P2P marketplaces and retailing in the presence of consumers' valuation uncertainty

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Abstract

Can peer-to-peer (P2P) marketplaces benefit traditional supply chains when consumers may experience valuation risk? P2P marketplaces can mitigate consumers' risk by allowing them to trade mismatched goods; yet, they also impose a threat to retailers and their suppliers as they compete over consumers. Further, do profit-maximizing marketplaces always extract the entire consumer surplus from the online trades?

Our two-period model highlights the effects introduced by P2P marketplaces while accounting for the platform's pricing decisions. We prove that with low product unit cost, the P2P marketplace sets its transaction fee to the market clearing price, thereby extracting all of the seller surplus. In this range of product unit cost, the supply chain partners are worse off due to the emergence of a P2P marketplace. However, when the unit cost is high, the platform sets its transaction fee to be less than the market clearing price, intentionally leaving money on the table, as a mechanism to stimulate first period demand for new goods in expectation for some of them to be traded later, in the second period, via the marketplace. It is not until the surplus left with the sellers is sufficiently high that the supply chain partners manage to extract some of this surplus, ultimately making them better off due to a P2P marketplace. We further analyze the impact of a P2P marketplace on consumer surplus and social welfare. In addition, we consider model variants accounting for a frictionless platform and consumer strategic waiting.

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1 Introduction

Buyer uncertainty can unfold in a variety of ways. Consumers may possess uncertainty regarding their consumption state—namely how many units they require and/or how often they use the product—the type of product they want to consume (Fay and Xie, 2010), or the fit of the good for their needs (e.g., as firms may intentionally limit the amount of information released to consumers (Chu and Zhang, 2011)). In addition, when shopping, consumers may make quick purchasing decisions only to later realize that the purchased product has limited or no value to them. This *valuation uncertainty* (as in Prasad et al., 2011) exposes consumers to risky decision making and, accordingly, their willingness to pay is diminished (Grewal et al., 1994; Teo and Yeong, 2003). Thus, valuation uncertainty can inhibit potential consumers from purchasing, and hence harm the supply chain partners—the retailers and their immediate suppliers. Returning unwanted goods is not always an option. For instance, numerous stores do not accept returns (apparel, consumer electronics) simply because a customer did not like it, arguing that the experience at the store should suffice to determine fit[1].

Although in other cases consumers can return unwanted goods, they usually face a number of hurdles, such as (excessive) restocking fees[2], non-refundable fees (e.g., activation fees for mobile phones), long waiting times (Tuttle, 2013) (which exacerbates time spent on traveling back to the store or to the post office), missing receipts[3], and conditions imposed by stores for the returned goods to be in like-new condition (AT&T, for instance, also demands the software accompanying a mobile device to be in unopened shape) or even unopened (for example computer components, drones, headphones or major appliances at BestBuy Canada)—a condition that is not always trivial to satisfy, especially if product fit is known

[1] See, e.g., http://www.china-mike.com/china-travel-tips/shopping-guide/, accessed 11/11/2015.

[2] A research stream has evolved to address optimal restocking fees which can control consumer returns and segment the market, and which may change based on supply chain as well as competitive considerations (see, for example, Shulman et al., 2009, 2010, 2011).

[3] A recent survey in the UK revealed that "around half of those who were refused a refund were told it was because they didn't have the receipt" and a little over 70% of those surveyed experienced problems getting an instore refund (Lezemore, 2010).

only through experience. Importantly, for many goods and many consumers, the trial period may not suffice to conclude whether they would like to keep the good or not. These reasons probably explain the vast amount of unwanted goods that find their way to peer-to-peer (P2P) platforms, such as Craigslist, eBay, Kijiji, and more recently FaceBay, which are marketplaces in which consumers sell goods directly to one another (Wright, 2014).[4]

We further validate our qualitative observations above via a survey conducted on Amazon's Mechanical Turk platform. In the survey we asked 113 self-selected participants in the USA about how they use online platforms to alleviate their valuation uncertainty. Our survey reveals that 33% of all participants have sold a product online only because it did not meet their expectations. Of those individuals, 92% stated that knowing that they may sell the product online alleviated their uncertainty regarding the product meeting their expectations. This survey further supports our qualitative observations. The complete survey description and results are provided in the Online Supplements that accompanies this manuscript.

Do these P2P platforms hurt retailers in the same fashion that online retailing was blamed in stealing market share away from brick-and-mortar stores (Bhatnagar, 2006)? Indeed, a McKinsey report (MacKenzie et al., 2013) pointed out that companies such as "Craigslist, eBay, and Etsy (home to almost a million small businesses) are creating [P2P] marketplaces . . . [that] are eating into traditional demand for retail goods." However, this view completely ignores the potential benefit for traditional retailing. Platforms argue that "they can help retailers because shoppers are more willing to spend if they know they can easily resale items later" (AP, 2014). Evidently, consumers purchase goods while keeping in mind the resale value they can fetch through online P2P platforms (AP, 2014). This was confirmed in our survey, however we consider platforms alleviating mismatch uncertainty more so than recouping costs.

While independent P2P platforms, which are generally profit-maximizing entities, are

[4]A systematic search on Kijiji.ca, an online frictionless P2P platform similar to Craigslist, found 4-8% of listings, category dependent, are "brand new in the box" (or "brand new with tags" for apparel) as described by the seller. This number increased to 10-20% if we only considered "brand new" items.

not established to hurt or support traditional supply chains per se, in this manuscript we ask whether the latter are better off, or worse off, due to the emergence of the former. On the one hand, supply chain partners can leverage the advantage of the P2P marketplaces to reduce the risk faced by consumers and increase their sales. On the other hand, the supply chain partners need to compete with the P2P platforms who offer used goods that eats into their profits.[5] Furthermore, profit-maximizing platforms may have the incentive to set the transaction fee equal to the selling price of the goods traded on the platform (see, Mantin et al. (2014)). By doing so, all surplus gained could be extracted by the platform, neutralizing all benefits to the supply chain partners.

Hence, in this manuscript we focus our discussion on the friction between traditional retailing and P2P platforms by addressing the two opposing forces brought on by P2P platforms. It is this perspective that highlights our contribution, as to the best of our knowledge, this manuscript is the only one to explore the trade-off between buyer valuation uncertainty and P2P platforms. In particular we address a number of important research questions: Would the platform always extract all benefits to sellers, and if not, why? Can, and under what conditions, P2P marketplaces benefit or harm supply chain partners in the presence of consumers' valuation uncertainty? Additionally, can consumers receive any benefits from P2P marketplaces, or are these benefits neutralized by the operators of these marketplaces and/or supply chain partners? Lastly, does a P2P marketplace induce a net social welfare gain? Namely, a P2P marketplace is more likely to emerge if it can generate positive profit. Is this profit merely a redistribution of wealth or generation of new welfare?

To study a P2P marketplace's pricing decision and the implications of its emergence on the supply chain partners, consumers, and social welfare, we consider, in this paper, a two-period setting in which a single retailer purchases a quantity of a single product from a single supplier and then sells to consumers. The consumers are forward-looking, as they take into consideration the possibility that the purchased product will not match their expectations

[5]Marketplaces are usually operated by a platform and we use the terms P2P marketplace and P2P platform interchangeably throughout this paper.

after purchase. In each of the periods, the supplier sets the wholesale prices and then the retailer places his order quantity, which corresponds to the selling price. Once a platform is established, it allows consumers to salvage the mismatched products by selling them in the second period. The profit-maximizing platform generates revenue by charging consumers a fixed transaction fee, which is set ahead of any actions taken by the supply chain partners. Given the transaction fee set by the platform, the supply chain partners optimize their decisions to maximize their respective profits.[6]

The analysis gives rise to several important insights. Our first finding is that the profit maximizing platform does not always extract all surplus form the consumers who sell their unwanted goods via the platform. While existing literature has either assumed an exogenous transaction fee or simply that the platform is a fringe and hence extracts all surplus from the marketplace sellers, we endogenize this decision made by the platform operator. Indeed, when the unit cost of the product is sufficiently low, the platform behaves as in Mantin et al. (2014) and extracts all surplus. However, when the unit cost is high, then the platform sets the transaction fee to be lower than the market clearing price. The incentive of the platform operator in this case is clear: the high unit cost, which is then reflected by a high selling price, inflicts a high loss to consumers when a mismatch occurs. To relieve consumers and stimulate first period demand, in expectation of increased platform traffic in the second period, the platform operator commits to a transaction fee that leaves sellers with some surplus.[7]

Second, when a profit-maximizing P2P platform is involved, both supply chain partners will be better off if the product's unit cost is sufficiently high and both will be worse off otherwise (we also note that the minimum unit cost that makes the supply chain partners better off is higher than the minimum unit cost that makes consumers better off). The intuition behind this is that a P2P platform may stimulate first period demand by eliminating

[6] In the Online Supplement we demonstrate that a percentage fee yields qualitatively similar insights.

[7] To implement the fee structure emerging from our analysis, the platform operator can, for example, set a fee that changes with the product category. Thus, the insights behind our results can help explaining Amazon's Marketplace transaction fee structure, which is open to individual sellers.

consumers' valuation uncertainty and induce the supply chain partners to increase the price of new products, however, the platform also imposes competition that impairs the supply chain partners' second period profit. When the product's unit cost is low, the ratio of transaction fee to mismatched goods selling price is high, which means the platform extracts all or most of the surplus form its consumers and hence reduces first period demand. As a result, the supply chain partners will not gain enough to compensate the loss from the competition brought on by the platform in the second period due to low first period demand.

Third, when the product's unit cost is sufficiently high, a P2P platform benefits consumers in two ways: 1) it introduces competition between new and used goods in the second period and 2) it relieves consumers from their valuation uncertainty as they recoup some of the loss by selling mismatched products through the platform. Thus, the price of new goods in the second period is lower and consumers surplus in the first period can be higher while inducing more consumers to purchase the good, overall making consumers better off. Importantly, we find that the social welfare can be improved as all parties—the consumers, the marketplace, and the supply chain partners—may be simultaneously better off. In the alternate case, when the product's unit cost is sufficiently low, the platform's harm outweigh its benefit, making consumers worse off. In this setting, the upward price pressure on the retailer in the first period eliminates some consumers from purchasing in the first period—an effect that outweighs the benefit of additional consumers purchasing from the platform. In this case, not only consumers are worse off: the upward price pressure on the retailer results in net loss in profits for the supply chain partners as well.

Fourth, as we also distinguish between a profit-maximizing platform and a frictionless P2P platform which charges no transaction fee for online trades among consumers, we find that the frictionless P2P platform further stimulates competition in the second period driven by the increased demand experienced in the first period. As the frictionless platform gains no profit from online transactions, the supply chain partners are generally better off unless the mismatched probability is high and the unit cost is low, and consumers are always better off compared to the benchmark scenario. All agents are never worse off and mostly better off compared to the profit-maximizing platform scenario.

Last, the analysis of the setting where consumers exhibit strategic waiting—those who arrive in the first period may delay their purchase of a new good to the second period—suggests that the retailer can still be better off due to the presence of a platform. Interestingly, the platform can further benefit the retailer when the probability of a mismatch is relatively high. This occurs as the platform, which provides consumers with a channel to trade their mismatched goods, allows the retailer to inter-temporally segment the consumers who arrive in the first period, by committing, in such a setting, to increase the price over time.

The rest of the paper is organized as follows. Section 2 presents a review of related literature. Section 3 describes the model framework. The benchmark scenario and the scenario that accounts for the presence of a profit-maximizing platform are analyzed in Section 4. In Section 5, we further discuss the implications of the platform on the supply chain partners, consumers and social welfare. The scenarios with a frictionless platform and strategic waiting are analyzed in Section 6. Lastly, Section 7 concludes the paper.

2 Literature Review

Several papers have studied the impact of secondary, used goods, markets on the primary, new goods, markets. For example, Chen et al. (2013) developed a dynamic model where consumers experience random valuation shocks and goods stochastically perish over time, and then calibrated the model using automotive sales data revealing a drop of 35% in retailers' profitability due to secondary used goods trading. Johnson (2011) focused on the role of the retailers' choice of product durability in a two-period setting with random redraw of consumers valuations, in suggesting constellations where secondary markets may increase a monopolist's profits. Our paper contributes to this stream by integrating the important aspect of buyer uncertainty and the corresponding product mismatch consumers face while accounting for the presence of a supplier to account for channel coordination considerations.

A related stream of literature considers the impact of various secondary marketplaces on the supply chain. Shulman and Coughlan (2007), who explicitly account for the role of the supplier, limit the scope of their study to a retailer-controlled secondary market: the retailer buys back used goods at a pre-determined price (which is a major lever in controlling the flow of used goods back to the market) from the consumers and resells them in the second period alongside new goods, implying that under certain conditions, the retailer effectively operates a rental market. We differ from this model by capturing both the role of the independent secondary market where prices are determined endogenously and the valuation uncertainty that consumers encounter. A similar paper by Ghose et al. (2005) investigate in the impact of a retailer operated P2P platform on the suppliers. Specifically, they show while a monopoly supplier might be worse off due to a platform, duopoly suppliers with quality differentiated goods might be better off. An independent secondary market is studied by Oraiopoulos et al. (2012), where the market operator purchases used goods from consumers, refurbishes them and then the consumers who buy these units purchase a license from the OEM. The OEM, by setting this relicensing fee, can control the secondary market (i.e., it can effectively shut down this market by charging a high licensing fee). The authors find that the OEM keeps the secondary market when consumers' willingness to pay for a refurbished good is high as the OEM benefits twice: relicensing fee and higher selling price (due to resale value). In our setting the retailer does not have this luxury of two streams of revenue while the entrant operates a platform (rather than as a retailer). Hence, our focus is on the effect of platforms in the absence of the relicensing fee while further accounting for the role of consumers' uncertainty.

Closely related to our contribution are the papers by Yin et al. (2010) and Gümüş et al. (2013). Yin et al. (2010) consider supplier induced product upgrades and the presence of a secondary used good market (either retailer-controlled and/or P2P platform), where they find that the supply-chain partners may benefit from the emergence of P2P platforms.

Gümüş et al. (2013) explore the role of P2P platforms in affecting the supplier's choice of return policies offered to the retailer in a two-period setting. The buyback option has an important role in mediating competition: the retailer returns all unsold goods back to the supplier to avoid competition with the platform. However, in both papers, consumers do not face valuation risk and after using the good, all consumers return or resell the good. Additionally, our manuscript further differentiates from the above contributions as we distinguish between platforms that charge a transaction fee from the sellers, with the transaction fee being endogenously determined in our model, (which are common in practice, such as eBay) and frictionless platforms (an assumption adopted by most of the above-mentioned papers). Endogenizing the platform transaction fee generalizes the only result we are aware of in profit maximizing P2P platforms by Mantin et al. (2014), who assumed the platform sets the transaction fee to the market clearing price. By contrast, we show that the profit maximizing platform does not always extract all consumer surplus and characterize the conditions, sufficiently high per-unit product cost, in which the platform extracts only some of the surplus.

Online P2P platforms have attracted other research questions, such as the empirical investigation of the role of online deal-forums in influencing the trading prices on P2P platforms (which supports our assumption of a market clearance mechanism) Gopal et al. (2006). Others have focused on Amazon's dual-format retailing, such as Mantin et al. (2014) and the substitution between new and used books offered on Amazon Ghose et al. (2006). More broadly, a P2P platform can be perceived as a two-sided market. The two-sided market literature endogenizes the transaction fee, but it is primarily concerned with market participation, by controlling access and usage fees. Generally, this literature does not consider competition between secondary and primary markets (Rochet and Tirole, 2006).

The other aspect of our modelling framework is consumers' buyer uncertainty, which then results with a product mismatch. A stream of research explores pricing strategies in the presence of such risk. Hsiao and Chen (2012) note that quality risk has an impact on the retailer's return policy and pricing strategies. Other papers extend the product return literature to account for various constellations such as competition and supply chain considerations (see, e.g., Shulman et al., 2009, 2010, 2011). Gu and Liu (2013) argue that better matching between consumers and products may hurt the retailer's profit, in which case, the retailer cuts its own sales commissions and blocks manufacturer SPIFF (Sales Person Incentive Funding Formula) programs so as to suppress retail sales assistance provided by its own personnel. In B2C channels, retailers and consumers face not only product quality risk, but also valuation uncertainty due to information asymmetry. Given consumers' uncertainty, Chu and Zhang (2011) show that a retailer can induce consumers into pre-ordering goods by controlling product information release. Consumers' valuation uncertainty plays an important role in their behaviors. Indeed, it is often considered in supply chain studies; yet, this consideration is rather absent when a P2P platform is present. Our paper contributes to the literature by highlighting the role of consumers' valuation uncertainty in the interaction between a P2P platform and supply chain partners.

3 Modeling Framework

In this section, we describe our model setup and the methods to solve the model. In order, to capture the inter-temporal interaction within supply chain members and consumers, we simplify time, by only considering two periods, with pricing, production, and purchase decisions being made in both periods. We first consider a benchmark scenario, where a single profit-maximizing retailer purchases new durable products from one profit-maximizing supplier and then retails them to consumers in the absence of a platform. We then consider a scenario, where a profit-maximizing platform is present and competes with the retailer in the second period by letting consumers trade mismatched goods purchased in the first period. Later in the manuscript, we also consider the special case of a frictionless platform scenario. For all scenarios, we consider ex ante equilibrium decisions and assume risk-neutral agents.

Similar to Yin et al. (2010), a new set of consumers shows up in each period and their initial valuations v are uniformly distributed between 0 and 1. Those consumers also face valuation uncertainty: due to a variety of issues, not entirely modeled in this paper, such as lack of information, consumers may find the good to be unfit for their purposes. Specifically, we assume that after some preliminary use, consumers realize their actual valuation for the good. In practice, consumers may develop expectations about their valuation for the goods based on, e.g., media attention, commercials, or word-of-mouth. However, they may not know their true valuation for the good until some preliminary use. This is true for a variety of products such as some electronic goods, where the user experience can be quite instrumental in determining whether the consumer would like to own the good or not. Unfortunately, for many of these goods, it is not possible to return the item after initial use, and thus a consumer may be left with a negative net utility after realizing their true personal value of the good. Using the terminology used in Hsiao and Chen (2012), we assume that with some probability, consumers find the product to be mismatched and hence has no value for them, and with the complementary probability the good has the full initial valuation, v. We use $\alpha_i \in \{0, 1\}$ to indicate consumer i's mismatch realization, where $\alpha_i = 1$ implies that the product is a mismatch and hence the realized valuation of the product is 0, and $\alpha_i = 0$ indicates a match and hence the full valuation v is materialized. We let $\theta \in [0, 1]$ represent the probability of consumers having full private valuation, that is, $\alpha_i = 0$. For the purpose of simplification, we assume consumers are homogeneous with respect to their uncertainty risk, which means θ is also the expected probability of consumers having a matched product. Since consumers are risk-neutral and forward looking,[8] they purchase the good only if their expected utility, $\theta v - p$, where p denotes the price, is non-negative.

[8]This notion of consumer forward looking behavior is different than that assumed in dynamic pricing models. Specifically, consumers are not engaged in the dynamic decision of whether to purchase the good right now or postpone the decision to a later period (an aspect that is explored later in Section 6.2). In our model, consumers decide whether to purchase the good right now or not at all. The rational behavior comes into play by capturing their expectations about the actual valuation for the good and the money they can recoup in case their valuation risk materializes and they resell the good through the secondary market, if one is available.

Throughout the analysis, we use the following notation: Let the first superscript, i, denote the scenarios and the second superscript, j, denote the players. The first subscript, t, denotes the periods and the second subscript, r, denotes the types of products. The complete notation is provided in Table 1.

U^i_{tr}	consumers' expected utility from buying type r product in period t in scenario i
w^{iS}_{tn}	wholesale price of new product in period t in scenario i
p^{ij}_{tr}	selling price of type r product from player j in period t in scenario i
q^{ij}_{tr}	demand of type r product from player j in period t in scenario i
t^{iP}	platform transaction fee in scenario i
Π^{ij}_t	player j's profit in period t in scenario i
Π^{ij}	player j's total profit in scenario i
CS^i	consumer surplus in scenario i
SW^i	social welfare in scenario i

Table 1: Some notation: $i \in \{B, P, F\}$, $j \in \{S, R, P\}$, $t \in \{1, 2\}$, $r \in \{n, p\}$, where $B, P,$ and F stand for the benchmark, profit-maximizing, and frictionless platform scenarios respectively; $S, R,$ and P stand for the supplier, retailer, and platform, respectively; n and p stand for new and platform products, respectively.

The sequence of events in the benchmark setting is depicted in the top row of Figure 1. In period 1, the supplier sets the wholesale price w^{BS}_{1n}, then the retailer purchases an amount, q^{BR}_{1n}, of new products from the supplier. This quantity corresponds to a first period's selling price p^{BR}_{1n}.[9] We use c to denote the unit cost of acquiring one product for the supplier, and we assume $c < \theta$. This assumption is necessary to satisfy the supplier's individual rationality constraint by guaranteeing positive profit in expectation in all scenarios. After p^{BR}_{1n} has been announced, consumers buy products based on their expected utility. At the end of period 1, individual mismatch, α_i, is realized and all consumers with mismatched products ($(1-\theta)q^{BR}_{1n}$ in expectation) experience a negative utility, $-p^{BR}_{1n}$. As discussed previously, we assume that customers cannot return used goods to the retailer for a refund, instead, in our model the consumer may only sell their used goods via a P2P platform, if it is available. This is indeed the case for most electronic goods, and such goods may be seen sold on P2P platforms.

[9] In our setting, due to the deterministic nature of the model, prices and quantities are equivalent: once the quantity is determined, the price follows immediately.

In period 2, a new set of consumers shows up. In our study we are not considering completely new products, period to period, and as such consumers that have made their decision in the first period have no reason to reconsider the decision again in the second. Implicitly, we do not consider strategic waiting by consumers in the main model of our paper, however we discuss the impact of strategic consumers, those that decide to wait between period 1 to period 2 in Section 6.2. The supplier sets the new wholesale price w_{2n}^{BS}, then the retailer purchases an amount, q_{2n}^{BR}, of new products from the supplier and hence the second period's selling price p_{2n}^{BR} is determined. As before, consumers buy products based on their expected utility.[10]

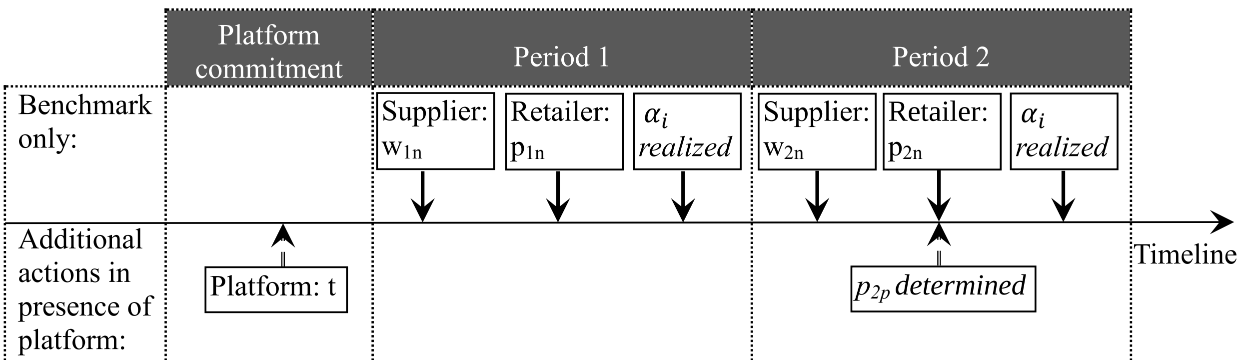


Figure 1: Timeline of events: events that occur only in the presence of the platform are with dashed arrows; non-decision events are in italic.

To capture the effect of a P2P platform, which allows used goods from the first period to be traded in the second period between consumers, on the supply chain partners and the consumers, we consider a variation to the benchmark scenario. In this augmented scenario, the retailer sells new products in both periods, while used products are traded through the

[10]Note that in our setting we maintain the same level of uncertainty about the product fit in both periods as the demand in the second period stems from a new cohort of consumers. One might consider an alternative approach where the uncertainty in the second period is alleviated. In the absence of late season uncertainty, holding everything else fixed, the (expected) consumer surplus may increase. Accordingly, the demand for the goods increases and we expect both prices in the late season to increase as well. With higher second period prices, consumers can recoup more of their loss in an event of mismatch, resulting with the retailer raising the price in the first period as well. This certainly benefits the supply chain partners. Indeed, as uncertainty is alleviated, the valuation for the good may change: if it increases universally, it further amplifies the intuitions above, while if it decreases universally, then it moderates, or even reverse, the intuitions above.

platform only in the second period. Used goods sold on the platform are all mismatched goods from the first period that consumers were not able to return to the retailer.

The Stackelberg game sequence of events in the presence of a platform, which is shown in Figure 1, is as follows: Following Mantin et al. (2014), in the first stage, the platform commits to *a fixed* transaction fee to charge consumers for selling through the platform; a profit-maximizing platform sets t^{PP}, whereas with a frictionless platform we have $t^{FP} = 0$. In practice P2P platform fees are posted online and are rarely changed, for example Amazon, EBay, and Etsy.[11] Then, as in the benchmark scenario, the supplier sets w_{1n}^{PS}, the retailer purchases q_{1n}^{PR} units (corresponding to a price p_{1n}^{PR}), and the consumers purchase based on their expected utility. At the end of period 1, all consumers with mismatched products ($(1-\theta)q_{1n}^{PR}$ in expectation) wait to sell their products through the P2P market in the second period. In period 2, as a new set of consumers shows up, the supplier sets w_{2n}^{PS},[12] and the retailer purchases q_{2n}^{PR} units. Meanwhile $q_{2p}^{PP} = (1-\theta)q_{1n}^{PR}$ used products are offered through the platform. Used products traded through the P2P market are devalued by a factor $\delta \in [0, 1]$. That is, the expected benefit of these products by consumers in the second period is $\theta\delta v$. Since used products on the P2P platform are sold to clear the market, the corresponding prices of new and mismatched products, p_{2n}^{PR} and p_{2p}^{PP}, are determined simultaneously. Note, although we use P for the first superscript, the logic holds for F.

[11] We also explored other fee structures for the platform. An analysis with zero transaction fee, representing a frictionless secondary market, is discussed later in Section 6.1 of this paper. Percentage transaction fee, which is adopted by a number of P2P platforms, is studied in the Online Supplement that accompanies this manuscript. The results suggest that the insights do not change as one adopts a percentage rather than a fixed fee. This observation is consistent with that of Chen et al. (2013) who state that with a percentage fee "the results are qualitatively and quantitatively very similar to those from our baseline specification" where they use a fixed transaction fee. In their model the transaction fee is merely a friction cost as they assume away the platform.

[12] We find that $w_{2n}^{PS*} \leq w_{1n}^{PS*}$ in the platform scenario, Section 4.2. Accordingly retailers have no incentive to hold inventory. Therefore, we abstract away from the issue of strategic inventories (see, e.g., Anand et al. (2008), Hartwig et al. (2015)).

4 Model Analysis

Next, we solve using backward induction for each of the scenarios described earlier. We start with the benchmark scenario (Section 4.1), and then proceed to the platform scenarios (Section 4.2).

4.1 Benchmark scenario: No P2P platform

In this section, we explore the supply chain partners' equilibrium decisions and resulting profit in the benchmark scenario. In period 1, the expected utility from buying a product is the consumer's expected valuation of the product minus its selling price, that is, $U_{1n}^{B} = \theta v - p_{1n}^{BR}$. The consumer, indifferent between buying and not buying a product in period 1, has a valuation of $\bar{v}_1^B \equiv p_{1n}^{BR}/\theta$. Then the quantity of products sold in period 1 is given by $q_{1n}^{BR} = 1 - \bar{v}_1^B = 1 - p_{1n}^{BR}/\theta$, which follows from the assumption that consumers' valuations are uniformly distributed between 0 and 1. Similarly, in period 2, we have $q_{2n}^{BR} = 1 - p_{2n}^{BR}/\theta$.

Having derived the demand functions, we can express the supplier's and the retailer's profit functions. In period 2, the profit of the retailer is given by $\Pi_2^{BR} = (p_{2n}^{BR} - w_{2n}^{BS})q_{2n}^{BR} = (\theta(1 - q_{2n}^{BR}) - w_{2n}^{BS})q_{2n}^{BR}$, which is concave in q_{2n}^{BR}. Maximizing Π_2^{BR} with respect to q_{2n}^{BR}, we find that $q_{2n}^{BR*} = (\theta - w_{2n}^{BS})/2\theta > 0$, $p_{2n}^{BR*} = (\theta + w_{2n}^{BS})/2$, $\Pi_2^{BR*} = (\theta - w_{2n}^{BS})^2/4\theta > 0$. Next, maximizing Π_2^{BS} with respect to w_{2n}^{BS} leads to $w_{2n}^{BS*} = (\theta + c)/2$, and consequently $\Pi_2^{BS*} = (\theta - c)^2/8\theta > 0$. In this benchmark setting, the two periods are independent of each other, hence all equilibrium decisions and profits in period 1 are as in period 2.

In summary, we find that $q_{1n}^{BR*} = q_{2n}^{BR*} = (\theta - c)/4\theta$, $p_{1n}^{BR*} = p_{2n}^{BR*} = (3\theta + c)/4$, $w_{1n}^{BS*} = w_{2n}^{BS*} = (\theta + c)/2$, $\Pi^{BR*} = (\theta - c)^2/8\theta$, and $\Pi^{BS*} = (\theta - c)^2/4\theta$. Recall that we assume $c < \theta$, which guarantees strictly positive quantities. The profits of the supplier and the retailer are decreasing in c, and increasing in θ. That is, higher unit cost and more consumers uncertainty regarding their valuation will harm the supply chain partners' profits.

In this benchmark scenario, there is no channel for consumers to trade their mismatched products; hence they receive negative utility when a product mismatch occurs. In the next subsection we explore if a P2P platform can remedy the mismatch issue.

4.2 A P2P platform scenario

In the presence of a platform, a consumer has the option of selling the product in the second period at the market clearing price, p_{2p}^{PP}, while paying a fee t^{PP} to the platform for using this service. Thus, in period 1, the expected utility from buying a product is a consumer's expected valuation of a product minus its selling price, plus his expected payoff from selling the product through the platform, that is, $U_{1n}^P = \underbrace{\theta v}_{\text{expected valuation}} - \underbrace{p_{1n}^{PR}}_{\text{price}} + \underbrace{(1-\theta)(p_{2p}^{PP} - t^{PP})}_{\text{expected payoff}}$. A consumer is indifferent between buying and not buying a product in period 1 when his valuation of the product is $\bar{v}_1^P = (p_{1n}^{PR} - (1-\theta)(p_{2p}^{PP} - t^{PP}))/\theta$, implying $q_{1n}^{PR} = 1 - \bar{v}_1^P$. In period 2, the expected utility from buying a new product is $U_{2n}^P = \theta v - p_{2n}^{PR}$, whereas the expected utility of buying a used product from the platform is $U_{2p}^P = \theta\delta v - p_{2p}^{PP}$. A consumer is indifferent between buying a new product and a used product in period 2 if his valuation of the used P2P product is $\bar{v}_{2p}^P = (p_{2n}^{PR} - p_{2p}^{PP})/(1-\delta)\theta$, implying $q_{2n}^{PR} = 1 - \bar{v}_{2p}^P$. A consumer is indifferent between buying and not buying a used product from the platform when his valuation of the used product is $\bar{v}_p^P = p_{2p}^{PP}/\delta\theta$, implying $q_{2p}^{PP} = \bar{v}_{2p}^P - \bar{v}_p^P$. Having derived the demand functions, we solve the Stackelberg game via backward induction.

Let $c_1 \equiv \theta - \frac{\theta(1-\theta)(\delta^2(1-\theta)^2(96-40\delta)+128\delta)}{128-(1-\theta)((1-\theta)((1-\theta)\delta^2(36-11\delta)+56\delta^2-144\delta)+16\delta\theta)}$, $c_2 \equiv \theta - \frac{8\theta\delta^2(1-\theta)^2}{64-(1-\theta)(19(1-\theta)\delta^2+64\theta\delta-56\delta)} \leq \theta$. We have the following Lemma. All proofs are provided in Appendix A.

Lemma 1. *In equilibrium, the profit-maximizing platform sets the transaction fee, t^{PP}, depending on three different segments as follows:*

Segment 1: if the unit cost of acquiring the products is sufficiently low, $c \leq c_1$, then the platform transaction fee is equal to the used product's selling price ($t^{PP*} = p_{2p}^{PP}$) to extract all benefits from its consumers;

Segment 2: if $c_1 < c \leq c_2$, then the transaction fee is lower than the used product's selling *price ($t^{PP*} < p_{2p}^{PP}$) to induce more consumers to purchase in the first period;*

Segment 3: if the unit cost of acquiring the products is sufficiently high, $c > c_2$, then the platform sets the transaction fee to price the supply chain partners out of the second period (i.e., $q_{2n}^{PR*} = 0$).

Lemma 1 is formally restated in Appendix A. The optimal transaction fee and supply chain partners' corresponding decisions are demonstrated in Figure 2. From the platform's perspective, his profit is affected by the transaction fee and the demand of new products in the first period, which in turn, determines the number of used goods available in the second period. Therefore, the platform is trading-off between setting a high transaction fee, referred to as the transaction fee effect, and having high first period demand, referred to as the demand effect, because a higher transaction fee decreases the demand, and vice verse. Therefore, the optimal transaction fee is a result of the interaction between the transaction fee effect and the demand effect.

Lemma 1 shows that when the product's unit cost is sufficiently low, the platform can set the transaction fee as high as possible, equal to the selling price of the used goods. In other words, the transaction fee effect dominates the demand effect, and the platform has the power to extract the entire surplus from consumers who use its service. As the unit cost increases, the transaction fee effect decreases while the demand effect increases, as seen in Segment 2 in Figure 2, in which case the platform's power is weakened. In order to stimulate first period demand, the platform must reduce its transaction fee so as to compensate consumers that may experience a mismatched product. As the unit cost continues to increase, the platform will induce the supply chain partners to abandon their business in the second period (Segment 3). Therefore, the mismatched goods on the platform are the only goods sold in the market during the second period. The platform may extract more of the surplus of the consumers using the platform to sell their mismatched goods, but not enough to extract the entire surplus because the threat of the retailer selling new goods in the second period. The existence of Segments 2 and 3 is important. They reveal that the platform has the incentive to leave money on the table by charging the users of the marketplace a fee that is strictly less than the market clearing price. This result is by contrast to the assumption made by Mantin et al. (2014) who assumed the the platform will extract all surplus from the platform sellers.

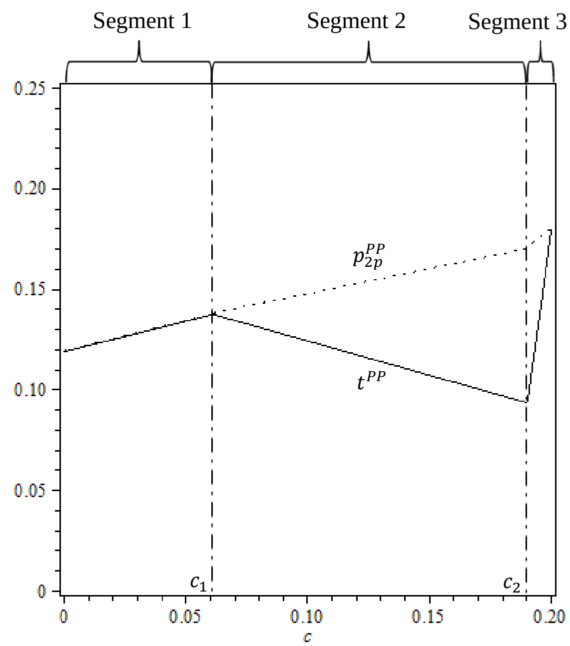


Figure 2: Transaction fee and used goods' price, $\theta = 0.2$, $\delta = 0.9$ [Note: θ is intentionally chosen to a low value to emphasize Segment 3. This segment always exist since $c_2 \leq \theta$.]

5 The impact of a profit-maximizing P2P platform

In this section we investigate the net effect of a profit-maximizing P2P platform on supply chain partners and consumers. Comparing the profits of the supply chain partners between the benchmark and platform scenarios, we find that the supply chain partners can be better off with a high unit cost and worse off otherwise. This is formally stated in the following theorem.

Theorem 1. *The introduction of a P2P platform*

(1) reduces the total expected profit of supply chain partners when the unit cost is sufficiently low, i.e., $c < \tilde{c}_{sc} \in [c_1, c_2]$*;*

(2) increases the total expected profit of supply chain partners when the unit cost is sufficiently high, i.e., $c \geq \tilde{c}_{sc}$*,*

where $\tilde{c}_{sc}$ *is the threshold value that solves* $\Pi^{BS} + \Pi^{BR} = \Pi^{PS} + \Pi^{PR}$.

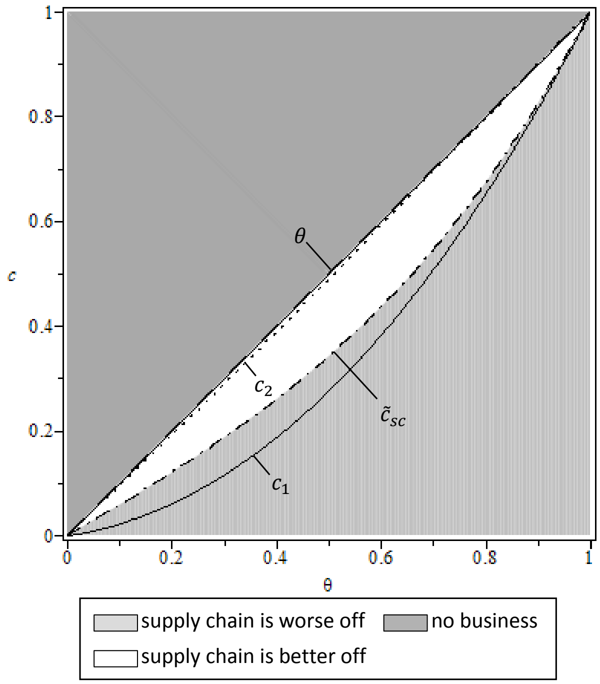


Figure 3: Unit cost thresholds for supply chain, $\delta = 0.9$

The threshold $\tilde{c}_{sc}$ in Theorem 1 and its corresponding regions are depicted in Figure 3. From the supply chain partners' perspective, the emergence of a P2P platform induces several effects. In the second period of the platform scenario relative to the second period of the benchmark scenario, the platform exposes the supply chain partners to competition from used products, which results in lower wholesale prices, selling prices, as well as lower demand for new products than those in the benchmark, and hence lower profit in the second period. At the same time, because the platform mitigates some of the mismatch risk, the supply chain partners can increase the prices of new products in the first period. However, higher selling price also has a negative effect on the first period demand. As the unit cost increases, $c \geq c_1$, the platform lowers the transaction fee to increase consumers' expected payoff to stimulate first period demand. When the platform's demand stimulation effect dominates

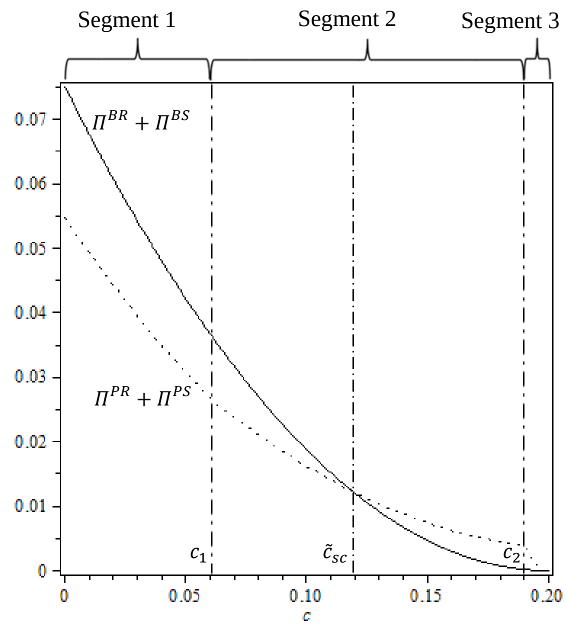


Figure 4: Comparisons of supply chain partners' total profits between Benchmark and Platform scenarios, $\theta = 0.2$, $\delta = 0.9$

the negative effect of higher prices, it results in greater first period profit compared to the benchmark scenario. As the unit cost increases, the gain in the first period stemming the presence of the platform eventually exceeds the loss in the second period from the platform competition, which leads to a net positive effect of the platform (once $c > \tilde{c}_{sc}$, in segment 2 in Figure 4). In other words, the advantage of a P2P platform is that it increases the price of new products and may stimulate first period demand, but the disadvantage is that the competition impairs the supply chain partners' profit. Only when the unit cost is sufficiently high, will the benefit compensate the potential harm of having a platform, making the supply chain partners better off.

While generally both supply chain partners are either better off or worse off with the introduction of a platform, there exists a relatively small range of c values where the retailer is better off while the supplier is worse off (see Proposition A.1 in Appendix A of the Online Supplement).

The results above indicate that the effect of a platform on the supply chain partners depends on the value of product's unit cost. We now consider the platform's impact on consumer surplus, which is the cumulative integration of consumers' net utility over valuation in two periods (see Proof of Theorem 2 in Appendix A for formal statement). That is, the monetary gain obtained by consumers for purchasing a product at a price less than the highest price that they would be willing to pay.

Theorem 2. *The introduction of a profit-maximizing P2P platform makes consumers worse off when the probability of consumers having full private valuation and the products' unit cost are both sufficiently low, i.e.,* $\theta \leq \tilde{\theta}(\delta)$ *and* $c \leq \tilde{c}_{cs}(\delta, \theta)$*. Otherwise, consumers are better off in the presence of a platform, i.e.,* $\theta > \tilde{\theta}(\delta)$ *or* $\theta \leq \tilde{\theta}(\delta)$ *and* $c > \tilde{c}_{cs}(\delta, \theta)$*.*

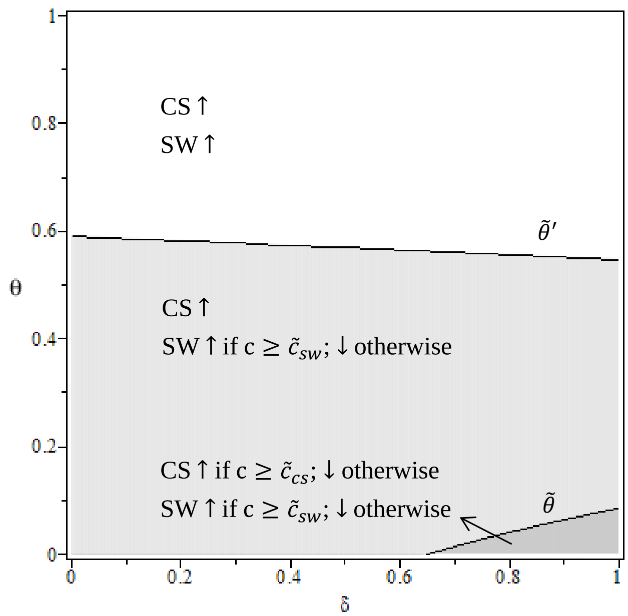


Figure 5: Effect of introduction of a profit-maximizing P2P platform on consumer surplus and social welfare

This is an important insight. The perceived knowledge is that a P2P platform always benefits consumers as it offers a channel to trade used goods and provides downward pressure on the existing supply chain partners to lower prices. We find that this is generally true but not universally, as a platform allows consumers to recover some of the loss from a mismatched product and benefit from a more diverse second period market as well. Although the higher first period price erodes these gains, it is not enough to make consumers worse off, unless consumers are extremely uncertain about the products' valuation and the unit cost is also very low. In that case, a profit-maximizing platform can be detrimental to consumers' welfare (see Figure 5).

Lastly, we consider the net effect of a profit-maximizing platform on social welfare, which is the aggregated welfare of all agents, i.e., $SW^B \equiv \Pi^{BS} + \Pi^{BR} + CS^B$, $SW^P \equiv \Pi^{PP} + \Pi^{PS} + \Pi^{PR} + CS^P$. Trivially, when product's unit cost is high, a platform is welfare-imposing, as the supply chain partners and consumers are better off and the platform makes positive profit. However, the two previous results reveal the erosion of the supply chain partners' and possibly the consumers' welfare in the presence of a platform when θ and c are both sufficiently low. Below we explore if a profit-maximizing platform creates welfare in the system, or simply gravitates welfare away from the existing agents, the supplier, retailer and consumers. We have the following insight.

Theorem 3. *The introduction of a profit-maximizing P2P platform makes total social welfare worse off when the probability of consumers having full private valuation and the products' unit cost are both sufficiently low, i.e.,* $\theta \leq \tilde{\theta}'(\delta)$ *and* $c \leq \tilde{c}_{sw}(\delta, \theta)$. *Otherwise, social welfare is better off in the presence of a platform, i.e.,* $\theta > \tilde{\theta}'(\delta)$ *or* $\theta \leq \tilde{\theta}'(\delta)$ *and* $c > \tilde{c}_{sw}(\delta, \theta)$.

This theorem indicates that a P2P platform is not always beneficial to society as shown in Figure 5. Specifically, when consumers are not certain about the product's valuation and the unit cost is sufficiently low, the emergence of a P2P platform has a detrimental effect on social welfare.

6 Model Extensions

In this section we consider two extensions to the model presented so far. We first consider a frictionless P2P platform, one in which the platform does not charge any transaction fee. We then consider the impact of strategic consumers.[13]

[13] In the Online Supplement that accompanies this manuscript we discuss the implication of switching from an additive transaction fee to a multiplicative transaction fee.

6.1 A frictionless P2P platform

We have shown that a profit-maximizing platform can critically affect supply chain partners' optimal decisions and profits. However, in practice we also observe a variety of frictionless platforms, such as Kijiji, Craigslist and autoTRADER, which allow their customers to trade through the platform generally for free but each profits from other sources, like advertisements and etc. In this section, we explore how a frictionless platform affects the supply chain partners and consumers as compared to the two scenarios studied earlier: the benchmark and in the presence of a profit-maximizing platform.

From modeling perspective, when the platform is frictionless, the only difference from the profit-maximizing platform setting studied earlier is that the platform commits to a zero transaction fee, that is, t^{PP}, which is t^{FP} in the current setting, is 0. Using backward induction, we derive the equilibrium decisions and corresponding profits. Similar to Lemma 1, we have the following result.

Lemma 2. *In the presence of a frictionless platform, in equilibrium, there exists a threshold unit cost,* $c_f \equiv \theta - \frac{8\theta\delta^2(1-\theta)^2}{32-\delta(1-\theta)(7\delta(1-\theta)-8(3-4\theta))}$*, such that, when* $c > c_f$*, the supply chain partners are priced out of the second period (i.e.* $q_{2n}^{FR*} = 0$*). Additionally,* $c_f < c_2$*, which implies that the range of unit cost values for which they are priced out is larger with a frictionless platform compared to a profit-maximizing one.*

Lemma 2 is very insightful and its intuition is as follows: When the platform charges no fee from its users, more mismatched goods are traded through the platform, thereby increasing the range of unit cost values under which the supply chain partners are priced out of the market in the second period. This raises a compelling question: as this occurs, are the supplier and retailer better off in the presence of a frictionless market? Importantly, no transaction fee stimulates the first period demand and further leads to greater supply of used goods in the second period. Consequently, we have the following statement.

Theorem 4. *A frictionless P2P platform,* *(1)generally makes the supply chain partners better off and always makes consumers better off, as compared to the benchmark scenario. Specifically, the supply chain partners are worse off when the probability of consumers having full private valuation and the products' unit cost are both sufficiently low, i.e., $\theta \leq \hat{\theta}(\delta)$ and $c \leq \hat{c}_{sc}(\delta, \theta)$. Otherwise, they are better off in the presence of a frictionless platform, i.e., $\theta > \hat{\theta}(\delta)$ or $\theta \leq \hat{\theta}(\delta)$ and $c > \hat{c}_{sc}(\delta, \theta)$.*

(2)always makes the supplier better off, and the retailer and consumers never worse off, as compared to a profit-maximizing platform scenario. Specifically, the retailer and consumers are better off when $c < c_2$ and no worse off otherwise.[14]

The introduction of a platform relieves consumers from some of their mismatch risk and exposes the supply chain partners to competition in the second period. A frictionless platform further stimulates competition in the second period, but the fact that it doesn't charge any transaction fee and induces greater demand in the first period, which more than compensates the supply chain partners for the lost, or reduced, opportunity in the second period. Similarly, consumers are also better off as the reduction of risk more than compensates for the higher price charged in the first period.

To conclude, a frictionless platform improves the profit of both supply chain partners as well as consumer welfare as compared to the benchmark scenario. Similar improvements are observed when compared to the presence of a profit-maximizing platform. Importantly, even when the supplier and the retailer are priced out of the second period, they can still be better off. These are important insights that suggest that supply chain partners could, and should, be engaged in facilitating such frictionless platforms for their consumers to trade mismatched goods.

[14] Although we do not provide visual illustration of Theorem 4 qualitatively, $\hat{\theta}$ behaves very similarly as $\tilde{\theta}$ in Figure 5.

6.2 Strategic Waiting by Consumers

Thus far we have assumed that consumers are forward-looking in that they take future payoff into consideration. Another aspect of forward-looking behavior is *strategic waiting*. There is a significant body of literature that addresses pricing and inventory decisions in the presence of strategic consumers (see, e.g., reviews by Aviv et al. (2009) and Chen and Chen (2015)). In this section, we explore the effect of consumers' strategic waiting as a P2P platform is introduced. A key simplifying assumption when considering strategic consumers is that the retailer commits to a pricing strategy before the first period starts. In particular, we assume that exact prices are unknown, but consumers know if the second period price will be lower or higher than the first. Knowing this relative price commitment a priori, either eliminates (second period price higher) or induces (second period price lower) strategic waiting.

Let us consider first the benchmark case (i.e., no P2P platform). To capture consumers' strategic waiting, in this case, we assume that in the first period, consumers choose between buying the new good right away or defer and purchase a new good in the second period. When they wait, they incur utility loss from not using the product in the first period, captured by a factor $\gamma \in [0, 1]$. Thus, in the first period, consumers compare the expected utility from buying right now, $\theta v - p_{1n}$, with the expected utility from waiting, $\gamma(\theta v - p_{2n})$.[15] We have the following intuitive result (which is provided without a proof):

Proposition 6.1. *In the absence of a P2P platform, the retailer commits to a decreasing prices trajectory. That is, the retailer encourages strategic waiting.*

The intuition is rather simple: by encountering strategic consumers again in the second period, the retailer is rewarded with a second opportunity to sell the goods to these consumers. This allows the retailer to price-discriminate between consumers. Traditional inter-temporal models generally suggest that in the presence of strategic consumers the retailer is better off by (credibly) committing to a fixed price (to eliminate the inter-temporal

[15] In practice, some consumers may wait to purchase a used good in the second period. We assume that such behavior is very limited as it relies on other consumers experiencing a mismatch and hence can be ignored.

competition)–the discussion on this aspect dates back to the seminal paper by Coase (1972). However, in our setting, since there is a new cohort of consumers who arrive in the second period, they serve as a counter balance against dropping the price too severely in the second period and allow the retailer to take advantage of the segmentation offered via the inter-temporal price discrimination.

We now turn our attention to the effect induced by the P2P platform. To capture consumers' strategic waiting, in this case, we assume that in the first period, consumers choose between buying the new good right away, and having the chance of selling it on the platform, or defer and purchase a new good in the second period. Similar to the earlier scenario, the loss from not using the product in the first period is models via $\gamma \in [0, 1]$. Thus, in the first period, consumers compare the expected utility from buying right now with the chance of returning, $\theta v + (1-\theta)(p_{2p} - t) - p_{1n}$, with the expected utility from waiting, $\gamma(\theta v - p_{2n})$. Recall from our analysis in Section 5 that in the absence of strategic waiting the retailer benefits from the emergence of a P2P platform when the product's unit cost is sufficiently high (as a function of other model's parameters). With consumers' strategic waiting two natural questions arise: 1. Can the retailer be better off when consumes strategically wait? 2. Does the presence of a platform still benefit the retailer? Our observations below, derived based on numerical simulations, address the two questions above.

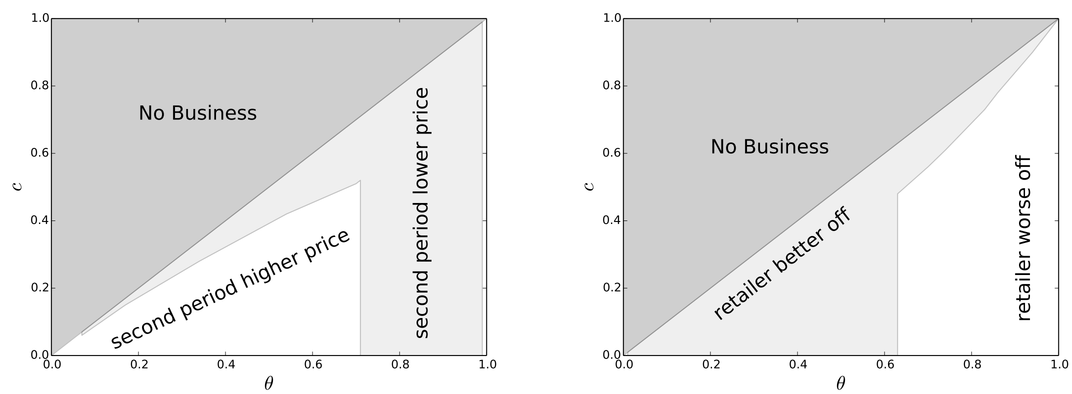
Observation 1. *The retailer encourages strategic waiting when either θ or c are sufficiently high.*

Figure 6a reveals the platform's competitive pressure on the retailer in the second period hurts the retailer's capacity to exercise inter-temporal price segmentation between consumers. However, we still find a wide range of parameters' values where the retailer encourages strategic waiting, thereby making the retailer better off. In particular, with a high θ, consumers are less likely to experience a mismatch and trade their goods through the platform, implying a limited competitive threat from the platform. Hence, with a high θ, the retailer still prefers to practice inter-temporal price segmentation. When c is high, a similar argument emerges:

the selling price of the good is high, limiting the market for used goods in the second period, again, allowing the retailer to benefit from inter-temporal price segmentation.

Observation 2. *The emergence of a P2P platform, benefits the retailer when either θ is sufficiently low or c is sufficiently high.*

This observation is demonstrated in Figure 6b. Importantly, the range of parameters values under which the retailer is better off due to a P2P platforms seems to be extended to include a wider range of θ values, as compared to the case where consumers do not exhibit strategic waiting. When c is sufficiently high, the same intuition applies as when consumers do not exhibit strategic waiting. With a low θ the retailer also benefits from the platform as it provides consumers with a channel to trade their mismatched goods with the added advantage of inter-temporal pricing segmentation. Namely, the platform allows the retailer to improve the segmentation of the consumers who arrive in the first period as now the consumers have the opportunity to trade goods in the latter period, and this benefit outweighs the competition imposed by the platform goods since the overall amount of goods traded is relatively low.



(a) Pricing commitment facing a P2P

(b) Effect of P2P on the retailer

Figure 6: The effect of consumers' strategic waiting on the retailer, $\gamma = 0.5$, $\delta = 0.5$

7 Conclusion

The development of P2P platforms has changed traditional retailing. Our paper fills a gap in the literature by incorporating a P2P platform as a decision maker, setting its own profit maximizing transaction fee, and while accounting for consumers' valuation uncertainty about goods. We show in this paper that when consumers' valuation uncertainty is present, a P2P platform can mitigate some of the risk by allowing consumers to trade their used goods, however, at the same time, used goods on the platform also compete with new goods from supply chain partners. Specifically, our model shows that when a product's unit cost is low, a P2P platform sets the transaction fee equal to the market-clearing price. Thus, the platform extracts all surplus from consumers who sells their unwanted goods, while inducing the retailer to increase prices of the goods in the first period. Consequently, a P2P platform makes both consumers and supply chain partners worse off relative to when it is not present by setting the transaction fee equal to the market-clearing price. However, as a product's unit cost increases, the platform no longer sets the transaction fee to equal the market-clearing price, as a result the presence of the platform initially makes consumers better off, and as the unit cost increases further, makes both consumers and supply chain partners better off. The intuition is simple. From consumers' perspective, a P2P platform brings the following trade-off: increased price of new products vs. allowing consumer to sell unwanted goods while consumers enjoy buying at a lower price in the second period. From supply chain perspective the trade-off is between higher prices and possibly increased demand in the first period demand vs eroded second period profits. Only when the unit cost is sufficiently high, the benefit compensates the potential harm of facing a platform, making the supply chain partners better off. In terms of consumer surplus and social welfare, a P2P platform can be detrimental when both the probability of consumers having full private valuation and the product's unit cost are sufficiently low. Additionally, a frictionless P2P platform generally makes the supply chain partners better off and always makes consumers better off compared to the benchmark scenario, when it is not present, and it makes all agents never worse off compared to the profit-maximizing platform scenario.

The results in this paper are based on a monopolistic model. In practice, there could be multiple suppliers and retailers offering identical or similar products and various P2P platforms can co-exist. Accordingly, fiercer competition may arise along more complicated interactions among market agents. A possible extension of the present model is to consider two or more supply chain channels and platforms. For instance, considering the competition between Microsoft and Sony in the video-game industry, or Staples and Office Depot, it could be better presented by a duopolistic or oligopolistic setting. However, we believe our core insights still apply in such setting, and our work is a necessary fist step in analyzing these, more complex, settings.

One may also consider the supply chain partners applying platform-mitigation strategies in order to improve their profit, such as buying out the platform, offering refunds, limiting the information released about products in order to increase consumer valuation uncertainty (similar to Chu and Zhang, 2011), revenue-sharing with the platform and so on. If any strategy is effective in increasing supply chain partners' profitability is an open question and needs to be explored further. For example, as shown in this paper, the platform can mitigate some of consumers' valuation uncertainty, but also impose competition. If the supply chain partners buy out the platform and operate it by themselves possibly at no charge to users, it might not be subgame: in the second period the incentive is to shut down the platform to eliminate competition; however, they also might go the other way by stimulating the first period demand to earn more transaction fees. Either way, it may help them eliminate the threat of a P2P platform and boost their profits. Another modeling opportunity emerges from trading sites that pay consumers upfront for their unwanted goods. In such a channel the platform owns the goods sold and is responsible for reselling them in the second period. This may result with a secondary market that does not clear the market.

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Appendices

Appendix A Proofs

Proof of Lemma 1. We first state the lemma formally.

$$t^{PP*} = \begin{cases} \frac{\delta(\delta(1-\theta)^2(33\delta\theta+7\delta c-84\theta-4c)-8\delta\theta(1-\theta)(1-c)-32\theta(\theta-c)-64(\theta+c))}{8(\delta(1-\theta)^2(5\delta-12)-16)} & \text{if } c \leq c_1; \\ \frac{\delta(1-\theta)(3\theta+5c)+8(\theta-c)}{16(1-\theta)} & \text{if } c_1 < c \leq c_2; \\ \frac{\delta^2(1-\theta)^2(15\theta-7c)+8(\theta-c)(7\delta\theta-4\delta\theta^2-3\delta-4)}{8\delta(1-\theta)^2} & \text{if } c > c_2. \end{cases}$$

The corresponding supply chain's decisions are given by:

$$\{w_{1n}^{PS*}, w_{2n}^{PS*}\} = \begin{cases} \{\frac{128(\theta+c)+(1-\theta)A}{32(8-\delta(1-\theta)^2(3\delta-8))}, \frac{\theta(1-\delta(1-\theta)q_{1n}^{PR*})+c}{2}\} & \text{if } c \leq c_2; \\ \{\frac{\delta(1-\theta)((1-\theta)(5\delta\theta+8c-4\theta-\delta c-4t^{PP*})+4\theta^2)-8(\theta-c)}{4\delta(1-\theta)}, \theta(1-\delta(1-\theta)q_{1n}^{PR*})\} & \text{if } c > c_2, \end{cases}$$

where $A = \delta(1-\theta)((1-\theta)(8(7\delta-16)t^{PP*} - 11\delta^2 c - 56\delta\theta^2 - 45\delta^2\theta) + 128(\theta+c) - 8\delta(7\theta^2 + 3c + 2\theta c)) + 16(\delta c + 7\delta\theta - 8t^{PP*})$.

$$\{q_{1n}^{PR*}, q_{2n}^{PR*}\} = \begin{cases} \{\frac{8(w_{1n}^{PS*}+(1-\theta)t^{PP*}-\theta)-\delta(1-\theta)(5\theta+3c)}{\theta(\delta(1-\theta)^2(5\delta-16)-16)}, \frac{\theta(1-\delta(1-\theta)q_{1n}^{PR*})-w_{2n}^{PS*}}{2\theta}\} & \text{if } c \leq c_2; \\ \{\frac{\theta-c}{\delta\theta(1-\theta)}, 0\} & \text{if } c > c_2. \end{cases}$$

The proof of Lemma 1 follows from backwards induction on the equilibrium decisions of the supply chain partners and the platform. We characterize the subgame perfect Nash equilibria for each game in our setting. Due to non-negativity constraints on production quantities, the transaction fee being at most the market-clearing price, and the wholesale price is at most the retail price, we have a large set of cases to consider in the analysis. The complete analysis may be found in the on-line supplement of this manuscript. □

Proof of Theorem 1. Denote Δ_{sc} as the difference of the entire supply chain's profits between the benchmark scenario and the profit-maximizing platform scenario, that is, $\Delta_{sc} = \Pi^{BS*} +$

$\Pi^{BR*} - \Pi^{PS*} - \Pi^{PR*}$. We then consider Δ_{sc} in each of the segments defined earlier in Lemma 1.

When $c \leq c_1$, Δ_{sc} is convex in c since $\frac{d\Delta_{sc}^2}{d^2c} \geq 0$. Also, when $d\Delta_{sc}/dc = 0$, minimum $\Delta_{sc} = 0$ is achieved at $c = \theta \geq c_1$. So Δ_{sc} is convexly decreasing when $c \leq c_1$ and $\Delta_{sc} |_{c=c_1} > 0$ for all $0 \leq \theta \leq 1$.

When $c_1 < c \leq c_2$, Δ_{sc} is convex in c since $\frac{d\Delta_{sc}^2}{d^2c} \geq 0$. Also when $\Delta_{sc} = 0$, $c = \tilde{c}_{sc}$ or $\tilde{c}'_{sc}$, where $c_1 < \tilde{c}_{sc} \leq c_2$ and $\tilde{c}'_{sc} \geq \theta$. Therefore, $\tilde{c}'_{sc}$ is infeasible because of violation of individual rationality, $c < \theta$. Hence, if $c \leq \tilde{c}_{sc}$, $\Delta_{sc} \geq 0$; otherwise, $\Delta_{sc} < 0$.

When $c > c_2$, Δ_{sc} is concave in c since $\frac{d\Delta_{sc}^2}{d^2c} \leq 0$. Also, when $d\Delta_{sc}/dc = 0$, maximum $\Delta_{sc} = 0$ is achieved at $c = \theta \geq c_2$. So Δ_{sc} is concavely increasing when $c > c_2$ and $\Delta_{sc} |_{c=c_2} < 0$ for any $0 \leq \theta \leq 1$. □

Proof of Theorem 2. Denote Δ_{cs} as the difference of consumer surplus between the benchmark scenario and the profit-maximizing platform scenario, that is, $\Delta_{cs} = CS^B - CS^P$, where $CS^B = \int_{\bar{v}_1^B}^1 U_{1n}^B \, dv + \int_{\bar{v}_2^B}^1 U_{2n}^B \, dv$, $CS^P = \int_{\bar{v}_1^P}^1 U_{1n}^P \, dv + \int_{\bar{v}_p^P}^{\bar{v}_{2p}^P} U_{2n}^P \, dv + \int_{\bar{v}_{2p}^P}^1 U_{2p}^P \, dv$. We then consider Δ_{cs} in each of the segments defined earlier in Lemma 1.

When $c \leq c_1$, solving $\frac{d\Delta_{cs}^2}{d^2c} = 0$ reveals a threshold value, $\tilde{\theta}$, such that when $\theta \geq \tilde{\theta}$, Δ_{cs} is concave in c since $\frac{d\Delta_{cs}^2}{d^2c} \leq 0$. Also, when $d\Delta_{cs}/dc = 0$, maximum Δ_{cs} is achieved at $c = \theta \geq c_1$. So Δ_{cs} is concavely increasing when $c < c_1$, $\theta \geq \tilde{\theta}$, and $\Delta_{cs} |_{c=c_1} < 0$ for all $0 \leq \theta \leq \tilde{\theta}$.

When $c_1 < c \leq c_2$, Δ_{cs} is convex in c since $\frac{d\Delta_{cs}^2}{d^2c} \geq 0$. Also when $d\Delta_{cs}/dc = 0$, the global minimum $\Delta_{cs} < 0$ is achieved at $c' \in [c_1, c_2]$. Solving $\Delta_{cs} = 0$ reveals two threshold values, $\tilde{c}_{cs}$ and $\tilde{c}'_{cs}$, where $\tilde{c}_{cs} \leq c_1$ if $\theta \geq \tilde{\theta}$, $\tilde{c}_{cs} > c_1$ otherwise; and $\tilde{c}'_{cs} \geq c_2$.

When $c > c_2$, Δ_{cs} is concave in c since $\frac{d\Delta_{cs}^2}{d^2c} \leq 0$. Also, when $d\Delta/dw = 0$, maximum $\Delta_{cs} = 0$ is achieved at $c = \theta \geq c_2$. So Δ_{cs} is concavely increasing when $c > c_2$ and $\Delta_{cs} |_{c=\theta} = 0$ for any $0 \leq \theta \leq 1$. □

Proof of Theorem 3. Denote Δ_{sw} as the difference of social welfare between the benchmark scenario and the profit-maximizing platform scenario, that is, $\Delta_{sw} = \Pi^{BS*} + \Pi^{BR*} + CS^B -$

$(\Pi^{PS*} + \Pi^{PR*} + CS^P + \Pi^{PP*})$. We then consider Δ_{sw} in each of the segments defined earlier in Lemma 1.

When $c \leq c_1$, Δ_{sw} is convex in c since $\frac{d\Delta_{sw}^2}{d^2c} \geq 0$. Solving $\Delta_{sw} \mid_{c=0}= 0$ for θ reveals a threshold value, $\tilde{\theta}'$, such that $\Delta_{sw} \mid_{c=0} \leq 0$ if $\theta \geq \tilde{\theta}'$, $\Delta_{sw} \mid_{c=0} > 0$ otherwise. Solving $\Delta_{sw} \mid_{c=c_1}= 0$ for θ reveals another threshold value, $\tilde{\theta}''$, such that $\Delta_{sw} \mid_{c=c_1} \leq 0$ if $\theta \geq \tilde{\theta}''$, $\Delta_{sw} \mid_{c=c_1} > 0$ otherwise, where $\tilde{\theta}' \geq \tilde{\theta}''$. Therefore, when $\theta < \tilde{\theta}'$, there exists a threshold value of c, $\tilde{c}_{sw} \in [0, c_1]$, making $\Delta_{sw} = 0$.

When $c_1 < c \leq c_2$, Δ_{sw} is convex in c since $\frac{d\Delta_{sw}^2}{d^2c} \geq 0$. Solving $\Delta_{sw} \mid_{c=c_1}= 0$ for θ reveals a threshold value, $\tilde{\theta}''$, such that $\Delta_{sw} \mid_{c=c_1} \leq 0$ if $\theta \geq \tilde{\theta}''$, $\Delta_{sw} \mid_{c=c_1} > 0$ otherwise, where $\tilde{\theta}'' \leq \tilde{\theta}'$. Also $\Delta_{sw} \mid_{c=c_2} \leq 0$ for any $0 \leq \theta \leq 1$, $0 \leq \delta \leq 1$. Therefore, when $\theta < \tilde{\theta}''$, there exists a threshold value of c, $\tilde{c}_{sw} \in (c_1, c_2]$, making $\Delta_{sw} = 0$.

When $c > c_2$, Δ_{sw} is convex in c since $\frac{d\Delta_{sw}^2}{d^2c} \geq 0$. $\Delta_{sw} \mid_{c=c_2} \leq 0$ for any $0 \leq \theta \leq 1$, $0 \leq \delta \leq 1$. Also, $\Delta_{sw} \mid_{c=\theta}= 0$ for any $0 \leq \theta \leq 1$, $0 \leq \delta \leq 1$. □

Proof of Theorem 4. The proof follows the same steps as in the proofs of Theorems 2 and 3. The complete proof is provided in the Online Supplement. □