (2011) describe the seller's problem as to find a balance between price discrimination and having a high reserve price. They focus on the case with no resale, analyzing both the commitment and no commitment cases. Beccuti & Coleff (2017) extends the no commitment scenario to the case where the resale option is allowed, showing that it improves the price discrimination strategy. The resale option helps the seller to appropriate a higher surplus from the buyers. We show that there is a complementarity between the resale option and the commitment to set prices in advance.

The literature on resale is not new. The studies of Courty (2003), Courty (2003), Calzolari & Pavan (2006), and Cui et al. (2014) analyze the impact of resale in the pricing strategy and seller's profit. Most papers find that the resale option hurts the seller by reducing her profits. We find, like Cui et al. (2014), that allowing the resale option increases seller's profit.

We differ from the literature in two main assumptions. First, most papers in the resale literature assume that consumers learn their valuation over time, which is consistent with the empirical evidence reported for instance by Leslie & Sorensen (2014). In contrast, we focus on a case where consumers know their valuations in advance with certainty, which is also consistent with the evidence that many people buy a ticket early (during the first days tickets are available). As Leslie & Sorensen (2014) claim "people make costly efforts to show up early when excess demand is expected to be high".

Second, most papers assume that there is an efficient rationing rule. This assumption is used for simplicity, to avoid cumbersome alternative rationing rules in a dynamic model of learning the private valuation. We assume that there is a random rationing rule, which is consistent with many cases where people make lines in order to get a ticket for a show or concert with high demand. This evidence is more consistent with a random rationing rule than with an efficient rationing rule. Actually, We believe that it is the existence of the resale option what is working to change this random rationing rule into an efficient rationing rule.

By relaxing these two assumptions, we extend the study of the resale option to a new environment. We find that the resale option provides an extra profit for the seller and may reduce the price sequence that is not present in the previous literature.

2 Model

Suppose a two period game in which there is one seller who has one unit of an indivisible good (one ticket) to sell and $n = 2$ buyers with private information about their valuation for it. The good can be purchased in any of both periods but can only be consumed at the end of the second period. A non-traded unit is valueless after it. We assume that there is no discounting of time (i.e., the discount factor is equal to one).

Buyer's private valuation v is independently and identically distributed according to $F : [0,1] \to [0,1]$, with F. The distribution F is continuous and differentiable with its density f also continuous. We assume that f is log-concave. Players (buyers and seller) are risk neutral and maximize their expected surpluses. The production and opportunity costs are normalized to zero.

The timing of the model is as follows: at $t = 1$ (*Today*) the seller (who has commitment to set prices in advance) announces a price sequence (p_1, p_2), p_1 for Today and p_2 for Tomorrow. Then, at $t = 1$ each player chooses whether to accept the p_1 offer. If only one buyer accepts the offer, he pays the price p_1 and receives the good. If two buyers accept the offer, a random tie-breaking rule allocates the good to one of them. If no buyer accept the offer, the game moves to the next period. At $t = 2$ (*Tomorrow*) there are two scenarios: (A) the seller still has the good or (B) one buyer has bought it. In the scenario (A) the seller has the good because no buyer has accepted the p_1 offer, in which case the good is available at a price p_2. In the scenario (B) one of the buyers has bought the good at $t = 1$. Without resale, the game ends. With resale, the buyer announces a resale price r that is accepted or not by the remaining buyer. After this last period the game ends.

3 Benchmark: resale is not allowed

If resale is not allowed we are in the environment of Hörner & Samuelson (2011) with commitment. The seller profit at period $t = 1$ is

$$\max_{(p_1,p_2)} p_1 \left(1 - F(\overline{v})^2\right) + F(\overline{v})^2 p_2 \left(1 - \frac{F(p_2)^2}{F(\overline{v})^2}\right).$$

This profit is given by the price p_1 times the probability of acceptance (i.e., the probability that at least one of the buyers have $v \geq \overline{v}$) plus the continuation value $p_2\left(1-\frac{F(p_2)^2}{F(\overline{v})^2}\right)$ times the probability of rejection at $t=1$.

The value of $\overline{v}$ is determined by the buyer type who is indifferent between buying Today and waiting until Tomorrow taking into account the other buyer and the announced sequence of prices (p_1, p_2) by the seller at $t=1$.

When a buyer with valuation v accepts the price, he achieves

$$(v-p_1)\left(\frac{1-F(\overline{v})}{2}+F(\overline{v})\right),$$

and, when he rejects and waits for a lower price he expect to get

$$(v-p_2)\left(\frac{F(\overline{v})-F(p_2)}{2}+F(p_2)\right).$$

Notice, that the buyer v takes into account the probability with which the remaining buyer also buys (in the first case) and the one with which his rival also waits until Tomorrow to buy the good.

Thus, the indifferent buyer $\overline{v}$ is the one that satisfies

$$(\overline{v}-p_1)\left(\frac{1-F(\overline{v})}{2}+F(\overline{v})\right) \quad = \quad (\overline{v}-p_2)\left(\frac{F(\overline{v})-F(p_2)}{2}+F(p_2)\right).$$

We look for symmetric strategies, then the problem of the seller at $t=1$ is

$$\max_{(p_1,p_2)} \quad p_1\left(1-F(\overline{v})^2\right)+F(\overline{v})^2 p_2\left(1-\frac{F(p_2)^2}{F(\overline{v})^2}\right), \quad \text{s.t.,} \qquad (OF)$$

$$(\overline{v}-p_1)\frac{1+F(\overline{v})}{2}=(\overline{v}-p_2)\left(\frac{F(\overline{v})+F(p_2)}{2}\right), \qquad (IC)$$

We illustrate the case for the uniform distribution $[0,1]$.

Example 1. ***Benchmark Case for the uniform.*** *Suppose v is uniformly distributed on $[0,1]$. Solving the benchmark problem, the seller makes in equilibrium $\pi^*=0.4071$, and announced prices are $(p_1^*, p_2^*)=(0.59015, 0.5265)$. The indifference valuation is $\overline{v}^*=0.763$.*

4 Resale is allowed

The resale option slightly changes the problem of the seller.[1] In particular, a buyer at $t=1$ has the option to resell the product purchased in the next

[1]Adding units and seller complicates the model, as the seller and buyers that resell units compete eventually to attract new buyers. Of course, the competition is asymmetric as the opportunity and production costs differ, adding a new dimension to the problem

stage. Then, the expected utility of buying at $t = 1$ becomes:

$$(v - p_1)\left(\frac{F(r) + F(\overline{v})}{2}\right) + (r - p_1)\frac{1 - F(r)}{2},$$

where r depends on buyer's valuation v, $r(v) := \arg\max_r [1 - F(r)](r - p_1) + [F(r) - F(v)](v - p_1)$. This only affects the Incentive Compatibility constraints of consumers between buying at $t = 1$ or wait until $t = 2$. Now the indifferent buyer $\overline{v}$ is characterized by.

$$(\overline{v} - p_1)\left(\frac{F(r) + F(\overline{v})}{2}\right) + (r(\overline{v}) - p_1)\frac{1 - F(r(\overline{v}))}{2} \quad = \quad (\overline{v} - p_2)\left(\frac{F(\overline{v}) - F(p_2)}{2} + F(p_2)\right).$$

Then, the seller's problem becomes

$$\max_{(p_1,p_2)} p_1\left(1 - F(\overline{v})^2\right) + F(\overline{v})^2 p_2\left(1 - \frac{F(p_2)^2}{F(\overline{v})^2}\right), \quad \text{s.t.}, \tag{SPR1}$$

$$\frac{1 - F(r)}{2}(r - \overline{v}) + \frac{1 + F(\overline{v})}{2}(\overline{v} - p_1) = (\overline{v} - p_2)\left(\frac{F(\overline{v}) + F(p_2)}{2}\right), \tag{ICR}$$

$$r^*(v) \equiv \underset{r}{\operatorname{argmax}} \ \frac{1 - F(r)}{2}(r - v) \tag{RP}$$

Again, we illustrate using the uniform distribution $[0, 1]$.

Example 2. ***Extending for Resale Markets for the uniform.*** *Suppose v uniformly distributed on $[0, 1]$ and we allow for a resale market. Now, the buyer who gets the good in $t = 1$ can resale it in $t = 2$. Hence, in $t = 2$ there are two possibilities: (i) the good was not sold in $t = 1$, then the buyers chooses whether to purchase the good at p_2 announced. (ii) the good was sold in period $t = 1$, the buyer who acquired the good can resale it, solving (RP). Now, the seller makes in equilibrium $\pi^* = 0.41223$, and posts prices $(p_1^*, p_2^*) = (0.5758, 0.5128)$. The indifference valuation is $\overline{v}^* = 0.67523$ and the reselling price of a consumer with valuation v is $r^*(v) = \frac{1+v}{2}$.*

5 Analyzing the effects of the resale option

There are a number of surprising results when the resale option is allowed. Some of the findings of Beccuti & Coleff (2017) for the no commitment case extends to the commitment case. On top of that the commitment generates new effects. We discuss the results in detail below.

First, the resale option motivates an increase in early purchases for a given price strategy.

Lemma 3. *For a given price sequence* (p_1, p_2)*, the indifferent buyer in the reselling case has a lower or equal valuation than in the benchmark case, i.e.,* $\overline{v}_R \leq \overline{v}$.

Proof. Given a (p_1, p_2), consider the buyer $\overline{v}$ who, in the no resale case, is indifferent between waiting until $t = 2$ and buying at $t = 1$. In the case with resale, this buyer $\overline{v}$ strictly prefers to buy at $t = 1$, as he can get an extra surplus by reselling the good at $t = 2$. On the other hand, as the other buyer also prefers to buy at $t = 1$ for types $v \sim \overline{v}$ with resale, the marginal consumer $\overline{v}_R$ is lower than $\overline{v}$. □

The pricing strategy balances intertemporal price discrimination with charging a high reserve price. When resale is allowed there is a direct effect on early purchases since the number of buyer's types that are willing to buy in advance increases in order to take advantage of the resale opportunity. If we keep the current price p_1 constant, the seller can reduce the buyer's utility of waiting until $t = 2$ by increasing p_2, motivating an extra number of consumers to make early purchases.

Lemma 4. *For a given price* p_1*, the optimal price* p_2 *with resale is higher than* p_2 *with no resale.*

Lemma 4 introduces an effect that takes place only in the commitment case. We discuss this difference in Section 6. Notice that p_2 is jointly determined with p_1 and that Lemma 4 does not ban the possibility of having a lower p_2 when p_1 changes. However, it motivates a new effect that also motivates an increase in $t = 1$ probability of trade and affects its trade sensitivity to p_1.

In the benchmark case, an increment of p_1 gives incentives to a buyer with valuation v to wait for a lower price. This effect is also present in the model with resale. However, in this resale case, an increment in p_1 also reduces the probability of reselling. As consequence, the demand at $t = 1$ is now more sensitive to changes in prices.

Lemma 5. *Suppose a buyer with valuation* v*. This buyer is more sensitive to a change in prices in the reselling model than in the benchmark case; i.e.,* $\partial v/\partial p_1 \mid_{Resale} \geq \partial v/\partial p_1 \mid_{Benchmark}$.

When resale is allowed there are three effects. First, there is an increase in demand in $t = 1$ since allowing resale increases the willingness to pay of the buyer (Lemma 3). Everything else equal, this **demand level effect** induces the monopolist to ask for a larger price in $t = 1$. Second, in the model with resale, the buyer is more sensitive to changes in prices. Everything else equal, this **demand sensitivity effect** induces the monopolist to reduce the price in $t = 1$. These two effects impact price p_1 in opposite directions. Third, the commitment to credibly choose p_2 in advance has a magnifier effect on the demand level (first) and demand sensitivity (second) effects: increase both demand level and demand sensitivity at $t = 1$ to price p_1.

In our examples with the continuous distribution function, the demand sensitivity effect dominates the higher demand level effect and the optimal prices with resale are lower than in the benchmark case. Consequently, a reduction in price is motivated by a first order effect of increasing the price-elasticity of Today's probability of selling (or Today's demand). We are positive that this result of reducing p_1 is quite general, but we are not certain if this is the only feasible result. That is, there may be extreme cases where some distribution functions motivate an increase in p_1 when the resale option is allowed. More work on this ground is needed. Thus, the change in price at $t = 1$ is undetermined. So far we can establish the following result.

Proposition 6. *Allowing the resale option is profitable for the monopolist. Moreover, the resale option may motivate a reduction in the price sequence* (p_1^*, p_2^*).

The welfare analysis is also undetermined. An increase in the probability of selling Today is driven by the fact that buyers with lower valuation buy Today. If this buyers buy the product, do not resale, and the other buyer has higher valuation, there is an inefficiency. A lower valuation buyer ends up with the product generating an inefficiency. In this line, the resale effect on consumer surplus is also undetermined.

We illustrate the relevance of our results with the uniform case shown in Table 1. Comparing both resale and no-resale examples, we can see that the seller makes greater profits in a resale case than in a no resale case. Also, the case with resale has lower sequence of prices than the no resale case; that is, the seller decreases prices in both periods when the resale option is allowed. Finally, early purchases increase and later purchases decrease with resale. The trade probability increases.

Table 1: Prices, marginal buyer, profits, and trade probabilities with and without the resale option.

	no-resale (1)	resale (2)
p_1	0.5906	0.5758
p_2	0.5265	0.5128
$\overline{v}$	0.7630	0.6752
Π	0.4071	0.4122
Prob(trade $t - 1$)	0.4178	0.5441
Prob(trade $t = 2$)	0.3050	0.1930
Trade probability	0.7228	0.7370

6 Commitment vs no commitment

In this section we illustrate the main difference of having commitment and not having commitment in the pricing strategy and its implications in analyzing the impact of the resale option on prices, trade, and profits.

The ability to commit to future prices allows the seller to credibly announce these prices at $t = 1$, affecting consumers' purchasing behavior. That is, at $t = 1$ the seller announces p_2 which is anticipated by buyers in their intertemporal purchasing decision. The first implication of this commitment framework is the relation between demand at $t = 1$ and p_2. Beccuti & Coleff (2017) show that for the no commitment scenario, a reduction in $\overline{v}$ directly implies a reduction in p_2. In other words, it is not credible that the seller can both decrease $\overline{v}$ and increase p_2 in a non-commitment environment. However, in the commitment case the seller does have this possibility.

Lemma 4 shows that, in fact, when resale is allowed the seller prefers to increase p_2 if p_1 is not modified. Both the possibility of resale the product at $t = 2$ and the increase in p_2 motivate a reduction in $\overline{v}$, generating an increase in demand at $t = 1$. Consequently, there is both a reduction in $\overline{v}$ and an increase in p_2 with commitment that has no place in an environment with no commitment. This result is new and has an additional effect.

Independently of the commitment power (with and without commitment), if p_1 decreases, demand at $t = 1$ increases. This reduction in p_1 inevitably generates a reduction in p_2 in the no commitment case, increasing also the utility of waiting until $t = 2$. This second effect ameliorates the increase in demand at $t = 1$ when p_1 is reduced, as some consumers that would buy early at a given p_2, postpone their purchasing decision anticipating a reduction in p_2. In the commitment case, the reduction in p_1 is independent of the choice of p_2; then for the same p_2, the sensitivity of demand at $t = 1$ to p_1 is higher in the commitment case than in the no commitment case.

We illustrate our results using the uniform distribution $[0, 1]$. In table 2 we show prices, marginal consumer, and profits for different cases. Columns (1) and (4) evaluate the optimal prices with (column 4) and without (column 1) resale. Column (2) shows the optimal p_2 with resale, when we fix price $p_1 = 0.5902$ as in the no resale case. Notice that the seller increases the $t = 2$ price from $p_2 = 0.5265$ to $p_2 = 0.5293$.

Similarly, in column (3) we show the optimal values for p_2, $\overline{v}$, and profits with no resale if p_1 is restricted to $p_1 = 0.5758$. Comparing the optimal values in columns (3) and (4), we observe an increase in p_2 from $p_2 = 0.5109$ to $p_2 = 0.5128$ when the resale option is allowed.

Consequently, Table 2 shows and example of the results in Lemma 4.

Table 2: With commitment: Prices, marginal buyer, and profits with and without the resale option.

	no-resale (1)	resale $p_1 = 0.5902$ (2)	no-resale $p_1 = 0.5758$ (3)	resale (4)
p_1	0.5902	0.5902	0.5758	0.5758
p_2	0.5265	0.5293	0.5109	0.5128
$\overline{v}$	0.7630	0.7025	0.7422	0.6752
Π	0.4071	0.4119	0.4067	0.4122

Table 3 shows the results of the case with no commitment. In this case, the resale option always motivates a reduction in p_2 for a given p_1. With this comparison we want to highlight the importance of Lemma 4.

Finally, we want to stress a preliminary but important new result. The effect of resale on profits is positive. However, there is no theoretical or

Table 3: No commitment: Prices, marginal buyer, and profits with and without the resale option.

	no-resale (1)	resale $p_1 = 0.579$ (2)	no-resale $p_1 = 0.570$ (3)	resale (4)
p_1	0.579	0.579	0.570	0.570
p_2	0.479	0.4744	0.4694	0.464
$\overline{v}$	0.829	0.8218	0.8131	0.803
Π	0.4003	0.4016	0.4001	0.4017

empirical evidence about the interaction between the resale option and the possibility of having commitment in setting the price in advance.

The effect of resale has some additional advantages in the case with commitment to set prices in advance over the no-commitment case:

(a) With no resale, early purchases are greater with commitment. This implies two separate things. First, the resale option helps the seller to price discriminate consumers. In particular, this helps realize when early buyers resell in the future periods. As early purchases are greater with commitment, the resale option works better with commitment.

(b) Second, the marginal consumer is smaller in the case with commitment. As the impact of the resale option on willingness to buy is higher (in absolute magnitudes) for consumers with lower valuation, the commitment case benefit more from the resale option. In other words, early purchases are more sensitive to price changes in the commitment case. This also implies that the seller can benefit more from the resale option in the commitment case.

(c) With resale, early purchases are more sensitive to price changes with and without commitment. As the seller chooses the future price in advance with commitment, consumers are not speculating to future price reductions as they are in the no commitment case. This is also highlight by Lemma 4. Then, with commitment the seller can increase or decrease p_2 and can choose the magnitude of this change. Again, the resale option works better with commitment.

These three effects implies that the increase in profits is higher under a commitment scenario. The results in Tables 2 and 3 are consistent with this claim, as profits increase by 0.00513 (1.26%) with commitment and by 0.00138 (0.344%) with no commitment. Alternatively, we interpret that there is a complementarity between commitment to set prices and the resale option.

7 Conclusions

We have presented a simple version to illustrate the impact of introducing a resale option into the revenue management problem of strategic buyers when there is a sequence of bargaining stages and the seller has commitment to set prices in advance. We have shown that under reasonable parameters the first order effect in the seller's pricing strategy motivates a reduction in prices in the first stages of the game.

These results opens the door for further research. In an empirical ground, there is testable implication of the correlation between commitment to set prices in advanced and the possibility to the resale a good. On the theoretical ground, to find conditions that guarantee a reduction in the sequence of prices when the resale option is allowed. These conditions may be weaker or stronger in the commitment environment than in the no-commitment environment.

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