Strategic Exclusion of the Highest-Valued Bidders in Wholesale Automobile Auctions*

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Abstract

By restricting bidders to be qualified dealers, wholesale automobile auctions exclude the highest-valued bidders: consumers. We explain this puzzling entry restriction by modeling a firm's inventory-management decision. If an automobile dealer has more vehicles in inventory than is optimal, it cannot reduce its inventory by selling directly to consumers without impacting the demand for the automobiles that remain. However, by selling its excess inventory to a competitor, the demand for the dealer's remaining vehicles increases as the competitor responds by acquiring fewer additional vehicles. We demonstrate the optimality of dealer-only auctions in a very general setting.

JEL classification: D44, L11, L62

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1 Introduction

Sellers rarely take steps to exclude buyers from the opportunity to purchase. Even in special cases where entry restrictions are observed, sellers rarely exclude those buyers who place the highest value on the goods for sale. We present one market where this exact type of entry restriction is common and provide a simple rationale. In particular, this paper considers the wholesale market for automobiles, where most automobiles are sold in auctions and the majority of automobile auction houses restrict entry such that only licensed automobile dealers are allowed to bid and consumers are expressly excluded.[1] To explain why automobile auctions are closed to consumers, we argue that entry restrictions are a strategic response to the structure of the market for automobiles. Because of fluctuations in the arrival of trade-in vehicles, some dealers in some periods have more vehicles than they find it profitable to sell in that period. As a result, these dealers are willing to participate in dealer-only auctions because these exclusionary auctions allow dealers to reduce their inventory without cannibalizing demand in the secondary market.

We consider this type of entry restrictions to be especially puzzling because a market exists for consumers to pay dealers to get them into automobile auctions. See www.dealerlicensepros.com, who say that potential dealers need a "license so that they can get into dealer-only auctions to maximize profits." As a result, these entry restrictions clearly present a binding constraint because consumers are willing to pay to enter the auction house but are only able to do so illicitly by finding a dealer who is willing to violate the auction rules or by obtaining a dealer's license simply for the purpose of buying a vehicle for their own use. Further examples include www.dealerlicense.com who discusses that unlicensed dealers "are not being able to buy cars at exclusive dealer-only car auctions" and numerous online forums where consumers discuss ways to circumvent entry restrictions by paying dealers who will "sneak" them into an auction for a fee (e.g., see a discussion of fees upwards of $500 for entry to buy a single car, ask.metafilter.com).[2]

[1] There is a great deal of evidence that the vast majority of automobile auctions are restricted to dealers. For particular examples, the following is a list of major auction houses: ADESA (the second largest auction house in the country), Manheim Auto Auction (the largest), and Rawls Auto Auction (the first automobile auction house in the United States). Each of these restricts entry to dealers or, in the case of Manheim, offers only limited public auctions in limited locations at infrequent intervals. For other examples, arbitrarily chosen, Carolina Auto Auction (Anderson, SC), Harrisburg Auto Auction (Mechanicsburg, PA), and Sparking City Auto Auction (San Antonio, TX) are dealer-only auction houses. Finally note that the auction house that was the site of the field experiment reported in Grether and Plott (2009) and the auction house that was the source of the data reported in Hortaçsu et al. (2010) were both restricted to dealers.

[2] Our discussions with independent used automobile dealers suggest that even dealers who refuse to sneak consumers

Our story is centered around the inventory-management decisions of firms in the automobile industry. If an automobile dealer has more vehicles in inventory than is optimal, it cannot reduce its inventory by selling directly to consumers without impacting the demand for the automobiles that remain. However, if the dealer sells its excess inventory to a competitor, the demand for its remaining vehicles increases as the competitor responds by acquiring fewer additional vehicles. We demonstrate that for any market demand function and any cost of the competitor acquiring additional vehicles, a dealer with excess inventory does better by selling a subset of its vehicles to a competitor rather than directly to consumers. In Section 5, we compare our explanation to alternative stories for entry restrictions that are drawn from the auction literature but we argue that none provide a good fit for the wholesale automobile market.

Work by economists on the automobile industry has considered a number of important issues, for example, adverse selection (Genesove, 1993) and the role of information via the linkage principle (Tadelis and Zettelmeyer, 2011). On the market itself, used vehicles serve as the main source of automobile industry sales and profits. In 2011, there were 238.4 million used vehicles still in operation, compared to 12.8 million new vehicles sold.[3] Further, used vehicles sales vastly exceed new vehicles sales, 37.0 million used versus 11.6 million new vehicle sales in 2010, and independent used automobile dealerships outnumber new automobile franchise dealerships roughly 40,000 to 17,650. Finally, the late-2000s economic crisis has seen new vehicle accounting profits turn negative (averaging –\$180 per vehicle in 2010), while used vehicles continue to earn accounting profits (averaging \$252 per vehicle in 2010).[4]

Auctions play an important role in the used vehicle market. In 2010, 51% of used vehicles inventories originated from auction purchases. While this figure includes both franchise and independent dealerships, more detailed data are available for franchise dealerships. Specifically, the inventory of used vehicles for new vehicle dealers originated from the following sources: 51% from trade-ins, 30% from auction purchases, 13% from other sources such as used vehicles brokers, and 6% from street purchases.[5] Auctions have been an equally important source of used vehicles over the past decade (e.g., auctions provided 33% of used vehicles inventories in 2000) but have grown increasingly

into dealer-only auctions have been approached by consumers who offer to pay a fee to gain entry.

[3]For more statistics on used vehicles, the source of those data above and in what follows is the National Automobile Dealers Association (NADA). For new vehicles, the source is the Wall Street Journal's Market Data Center.

[4]Again, see the NADA for more information on these figures.

[5]See the 2011 NADA DATA Report.

common since the early 1980s, when they were the source of less than 10% of inventories.

In the next section, we discuss the market in question in more depth to illustrate that there are no institutional features that explain why consumers are excluded from automobile auctions. We then compare the automobile industry to related markets that use auctions to establish a framework for evaluating the competing hypotheses for the dealer-only auction structure that exists for automobiles. Section 4 presents our preferred explanation of dealer-only auctions with a model of inventory management, where a dealer who has more vehicles in inventory than is optimal chooses to sell its excess inventory to a competitor without impacting the demand for the automobiles that remain. Finally, we compare our inventory-management explanation to alternative explanations and argue that our story can explain the unique structure of the wholesale automobile market.

2 Details on Wholesale Automobile Markets

We now discuss how wholesale automobile auctions work, focusing on the institutional details in order to argue that entry restrictions are strategic decisions by wholesalers and not part of an externally imposed legal or organizational structure. See Genesove (1995) for further details on the functioning of wholesale automobile auctions, Wernle (1996) for a treatment in the trade press, and Blackwell (1994) for a marketing perspective on these auctions and historical background in their evolution.[6]

Our description of wholesale automobile auctions is drawn from visits to auction houses and from information gathered in interviews of market participants, including representatives of used automobile dealerships with 10 to 20 vehicle inventories and representatives of new automobile franchise dealerships with hundreds of new and used vehicles. The specific details are drawn from the Manheim automobile auction company, one of the largest in the world (www.manheim.com), but further evidence suggests the same structure exists at other large auction houses in the United States. In particular, note the similarities with the auction houses that are described by Genesove (1995) and Hortaçsu et al. (2010).[7]

[6] Also see Lafontaine and Morton (2010) for further details on franchising laws within automobile markets. Here, franchising does not play an important role because franchise contracts do not restrict dealers from selling in a public auction. As a result, the entry restrictions that we seek to explain are not explained by franchising. We have verified that franchisees are not required to sell in closed auctions by inspecting several franchise contracts and by interviewing several franchise dealers.

[7] The description in Hortaçsu et al. (2010) matches ours: "Sellers include other dealers, auto manufacturers, rental

Automobile auctions restrict entry to qualified dealers. The qualification process requires that dealers who wish to become registered with a particular auction house provide a copy of their automobile dealer's license and business license. In addition, dealers are required to provide proof of garage liability insurance (or garage keepers' insurance), which covers legal liability of vehicles related to dealership business for bodily injury or property damage. Finally, auction houses perform credit checks and often request access to account statements for business bank accounts to ensure financial stability. Some dealers undergo additional financial pre-screening in order to open a line of credit with the auction house, where vehicle purchases can be financed for one to several months (what is commonly known as floor plan financing).[8]

An automobile auction house is generally situated within a large complex (often more than 100 acres) that facilitates the storage of hundreds of vehicles that surround a central building where vehicles are brought to auction. Vehicles are lined up in a predetermined order before being driven through one of several bay doors that lead to auction lanes. Large auction houses can have 100 lanes where auctions are conducted simultaneously and bidders freely move between lanes (depending on the specification of the lane as will be explained). Smaller auction houses have fewer than 10 lanes but, because of the increase in the concentration of auction houses (Blackwell, 1994), now few remaining auction houses operate with fewer than five lanes.

On a given lane, the auction takes place quickly and, according to Manheim: "On average a vehicle is sold about every 30 seconds in each lane."[9] The auction house publishes a "run list" that includes the make, model, model year, and trim level of each vehicle. Further, the run list prominently displays information on the size and style of the engine as well as the odometer reading and Vehicle Identification Number (VIN). By clicking on a particular vehicle, a potential bidder can see several pictures of the vehicle, a full list of installed optional equipment, and information on damage to the vehicle and non-functioning parts or equipment. Finally, the run list provides the lane number and run number of the vehicle, where the lane number indicates where within the auction house the vehicle will be auctioned and the run number indicates the order in which it will

car agencies, and corporate fleet resellers. Dealers often rely on such auctions to adjust their used car portfolios to changing local market conditions. Manufacturers use these auctions sell fleet and program cars. Car rental agencies use these auctions to trade-in their used cars before they get out of factory warranty. Sellers may also be financial institutions who use the wholesale auction to reduce their inventory of program and repossessed cars."

[8]Examples of the requirements for qualification and floor plan financing, respectively, are available from www.adesa.com/dealer-regn-forms and www.manheim.com/products/financing.

[9]See www.manheim.com/products/buying_selling.

enter the queue for that lane.

Some auction houses provide a rating of vehicle condition; for example, Manheim shows a condition variable that is a continuous value from 1 (poor) to 5 (excellent), which is generated by the company's Auto Grade division. All auction houses provide in-house grading services available to potential bidders for a fee. With auction houses like Manheim that offer summary information for free, these costly inspection services supplement the freely available information to provide more detail, primarily for potential bidders who will bid online without the opportunity to personally inspect the vehicle. For potential bidders who bid in-lane, vehicles can be inspected on the facility prior to the vehicle entering the queue for auction. Depending on the particular auction house, an earlier day (often the day before) or earlier in the day of the auction is reserved for dealers to inspect vehicles.

Auction houses often operate on particular days of the week and only the largest locations would operate more than three days a week. For concreteness, consider Manheim's location in Darlington, SC, which is a rural area. On the 10 lanes at this location, 1,500 vehicles are auctioned in an average week. Dealers can bid either in-lane or online through Manheim's bidding software Simulcast. Manheim Darlington conducts auctions on every Thursday of the month starting at 9:30AM. In the middle of the previous month, a calendar of the next month's schedule is posted and sent to registered dealers. For February 2012, fleet and lease vehicles are auctioned starting at 9:30AM and dealer consignment auctions start at 10:00AM. The calendar provides the name of each large seller that will be present but any dealer that is registered at this location can sell a vehicle. The calendar provides the lane number and starting times for the largest sellers.[10]

A particular auction takes place as follows: the vehicle is waiting in sight in the queue and is "wheeled in" once the previous auction ends. The auctioneer stands at the auction block and the seller of the vehicle (if a small dealer) or a representative of the seller (if a large dealer or a fleet or lease company) stands beside the auctioneer. Potential bidders gather around the vehicle and are allowed to look under the hood and open the doors but such inspections are superficial given how quickly the bidding begins. Summary vehicle information is displayed on the front window along with identifying information that allows potential bidders to match vehicles to the run list, on which they may have identified vehicles of interest. The auction process is an English auction,

[10] See www2.manheim.com/pdfs/auctions/CAAI-DarlingtonCalendar_Feb2012.pdf.

where bids are called out orally and bidding ends when no bidder is willing to exceed the current bid. A minority of auctions are listed in advance as absolute auctions, where the winning bid is automatically accepted as long as there was a bid. In contrast, most automobiles are auctioned subject to a secret reserve price to which the seller is not required to pre-commit. In these cases, the auctioneer asks the seller if the winning bid is acceptable. If the seller accepts, then the highest bidder moves to a counter of the auction house to begin signing the required paperwork. It is more common, however, that the seller refuses and the highest bidder is then sent to the side of the auction block, where the seller and the highest bidder bargain over the final price. If no bids are placed or the bargaining process breaks down, a vehicle is unsold and may be wheeled in again for auction later in the day (and, in fact, may be wheeled in several times). Genesove (1995) models this process and provides more detail. We now compare automobile auctions with markets that are related in the sense that they also are commonly associated with auctions but are not known to use entry restrictions such as the ones that we document for automobiles.

3 Comparison with Other Auction Markets

A wide range of goods are sold in auctions, raising the question if markets other than automobiles sell in closed auctions that exclude consumers. As a preview of the discussion that follows, we know of no other auction market where entry is restricted to dealers. While it is possible that certain other examples exist of entry restrictions that exclude consumers for some market other than automobiles, we have not located any such restrictions. In any case, the thrust of this discussion implies that the structure of the wholesale automobile market is unique and worth exploring.

First, consider the market for works of art, which has a long and widely cited history of using auctions (Ashenfelter and Graddy, 2003). There are no restrictions in art auctions that potential bidders be art dealers. This is true of the well-known market leaders Christie's and Sotheby's, as well as for numerous smaller art auction houses and online auction houses (e.g., www.bonhams.com, www.dorotheum.com, and www.saffronart.com). Of particular note are the online sites Artnet and eBay. Artnet holds a growing share of the art market and makes sales to both art dealers and consumers. In contrast, eBay plays a smaller role in this market, especially after Sotheby's withdrew from its relationship with eBay in 2003 following sustained losses. In total though, no known restrictions exist in the art market that prevent consumers from buying works of art directly through an auction house. The high value of many auctioned works casts doubt on any explanation of entry restrictions into automobile auctions based around the expense of some vehicles that are being auctioned.

Second, another common example of an auction market is for fish and other commodities markets (e.g., livestock such as cattle and horses). The two largest fish markets in the world are the Tsukiji Fish Market in Tokyo and the Fulton Fish Market in New York City. For both of these fish markets, and for a variety of similar, smaller markets, buyers include intermediate wholesalers and agents who represent restaurants, food processors, etc. (Graddy, 2006). This implies that wholesalers (automobile dealers in our case) and restaurants (automobile consumers) coexist in the market, with no restriction that restaurants go through the intermediate wholesale dealers. Instead, both the Tsukiji and Fulton markets require that all buyers be licensed but do not prevent consumers from gaining a license. Relatedly, cattle auctions, such as www.cattleusa.com and www.superiorlivestock.com, require that bidders become pre-qualified before bidding, which involves a credit check and documentation of available funds. Beyond that certification process, any bidder, regardless of incorporation status, can bid in numerous types of cattle auctions. Similar pre-qualification exists for other livestock auctions such as horses but none of these markets (to our knowledge) use entry restrictions beyond certification.

To conserve space, we will list several auction markets and representative auction houses for each. In each of the following markets, we have verified that no entry restrictions on consumers exist, at least for the auction houses that we have checked. The following markets operate, at least in part, using auctions and do not exclude consumers: antiques (e.g., www.bukowskis.com and www.skinnerinc.com); event tickets (e.g., www.ticketmaster.com and www.tickpick.com); real property, such as residential and commercial real estate, land, etc. (e.g., www.realtybid.com and www.treasury.gov/auctions/irs); second-hand goods (e.g., www.ebay.com and www.ubid.com); stamps (e.g., www.davidfeldman.com and www.mysticstamp.com); travel (e.g., www.sj.se and www.skyauction.com); and wine, including first-hand wine auctions, where the seller is the winery itself (e.g., www.napavintners.com), and second-hand wine auctions, where the seller is an auction house (e.g., www.winebid.com).

4 A Model of the Secondary Market for Automobiles

We consider a standard Stackelberg model with one significant variation. To simplify the analysis, we assume vehicles are homogeneous, and there are two firms that face an inverse demand function $p = F(Q)$, where F is a decreasing, convex function and Q equals the total quantity of vehicles sold in the market. We also assume there is a competitive secondary market for the automobiles where firms may acquire vehicles at a constant cost of c.[11] We first present the results for an arbitrary inverse demand, then to aid with intuition, we illustrate the equilibrium for the standard case of a linear inverse demand.

Firm 1 is endowed with ω vehicles. We are interested in the scenario where Firm 1 has an endowment that is larger than its choice in the standard Stackelberg model. Let q_1^S, π_1^S, q_2^S, and π_2^S be the equilibrium quantities and profits for Firm 1 and 2, respectively, in the standard Stackelberg game when neither firm is endowed with any vehicles. We assume that $\omega > q_1^S$. For example, in the linear demand case we assume that $\omega > \frac{A-c}{2}$. As a result, Firm 1 does not wish to acquire additional vehicles and instead does strictly better by reducing its quantity. We consider two mechanisms for Firm 1 to reduce its inventory: (1) a dealer-only auction and (2) a non-exclusionary auction where both dealers and consumers are allowed to participate. In both auction formats, firms in the competitive secondary market are allowed to participate. We compare the results of these two mechanisms to the outcome when there is no auction.

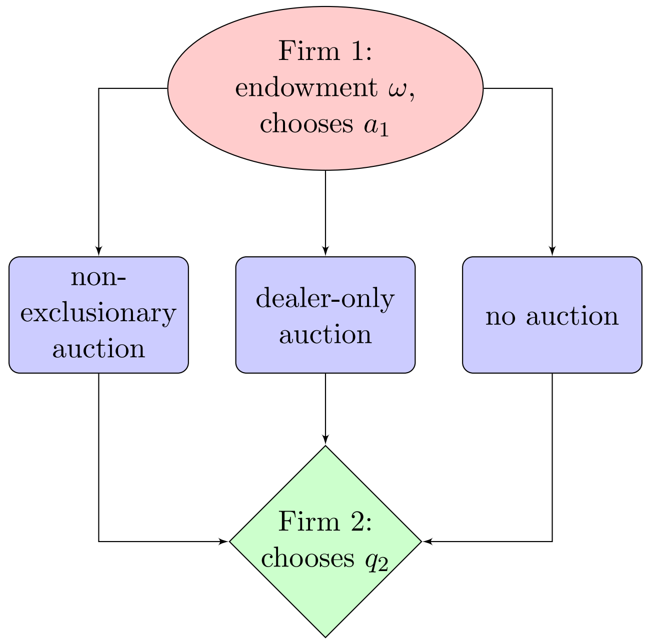
The sequence of decisions is as follows. First, Firm 1 decides how much of its endowment it will sell at the auction, a_1, and how many vehicles it will sell directly to consumers, q_1, where $\omega = a_1 + q_1$. The a_1 vehicles are sold at the auction, and depending on the auction format, α many consumers purchase their vehicles via the auction instead of the market. It is also possible that Firm 2 purchases vehicles at the auction. In the final stage, Firm 2 decides how many additional vehicles to purchase from the secondary market, q_2.

4.1 Firm 2's Decision

Firm 2's decision depends only on the quantity chosen by Firm 1, q_1, the number of consumers that purchased a vehicle at the auction, α, and the number of vehicles it purchased at the auction,

[11] Our results hold for an arbitrary cost of acquiring additional vehicles. We assume a constant price in the secondary market to simplify the analysis.

Figure 1: The three scenarios we consider.



x. If Firm 2 acquires q_2 additional vehicles, its profits are:

$$\pi_2(q_2; q_1, \alpha, x) = F(q_1 + \alpha + q_2)(q_2 + x) - cq_2. \tag{1}$$

The convexity of F implies there is a unique solution: $q_2^*(x)$. Let $P^*(x) = F(q_1 + \alpha + q_2^*(x))$.

4.2 Auction Stage

No Auction Without an auction, Firm 1 has no way of reducing the number of vehicles it chooses. As it already has more vehicles than is optimal, acquiring any additional vehicles only reduces its profits. It is straightforward to verify that in the subgame perfect equilibrium of this game $q_1 = \omega$. Moreover, Firm 1's profits are strictly less than if it has an endowment of q_1^S vehicles. As Firm 2's profits are decreasing in the quantity Firm 1 chooses, Firm 2's profits are strictly less than π_2^S, Firm 2's profits in the Stackelberg game where Firm 1 has no initial endowment of vehicles.

Next we consider two different auction formats. In the first, the dealer-only auction, consumers are excluded from participating. In the second, consumers are included. In both, we consider a uniform price auction although we would reach identical conclusions if we used a discriminatory or

Vickery format. In both auction formats, firms from the competitive secondary market are allowed to participate.

Dealer-Only Auction Each firm from the competitive secondary market is willing to buy an arbitrary quantity of vehicles at any price less than or equal to c. Firm 2 never wishes to pay more than c for a vehicle at the auction as it may purchase vehicles in the next stage at a price of c. Therefore, the market clearing price in the auction is c. As Firm 2 is indifferent between purchasing vehicles during the auction or during the next phase, for simplicity we assume Firm 2 buys no vehicles at the auction in the dealer-only auction.

Dealer and Consumer Auction Consider any quantity a_1 of vehicles that Firm 1 chooses to sell at the auction. We will demonstrate that no outside firm purchases a vehicle at an auction that includes consumers. Let $q_2^*(x)$ denote the solution to Equation (1) where x is the number of vehicles Firm 2 purchases at auction, $q_1 = \omega - a_1$, and $\alpha = a_1 - x$. Let $P^*(x) = F(q_1 + \alpha + q_2^*(x))$. Consumers are forward looking and able to anticipate that if Firm 2 purchases x vehicles at the auction then the market price will be $P^*(x)$. We claim the unique equilibrium of the auction is Firm 2 to buy no vehicles and for a_1 consumers to purchase the vehicles at a price of:

$$P^* = F(\omega + q_2^*(0)). \tag{2}$$

If consumers purchase all $a_1 = \omega - q_1$ vehicles in the auction at a price of P^*, then each consumer is indifferent between purchasing at the auction and purchasing at the market as the prices are identical. Later we give specific bids that support this clearing price at the auction. Note that no outside firm wishes to bid greater than c at the auction. Therefore, if the auction clearing price is P^*, no outside firm wants to win a unit. Finally, we need to check that in equilibrium, Firm 2 does not wish to purchase any units at the auction. The benefit for Firm 2 from purchasing at the auction is increasing the residual demand; the detriment to Firm 2 is acquiring vehicles at a price higher than c.

Proposition 1. *Let $P(Q)$ be any inverse market demand function, and let $C(q_2)$ be any cost function for Firm 2. Then Firm 2 never does better buying vehicles at the dealer and consumer* *auction. Moreover, if the profit function $\pi_2(q_2) = F(\omega + q_2)q_2 - C(q_2)$ has a unique maximizer, then there is no equilibrium where Firm 2 purchases vehicles at the non-exclusionary auction.*

Proof. A key observation is that consumers in the non-exclusionary auction are forward looking. Since they can anticipate the market clearing price, in any subgame perfect equilibrium it must be that the price per unit in the auction equals the final market clearing prices.

When there is no auction, Firm 2 chooses a q_2^* to optimize the equation:

$$\pi(q) = F(\omega + q_2)q_2 - C(q_2). \tag{3}$$

In particular, first order conditions imply that:

$$F'(\omega + q_2^*)q_2^* + F(\omega + q_2^*) - C'(q_2^*) = 0. \tag{4}$$

If Firm 2 buys x vehicles at the dealer and consumer auction, then its profit maximization problem in the final stage is slightly different. It maximizes:

$$\pi(q_2; x) = F(q_1 + (a_1 - x) + q_2)q_2 - C(q_2' - x) - P^*x, \tag{5}$$

where P^* is the market clearing price in the auction. However, in any equilibrium, the market clearing price in the auction equals the final price. Therefore, if there exists an equilibrium where Firm 2 buys $x > 0$ vehicles at the auction and chooses a quantity of q_2' in the final stage, it must be that $P^* = F(q_1 + (a_1 - x) + q_2')$. Therefore, Firm 2's profits in this equilibrium are:

$$\begin{aligned}
\pi(q_2'; x) &= F(q_1 + (a_1 - x) + q_2')q_2' - C(q_2' - x) - P^*x \\
&= F(q_1 + (a_1 - x) + q_2')(q_2' - x) - C(q_2' - x) \\
&= F(\omega + (q_2' - x))(q_2' - x) - C(q_2' - x).
\end{aligned}$$

But $q_2' - x$ was a candidate solution to Equation (3). Therefore:

$$\begin{aligned}\pi(x; q_2') &= \pi(q_2' - x)\\ &\leq \pi(q_2^*),\end{aligned}$$

since q_2^* maximizes Equation (3). We conclude that there is no equilibrium where Firm 2 does strictly better by purchasing x units at the auction. Now suppose that q_2^* uniquely maximizes Equation (3). Notice that for $x > 0$:

$$\pi(q_2^* + x; x) = F(\omega + q_2^*)(q_2^* + x) - C(q_2^*) - P^* x$$

and therefore:

$$\begin{aligned}\frac{d}{dq_2}\pi(q_2; x)\Big|_{q_2^*+x} &= F'(\omega + q_2^*)(q_2^* + x) + F(\omega + q_2^*) - C'(q_2^*)\\ &= F'(\omega + q_2^*)(q_2^*) + F(\omega + q_2^*) - C'(q_2^*) + F'(\omega + q_2^*)x\\ &= F'(\omega + q_2^*)x\\ &> 0,\end{aligned}$$

where the third equality follows from Equation (4). Therefore, if Firm 2 buys $x > 0$ vehicles at the auction, then it optimally chooses a quantity $q_2' \neq q_2^* + x$ in the final stage. However, since $q_2' \neq q_2^* + x$ and q_2^* uniquely maximizes Equation (3), we conclude that:

$$\pi(x, q_2') = \pi(q_2' - x) < \pi(q_2^*). \tag{6}$$

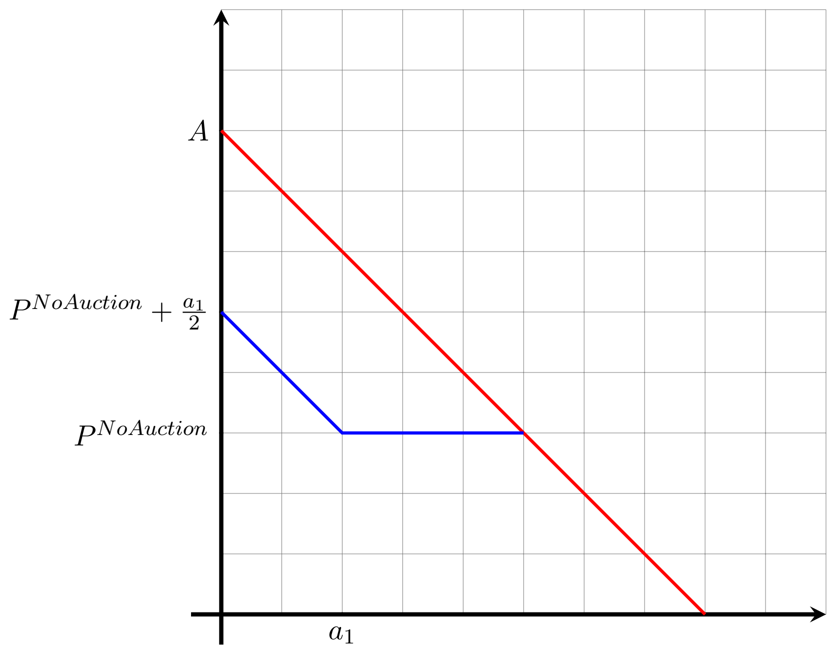
In particular, if there is a unique quantity that maximizes Equation (3), there is no equilibrium in which Firm 2 buys any vehicles at the non-exclusionary auction. Suppose for contradiction there were. Then (6) implies that Firm 2 receives strictly less profits than if it bought no vehicles. As buying no vehicles is always an option at the auction, this cannot be an equilibrium. □

Finally, we present equilibrium bid functions where the auction price and market price always coincide. Let v_i be consumer i's valuation for a vehicle, and let $\chi_i = |\{j | v_j > v_i\}|$. For each bidder

i, we define the following bid function:

$$b(v_i) = \begin{cases} F(\omega + q_2^*(\chi_i)) & \chi_i \geq a_1 \\ 0 & \text{otherwise.} \end{cases}$$

Figure 2: For the linear inverse market demand, if Firm 2 purchases x units at auction, then its optimal market clearing price is $\$\frac{x}{2}$ higher than if it purchases zero units at auction. In the following bid function, for any quantity x that Firm 2 wins at auction, consumers are indifferent between purchasing a vehicle at the auction and on the market.



If Firm 2 wins x units, then the $a_1 - x$ highest bid by a consumer sets the market clearing price. Therefore, the price in the auction equals $F(\omega + q_2^*(\chi_i))$ which is exactly the market clearing price after Firm 2 chooses its optimal quantity in the final stage.

In summary, if consumers are allowed to participate in the auction, then the unique subgame perfect equilibrium is for the consumers to purchase all a_1 vehicles at auction. The market clearing price and the price at auction are both equal to $P^* = F(\omega + q_2^*(0))$. Note that this is precisely the price if there is no auction at all. Moreover, the outcome is independent of the number of vehicles that Firm 1 sells at the auction.

4.3 Firm 1's Decision

Dealer-Only Auction

Firm 1 is able to sell as many vehicles as it wishes at a price of c in the dealer-only auction. Since it is endowed with a greater than optimal number of vehicles, its problem is deciding how many vehicles to sell at the dealer-only auction. In equilibrium, it receives a price of c for each vehicle that it sells at auction. Therefore, it seeks to optimize the following equation:

$$\max_{q_1} F(q_1 + q_2^*)(q_1) + c \cdot (\omega - q_1). \tag{7}$$

This problem is equivalent to Firm 1 selling its entire endowment at a price of c per vehicle and then purchasing its desired quantity at a price of c. Therefore, the optimal quantity for Firm 1 to sell at auction is $\omega - q_1^S$. Firm 1 receives a total profit of $\pi_1^S + c * \omega$. Firm 2's profits are therefore π_2^S.

Dealer and Consumer Auction

In equilibrium, the auction price equals the market clearing price. In particular, this price is independent of the number of vehicles that Firm 1 chooses to sell at the auction. All of the vehicles are purchased by consumers, and in equilibrium, the consumers are indifferent between purchasing a vehicle in the auction or in the market. Consequently, Firm 1 is indifferent between selling the vehicles in the auction and in the market. As a result, Firm 1 has no decision to make. It makes the same profits regardless of the number of vehicles it sells through the auction versus the market. Note that these profits are equivalent to its profits when there is no auction.

4.4 Comparison of Formats

We considered three different cases: no auction, a dealer-only auction, and a non-exclusionary auction. Interestingly, Firm 1 and 2 earn identical profits when there is no auction and when there is an auction that includes consumers. When there is a dealer-only auction, Firm 1 chooses the same quantity as when there is no endowment. As this quantity is strictly less than Firm 1's endowment and as Firm 2's profits are decreasing in the quantity Firm 1 chooses, both Firm 1 and Firm 2 receive strictly higher profits when there is a dealer-only auction then when there is an auction that includes consumers.

4.5 Illustration with Constant Inverse Market Demand

We solve the case of a linear inverse demand function in order to provide intuition for the preceding analysis. Specifically, we assume that there are two firms that face a linear inverse demand of $p = A - Q$. Both firms may acquire vehicles at a constant marginal cost of c. Firm 1 is endowed with $\omega > \frac{A-c}{2}$ vehicles.

No Auction Without an auction, Firm 1 has no way of reducing the number of vehicles it chooses. As it already has more vehicles than is optimal, acquiring any additional vehicles only reduces its profits. It is straightforward to verify that the subgame perfect equilibrium of this game is:

$$q_1^{NA} = \omega \qquad q_2^{NA} = \frac{A - \omega - c}{2} \tag{8}$$

$$Q^{NA} = \frac{A + \omega - c}{2} \qquad P^{NA} = \frac{A - \omega + c}{2} \tag{9}$$

$$\pi_1^{NA} = \frac{(A - \omega + c)\omega}{2} \qquad \pi_2^{NA} = \frac{(A - \omega - c)^2}{4}. \tag{10}$$

Firm 2's Decision Firm 2's decision depends only on the quantity chosen by Firm 1, q_1, the number of consumers that purchased a vehicle at the auction, α, and the number of vehicles it purchased at the auction, x. Firm 2 is a monopolist over the residual demand $A - \alpha - q_1$ and optimally chooses to purchase:

$$q_2^* = \frac{A - \alpha - x - q_1 - c}{2}. \tag{11}$$

The total number of vehicles it sells at the market is therefore $x + q_2^*$, and the market clearing price is:

$$P^* = \frac{A - \omega + x + c}{2}. \tag{12}$$

Dealer-Only Auction The market clearing price is c regardless of how many vehicles Firm 1 sells at the auction.

Dealer and Consumer Auction If Firm 1 chooses to auction a_1 vehicles, then the unique subgame perfect equilibrium is for only consumers to purchase vehicles at the auction at a price of:

$$P^* = \frac{A - \omega + c}{2}. \tag{13}$$

If consumers purchase all $a_1 = \omega - q_1$ vehicles, then the residual demand Firm 2 faces in the final period is $A - a_1 - q_1 = A - \omega$. Therefore, Firm 2 faces the same problem as in the no auction case, and as a result the quantity Firm 2 chooses and the market clearing price are as in Equations (8) and (9):

$$q_2 = \frac{A - \omega - c}{2} \qquad\qquad P = \frac{A - \omega + c}{2}.$$

The following are bid functions for the consumers that support this equilibrium in the linear demand case (see Figure 2 on Page 14). Let v_i be consumer i's valuation for a vehicle, and let $\chi_i = |\,\{j|v_j > v_i\}\,|$. For each bidder i, we define the following bid function:

$$b(v_i) = \begin{cases} \frac{A-\omega+c}{2} + \frac{a_1-\chi_i}{2} & \chi_i \geq a_1 \\ 0 & \text{otherwise.} \end{cases}$$

With these bid functions, if Firm 2 wishes to purchase x units at the auction, then it must submit a higher bid than the $a_1 - x$ highest bid by a consumer. Therefore, the price in the auction equals $\frac{A-\omega+c}{2} + \frac{a_1-(a_1-x)}{2} = P^{NA} + \frac{x}{2}$.

If Firm 2 purchases x vehicles at the auction, we found in Equation (11) that Firm 2 optimally acquires $\frac{A-x-\omega-c}{2}$ additional vehicles. Since no outside firms purchased at the auction, $a_1 = \alpha + x$.

The total number of vehicles Firm 2 sells is:

$$q_2 + x = \frac{A - x - \omega - c}{2} + x \tag{14}$$

$$= \frac{A - \omega - c}{2} + \frac{x}{2} \tag{15}$$

$$= q_2^{NA} + \frac{x}{2}. \tag{16}$$

Therefore, the market clearing price is:

$$
\begin{aligned}
P^* &= A - \alpha - q_1 - (x + q_2) \\
&= A - (\alpha + x + q_1) - q_2 \\
&= A - \omega - \left(\frac{A + x - \omega - c}{2} \right) \\
&= P^{NA} + \frac{x}{2}.
\end{aligned}
$$

Therefore, the market clearing price exactly equals the price Firm 2 paid for the x units it won at the auction. Firm 2 chooses a quantity of $q_2^{NA} + \frac{x}{2}$, but it does not make a profit on the x units it bought at auction, and it only needs to acquire $q_2^{NA} - \frac{x}{2}$ additional vehicles. Therefore, the profits it makes are:

$$
\pi_2 = (P^{NA} + \frac{x}{2})(q_2^{NA} - \frac{x}{2}) - c(q_2^{NA} - \frac{x}{2}).
$$

Notice that these are exactly the profits it makes in the no auction case if it chooses a quantity of $q_2^{NA} - \frac{x}{2}$ instead of q_2^{NA}. However, q_2^{NA} is the unique profit maximizing quantity when there is no auction, so Firm 2 must receive strictly smaller profits if it purchases any positive number of vehicles at the auction than if it buys no vehicles at the auction.

Firm 1's Decision When there is a dealer-only auction, Firm 1 chooses the familiar Stackelberg quantity $q_1^* = \frac{A-c}{2}$ and sells $\omega - q_1^*$ vehicles at auction. When consumers are included in the auction, the auction price is independent of the number of vehicles Firm 1 chooses to sell at the auction. All of the vehicles are purchased by consumers, and in equilibrium, the consumers are indifferent between purchasing a vehicle in the auction or in the market. Consequently, Firm 1 is indifferent between selling the vehicles in the auction and in the market. Therefore, Firm 1 has no decision to make. It makes the same profits regardless of the number of vehicles it sells through the auction versus the market.

4.6 Summary

Dealer-Only Auction

When only dealers are allowed to participate in the auction, the model is equivalent to the Stackelberg model. Since the equilibrium price in the auction is c regardless of the number of vehicles it chooses to auction, effectively, Firm 1 may sell its entire endowment at a price of c and then choose the quantity of vehicles it wishes to obtain at a constant marginal cost of c. Therefore, our solution is identical to the Stackelberg solution except that Firm 1 obtains $c \cdot \omega$ additional profits. To summarize:

$$q_1^{D-O} = \frac{A-c}{2} \qquad q_2^{D-O} = \frac{A-c}{4}$$

$$Q^{D-O} = \frac{3(A-c)}{4} \qquad P^{D-O} = A - \frac{3(A-c)}{4}$$

$$\pi_1^{D-O} = \frac{(A-c)^2}{8} + c \cdot \omega \qquad \pi_2^{D-O} = \frac{(A-c)^2}{16}.$$

Dealer and Consumer Auction

When consumers are allowed to participate in the intermediate auction, then in equilibrium the auction price and the market price are equivalent. The equilibrium quantities are:

$$q_1^{D+C} = x,\ 0 \le x \le \omega \qquad q_2^{D+C} = \frac{A-\omega-c}{2}$$

$$Q^{D+C} = \frac{A+\omega-c}{2} \qquad P^{D+C} = \frac{A-\omega+c}{2}$$

$$\pi_1^{D+C} = \frac{(A-\omega+c)\omega}{2} \qquad \pi_2^{D+C} = \frac{(A-\omega-c)^2}{4}.$$

5 Alternative Explanations

We now compare our inventory-management story to other explanations that one may imagine to explain an entry restriction where consumers are not allowed to participate in an auction market.

First, many auction papers consider the winner's curse. The most closely related work to ours is Bose and Deltas (2007). They demonstrate that when both resellers and consumers are present, it may be profitable for the auctioneers to exclude the consumers. The result is driven by the exposure of the resellers in their model to the winner's curse. If there are no consumers, each reseller bids its expected profits in the secondary market. However, if a consumer is present, then a reseller wins only when the consumer had a low valuation for the object. Therefore, in equilibrium each reseller lowers its bid when a consumer is present. They demonstrate that the decrease in seller's revenue associated with the lower bids by resellers can outweigh the increase in revenue associated with the participation of a potentially high-valued consumer.

In general, bidders with asymmetric information are exposed to the winner's curse in a common-value (CV) auction, where bidders receive a signal about the ex post value of the good but the ex post value is common to all bidders. The more bidders that are present in a CV auction, the more each bidder should shade their bids downward. Bulow and Klemperer (2002, p. 2) discuss the possibility that: "Buyers must bid more conservatively the more bidders there are, because winning implies a greater winner's curse. This effect can more than compensate for the increase in competition caused by more bidders, so more bidders can lower expected prices." Interestingly, Bulow and Klemperer (2002) find in a stylized framework that excluding the bidder that is ex ante most likely to have the highest valuation may be profitable for the seller. The intuition is that a low bid by such a bidder implies even worse news than when bidders are symmetric.

However, a winner's curse argument does not seem plausible to explain the exclusion of consumers in automobile auctions. While both dealers and consumers have asymmetric information about the same vehicle, the information they value is not the same. A consumer is uncertain of the inherent quality of the vehicle. A dealer is uncertain of the demand for the vehicle. While these two things are related, they are not the same. Moreover, we expect a consumer to be more exposed to the winner's curse than a dealer. First, it is more difficult to ascertain the quality of an automobile than it is to estimate its resale value. Second, because consumers have less experience buying or selling automobiles than dealers, we expect them to have poorer information. Therefore, it does not seem likely that consumers are excluded to mitigate the winner's curse as consumers are the ones most exposed. In the case of Bose and Deltas (2007), there is no winner's curse in an English auction since if middlemen could "update their estimate of the consumer's valuation as the auction progresses,... the non-exclusive and exclusive [auctions] would yield the same revenue" (Bose and Deltas, 2007, 11). However, most automobile auctions are open, ascending (English) auctions.

Second, another strand of the auction literature has focused on endogenous entry, where bidders in an auction market decide whether or not to enter the auction, a decision that is generally governed by the bidder's willingness to pay an entry cost. Levin and Smith (1994) find that entry restrictions can be profitable because they reduce socially wasteful expenditures on entry costs.[12] The notion of socially wasteful exists here only in the case of a CV auction. Sellers prefer entry restrictions in CV auctions with entry costs because lower total expenditures on entry increases bids and raises seller expected revenue. Levin and Smith (1994) anticipate one feature of automobile auctions that make this an unlikely explanation for the entry restrictions that we see, namely that this explanation requires that entry costs are large relative to the value of the good being auctioned.[13] This is unlikely for automobiles, where hundreds of vehicles are auctioned within a few hours and where information on the auctioned automobiles is efficiently disseminated to potential bidders.

Further, Levin and Smith (1994) show that the result of profitable entry restrictions holds only in the CV case and not in more general environments such as affiliated-private values (APV). However, because consumers and dealers are fundamentally different, assuming every consumer and every dealer have identical ex post valuations for a vehicle is unreasonable. Even within the class of consumer and dealers, we do not expect agents to have identical valuations. Consumers have idiosyncratic variations in preferences, and the value to a dealer is a function of its current inventory and local market conditions. Therefore, entry costs do not explain the entry restrictions in automobile auctions even under the assumption that entry is very costly relative to the vehicle's value.

Third, resale can provide a rationale for entry restrictions (Haile, 1999, 2003). When a resale market exists following an auction and information is revealed prior to resale, restricting entry can save on duplicative entry costs. Combining the literature with costly and endogenous entry with the literature on post-auction resale, Xu et al. (2012) find that the presence of a resale market alters entry strategies and can increase or decrease seller revenue. While their paper does not consider entry restrictions, it can provide a framework for thinking about the issue in a market, such as automobiles, where resale is present. Consider entry costs and valuations of consumers, relative to entry costs and valuations of dealers. Intuition suggests that consumers have higher entry costs than dealers (because of consumers' unfamiliarity with wholesale auctions) and higher valuations

[12] Our discussion of endogenous entry also holds for the entry model of Samuelson (1985), who analyzes a similar problem as Levin and Smith (1994) but instead assumes that bidders know their value at the time of entry.

[13] The authors say: "sellers (or procurers) who deal in unique or technical items that are by nature relatively hard to evaluate are more likely to gain by restricting the number of qualified bidders than sellers (or procurers) who deal in items whose value is straightforward" (Levin and Smith, 1994, p. 596).

than dealers (because consumers buy from dealers in the secondary market). In the terminology of Xu et al. (2012), consumers are resale hunters who do not enter the auction, while dealers are speculators, similar to the middlemen in Bose and Deltas (2007).

This line of thought implies that wholesale automobile auctions do not need to restrict entry because the dealer-only auction structure would arise naturally as a result of equilibrium bidding behavior. We argue that this is unlikely to explain automobile auctions for two reasons. First, the argument relies on an entry cost into the auction, yet costless entry into the resale market. For this market, it is likely to be cheaper for consumers to attend auctions (if allowed) than to go from dealer to dealer to buy in the post-auction secondary market. Second, the argument implies that entry restrictions are unnecessary and that removing them would have no effect. As discussed in the introduction, a market exists for consumers to pay dealers to sneak them into the automobile auction, which strongly suggests that entry restrictions place a binding constraint on consumers.

Finally, note that other markets that use auctions have found solutions to various problems that one might pose to open auctions without resorting to entry restrictions. As discussed in Section 3, cattle and other livestock auctions require that bidders be pre-qualified (e.g., a credit check to ensure the ability to pay) but do not prevent consumers from undergoing the qualification process. Likewise, fish and other commodity markets require that bidders employ bidding agents but allow consumers to use agents just as dealers do. As a result, any explanation of consumer-entry restrictions that is based on consumers' unfamiliarity with the bidding process or the potential for bidders to exceed their budget must explain why a draconian measure such as excluding all consumers is more profitable than a method that is simpler and easier to enforce such as pre-qualification or an agency process.

6 Conclusions

Automobile auction houses expressly prohibit consumers from participating in auctions despite the fact that these are the exact bidders who place the highest values on the goods that are being auctioned. This is surprising because it runs counter to standard profit-maximizing behavior and because it is unique relative to a wide variety of related markets that use auctions. We present a model that explains these entry restrictions as equilibrium outcomes of the inventory-management decisions of automobiles dealers whose inventory fluctuates from period to period. If a dealer has more vehicles in inventory than is optimal, it cannot reduce its inventory by selling directly to consumers without impacting the demand for the automobiles that remain. However, if the dealer sells its excess inventory to a competitor, the demand for its remaining vehicles increases as the competitor responds by acquiring fewer additional vehicles. We demonstrate that for any market demand function and any cost of the competitor acquiring additional vehicles, a dealer with excess inventory does better by selling a subset of its vehicles to a competitor rather than directly to consumers. As a result, we are able to explain the structure of wholesale automobile auctions without relying on informational asymmetries or other ad hoc frictions. Instead, we build our inventory-management model on two key features of the used-automobile market: (1) automobile dealers occasionally have excess inventory and (2) dealers have the ability to acquire additional inventory. When both hold simultaneously, a firm finds it optimal to exclude consumers from the auctions. By comparing the market for used automobiles to other markets that also feature auctions, we rule out competing hypotheses for this type of entry restriction.

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