Targeted Couponing in Online Auctions

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Abstract

Sellers in traditional markets with posted prices employ mass-media or targeted couponing as a price discrimination mechanism or as a competitive strategy. Advent of the Internet has led to explosive growth of online auctions and given that auctions allocate the good to the bidder with highest valuation, there appears to be no role for coupons in online auctions. But surprisingly coupons are often provided by sellers such as Google Adwords and auction platforms like eBay. We develop a stylized model with heterogeneous buyers and a single seller who may issue targeted coupons which are encashed by the winning bidder. We study two settings: one in which the coupons do not impact and another in which they do impact the entry probability of buyers. We find that the seller is never worse off with targeted couponing strategy when two or more coupon-bearing buyers enter the auction. Surprisingly, we find that targeting only the low-type buyer is optimal under some conditions but it is never optimal to target only the medium-type buyer. When the high-type buyer is more likely to enter, then it is optimal to target low- and medium-type buyers simultaneously. When coupon impacts buyers' entry probability, then the seller issues two types of coupons – minimal coupon and maximal coupon, targets all buyers, earns higher profits and the region in which low- and medium-type buyers are simultaneously targeted with maximal coupons becomes larger.

Keywords: Online auction, couponing, second-price auction, targeted couponing, price discrimination

1. Introduction

The coupon industry in the US is a multibillion dollar industry with more than 332 billion coupons valued at over $485 billion being distributed in 2010 and shoppers' savings estimated at more than $3.7 billion dollars (NCH, 2011). With the changing trends in technology and consumer shopping habits, digital coupons (online and mobile coupons) grew more than 100 percent, outpacing printed coupons by 10 to 1 in 2010 (Kruger, 2010). Google Adwords runs billions of auctions each month with 4.9 trillion display ads in 2010. The number of searches for any particular keyword is stochastic and the product (keyword ad) itself is highly perishable. Google issues targeted coupons worth $75 to $100 to businesses that participate in adwords auctions[1].

With the advent of the Internet, e-commerce has witnessed explosive growth, much of which comes from online auctions (Yao & Mela, 2008). In consumer-oriented markets, online auctions provide a dynamic pricing mechanism wherein consumers can hope to "win" the auction at a lower price than posted price stores (Bapna et al., 2003), and it is estimated that auctions on eBay alone have generated more than $7 billion in total consumer surplus (Bapna et al., 2008). Auctions in general and online auctions in particular, due to the absence of "spatial, temporal, and geographic constraint" (Bapna et al., 2003), provide a mechanism to the seller of a single good, to allocate it to the prospective bidder with highest valuation. To that extent "the seller's problem in devising an optimal auction is virtually identical to the monopolist's problem in third-degree price discrimination" (Bulow & Roberts, 1989), and therefore, the auction itself is a price discrimination mechanism. Hence, in the context of online auctions, one would expect no role for coupons because the seller is already achieving price discrimination through auction.

Surprisingly, we find that coupons are widely distributed by the sellers to prospective bidders in online auctions. *Google*, which derived 97 percent of its revenues from advertising in 2011, promotes Adwords auctions using targeted coupons. The *Google Online Marketing Challenge* is a student-oriented

[1] http://support.google.com/adwords/bin/answer.py?hl=en&answer=1703648

program that gives a $250 coupon to teams for creating online advertising campaigns for small or medium-sized businesses and not-for-profits, which have not used Adwords for six months[2]. *eBay* provides a third-party hosted couponing solution through MyStoreRewards "to offer cash back and coupons to buyers."[3] *Aucser.com* allows online auction sellers to create a working coupon on the fly. The coupon can be one of four types: (i) dollar value, (ii) a percentage of the winning bid, (iii) set to expire on a certain date, or (iv) after certain number of uses. *Aucser.com* also allows sellers to target the coupons and track redemption. Similarly, *SkyAuction.com* gives coupons to bidders and the winning bidder receives a $50 discount for auctions in certain time periods. *Rivercityfurnitureauction.com* provides coupons that first-time buyers can use to get a 5 percent discount from the winning bid price.

It is puzzling why sellers provide coupons in online auctions that are designed to sell a single item to the highest valuation buyer among those who participate in the auction. Why does a seller offer coupons to prospective bidders and in turn get less revenue if the winning bidder has a coupon? How does couponing impact the bidding strategies in a single-item auction? What targeting strategies should a seller adopt? When is couponing in auctions profitable for the seller? Are the only roles of couponing in auctions to "drive repeat sales, build buyer loyalty, and expand their buyer base" as proposed by *eBay*?[4] This paper develops analytical models to examine these questions.

The concept of targeted offers and couponing has been widely studied in Information Systems and Marketing. This paper extends the concept of targeted couponing to auction markets which are favored under many conditions including the following: (i) seller faces demand uncertainty (Wang, 1993); (ii) goods are highly perishable (Milgrom, 1989); (iii) transactions require trust and reputation mechanisms often supplied by auction platforms (Hu et al., 2004; Pavlou & Gefen, 2004); and (iv) simultaneous auction and posted prices for price discrimination (Etzion et al., 2006). Targeted couponing requires that the seller be able to broadly identify different types of buyers who are heterogeneous in valuations. If the seller can identify the type of each buyer, then should she make targeted offers to sell

[2] http://www.google.com/onlinechallenge/
[3] http://workshops.ebay.com/thread.jspa?threadID=130000733
[4] http://workshops.ebay.com/thread.jspa?threadID=130000733

directly or still use the auction mechanism? First, knowledge of buyer type may not communicate full information about the buyer's valuation, making it difficult to offer a personalized price. Second, direct offers often are not credible because they are viewed as *spam* or *phishing* (Moustakas et al., 2006; Morimoto & Chang, 2006). The auction platform provides the necessary feedback and reputation mechanisms to allow buyers to trust the seller (Chen et al., 2009). Third, when the good is highly perishable, then the seller may not have enough time to make sequential offers to each of the buyers. Thus, we see that perishable items such as cut flowers, fish, and Google Adwords slots are auctioned. Because of these reasons, in our model, the seller who has information about buyer types adopts auction mechanisms rather than posted prices.

Researchers have studied mass media couponing as a price discrimination mechanism (Narsimhan, 1984); targeted couponing as a competitive strategy to poach rival firms' loyal customers (Shaffer & Zhang, 1995; Bester & Petrakis, 1996; Fudenberg & Tirole, 2000); and couponing to convert buyers into repeat loyal consumers (Fong & Liu, 2012). This literature does not provide a framework to answer our questions because a monopoly seller who is auctioning a single item on an online auction platform does not aim to sell multiple items at different prices to consumers with heterogeneous valuations (second-degree price discrimination), does not gain by attracting buyers from competing rival sellers, or does not induce repeat purchases. Therefore, extant literature does not appear to provide any guidance to sellers or online auction platforms like *eBay* in formulating and implementing appropriate targeting strategies. To the best of our knowledge, this is the first research study to analyze the role of targeted coupons in auctions and recommend optimal targeting strategies.

Before we study the role of coupons in auctions, we need to examine some of the key features that differentiate auction markets from traditional posted-price markets. In traditional markets, sellers compete for buyers, but in single-item auctions, buyers compete with buyers because only one buyer gets the item. While the price at which the product is sold is determined by the seller in traditional markets, in auctions it is determined by the highest and second highest valuation buyers. To that extent, the seller does not control the price at which the winner acquires the good in an auction, beyond setting the reserve

price. The price at which a good is sold is deterministic in traditional markets; it is stochastic in auction markets. When couponing is employed in traditional markets, a customer with coupon pays less than a customer without one and these prices are fixed. On the other hand in an auction setting, the payout of a winning bidder depends not only on whether he has a coupon, but also on whether other bidders have coupons. In traditional markets, couponing leads to market expansion and increased revenue because customers with low willingness to pay who are unlikely to buy the product at the regular price are incentivized to buy. In single-good auctions couponing does not increase the market size in terms of numbers of buyers because only one bidder gets the item, but it may lead to decrease in revenue if the winning bidder has a coupon. Given these key differences in the characteristics of the role of coupons in traditional markets and in auction markets, the extant literature on couponing does not provide a framework to study the role of coupons in an auction setting, which presents an opportunity to develop such a framework.

While most of the early research in auctions in economics has focused on theoretical investigation, extensive IS literature has focused on empirical investigations because of relative ease of collecting bidding and outcome data in online auctions. Empirical researchers in IS have studied differences between online and offline auctions (Overby & Jap, 2009), role of bidders and bidder characteristics (Ariely & Simonson, 2003; Bapna et al 2004), interdependence between different auctions (Bapna et al., 2009), and the impact of auction design on outcome and bidding behavior (Bapna et al., 2003; Gallien & Gupta, 2007; Goes et al., 2010). The role of seller search for a high-valuation buyer and buyer search for an appropriate product and low price are key to growth of online auctions, and the search behavior impacts market outcome and efficiency (Kuruzovich et al., 2010). There has been some notable exceptions where IS researchers have undertaken analytical investigations of online auctions, especially design of keyword auctions (Liu et al., 2010), design of online auctions (Liu & Chen 2006; Kannan, 2012; Kannan, 2010), and analysis of simultaneous use of online auctions and posted prices (Etzion et al., 2006). These studies informed our research, although we restrict our attention to the role of targeted coupons in single-item online auctions.

We model the online auction as a second-bid auction consistent with *eBay* (Zeithammer, 2006) and *Google Adwords* auctions. Our auction setting is similar to the Web-based auctions of Van Heck and Vervest (1998) in which one seller auctions a single item to many prospective buyers; much of the research in auctions has focused on this setting (see Klemperer [1999], for extensive literature survey of auction theory).

In the context of auctions, buyers' valuations may be *private-value* or *common-value.* In the case of private-value auctions, each buyer knows his valuation for the item, which is private and independent of others' valuations. In the case of common-value auctions, the true value of the item is the same for everyone, but the buyers do not know the true value; instead, they have different private information about the true value, which is updated by others' bidding behavior. As we consider online auctions such as *eBay* in which nondurable goods are often auctioned, this paper discusses private-value auctions[5]. The private-value setting has been supported by extensive literature empirically studying online auctions (Hou & Rego, 2007; Ockenfels & Roth, 2006; Roth & Ockenfels, 2002; Zeithammer, 2006).

Substantial literature focuses on couponing as a price discrimination mechanism to expand the market by providing discounted prices to those who may have lower willingness to pay for the product. Such price discrimination through couponing is profitable as long as the coupon-using consumer segment is more price sensitive than the segment that does not use coupons (Narasimhan, 1984; Levedahl, 1984; Sweeney, 1984; Varian, 1989; Shaffer & Zhang, 1995).[6] While targeting direct-mail coupons to the most responsive buyer segment has been found to be the most profitable strategy (Bawa & Shoemaker, 1989), customized coupon campaigns' effectiveness depends on sales lift from the nonredeemers, too (Venkatesan & Farris, 2012). With the advent of personalization technologies, it has become rather commonplace for sellers to identify individual consumers and "tailor their promotional prices to consumers on a one-to-one basis" (Shaffer & Zhang, 2002). For example, online content-enabled

[5] Milgrom and Weber (1982) also suggested that in the case of nondurable consumer goods, the satisfaction derived from consuming such goods can be reasonably regarded as a personal matter, where it is plausible that bidder knows the value of the good to himself and knows that others could value the good differently.

[6] For the role of coupons as a price discrimination mechanism in a distribution channel, see Gerstner et al (1994).

workflow solutions provider *LexisNexis* sells to different users at different prices (Shapiro & Varian, 1999). Online commercial transactions enable sellers to collect and analyze data at the individual buyer level to decipher each buyer's willingness to pay for a certain good and adopt personalized pricing strategies (Choudhary et al, 2005; Chen & Iyer, 2002). Following the extant literature, we model targeted couponing in online auctions in which the seller has information about the prospective buyers such that she has the ability to target coupons of differential value to different types of buyers. Targeted couponing is similar to third-degree price discrimination in which different segments of buyers have a different willingness to pay and the seller can identify these segments and issue coupons that can be used only by the targeted segment. For example, *Google Adwords* often targets small businesses that are likely to have lower valuation and their coupons require that the advertiser's account meet the stated criteria[7].

In this research, we develop an analytical model to study the role of targeted coupons in auctions. We show that unlike posted price markets, the role of coupons in auctions is twofold. Since a bidder who has a coupon will be willing to bid higher than his true valuation, one role of coupon in auction is to enhance value extraction from the winner of the auction. Note that the value extraction role of coupons is moderated by the potential downside of providing a coupon, that is, if the highest type buyer has the coupon. Therefore, the optimal couponing strategy is based on the tradeoff between the expected gain and expected loss from the coupon.

We find that the seller is never worse off with targeted couponing strategy when two or more coupon-bearing buyers enter the auction. On the other hand if only one coupon-bearing buyer enters the auction then the seller may be worse off. Surprisingly, we find that targeting only the low-type buyer is optimal under some conditions, but it is never optimal to target only the medium-type buyer. Also, it is optimal to target the high-type buyer only when the coupon impacts entry probability. When coupons do not impact entry probability and the high-type buyer is more likely to enter, then targeting low and medium-type buyers simultaneously is optimal. The optimal coupon amount depends on the difference in valuations of different types of buyers. When the coupon impacts buyers' entry probability, then the seller

[7] http://support.google.com/adwords/bin/answer.py?hl=en&answer=1703648

issues two types of coupons—minimal coupon and maximal coupon—and targets all buyers. The minimal coupon is designed to increase buyers' entry only, whereas the maximal coupon is designed to increase entry as well as value extraction. When coupon impacts entry probability, the seller earns higher profits and the region in which low- and medium-type buyers are simultaneously targeted with maximal coupons becomes larger. Counter to intuition, we find that under some conditions, targeted couponing in auctions may lead to "inefficiency" in the context of Dasgupta and Maskin (2000), as the auction may fail to allocate the good to the buyer with highest valuation, but achieves "efficiency" in the context of Myerson (1981), as the expected revenue is maximized.[8]

The remainder of this paper is organized as follows: In §2, we present the model, and in §3, we examine the optimality of different coupon targeting strategies of the seller when the coupon does not impact the entry probability of buyers. In §4, we examine the seller's optimal couponing strategy when the coupon increases the entry probability of buyers. We discuss our results and identify suitable theoretical and managerial implications in §5,

2. Model

We consider an auction setting in which a seller has a single good to sell. Without loss of generality, we assume that the auction is a second-price private-value auction. Therefore, each buyer knows his[9] valuation for the product and is unaffected by the valuations of other buyers. The seller has no intrinsic value for the good, and therefore, her reservation price is zero. Following the literature, we assume that the cost of the good to the seller is sunk, and therefore, the seller's objective is to maximize revenue from the auction (Myerson, 1981).

We develop a stylized model with buyers that have uncertain valuations. For mathematical tractability, we model this uncertainty by assuming that the valuation is either low or high. We model three distinct types of prospective buyers: a high-type buyer, medium-type buyer, and low-type buyer

[8] The literature has viewed efficiency in auctions in two different ways: Dasgupta and Maskin (2000) define an efficient auction as an "auction that puts goods into the hands of the buyers who value them the most." The other view of efficiency is that the efficient auction maximizes revenue (Myerson, 1981; Milgrom & Weber, 1982).
[9] The seller is she and buyer is he throughout the paper.

with uncertain valuations. We normalize the low valuation to zero so that the valuation of the high-type buyer is v_H with probability α_H and zero with probability $1-\alpha_H$. Similarly, the valuations of the medium- and low-type buyers is v_M and v_L with probability α_M and α_L respectively and zero otherwise. Without loss of generality, we order the valuations as $v_H > v_M > v_L$. Prospective buyers' valuation uncertainty implies that they are heterogeneous in their likelihood of participation in the auction. We assume that they participate only when they have non-zero valuation for the good. Therefore, the probability of participation of high-type buyer is α_H, that of medium-type buyer is α_M and of low-type buyer is α_L. Our formulation of uncertain entry by buyers is consistent with Levin and Smith (1994) and Etzion et al. (2006). Since our setting is of second-price, private-value auction, the optimal bidding strategy for a buyer of type i ($i \in \{L, M, H\}$) is to bid his true valuation v_i (Vickrey, 1961; McAfee & McMillan, 1987), and the on-line auction ends with the highest bidder's winning the auction and paying the second highest bid amount. We do not model the dynamics of the auction such as the sequence of bids and assume that the valuations are exogenous and each bidder knows only his valuation.

The seller can auction the good with or without providing coupons. When she decides to adopt couponing strategy, she may adopt (i) uniform couponing, in which all three buyers receive coupons of same value, or (ii) targeted couponing, in which the seller can target the coupon to specific buyer(s) and the value of coupon can be different for different types of buyers. A targeted couponing strategy involves the seller targeting a coupon of value c_i to buyer of type i. The coupon has no value if the buyer does not win the auction. If the buyer with coupon wins the auction, then he pays the second highest bid amount less the value of the coupon. Note that coupon amount c_i may be greater than the second highest bid amount, resulting in net negative revenue to the seller.

The summary of notations is in Appendix A. We make the following additional assumptions.

1. The seller and all buyers are risk neutral; there is no collusive bidding by the buyers and no shill bidding. Note that since our setting is one of private-value, shill bidding will have no impact as

buyer valuations are independent and are not influenced by others' bids. Shill bidding may play a role in a common value auctions (Chakraborty & Kosmopoulou, 2004).

2. When two buyers bid the same amount, then the buyer with higher valuation wins the auction and the buyer who wins the auction always claims the product.
3. The seller's cost of holding the auction and buyers' cost of participation in the auction is normalized to zero. Sellers can identify buyer types, their entry probability and estimate the difference in their valuations. The cost of targeting coupons and the buyer's cost of using a coupon are normalized to zero.
4. Coupons are buyer-type specific and cannot be traded.

In the following section, we analyze the impact of couponing on seller's revenue under different coupon targeting strategies. In Section 4, we consider the case where coupons impact the entry probability of buyers. In Subsection 4.1 we discuss the impact of our assumptions on the results.

3. No impact of coupon on probability of participation

As discussed in the Introduction, targeted couponing implies that the seller has the ability to provide a coupon of a particular value to any one type or more than one type of buyers. In this section, we consider the case where the seller's couponing strategy has no impact on the buyers' probability of participating in the auction. Couponing can be beneficial to the seller because targeted couponing may make a coupon-bearing buyer raise the bid amount, which may generate higher revenue from the winning buyer in a second-price auction. If the auction-winner is a buyer without a coupon, then the seller's profit increases due to couponing. On the other hand, couponing may hurt the seller if only one buyer enters the auction because the winning buyer redeems the coupon without any increase in the bid value. Couponing also may hurt the seller if a buyer with coupon outbids a higher valuation buyer because the revenue to the seller, less the coupon value, is lower. Therefore, it's clear that the optimality of a couponing strategy is critically dependent on the balance of tradeoff between the potential gain and potential loss to the seller from targeted couponing.

The seller has several strategies for targeted couponing: (i) she may target all buyer-types simultaneously; (ii) she may target only one buyer-type; or (iii) she may target two buyer-types simultaneously. First, we consider the benchmark case in which the seller does not issue any coupons. Next, Section 3.2 considers the cases in which the seller issues a coupon to the high-type buyer and may issue coupons to others as well. In Section 3.3, we examine the case in which the seller targets only the medium-type buyer. Section 3.4 studies the case in which the seller targets only the low-type buyer, and Section 3.5 examines the case in which the seller simultaneously targets the low- and medium-type buyers. Section 3.6 evaluates the overall optimal couponing strategy.

3.1 Benchmark Case—No Coupons

We start with a benchmark case to compute the seller's profit when no coupons are issued. We will compare the profit from various couponing strategies to this benchmark to determine whether the couponing strategies are profit increasing. When no coupons are issued, the profit of the seller depends on the entry of different types of buyers in the auction. The probability of entry of all three buyers is $\Pr(\text{L,M,H}) = \alpha_L \alpha_M \alpha_H$ and if all three enter, then the seller's profit is v_M. Similarly, the probability of entry of two buyers (*i*-type, *j*-type with $v_j > v_i$) is $\Pr(i,j) = \alpha_i \alpha_j (1-\alpha_k)$ where *i*, *j*, and *k* represent three distinct types of buyers. The resulting profit is v_i. The probability that only one buyer of *i*-type will enter the auction is $\Pr(i) = \alpha_i (1-\alpha_j)(1-\alpha_k)$ and the resulting profit is zero. The probability that none of the buyers will enter the auction is $\Pr(\phi) = (1-\alpha_i)(1-\alpha_j)(1-\alpha_k)$ and the resulting profit is zero. The expected profit of the seller from this auction is reported in Lemma 1 below.

LEMMA 1: *When a seller does not provide any coupon, the expected profit is* $\pi_N = v_L \alpha_L \left(\alpha_M (1-\alpha_H) + \alpha_H (1-\alpha_M) \right) + v_M \alpha_M \alpha_H$.

First, note that the expected profit is independent of the high-valuation (v_H) of the high-type buyer. The intuition is easy to see. In a second-price auction, the highest revenue the seller can get is the high-valuation (v_M) of the second highest bidder, that is, the medium-type buyer. Second, note that the

seller benefits from increase in entry probability of all three types of buyers because the expected profit conditional on all three buyers entering the auction is greater than the expected profit conditional on only two buyers entering the auction. Similarly, the expected profit conditional on two buyers entering the auction is greater than the expected profit conditional on only one buyer entering the auction. Therefore, an increase in entry probability is always beneficial to the seller, which can be verified by examining the partial derivative of expected profit in Lemma 1 with respect to each of the entry probabilities that are all strictly positive. Further, it is easy to see from Lemma 1 that the impact on expected profit of increase in entry probability of low-type is independent of v_H and v_M. However, the impact on expected profit of increase in entry probability of medium- and high-types depends on valuation of the low- and medium-types. Next we examine couponing strategy in which the high-type buyer always receives a coupon.

3.2 Targeted couponing to high-type buyer

In this subsection, we examine four cases: (i) the seller targets high-, medium-, and low-type buyers; (ii) the seller targets high- and medium-type buyers; (iii) the seller targets high- and low-type buyers; and (iv) the seller targets only high-type buyers. By examining these four cases, we show that it is never profit increasing to target the high-type buyer. The sequence of moves is as follows: First the seller determines her couponing strategy, which consists of determining the value and target of each coupon. Next, buyers enter the auction (with or without a coupon) with their respective entry probabilities. Finally, buyers place their bids and the winning bid is finalized.

First, we analyze the case in which the seller targets a coupon of value c_A at all three buyer-types. The profit of the seller depends on the entry of different types of buyers and these entry probabilities are the same as those reported in Section 3.1. If all three enter, then the high-type buyer bids $v_H + c_A$, the medium-type buyer bids $v_M + c_A$, and the low-type buyer bids $v_L + c_A$. The high-type buyer wins and pays a price of $v_M + c_A$ but redeems his coupon so that the seller's net profit is v_M. Similarly, when two buyers (*i*-type, *j*-type with $v_j > v_i$) enter, then *j*-type buyer wins at price $v_i + c_A$ but redeems his coupon so that the resulting net profit is v_i. Similarly, when only one buyer of *i*-type enters the auction,

then he wins at zero price but redeems his coupon so that the resulting net profit is ($-c_A$). When none of the buyers enters the auction, the resulting profit is zero. The expected profit of the seller from the auction with coupons to all is reported in Lemma 2 below.

LEMMA 2: *When a seller provides a coupon of value* c_A *to all, the expected profit is* $\pi_A = v_L\alpha_L\left(\alpha_M\left(1-\alpha_H\right)+\alpha_H\left(1-\alpha_M\right)\right)+v_M\alpha_M\alpha_H - c_A\left(\alpha_H(1-\alpha_L)(1-\alpha_M)+\alpha_M(1-\alpha_L)(1-\alpha_H)+\alpha_L(1-\alpha_M)(1-\alpha_H)\right)$.

In contrast to Lemma 1, in which increasing the probability of entry of any of the buyers leads to an increase in profit, in Lemma 2, increasing the entry probability has two opposite impacts. The positive impact is when two or more buyer types enter the auction: The net effect of their coupons is zero, while increased entry leads to higher profits as in Lemma 1. The potential negative impact is when only one buyer enters the auction because the buyer redeems the face value of the coupon and net profit of the seller is negative. When the coupon amount is sufficiently large and under certain conditions on the entry probabilities, then increasing entry probability leads to decrease in profit as the negative impact outweighs the positive impact. Proposition 1 details the net impact on seller profit of couponing to all buyer types.

PROPOSITION 1: *Giving same value coupons to all prospective buyers is never profit enhancing. When two or more bidders enter the auction, then couponing is profit neutral compared with no coupons.*

When the entry probability of bidders is not influenced by coupons, then giving coupons to all buyers leads to lower expected profit. This occurs because when two or more buyers enter the auction, then the net profit of the seller remains unchanged; but when only one buyer enters the auction (with some positive probability), then the buyer wins at zero price and redeems the coupon leading to decrease in profit. Therefore, the expected profit is always lower when coupons are targeted to all buyers. However, in most real world settings, the seller expects entry of two or more buyers, and Proposition 1 shows that in such settings, giving coupons to all is profit neutral. On the other hand, a targeted strategy may be profit increasing in which the seller provides coupons only to one buyer type or simultaneously provides coupons to two buyer types. Next, we examine the case in which the seller targets coupons to

only high-type buyers or simultaneously targets the coupons to low- and high-type or medium- and high-type buyers.

If the high-type buyer enters the auction, then the seller's couponing strategy must ensure that the high-type buyer wins because he can make the highest payment net of coupon. Therefore, in an auction with couponing, the maximum profit that a seller can aim for is the high-valuation of the high-type buyer (v_H). The proposition below formalizes the result when a coupon is targeted at the high-type buyer.

PROPOSITION 2: *(a) Targeting a coupon to only the high-type buyer is profit decreasing compared with no couponing; (b) targeting a coupon simultaneously to the (i) high- and low-type buyer or to (ii) the high- and medium-type buyer is profit decreasing compared with no coupon to the high-type buyer.*

Proposition 2(a) shows that it is profit decreasing for the seller to target only the high-type buyer with a coupon, and Proposition 2(b) shows that it is profit decreasing for the seller to simultaneously target the low- and high-type buyer or medium- and high-type buyer with coupons. Therefore, the seller should never provide a coupon to the high-type buyer. The economic intuition of this result is easy to see. When only the high-type enters the auction, then he wins with or without a coupon, but net revenue to the seller is lower if the high-type buyer has a coupon. Similarly, when the seller provides a bigger coupon to the high-type than to the low- or medium-type, then when these buyers enter the auction, the value of the bigger coupon is offset by the value of the smaller coupon and the situation is equivalent to only the high-type having received a coupon; again, the net revenue to the seller is lower. When the seller provides a smaller coupon to high-type than to the low- or medium-type, then when these buyers enter the auction, the value of the bigger coupon is offset by the value of the smaller coupon and the situation is equivalent to only the low-or medium-type having received a coupon. The seller would receive the same revenue by giving a coupon only to the low- or medium-type buyer when two coupon-bearing buyers enter. However, the net revenue to the seller is lower when only one of them enters the auction. Hence, the expected profit of the seller decreases when the coupon is simultaneously targeted to low- and high-type buyers or medium- and high-type buyers compared with not giving a coupon to the high-type buyer.

In the next subsection, we examine the strategy in which the seller targets only the medium-type buyer.

3.3 Targeted couponing to medium-type buyer

We showed in Section 3.2 that the seller should not target a coupon to the high-type buyer. We know that in the absence of couponing, the maximum revenue the seller can attain is the high-valuation of the medium-type buyer (v_M). However, when the seller can target the medium-type buyer, then the seller's revenue can be higher than v_M. In this subsection, we examine the seller's profit from targeting only the medium-type buyer.

LEMMA 3: (i) *When a coupon of value* $c_M \le v_H - v_M$ *is given to the medium-type buyer, then the seller's expected profit is:* $\pi_M = v_L\alpha_L\left(\alpha_H\left(1-2\alpha_M\right)+\alpha_M\right)-\alpha_M\left(c_M-\left(2c_M+v_M\right)\alpha_H\right)$.

(ii) When a coupon of value $c_M > v_H - v_M$ *is given to the medium-type buyer, then the seller's expected profit is:* $\pi_M = (v_H\alpha_H - c_M)\alpha_M + v_L\alpha_L(\alpha_H(1-2\alpha_M)+\alpha_M)$ *and it is always profit decreasing.*

It is clear from Lemma 3 that when the seller targets the medium-type buyer, she never provides a coupon of value greater than $(v_H - v_M)$. If the coupon $c_M > v_H - v_M$, then when the medium- and high-type buyers enter the auction, the medium-type buyer wins the auction. This upsets the allocative efficiency of the auction and the net revenue from the medium-type buyer to the seller is no greater than v_M, whereas the high-type buyer would have made a net payment of v_H, if the coupon to the medium-type buyer were $c_M = v_H - v_M$. Proposition 3 states the conditions under which it is profit increasing for the seller to target the medium-type buyer compared with no couponing.

PROPOSITION 3: ***Targeted couponing to medium-type buyer:*** (a) the s*eller considers targeting the medium-type buyer only when the probability of entry of the high-type buyer is more than half* $\left(\alpha_H > \frac{1}{2}\right)$ *and offers coupon of value* $c_M = v_H - v_M$. *The expected profit increase due to targeted couponing to the*

medium-type buyer is $\alpha_M (v_H - v_M)(2\alpha_H - 1)$ *; (b) the seller does not consider targeting the medium-type buyer when* $\alpha_H \leq 1/2$.

When (i) only the medium-type buyer enters or (ii) the low- and medium-types enter, then the coupon value reduces the seller's revenue because the medium-type buyer claims the coupon but the bid price does not increase. When (i) the medium- and high-types enter or (ii) the low-, medium- and high-types enter, then the coupon benefits the seller because the bid price increases by the coupon value but the winner (high-type) has no coupon. There is no impact on profit in all other cases. The net impact on profit depends on the relative probability of the events listed above.

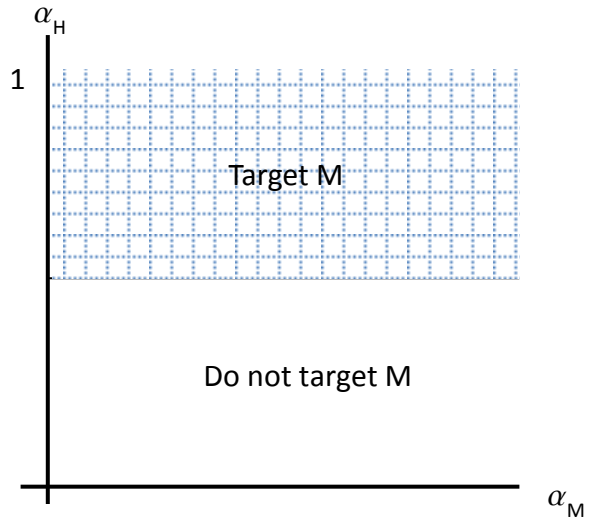

Figure 1: Region for targeting medium-type buyer

Note that the probability of each event that benefits the seller can be paired with an event that causes a loss to the seller in this way: (a) probability {M} paired with probability {M & H}; (b) probability {L & M} paired with probability {L & M & H}. We can see that the difference in the probabilities in each pair is driven entirely by the probability of the high-type buyer's entering the auction. Note also, that the gain from the profit increasing event is exactly the same as the loss from the profit decreasing event for each pair. Therefore, it follows that when the entry probability of the high-type buyer is greater than half then the net expected gain is positive and giving a coupon to the medium-type

buyer is profit increasing, as shown in Figure 1. The seller targets the medium-type buyer with a coupon in such a way that whenever medium-type and high-type buyers enter, the seller can extract the full surplus from the high-type buyer while ensuring that the medium-type buyer does not win the auction, and therefore, does not use the coupon. Hence the optimal value of the coupon is $c_M = v_H - v_M$.

In the next subsection, we examine the case in which the seller targets the low-type buyer. Note that the seller has two options in terms of coupon value: a small-value coupon such that when the low-type and medium-type buyers enter the auction, the medium-type wins, or a big-value coupon such that the coupon is big enough for the low-type buyer to outbid the medium-type buyer if both enter the auction.

3.4 Targeted couponing to low-type buyer

The seller may target the low-type buyer with a small coupon to extract surplus from the medium-type, or she may target a high-value coupon to extract surplus from the high-type buyer. Hence, the seller has three options for targeting a coupon to the low-type buyer: (i) she can give a small-value coupon $c_{LS} \le v_M - v_L$ such that a low-type buyer can never outbid a medium- or high-type buyer; (ii) she can give a big-value coupon $v_M - v_L < c_{LB} \le v_H - v_L$ such that a low-type buyer can outbid a medium-type buyer but not a high-type buyer; or (iii) she can give a very big-value coupon $c_{LB} > v_H - v_L$ such that a low-type buyer can outbid both a medium- and a high-type buyer. Lemma 4 states the profit under each of these couponing strategies.

LEMMA 4: (i) *When coupon of value* $c_{LS} \le v_M - v_L$ *is given to the low-type buyer, then the seller's expected profit is* $\pi_{LS} = v_M \alpha_M \alpha_H + \alpha_L \left(\alpha_M \left(2c_{LS} + v_L \right) + \alpha_H \left(2c_{LS} + v_L - \alpha_M \left(3c_{LS} + 2v_L \right) \right) - c_{LS} \right)$*; (ii) when coupon of value* $v_M - v_L < c_{LB} \le v_H - v_L$ *is given to the low-type buyer, then the seller's expected profit is* $\pi_{LB} = v_M \alpha_M \alpha_H + \alpha_L \left(\alpha_M \left(c_{LB} + v_M \right) + \alpha_H \left(2c_{LB} + v_L - \alpha_M \left(c_{LB} + 2v_M \right) \right) - c_{LB} \right)$*; (iii) when coupon of value* $c_{LB} > v_H - v_L$ *is given to the low-type buyer then the seller's expected profit is always lower than the profit without couponing.*

From Lemma 4, it is clear that the seller may give a small coupon $c_{LS} \le v_M - v_L$ or a big coupon $v_M - v_L < c_{LB} \le v_H - v_L$, but she will never provide a coupon with value $c_{LB} > v_H - v_L$ because doing so allows the low-type buyer to win whenever he enters the auction and the seller gets lower revenue than without the coupon. In the following proposition, we analyze the impact of targeting small coupon to the low-type buyer on seller's profit compared with no couponing.

PROPOSITION 4a: ***Targeted couponing to low-type buyer with small coupon:*** *(i) Targeting a small coupon ($c_{LS} = v_M - v_L$) to low-*type *buyer is profit increasing when (1)* $\alpha_M \ge 1/2$ *or (2)* $\alpha_M < 1/2$ *and* $\alpha_H > \frac{1-2\alpha_M}{2-3\alpha_M}$. *(ii) Targeting a small coupon to low-type buyer is profit decreasing when* $\alpha_M < 1/2$ *and* $\alpha_H < \frac{1-2\alpha_M}{2-3\alpha_M}$.

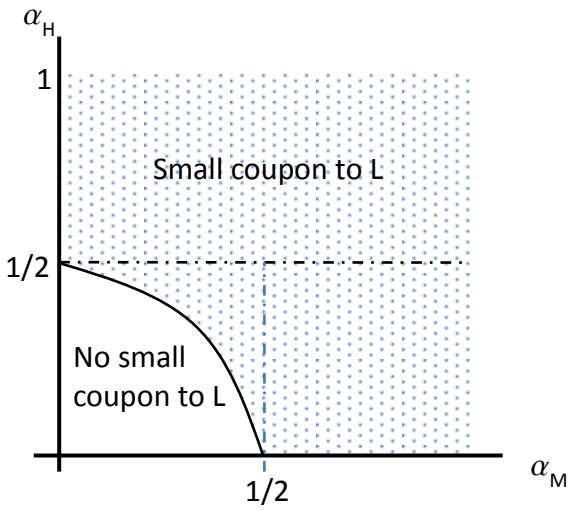

Figure 2: Region for targeting low-type buyer with small coupon

The results presented in Proposition 4a can be understood by comparing the incremental change in the seller's profit when targeting a coupon to the low-type buyer. When a low-type buyer with a coupon is the only one to enter the auction, then the seller suffers a loss (relative to the case when no coupon is issued) equal to the coupon value. When either low- and medium-type buyers or low- and high-type buyers enter the auction, then the seller obtains a gain (relative to the case when no coupon is issued) equal to the coupon value. Comparing the probability of only low-type buyer entering the auction with either low- and

medium-types entering or low- and high-types entering, we can see that whenever (i) $\alpha_M > 1/2$ or (ii) $\alpha_H > 1/2$ then the expected gain from the coupon is greater than the expected loss, and therefore, giving a small coupon is profit increasing. When $\alpha_M < 1/2$ or $\alpha_H < 1/2$ then couponing may still be profit increasing if the joint gain from low- and medium-types entering and low- and high-types entering the auction is more than the loss from only low- type entering: $c_{LS}\alpha_L(1-\alpha_M)(1-\alpha_H) < c_{LS}\alpha_L\alpha_M(1-\alpha_H) + c_{LS}\alpha_L\alpha_H(1-\alpha_M)$. Simplifying, we get the condition stated in Proposition 4a (i)(2). Part (ii) of Proposition 4a follows from the above reasoning. We show these regions in $\alpha_M - \alpha_H$ space in Figure 2. Note that in the region where targeting a small coupon to a low-type buyer is profit increasing, the seller's expected profit is increasing in coupon value. Hence, the optimal value of a small coupon is $c_{LS} = v_M - v_L$.

In the following proposition, we analyze the impact of targeting big coupon to the low-type buyer on seller's profit. Note that when a low-type buyer receives a big coupon, he can outbid the medium-type buyer.

PROPOSITION 4b: ***Targeted couponing to low-type buyer with a big coupon:*** *(i) When* $\alpha_H \geq 1/2$ *then giving big coupon (*c_{LB}*) to a low-type buyer is profit increasing and the seller offers a coupon of value* $c_{LB} = v_H - v_L$*. (ii) When* $\alpha_H < 1/2$ *then giving a big coupon (*c_{LB}*) to a low-type buyer is profit decreasing.*

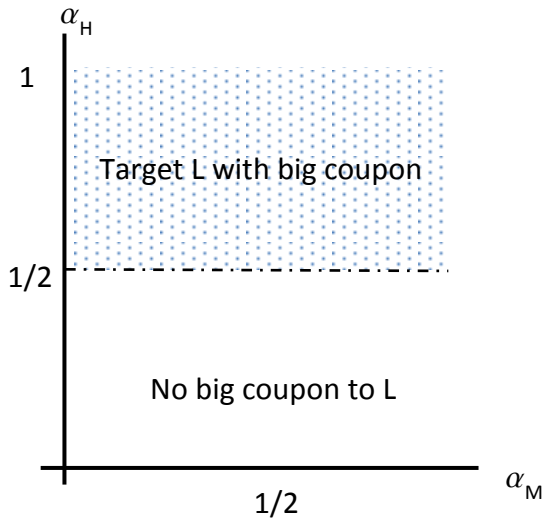

Figure 3: Region for targeting low-type buyer with big coupon

The intuition behind the result in Proposition 4b is similar to that in Proposition 3. When only low-type buyers enter or low- and medium-types enter, then the coupon value reduces the seller's revenue; and when low- and high-types enter or low-, medium- and high-types enter, then the coupon benefits the seller. Comparing the expected loss and expected gain, we can see that the expected gain is greater whenever the entry probability of the high-type is greater than half. Figure 3 shows the region in the $\alpha_M - \alpha_H$ space in which targeting the low-type buyer with a big coupon is profit increasing.

Now we determine the optimal strategy if the seller decides to target only the low-type buyer and must determine when to target with a small coupon and when to target with a big coupon. Combining the conditions in Propositions 4a and 4b and comparing profits given in Lemma 1 and Lemma 4, π_N, π_{LS}, and π_{LB}, we obtain Proposition 5. We compare these profits assuming that $v_H - v_M = v_M - v_L$.

PROPOSITION 5: ***Targeted couponing to the low-type buyer:*** *(a) the seller does not target the low-type buyer with a coupon when* $\alpha_M < \frac{1}{2}$ *and* $\alpha_H < \frac{1-2\alpha_M}{2-3\alpha_M}$*;*

(b) the seller targets the low-type buyer with a big-value coupon $c_{LB} = v_H - v_L$ *when* $\alpha_H > 1 - \frac{(v_H - v_M)}{2(v_H - v_M) + \alpha_M (v_M - v_L)}$.

(c) the seller targets the low-type buyer with a small-value coupon $c_{LS} = v_M - v_L$ *when probability of entry of the medium-type buyer is (i)* $\alpha_M < \frac{1}{2}$*, and* $\alpha_H > \frac{1-2\alpha_M}{2-3\alpha_M}$ *and* $\alpha_H < 1 - \frac{(v_H - v_M)}{2(v_H - v_M) + \alpha_M (v_M - v_L)}$ *or (ii)* $\alpha_M > \frac{1}{2}$ *and* $\alpha_H < 1 - \frac{(v_H - v_M)}{2(v_H - v_M) + \alpha_M (v_M - v_L)}$.

Part (a) of Proposition 5 follows from Proposition 4a and 4b. When $\alpha_H < 1/2$, then it is never profit increasing to target the low-type buyer with a big coupon. To see part (b), note that when $\alpha_H > 1/2$, then targeting the low-type buyer with a big or small coupon is profit increasing; therefore, in this region, we need to compare the expected profits from big coupon and small coupons. When $v_H - v_M = v_M - v_L$, then whenever $\alpha_H > 2/3$ irrespective of the value of α_M, the seller should target the low-type buyer with

a big coupon. When $1/2 < \alpha_H < 2/3$, then the optimality of giving a big coupon to the low-type buyer depends on the entry probability of the medium-type. $\alpha_H > 1 - \frac{(v_H - v_M)}{2(v_H - v_M) + \alpha_M (v_M - v_L)}$ provides the locus of separation between the optimality of a big coupon and a small coupon. When $\alpha_M = 0$, this condition reduces to $\alpha_H > 1/2$, and its value when $\alpha_M = 1$ depends on the relative magnitude of $(v_H - v_M)$ with respect to $(v_M - v_L)$. Point labeled "C" in Figure 4 corresponds to the case: $v_H - v_M = v_M - v_L$. When $(v_H - v_M)$ is much larger than $(v_M - v_L)$ then the point labeled "C" in Figure 4, approaches 0.5 and the region where the seller targets low-type buyer with big coupon expands. Whereas when $(v_H - v_M)$ is much smaller than $(v_M - v_L)$ then the point "C" approaches 1 and the region where the seller targets the low-type buyer with a big coupon shrinks.

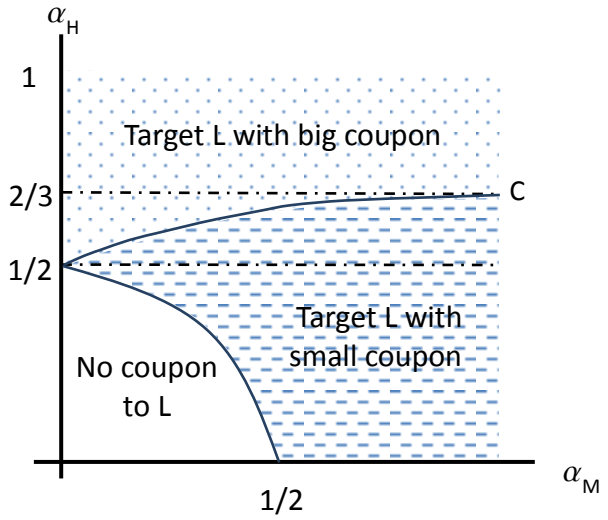

Figure 4: Optimal regions for targeting only low-type buyer. Plotted with $v_H - v_M = v_M - v_L$

To understand the intuition for these regions, note that the expected benefit to the seller from giving small coupons depends on $(v_M - v_L)$ while the expected benefit from a big coupon depends on $(v_H - v_L)$ and $(v_H - v_M)$. As $(v_H - v_L)$ becomes larger, the region in which giving big coupons is optimal becomes larger. The benefit from a big coupon compared with a small coupon to a low-type buyer

increases with the probability of entry of a high-type buyer; therefore, as α_H increases, a big coupon strategy becomes optimal. To see part (c) of Proposition 4, note that the region $\alpha_H < 1/2$ follows from Proposition 4a and the region where $\alpha_H \geq 1/2$ is explained above.

It is interesting to note in Proposition 5 that the probability of entry of the low-type buyer (α_L) does not play a role in determining whether or not coupons should be targeted at the low-type buyer. (α_L) determines the magnitude of the profit when the low-type buyer is targeted, but not whether the low-type buyer should be targeted. This is because (α_L) is a common factor in the probability of each event that impacts profit when the low-type buyer is targeted.

In Propositions 4 and 5 we examine the impact of couponing strategy on the seller's profit when the coupons are targeted to only the medium-type buyer and only the low-type buyer respectively. Next we compare the expected profit to determine the best couponing strategy when the seller can target only one buyer-type. The following proposition states the result.

PROPOSITION 6: ***Targeted couponing to the medium- or low-type buyer:***

(a) the seller does not target low- or medium-type buyer with coupon when $\alpha_M < \frac{1}{2}$ *and* $\alpha_H < \frac{1-2\alpha_M}{2-3\alpha_M}$.

(b) the seller targets the low-type buyer with a small coupon $c_{LS} = v_M - v_L$ *when (i)* $\alpha_M < \frac{1}{2}$, *and* $\alpha_H > \frac{1-2\alpha_M}{2-3\alpha_M}$, *and* $\alpha_H < 1/2$; *or (ii)* $\alpha_M > \frac{1}{2}$ *and* $\alpha_H < 1/2$; *or (iii)* $\alpha_H > 1/2$ *and* $\alpha_H < 1 - \frac{(v_H - v_M)}{2(v_H - v_M) + \alpha_M (v_M - v_L)}$ *and* $\alpha_L > \frac{\alpha_M (2\alpha_H - 1)(v_H - v_M)}{(\alpha_H (2 - 3\alpha_M) + 2\alpha_M - 1)(v_M - v_L)}$.

(c) the seller targets the low-type buyer with a big coupon $c_{LB} = v_H - v_L$ *when* $\alpha_H > 1 - \frac{(v_H - v_M)}{2(v_H - v_M) + \alpha_M (v_M - v_L)}$ *and* $\alpha_L > \frac{\alpha_M (v_H - v_M)}{(v_H - v_L) - \alpha_M (v_M - v_L)}$.

(d) the seller targets the medium-type buyer with a coupon $c_M = v_H - v_M$ *when (i)* $\alpha_H > 1/2$, *and* $\alpha_H < 1 - \frac{(v_H - v_M)}{2(v_H - v_M) + \alpha_M (v_M - v_L)}$, *and* $\alpha_L < \frac{\alpha_M (2\alpha_H - 1)(v_H - v_M)}{(\alpha_H (2 - 3\alpha_M) + 2\alpha_M - 1)(v_M - v_L)}$; *or (ii)* $\alpha_H > 1 - \frac{(v_H - v_M)}{2(v_H - v_M) + \alpha_M (v_M - v_L)}$ *and* $\alpha_L < \frac{\alpha_M (v_H - v_M)}{(v_H - v_L) - \alpha_M (v_M - v_L)}$

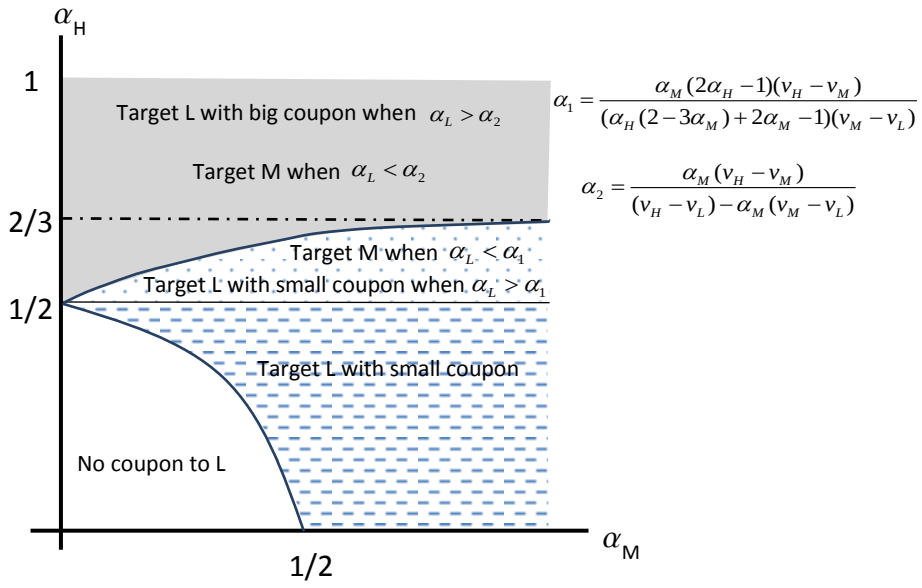

Figure 5: Targeted couponing to medium or low-type buyer plotted with $v_H - v_M = v_M - v_L$

When the entry probability of a high-type buyer is less than half, then the seller never provides a big coupon to a low-type buyer or a coupon to a medium-type buyer. When $\alpha_H > 1/2$ then we need to compare the profit to the seller from a small coupon to the low-type, a big coupon to the low-type, and a coupon to the medium-type. The region of $\alpha_H > 1/2$ is divided into two parts by the curve $\alpha_H = 1 - \frac{(v_H - v_M)}{2(v_H - v_M) + \alpha_M (v_M - v_L)}$. This condition is the same as in Proposition 5. Therefore the comparison between giving a big coupon to the low-type and giving a small coupon to the low-type is unchanged. In both these regions, we then need to compare the profit from targeting the low-type with the profit from targeting the medium-type. The expected profit from targeting the low-type depends on the entry

probability of the low-type buyer. Therefore, when $\alpha_L > \alpha_1 = \frac{\alpha_M(2\alpha_H - 1)(v_H - v_M)}{(\alpha_H(2-3\alpha_M) + 2\alpha_M - 1)(v_M - v_L)}$ then the expected profit from giving a small coupon to the low-type buyer is greater than giving a coupon to the medium-type buyer. Similarly, when $\alpha_L > \alpha_2 = \frac{\alpha_M(v_H - v_M)}{(v_H - v_L) - \alpha_M(v_M - v_L)}$ then the expected profit from targeting the low-type with a big coupon is greater than giving a coupon to the medium-type. These regions are shown in Figure 5. In the next subsection, we consider the case where the seller simultaneously targets low- and medium-type buyer.

3.5 Simultaneous couponing to low- and medium-type buyers

In this case, the seller simultaneously targets the low-type buyer with a coupon c_L and the medium-type buyer with a coupon c_M. In contrast to Lemma 4, in which we solved separately for two possible coupon values—small coupon, c_{LS}, and big coupon, c_{LB}, to the low-type buyer—in the case of simultaneous couponing we need to solve only for one coupon value, c_L. This is because, in Lemma 4, if the coupon value exceeded $(v_M - v_L)$, then the low-type buyer would win when both low- and medium-type buyers enter the auction. In contrast, in simultaneous targeting, the medium-type buyer also receives a coupon (and it is optimal to give him a coupon), then it will be of value $(v_H - v_M)$ so that even when the low-type buyer receives a coupon of value greater than $(v_M - v_L)$, the medium-type buyer still wins when both low- and medium-types enter the auction. Therefore, c_L can take values up to $(v_H - v_L)$. The following Lemma reports expected profit to the seller when she targets both low- and medium-type buyers simultaneously.

Lemma 5: *When seller targets low-type buyer with coupon* $c_L \le v_H - v_L$ *and medium-type buyer with coupon* $c_M \le v_H - v_M$*, then the expected profit is:*

$$\pi_{LM} = \alpha_M(\alpha_H(2c_M + v_M) - c_M) + \alpha_L c_L(\alpha_H(2-3\alpha_M) + 2\alpha_M - 1) + \alpha_L v_L(\alpha_H + \alpha_M - 2\alpha_H\alpha_M).$$

We compare the profit in Lemma 5 to the profit from no couponing as well as the profit from targeting only one buyer type, either low or medium type. The result is stated in Proposition 7 below.

PROPOSITION 7: ***Simultaneous targeting of medium- and low-type buyers:*** *(a) simultaneously targeting medium- and low-type buyers is profit increasing when* $\alpha_H > 1/2$ *; (b) the seller does not simultaneously target medium- and low-type buyers when* $\alpha_H \leq 1/2$.

The region in which it is profit increasing to simultaneous target low- and medium-type buyers $(\alpha_H > 1/2)$ is the same as the region in which it is profit increasing to target only the medium-type buyer and the region in which it is profit increasing to target only the low-type buyer with a big coupon. It can be seen that a couponing strategy that targets all three buyer-types with different coupons is strictly dominated by the strategy in which the seller simultaneously targets low- and medium-type buyers with coupon values reduced by the face value of the high-type buyer's coupon. In the next subsection, we examine the overall optimal couponing strategy of the seller.

3.6 Optimal strategy for targeted couponing

We raised a number of questions in the introduction: What is an optimal couponing strategy? Is it optimal to target only one buyer type or multiple types? Under what conditions would each of these strategies be optimal? We examined each of the strategies to identify regions in which these strategies are profit increasing. Next, we compare the profit from these strategies to identify the dominant strategy and the respective region of optimality.

PROPOSITION 8: ***Optimal Strategy for Targeted Couponing:***

(i) *the seller simultaneously targets low- and medium-type buyers with* $c_L = v_H - v_L$ and $c_M = v_H - v_M$ *when* $\alpha_H > 1/2$ *;*

(ii) *the seller targets low-type buyer with a coupon* $c_{LS} = v_M - v_L$ *when (a)* $\alpha_M < \frac{1}{2}$, *and* $\alpha_H > \frac{1-2\alpha_M}{2-3\alpha_M}$, *and* $\alpha_H < 1/2$, *or (b)* $\alpha_M > \frac{1}{2}$, *and* $\alpha_H < 1/2$ *;*

(iii) *the seller does not pursue a couponing strategy when* $\alpha_M < \frac{1}{2}$ *and* $\alpha_H < \frac{1-2\alpha_M}{2-3\alpha_M}$

Proposition 8 lays out the optimal targeting strategy of the seller, which is illustrated in Figure 6. We found two distinct couponing strategies that are optimal under various entry probabilities: (i) simultaneous targeting the low- and medium-type buyers when the entry probability of the high-type buyer is sufficiently high; and (ii) targeting only the low-type buyer when the entry probability of the medium-type buyer is high or the combination of entry probabilities of medium- and high-type buyers is moderate. Couponing is not optimal when the combination of entry probabilities of medium- and high-type buyers is low.

It is interesting to note that while it is sometimes optimal to target only the low-type buyer, it is never optimal to target only the medium-type buyer. This result can be explained in two parts: First, note that targeting the medium-type buyer is profit reducing when $\alpha_H < 1/2$ because the seller incurs a loss when the medium-type enters with a coupon and the high-type does not enter. Therefore, in region B (Figure 6), it is optimal to target the low-type buyer but not the medium-type buyer. Second, when $\alpha_H > 1/2$ then it is optimal to target the medium-type and low-type buyers because the entry probability of the high-type is high enough to offset the potential loss when the low-type and medium-type enter alone. Therefore, in region A, it is profit increasing to target the medium-type buyer while simultaneously targeting the low-type buyer. In region C, it is not optimal to target any of the buyers. In this region, the entry probability of both high- and medium-type buyers is low. This implies that there is sufficiently high probability that only the low-type will enter the auction relative to the events in which the low- and medium enter or the low- and high-types enter. When only the low-type enters with a coupon, the seller incurs a loss, while in other two cases, the seller benefits. Therefore, it is profit reducing to target the low-type buyer with coupon. As explained previously, it is profit reducing to target the medium-type buyer when $\alpha_H < 1/2$. Therefore, in region C, the seller does not pursue a couponing strategy.

In this section, we assumed that the seller's couponing strategy does not impact the probability of a buyer entering the auction. In practice, coupons create awareness of products and may lead to increased entry probability. The leading auction promotion Website *Aucser.com* enables *eBay* sellers to create and

distribute their own coupons to targeted segments and promote their services. The site's stated value proposition is "It's the #1 tool sellers use to reward their past bidders or entice new buyers." Similarly, *eBay* recommends that sellers employ on their platform coupons to expand the base of buyers. In the following section we examine couponing strategies when couponing can lead to an increase in buyers' entry probability.

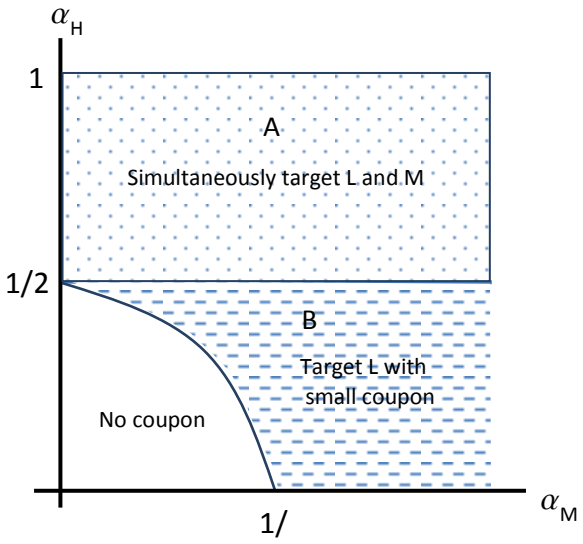

Figure 6: Overall Optimal Regions for Different Targeting Strategies $v_H - v_M = v_M - v_L$

Coupon impacts probability of participation

Coupons are known to create product awareness and increase purchase probability of new buyers in posted price markets (Bawa & Shoemaker, 1989; Neslin & Shoemaker, 1983). Nevo and Wolfram (2002) suggested that coupons might be associated with the factors that increase demand for a product at all prices. Therefore, one would expect that the probability of entry of a prospective buyer may increase if the seller provides that buyer with a coupon.[10] In this section, we allow for coupons to have a positive impact on the participation probability of the buyers.

[10] See Sen and Johnson (1997) for a psychological analysis to explain the increase in purchase probability due to mere possession of a coupon.

We model the impact of coupons on entry probability in the following manner: There is a minimal coupon amount $(\underline{c})$ such that a buyer who receives a coupon of value greater than $\underline{c}$ is more likely to participate in the auction. When a buyer receives a coupon $(c_i \geq \underline{c})$ his probability of participation in the auction increases by β. Therefore, the entry probability of the high-type buyer, the medium-type buyer, and the low-type buyer with coupon $c_i \geq \underline{c}$ is $(\alpha_H + \beta)$, $(\alpha_M + \beta)$ and $(\alpha_L + \beta)$ respectively and α_H, α_M and α_L respectively when $c_i < \underline{c}$. We make the following two assumptions: Assumption A, the entry probability for all buyers with coupon $c_i \geq \underline{c}$, is $(\alpha_i + \beta) \leq 1$. We also assume that the value of the minimal coupon $(\underline{c})$ is small relative to the increase in buyers' entry probability so that, Assumption B, the value of the minimal coupon $(\underline{c})$ and its impact on entry probability is such that providing a minimal coupon is revenue increasing $\pi^e(\beta, c = \underline{c}) > \pi(\beta, c = 0)$.

Note that there is a cost associated with a minimal coupon because the recipient may use that coupon and Assumption B implies that the increase in entry probability is sufficient to compensate for the expected cost of the minimal coupon. If this assumption were not satisfied, then minimal couponing would not occur and the seller would consider giving only maximal coupons. We already examined maximal couponing in Section 3.

When couponing has an impact on entry probability of buyers, there are two benefits to couponing: (i) the benefit from potential value extraction examined in Section 3, and (ii) the benefit from increase in entry probability. The second benefit can make it optimal for the seller to offer a coupon just to entice buyers to enter the auction, even when it does not lead to any value extraction. In this case, the seller may prefer to give a small coupon to minimize the potential cost of couponing while retaining full benefits from the increase in probability of entry. Thus, we use the term minimal coupon and maximal coupon. A minimal coupon is designed to maximize the second benefit while a maximal coupon is designed to maximize the first benefit.

Next, we examine the couponing strategies of the seller when coupons impact entry probability. It is easy to see that it is never optimal to give a maximal coupon to high-type buyer. The intuition is the

same as explained in Proposition 2. Further, note that the seller is never worse off by giving a minimal coupon to any buyer compared with the case of no coupons. This follows directly from Assumption B. Therefore, it follows that the seller will target the high-type buyer with a minimal coupon only. There are five remaining couponing strategies: (i) target all buyers with a minimal coupon; (ii) target low-type buyer with small coupon $(c_{LS} \le v_M - v_L + \underline{c})$ and medium- and high-type buyers with a minimal coupon; (iii) target low-type buyer with a big coupon $(v_M - v_L + \underline{c} \le c_{LB} \le v_H - v_L + \underline{c})$ and medium- and high-type buyers with minimal coupon; (iv) target medium-type buyer with a coupon $(c_M \le v_H - v_M + \underline{c})$ and medium- and high-type buyers with a minimal coupon; and (v) target low- and medium-type buyers with coupons $(c_L \le v_H - v_L + \underline{c})$ and $(c_M \le v_H - v_M + \underline{c})$ respectively and high-type buyer with minimal coupon. We analyze the profit functions under each of these five strategies and derive the overall optimal strategy given in the proposition below.

PROPOSITION 9: ***Optimal strategy for targeted couponing when coupon impacts entry probability:***

(i) *when* $(\alpha_H + \beta) > 1/2$ *then simultaneously targeting low- and medium-type buyers with maximal coupons* $c_L^e = v_H - v_L + \underline{c}$ and $c_M^e = v_H - v_M + \underline{c}$ *respectively and high-type buyer with minimal coupon (* $c_H^e = \underline{c}$ *) is optimal;*

(ii) *the seller targets low-type buyer with small maximal coupon* $c_L^e = v_M - v_L + \underline{c}$ *and medium- and high-type buyers with minimal coupon* $c_M^e = \underline{c}$ and $c_H^e = \underline{c}$ *when (a)* $(\alpha_M + \beta) < \frac{1}{2}$, *and* $(\alpha_H + \beta) > \frac{1 - 2(\alpha_M + \beta)}{2 - 3(\alpha_M + \beta)}$, *and* $(\alpha_H + \beta) < 1/2$ *or (b)* $(\alpha_M + \beta) > \frac{1}{2}$ *and* $(\alpha_H + \beta) < 1/2$ *;*

(iii) *the seller targets all buyers with a minimal coupon* $c_L^e = \underline{c}, c_M^e = \underline{c}$ and $c_H^e = \underline{c}$ *when* $(\alpha_M + \beta) < \frac{1}{2}$ *and* $(\alpha_H + \beta) < \frac{1 - 2(\alpha_M + \beta)}{2 - 3(\alpha_M + \beta)}$.

Proposition 9 lays out the optimal targeting strategy of the seller when couponing impacts entry probability of buyers, as illustrated in Figure 7. We find three distinct couponing strategies that are

optimal under various entry probabilities: (i) simultaneously target the low- and medium-type buyers with a maximal coupon and the high-type buyer with a minimal coupon when the entry probability of the high-type buyer is high; (ii) target the low-type buyer with a maximal coupon and the medium- and high-type buyers with a minimal coupon when the entry probability of the medium-type buyer is high or the combination of entry probabilities of medium- and high-type buyers is moderate; and (iii) target all buyers with minimal coupons when the combination of entry probabilities of medium- and high-type buyers is sufficiently low. It is never optimal not to issue coupons.

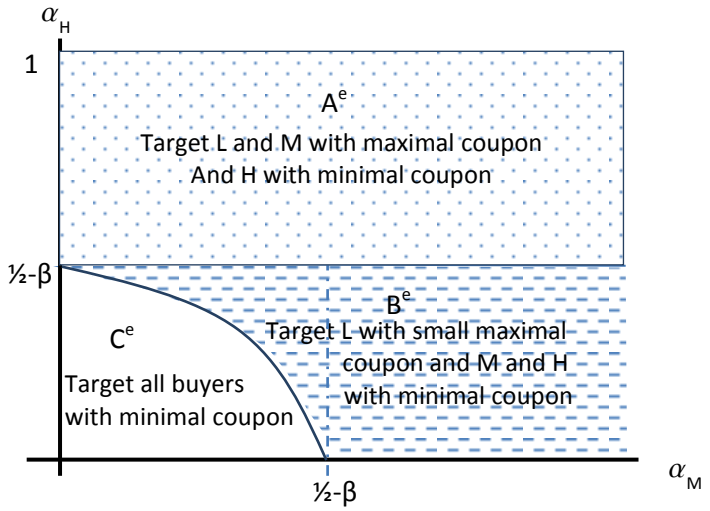

Figure 7: Overall optimal regions for different targeting strategies when the entry probability is impacted by couponing. $v_H - v_M = v_M - v_L$

How would the impact of couponing on entry probability change the results? Would the region in which simultaneous targeting of L and M is optimal grow? Would the region in which it is optimal to target L grow? Since the impact of couponing on entry probability is uniform—meaning that each type's entry probability increases by the same amount (β)—one might think that these regions will be unchanged. In contrast, we will show that these regions change in a systematic manner. Proposition 10 examines these questions.

PROPOSITION 10: ***Comparison of couponing strategy when coupon does and does not impact entry probability:***

(i) the optimal coupon amount and the seller's profit is larger when coupons impact buyers' entry probability relative to the case where coupons do not impact buyers' entry probability;

(ii) the region in which it is optimal to simultaneously target low- and medium-type buyers with maximal coupons when coupons impact entry probability is larger than the corresponding region when coupons do not impact entry probability;

Proposition 10 states that the optimal coupon amount changes from Proposition 8 to Proposition 9 so that it is optimal to issue larger coupons when couponing impacts buyers' entry probability. This result can be understood by noting that the expected revenue to the seller depends on the valuations of all buyers. A coupon changes the recipients bidding behavior, thereby changing the bidding behavior of other buyers even if they do not receive a coupon, and changes expected revenue. Therefore, issuing a coupon to one buyer affects the optimal coupon amount for other buyers. When coupons impact entry probability, the seller finds it optimal always to issue a minimal coupon to the high-type buyer, whereas she never finds it optimal to give a coupon to him when coupons do not impact entry probability. This changes the optimal coupon amount for targeted buyers.

From Proposition 10, the simultaneous targeting region is larger when the coupon impacts entry probability, and the difference becomes larger as β increases. This result can be explained in two parts: First, note that targeting the medium- or low-type buyer is profit reducing when the high-type buyer does not enter because the seller incurs a loss when a medium- or low-type enters alone with a coupon. Second, when a high-type buyer does enter, then it is optimal to target the medium-type and low-type buyers because the seller is able to extract a higher value from the high-type buyer. When a coupon impacts entry probability, then the high-type buyer's entry probability increases (due to the minimal coupon) and this expands the region in which it is optimal to simultaneously target the low- and medium-type buyers with a maximal coupon.

Similarly, we see in Figure 7 that the region B^e is smaller than region B in Figure 6, so that targeting only the low-type buyer with small coupon is optimal in a smaller region and it becomes even smaller as β increases. As discussed in the previous paragraph, the region A^e is larger. However the region C^e is smaller and the balance is such that the net effect is to shrink region B^e.

Proposition 10 also reports that the seller's profit is larger when coupons affect entry probability. This occurs because the entry probability of buyers is larger in each region due to the minimal coupon, even though the net amount paid by each winning buyer is unchanged. In the following section, we provide a summary of our results, contributions, and the managerial implications.

4. Discussion and Conclusion

In this paper, we analyzed the impact of targeted coupons issued by a seller to buyers in an auction setting. Our analysis focused on the increasing use of coupons in auctions where they may lead buyers to increase the bid amount as the coupons can be redeemed only if the coupon-holder wins the auction and purchases the item.

To summarize, we found that the seller is never worse off with a targeted couponing strategy when two or more coupon-bearing buyers enter the auction. On the other hand, if only one coupon-bearing buyer enters the auction, the seller may be worse off. We showed that targeting only the low-type buyer is optimal under some conditions, but it is never optimal to target only the medium-type buyer. Also, it is optimal to target the high-type buyer only when the coupon impacts entry probability. When coupons do not impact entry probability and the high-type buyer is more likely to enter, then it is optimal to target low- and medium-type buyers simultaneously. The optimal coupon amount depends on the difference in valuations of different types of buyers. When the coupon impacts buyers' entry probability, then the seller issues two types of coupons—a minimal coupon and a maximal coupon—and targets all buyers. The minimal coupon is designed only to increase buyers' entry, whereas the maximal coupon is designed to increase entry as well as value extraction. When the coupon impacts entry probability, the

seller earns higher profits and the region in which low- and medium-type buyers are simultaneously targeted with maximal coupons becomes larger.

Following is the economic intuition behind these results. Couponing serves two purposes: value extraction from high-type buyers and an advertisement for the auction, raising awareness of the product and the likelihood of buyers' entry. The optimal regions in Propositions 8 and 9 are driven by the benefits of value extraction. The seller benefits from targeting the medium-type buyer only when the high-type buyer enters the auction together with the medium-type buyer. Targeting the medium-type buyer is profit reducing when the high-type buyer does not enter, irrespective of the entry of the low-type-buyer. On the other hand, the seller benefits from targeting the low-type buyer when either the medium- or high-type buyer enters the auction together with the low-type buyer. Therefore, this strategy is profit increasing in regions A and B in Figure 6 (A^e and B^e in Figure 7) where the entry probability of medium- and high-type buyers is sufficiently high. The positive effect of couponing in terms of value extraction dominates the negative effect in terms of the winning bidder having a coupon only when the entry probability of higher-type buyers is larger than some critical values. When the entry probability of medium- and high-type buyers is low, then couponing is not optimal.

When there are advertising effects of coupons, we found that the seller improves her profit by issuing coupons to all buyers. Consider a given number of buyers in an auction, all of whom possess identical coupons; then in a second-price auction, the winning bid increases by exactly the face value of the coupon so that the net price paid by the buyers is unaffected. However, the distribution of coupons leads to an increased probability of entry, which increases the expected winning bid price. The seller incurs a profit reduction in the remote occurrence when only one coupon-bearing buyer arrives at the auction.

Prior literature examined couponing and one-to-one targeting in the context of posted prices. In that context, the benefits of couponing stem from its ability to price discriminate among consumers. Consumers who have low costs in clipping coupons also are typically more price sensitive and less brand loyal. This paper, to the best of our knowledge, is the first to study couponing in the context of auctions.

In markets with a posted price, the seller benefits from giving coupons to low-type buyers (Narsimhan, 1984). However in the context of auctions, it is sometimes not profitable to give a coupon to low-type buyers. It is profitable only if medium- or high-type buyers' entry probability is above certain thresholds. In the context of posted prices, since there are no supply-side constraints, the optimality of the targeted couponing strategy is independent of the expected demand from high types; whereas in a single item auction, the entry probability of the high-type buyer is critical to the optimality of couponing strategy.

To keep the analysis tractable and to focus our attention on the role of coupons in auctions, we made some assumptions. Below, we qualitatively discuss the impact of relaxing these assumptions on our results.

Our stylized model assumes a private-value auction. If the buyer valuations were to be a common value, then a buyer with a coupon may not only bid higher, but also influence others to bid higher. The role of coupons as far as value extraction is concerned will remain the same. Coupons in a common-value auctions setting may have some similarities to the dynamics of shill bidding, which is beyond the scope of this paper. We assumed that coupons have a homogenous impact on the entry probability of different buyer types. If the impact of coupons on probability of participation were heterogeneous, then our qualitative results would still hold, though the conditions stated in Proposition 9 would change. We assumed that all buyers are risk-neutral. When the buyers are risk averse, then standard revenue equivalence rule does not hold (Riley & Samuelson, 1981). As pointed out by Rothkopf et al (1990), risk-averse buyers are averse to the possibility of losing the auction. Therefore, when buyers are risk averse, we may not be able to model the online open-cry ascending bid auction as a second price auction, though the role of coupons in value extraction from the winner remains the same.

Our analysis generates insights that have implications for online auctioneers and platforms. Google is currently targeting $75 to $100 Adwords coupons to small and medium-sized businesses. They also provide $250 to small and medium-sized business via their Google Online Marketing Challenge program. Our results show that it is indeed beneficial to target the low and medium buyer segments. While it is commonly understood that such coupons serve to attract new business, our results show that in

the specific context of auctions, they also enhance the value extraction from large advertisers who are likely to have high valuations. For small and emerging auctions such as uBid.com where there is less likelihood of high-type buyers, the seller should offer larger coupons to low-type buyers to enhance value extraction from medium- and high-type buyers and smaller coupons to medium- and high-type buyers to encourage more entry. Our results suggest that auction platforms such as eBay and targeted couponing firms like Aucser.com should provide tools to the seller that enable easy tracking of buyers' entry. This will provide performance metrics for couponing and allow sellers to understand the impact on entry as well as on value extraction to adjust their couponing strategy.

In this paper, we analyzed a stylized model in which a seller offers a coupon to prospective buyers. Future research can relax some of our assumptions and develop extensions. One such extension could be the analysis of couponing by the platform owner. For example, eBay has an "eBay Bucks" program that awards a 2 percent cashback to auction winners. Other extensions can relax some of our assumptions to examine the role of coupons in common-value auctions and multi-unit auctions.

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Appendix A: Summary of Notations

Notation	Definition	Notation	Definition
v_H	High valuation of high-type buyer	π_N	Expected profit without couponing
v_M	High valuation of medium-type buyer	π_A	Expected profit with coupon to all buyer-types
v_L	High valuation of low-type buyer	π_M	Expected profit with coupon to only medium-type
α_H	Probability of participation of high-type	π_{LS}	Expected profit with small coupon to only low-type
α_M	Probability of participation of medium-type	π_{LB}	Expected profit with big to only low-type
α_L	Probability of participation of high-type	π_{LM}	Expected profit with simultaneous targeting low- and medium-type
c_M	Value of coupon targeted to medium-type	c_L^e	Value of coupon targeted to low-type with coupon boosted entry probability
c_{LS}	Small value of coupon targeted to low-type	c_M^e	Value of coupon targeted to medium-type with coupon boosted entry probability
c_{LB}	Big value of coupon targeted to low-type	c_H^e	Value of coupon targeted to high-type with coupon boosted entry probability
c_L	Value of coupon to low-type with simultaneous targeting	π^e	Expected profit with coupon boosted entry probability
$\underline{c}$	Minimum value of coupon to impact participation probability	β	Increase in participation probability with coupon