The Informational Role of Product Trade-Ins for Pricing Durable Goods

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Abstract

We develop a theoretical model of the pricing of a new durable good to determine the conditions under which the seller can utilize inferences about the buyer’s willingness to pay based not only on her decision to trade in the old good but also on its characteristics. We test the predictions of our theory using transaction data for new car purchases that includes information on the vehicles that new car buyers traded in. The results show that dealers infer a higher willingness to pay and charge higher prices to consumers who traded in a used vehicle than to those who did not. We also find that dealers charge even higher prices to those consumers who trade in used cars that were of the same make and model as the new one. We show that ignoring the information available in the type of trade-in can inflate the estimated value of the trade-in effect.

Key words: Pricing, Price Discrimination, Durable Goods, Trade-Ins
1. Introduction

Consumers in durable goods markets often trade in a used product to a retailer when they purchase a new one. The traded in product is typically accepted by a retailer as a partial payment for the new good. Retailers accepting trade-ins make a profit by reselling traded in products at a higher price, either through auction markets, or directly to other consumers in the second-hand market. While acknowledging the profitability of such arbitrage transactions, we investigate whether trade-ins also enable retailers to draw more precise inferences about a consumer’s willingness to pay for the new product and thus price discriminate among consumers more effectively. Such information should be particularly valuable in durable goods markets, such as automobiles, in which prices are individually transacted and dealers quote consumer-specific prices.\(^1\) Our research identifies the conditions under which the seller of a durable good can utilize the information about a customer’s trade-in to set the price of the new product.

A key purpose of this research is to understand the nature of the information that can be communicated to the seller by the buyer’s trade-in decision. When a seller encounters an interested buyer, he observes the buyer’s decision on whether or not to trade in a previously owned vehicle and the characteristics of the traded in vehicle. Our objective is to posit a set of conditions that permit the dealer to make meaningful inferences about buyer willingness to pay based upon this information. To accomplish this, we develop a theoretical model in which a new car buyer decides whether or not to trade in her old vehicle, and a seller observes this decision and sets the profit maximizing price for the new vehicle. The model allows us to specify the conditions under which a particular buyer will pay a higher or lower price for the new car depending upon her trade-in decision and the characteristics of the traded in vehicle. We test model predictions using data on new car transactions in the premium midsize sedan category occurring between 2002 and 2004. The data also permit us to measure the monetary impact of the information contained in the trade-in decision.

To illustrate the first of two basic insights provided by our model, consider a potential new car buyer who wants to replace her old vehicle. She may decide either to sell it privately or to bring it to a new car dealer as a trade-in. The benefit to the buyer of not trading in is that she

\(^1\) Musical instruments, yachts, and home appliances are other examples of durable goods for which dealers accept trade-ins. Given its prominence, we focus on the automobile context throughout.
can realize a higher price in the used-car market than at the dealer. However, the fact that roughly half of all new car transactions involve a trade-in vehicle (Busse and Silva-Risso 2010) suggests that some new car buyers find the convenience of trading in worth more than the premium from selling the used car privately. If the buyer’s value of this convenience is related to her reservation value for the new car, the dealer can incorporate this information into the new car pricing decision. Our theoretical model of dealer pricing predicts that, all else being equal, the presence of a trade-in has an upward impact on the price of the new car.

The second basic insight is about how the type of traded in vehicle can provide the dealer with additional information about the buyer’s willingness to pay. By trading in, the consumer enables the dealer to observe the make and model of the car she previously owned. If consumers have a tendency to re-purchase the same make and/or same model, then the dealer could potentially make inferences about the buyer’s preference for the new car based on the type of vehicle she trades in. For example, the buyer of a new Honda may indicate a strong preference for Honda if she has an old Honda to trade in. Alternatively, if the consumer considers buying a brand that is considerably different than the brand of the trade-in, the dealer might infer a weak preference for the new car (e.g. a used Ford for a new Lexus). Because a dissimilar trade-in has a downward effect on the dealers’ inference of the buyer’s willingness to pay, this raises the possibility that a trade-in buyer may obtain a lower price by trading in a vehicle. Our model shows that this can occur in equilibrium, but only if the inference from the (dis)similarity is sufficiently large to offset the inference from the decision to trade in.

Our empirical analysis shows general support for our theory of trade-in inferences. First, buyers with a trade-in pay an average of $276 more than non-trade-in buyers. Second, compared to a buyer who trades in a vehicle of a different make and model than the new one, a buyer pays an additional $75 more if the trade-in is the same make as the new car, and $135 more if it is the same make and model. The total trade-in premium amounts to about half of the median dealer margin per car in the data, or $759. Finally, the fact that the trade-in decision itself has a greater impact on price than the (dis)similarity of the trade-in is consistent with the equilibrium conditions required for the total trade-in effect to be positive.

Other research has documented a trade-in effect on the price of a new car. Using survey data, Putsis and Srinivasan (1994) and Goldberg (1996), identify several buyer characteristics that affect the price of a new car, one of which is the presence of a trade-in. They do not,
however, formally identify the underlying reasons for the trade-in effect and are unable to identify the conditions under which new car prices are higher or lower with a trade-in, as is done in this study. Purohit (1995) was perhaps the first to attempt to offer an explanation for the trade-in effect. He posits that the endowment effect (Thaler 1980, Kahneman et al. 1990) kicks in when consumers receive higher valuations for their trade-ins, thus increasing their willingness to pay for the new car. The laboratory studies of Zhu et al. (2008) advocate another behavioral explanation for the trade-in effect attributing it to consumers’ limited mental resources for multiple negotiations. In particular, if consumers feel it is more important to obtain a favorable offer for the trade-in than to pay a low price for the new car, they will devote more resources to the trade-in negotiation. In response, the dealer offers relatively better terms for the trade-in and makes up the difference on the price of the new car. In another series of lab experiments, Srivastava and Chakravarti (2011) find the opposite effect – consumers are more focused on getting a lower price on the new car than on obtaining a higher price on the trade-in.

Our research shows that these existing behavioral explanations are insufficient to explain the findings in our data. First, previous studies rely only on the possibility that dealers “juggle” the trade-in and new car prices by paying consumers a higher [lower] price for the traded in vehicle and then charging them a higher [lower] price for the new car.\(^2\) In contrast, we examine the buyer’s net monetary standing after controlling for the seller’s price juggling. Specifically, our data include the dealer’s over/under-allowance, a measure of how much extra or less the dealer actually offered for the trade-in relative to its actual assessed market value (Scott-Morton et al. 2001). Our empirical analysis controls for the dealer’s over/under-allowance which enables us to identify the net monetary exchange and the financial impact of trade-ins on the entire transaction. Even after adjusting the new car price by the over/under-allowance, \textit{we find that a consumer with a trade-in hands over more money to the dealer than non-trade-in consumers.} We also show that estimates of the trade-in effect are biased when the new car price is not adjusted in this manner. Second, we find that, not only does the presence of a trade-in matter, but that the type of trade-in

\(^2\) For example, a dealer may charge a consumer who trades in $20,500 for a new car whose target value is $20,000, while the dealer pays $5,500 to the consumer for her traded in car whose value is $5,000. This corresponds to a trade-in \textit{over allowance} of $500. Although the consumer pays a higher price for a new car ($=20,500) than an average non-trade-in consumer does ($=20,000), the trade-in consumer does not make any financial gain or loss due to the fact that she trades in a car; she pays $500 more for a new car, while she receives $500 more for a used car.
also plays a significant role in determining the new car’s final price, a factor that cannot be explained by the extant research. In fact, our analysis suggests that the trade-in effect in Zhu et al. (2008) may be over-estimated when not accounting for the type of trade-in.

Another potential psychological explanation for the trade-in effect comes from the notion that consumers face emotional costs when replacing an old product. Okada (2001), for example, finds that the replacement decision is made psychologically easier if the buyer has someone who will take the old product. This research suggests that a new car buyer may be willing to pay a premium to the dealer who accepts her old car as a trade-in. While this is consistent with our finding, it again cannot explain why the type of trade-in should affect the price of the new car. Bruce et al. (2006) point out that some potential new car buyers face a “negative equity” problem with the existing car and may require help from the manufacturer (in the form of a rebate on the new car) to induce replacement. Similar to our research, they illustrate how new car buyers pay effectively different prices depending on the state of their existing car. However, we do not consider the equity state of the existing car and replacement timing. Rather, we focus on the dealer’s inference from the state of trade-in assuming that the buyer is already in the market for a new car.

Our research also relates to the literature on behavior-based price discrimination (c.f. Fudenberg and Villas-Boas 2006). A large body of literature in marketing and economics has shown how firms can incorporate customers' purchase history to improve pricing decisions (e.g. Rossi et al.1996, Besanko et al. 2003). Chen (1997), Taylor (2003), Shin and Sudhir (2010), and Subramanian et al. (2011) identify conditions under which firms can charge higher prices to existing consumers than to the competitors' consumers. Similar to this stream of research, we illustrate how a seller, a new car dealer, utilizes past purchase behavior to price discriminate. However, in our research, we also incorporate a consumer’s decision to hide this information from the seller by choosing not to trade in her used car. Nevertheless, as we show, the decision to not trade in is meaningful information for the seller even if the previous purchase history is unavailable.

Finally, our research also speaks to the question of why dealers in some durable goods categories accept trade-ins. One reason, as noted above, is that dealers can earn profits on the resale of trade-ins (Rao et al. 2009), but other motivations have been identified in the literature. Levinthal and Purohit (1989) suggest that by encouraging consumers to trade in their used
products via rebates or incentives, firms can expedite replacement of old technology products or induce consumers to purchase their products more frequently. Cole et al. (2011) examine the sustainability motives of firms to acquire trade-ins for remanufacture. Our research provides the additional explanation that dealers accept trade-ins to make inferences about a buyer’s willingness to pay. The benefit of accepting trade-ins for price discrimination appears in van Ackere and Reyniers (1995), who argue that accepting trade-ins allows the dealer to price discriminate between first time buyers and those who have previously purchased a product in that category. Our model, in contrast, explicitly recognizes that consumers have the option to sell their used vehicle on the secondary market instead of trading in. As we show, this consideration leads to opposite conclusions about the relative prices that buyers pay.

In the remainder of the paper, we first develop a model of new car pricing, which incorporates inferences about the buyer’s willingness to pay based on the buyer’s trade-in decision and the characteristics of the traded in car. This model allows us to understand how and when car prices will be higher or lower with a trade-in and how the (dis)similarity properties of the trade-in can affect the new car price. We then empirically identify the direction and factors of the trade-in effect using data on prices of new car transactions in the premium midsize sedan market. Finally, we summarize our conclusions and discuss some directions for future research.

2. A Theory of Dealer Inference Using Trade-Ins

In this section, we develop a theoretical model of dealer pricing that illustrates the informational role of the buyer's trade-in decision and the characteristics of the traded in vehicle. The purpose of our model is to lay out the conditions for which dealer inference is possible and then utilize these conditions to empirically identify the effects of trade-ins on new car prices.

The model focuses on the buyer’s decision of whether to trade in her old car to the dealer and on the transacted price of the new car. Our objective is to determine how information contained in the consumer’s trade-in decision can explain differences in price on the same vehicle under, otherwise, same transaction conditions. Therefore, the model does not include dealer competition, heterogeneity in the buyer’s negotiating skills, the timing of manufacturer promotions and a variety of other factors that may also explain variation in the transacted price of a particular automobile, but not affect the informational content of the trade-in decision.
We first specify the set of properties of the distribution of buyer’s private information that permits the seller to make inferences about the buyer’s willingness to pay from the buyer’s trade-in decision. These properties are specified in Section 2.1. Based on these properties, we next examine how the seller utilizes consumers' trade-in information and derive the equilibrium prices, first for the buyer who trades in her used car (Section 2.2) and then for the buyer who sells it privately (Section 2.3). Finally, in Section 2.4, we use the model to delineate the conditions under which trade-ins lead to higher or lower new car prices. At the close of this section, we illustrate the basics of the general model in a worked out example.

2.1 Model Setup

There are two agents in the model: a new car buyer and a seller, whom we refer to as the car dealer. Let $V > 0$ denote the buyer’s willingness to pay for a new car. The buyer possesses a used car that provides information about a past choice that she has made. Because such choices reflect the consumer’s past preferences, they are potentially informative about the consumer’s preference for the new car. We characterize this information by a loyalty index, $t \geq 0$, such that a larger value of $t$ indicates a higher level of loyalty to the new car carried by the dealer. For instance, if the used car is of the same make, or even same model, as the new car, then we assume the buyer is more loyal to the make or model of the new car. Finally, the buyer can either sell her used car privately (e.g. by posting an advertisement and meeting potential buyers) or bring the car to the dealer as a trade-in. We assume that a buyer selling the used car privately incurs cost, $C > 0$, which reflects the effort and/or time transacting the sale. Hence, we characterize a buyer by the triple of random variables $(V, T, C)$ with joint distribution function $F(V, T, C)$ and density $f(V, T, C)$. Dealers do not a priori observe a buyer’s realized $(V, T, C)$ values, but can infer information about these variables from the buyer’s trade-in decision.

The relationships between the pairs of random variables $(V, C)$ and $(V, T)$ play an important role in the ability of the dealer to make inferences about the buyer. For instance, one expects that a higher cost of selling the used car on the private market indicates a higher opportunity cost of time, which may negatively affect a buyer’s incentive to search for comparative prices and imply a higher reservation value for the new car. In addition, the extent to which the used car reflects loyalty to the new car, there would be a positive relationship between the two variables, $V$ and $T$. For example, if a consumer who previously purchased a
certain model intends to purchase a newer version of the same model, then she has a higher willingness to pay for the new car than someone who previously purchased a different model. When these relationships hold, we invoke the following condition:

**A1**: The pairs of random variables \((V, T)\) and \((V, C)\) are affiliated.

The affiliation condition implies that each pair of random variables is positively correlated. As we show later, these conditions are necessary for the dealer to make meaningful inferences when setting prices.

It may appear that our results follow directly from this assumption, but this is not the case. In other words, it is not a priori obvious from the affiliation assumption, whether the trade-in effect will be positive or negative. Our research identifies the different conditions on the joint distribution of \(V, T,\) and \(C\) that lead to a positive sign of the trade-in effect (in Propositions 2 & 3) and this identification plays an important role in empirically testing our theory of dealer inference in the data. Specifically, we empirically assess not only whether the trade-in effect is positive or negative but also whether the conditions in the data correspond to those identified by our theory. Thus, our theoretical model is a means to empirically check whether dealer inference can help explain the observed trade-in effect rather than simply a prediction of it.

The game begins with the consumer, who, upon realization of her private information \((v, t, c)\), decides whether or not to bring her used car as a trade-in to the new car dealer. Next, the dealer observes this decision and determines the optimal price for the new car. The model assumes that the prices of the used car under the trade-in or private sale conditions, respectively, are fixed and known to both the buyer and seller. This assumption simplifies the model and permits us to focus on how the dealer utilizes trade-in information to extract surplus from the buyer.

If the buyer faces a new car price \(p\), then she buys if and only if \(V \geq p\). Therefore, given a marginal distribution of \(V, F_v(v)\), the probability the buyer purchases the new car at price \(p\) is \(1 - \)
We assume that the probability of a consumer's purchase at a given price, normalized by the density, does not increase with \( p \). This requires that all marginal distributions of \( V \) are regular, in the sense that they have non-increasing inverse hazard functions.

**A2**: For all relevant marginal distributions of \( V \), the inverse hazard function

\[
\Phi(p) = \frac{1 - F_\pi(p)}{f_\pi(p)}
\]

is non-increasing in \( p \).

Most common distributions exhibit a non-increasing inverse hazard function, which, in our context, reflects the notion that consumer demand is weakly decreasing in price.

The consumer decides to sell her used car privately if, and only if, her cost of selling, \( C \), does not exceed some threshold. This threshold, which we denote as \( s \), is the sum of the premium she would obtain on the private market and the difference in the new car price with and without a trade-in. Mathematically \( s \) is expressed as:

\[
s \equiv k + (p_{TI} - p_{NTI}).
\]

\( p_{TI} \) and \( p_{NTI} \) represent the new car prices paid by the consumer under the trade-in (\( TI \)) and no trade-in (\( NTI \)) conditions, respectively. Note that a strategic consumer correctly anticipates the price difference \( p_{TI} - p_{NTI} \) in equilibrium and, therefore, recognizes how the dealer can use all information contained in the trade-in decision.\(^5\) The parameter \( k > 0 \) denotes the *private-sale premium* that the buyer can realize by selling the used car privately rather than by trading it in to the dealer. We assume that \( k \) is exogenous and common knowledge – known by all parties involved – based on the fact that information sources about prices in the used car market (e.g., Kelley Blue Book) are widely available.\(^6\) The consumer trades in her used car if her cost, \( C \), exceeds benefit, \( s \). Otherwise, she sells it privately. We first analyze the case in which a consumer brings in her used car.

### 2.2 Buyer with Trade-In

If a buyer brings her trade-in, then the following condition must hold:

\[
C > s.
\]

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\(^5\) The qualitative implications of our theory also hold under the assumption that the buyer is not fully strategic (e.g. boundedly rational) and does not anticipate the dealer’s use of trade-in information.

\(^6\) It is possible, however, to view \( k \) as privately observed by the buyer. Some buyers, for example, may have more knowledge than others about the used car market. The basic results remain unchanged when \( k \) is private information.
The dealer observes the loyalty index of the used and new cars \( T=t \) and chooses \( p_T \) to maximize expected profit:

\[
(p_T - w) \times \left[ 1 - F_v(p_T \mid T=t, C > s) \right],
\]

where \( w \) is the dealer's wholesale price and \( F_v \) denotes the distribution function of \( V \) conditional on the decision to trade in and the trade-in type. The profit-maximizing price with observed trade-in must satisfy the following first order condition:

\[
(p_T - w) \left[ 1 + \frac{(\partial F_v / \partial s)(\partial s / p_T)}{f_v(p_T \mid T=t, C > s)} \right] - \frac{1 - F_v(p_T \mid T=t, C > s)}{f_v(p_T \mid T=t, C > s)} = 0. \tag{4}
\]

We can interpret the dealer’s trade-off in (4) by considering the classic marginal revenue of a monopolist. If we interpret probability of purchase as quantity, \( q = 1 - F(p) \), then \( p = F^{-1}(1 - q) \). The corresponding optimization, \( \max_q [p(q) - w]q \), then leads to following trade-off.\(^7\) Increasing the probability of purchase by lowering price enables the dealer to earn additional expected revenue: \( (p_T - w)f(p) \). But this implies a lower price to all possible consumer types with \( V > p_T \), a loss measured by \( 1 - F(p) \). Normalizing by \( f(p) \) gives \( (p - w) - \frac{1 - F(p)}{f(p)} = 0 \), which is reflected in (4) but without the bracketed term multiplying the dealer margin.

The distinction between the classic monopolist problem and ours is the fact that changes in the new car price affect the buyer’s relative benefits of trading in and the corresponding inference about \( V \). This effect is represented by the second term inside the closed brackets on the left hand side of (4). To understand this effect, first note that \( \partial F_v / \partial s \) is negative (by A1) and \( \partial s / \partial p_T = 1 \) from (1). The negative sign of this term reflects the fact that, as the dealer decreases the new car price, it lowers the threshold for the trade-in decision in (2). The dealer, therefore, infers a lower \( V \) when the buyer brings a trade-in. We refer to this effect as the \textit{trade-in deterrent effect of price} and assume it does not dominate the dealer’s central trade-off between margin and purchase. Formally, this requires that the term in closed brackets is positive or, equivalently, that \( \psi = f_v + \partial F_v / \partial s > 0 \).

Figure 1 depicts the two terms on the left hand side of (4). The first term is upward sloping in \( p \) under the condition on \( \psi \), while the second term, abbreviated by \( \Phi_T(p,t,k) \), is

\(^7\) This interpretation is due to Bulow and Roberts (1989).
decreasing in \( p \) by A2. The intersection of these two curves represents the equilibrium new car price when the buyer brings a trade-in.

We are interested in two properties of the equilibrium new car price paid by a trade-in consumer, \( p_{TII}^* \). The first regards how \( p_{TII}^* \) changes with respect to the loyalty index, \( T = t \) and to the private-sale premium, \( k \). Afterwards, we compare \( p_{TII}^* \) with the corresponding equilibrium price, \( p_{NTII}^* \), when the buyer does not bring a trade-in to the dealer. The first property is described in the following proposition.

**PROPOSITION 1:** Suppose the buyer brings a trade-in, A2 holds and
\[
\psi_t - \psi_k < -\left(\frac{\partial F_v}{\partial x} \right) \left(1 - \frac{\partial F_v}{\partial x}\right), \text{ for } x \in \{t,k\}.
\]

(i) If \( V, C, \) and \( T \) are independent, the dealers’ optimal price \( p_{TII}^* \) is invariant to changes in \( t \) and \( k \).

(ii) Under assumption A1, however, the dealers’ optimal price, \( p_{TII}^* \), is increasing in loyalty index, \( t \), and the private-sale premium, \( k \).

The proposition confirms that a positive relationship between willingness to pay and the trade-in variables is necessary for the dealer to utilize inferences in its pricing of the new car. Under the conditions of part (ii) of the proposition, the price of a new car is higher when the buyer brings a trade-in vehicle which is more similar to the new vehicle and thus, has a higher loyalty index. Note that A1 implies that \( \Phi_{TII}(p,t,k) \) is increasing in \( t \) and \( k \) for all \( p \). This implication is depicted in Figure 1 by the arrow representing an upward shift in the \( \Phi_{TII}(p,t,k) \) curve. As \( t \) or \( k \) increases, the dealer assigns more weight on the higher values of the buyer’s \( V \) and the intersection point shifts rightward, corresponding to an increase in the equilibrium price, \( p_{TII}^* \).
The upward sloping curve, representing the left-most term in (4), is also subject to changes in $t$. As the loyalty index, $t$, increases, the marginal density $f_v$ may increase or decrease, depending on the realized value of $V$. For example, if $V$ is relatively large [small], then density $f_v$ will increase [decrease] with $t$ or $k$. If the trade-in deterrent effect of price is highly sensitive to changes in $t$ or $k$, then a small change could drastically alter the decision to bring a trade-in. The condition on $\psi$ in Proposition 1 ensures that a change in loyalty index $t$ or private sale premium $k$ does not affect the trade-in deterrent effect of price more than it affects the direct effect of $t$ or $k$ on the dealer’s inference of $V$. Figure 1 depicts this condition by the fact that the upward sloping curve does not shift to the left much relative to the shift in the curve $\Phi_{TI}$.

2.3 Buyer without Trade-In

Now suppose that the consumer does not trade in her old vehicle. In this case, the only inference the dealer can make is that the consumer’s cost of selling the used car does not exceed the premium from selling it privately, i.e.,

$$C < k + E_T(p_T) - p_{NTI} = \hat{s},$$

which reflects the fact that, without a trade-in, the dealer can only form an expectation of the price that could be realized with a trade-in. The dealer then chooses new car price, $p_{NTI}$, to maximize the expected profit:

$$(p_{NTI} - w) \times [1 - F_v(p_{NTI} \mid C < \hat{s})],$$

which leads to the following first order condition:

$$\left(p_{NTI} - w\right) \left[1 + \frac{\partial F_v / \partial \hat{s}}{f_v(p_{NTI} \mid C < \hat{s})} \frac{\partial \hat{s} / \partial p_{NTI}}{1 - F_v(p_{NTI} \mid C < \hat{s})} - \frac{1 - F_v(p_{NTI} \mid C < \hat{s})}{f_v(p_{NTI} \mid C < \hat{s})}\right] = 0.$$ (7)

The interpretation of (7) is similar to that of (4). In contrast to the trade-in case, however, the expression in closed brackets on the left-hand side of (7) is greater than unity, since $\partial \hat{s} / \partial p_{NTI} = -1$, while $\partial F_v / \partial \hat{s}$ is negative under A1. This lowers the optimal level of $p_{NTI}$, since the dealer seeing no trade-in infers that the consumer has a very low $C$ and, therefore, a low $V$. Our assumptions ensure that (7) defines a unique solution to the dealer's optimization problem when pricing to consumers with no trade-in. We denote this optimal price as $p_{NTI}^*$ and now compare this equilibrium price to that with a trade-in.
2.4 Comparing New Car Prices with and without Trade-In

We first examine the condition under which a trade-in leads to either a higher or lower price of the new vehicle. Let $\Phi_{NTI}(p)$ denote the second term on the left-hand side of (7), which is non-increasing in $p$ by A2. Comparing (4) and (7), we see that $p_{NTI}^* < p_{TI}^*$ if $\Phi_{NTI}(p) < \Phi_{TI}(p,t,k)$ for all $p$. To compare these two functions we must specify an additional property on the marginal distribution of $V$ conditional on $T$. This property is given in Proposition 2.

**PROPOSITION 2** Under A2 the dealer has a unique equilibrium pricing strategy characterized by $(p_{TI}^*, p_{NTI}^*)$. Furthermore, we have the following.

(i) If $V$, $C$, and $T$ are independent then $p_{NTI}^* = p_{TI}^*$.

(ii) Suppose A1 holds and $\Phi_{TI}(p,t,k)$ is non-convex in $t$. Then, if the buyer brings a trade-in with $t \geq T$, the price is higher than with no trade-in: $p_{NTI}^* < p_{TI}^*$.

This proposition demonstrates that the dealer cannot exploit buyers’ trade-in decision if willingness to pay $V$ is independent of both $C$ and $T$. Alternatively, under A1, if the trade-in vehicle has above the (unconditional) average loyalty index of the focal vehicle, then the dealer's price will be higher than it would be without the trade-in. The non-convexity property on $\Phi_{TI}$ in the proposition, stated loosely, means that for any trade-in consumer ($C > s$), price sensitivity does not increase as the trade-in becomes more similar in make and model. Figure 1 graphically characterizes Propositions 1 and 2.

Now we turn to the possibility of obtaining the reverse result. That is, under what circumstances does bringing a trade-in lead to a lower price ($p_{NTI}^* > p_{TI}^*$)? Recall that bringing a trade-in, regardless of the loyalty index, $t$, gives the dealer an upward inference on $V$ since the new car buyer reveals a high cost of private selling of the used car (e.g. low $k$). For the dealer to be convinced that $V$ is low in spite of this, the used car must be very dissimilar (very low $t$). Proposition 3 gives these conditions formally.

**PROPOSITION 3** Let $(p_{TI}^*, p_{NTI}^*)$ be the unique equilibrium pricing strategy under A1 and A2. Suppose there exist thresholds $\eta_1, \eta_2 > 0$ such that for all $p$
(i) The distribution function $F$ satisfies
\[ \frac{\partial F_s}{\partial s} \bigg|_{f_c(p,C<s)} - \frac{\partial F_s}{\partial s} \bigg|_{f_c(p,C>s)} < \eta_1. \]

(ii) \[ \Phi_{TI}(p,\tilde{T},k) - \Phi_{NTI}(p,\tilde{t},k) > \eta_2 \text{ for some } \tilde{t} < \tilde{T}. \]

If the conditional inverse hazard function $\Phi_{TI}(p,t,k)$ is non-concave in $t$ then $p_{TI}^* < p_{NTI}^*$ for all $t < \tilde{t}$.

The important implication of Proposition 3 is that the outcome $p_{TI}^* < p_{NTI}^*$ requires a more stringent set of conditions than required for the opposite outcome: $p_{TI}^* > p_{NTI}^*$. Because we use this result to identify supporting conditions in the data, it is helpful to understand the conditions of this proposition. Intuitively, condition (i) states a property of the buyer preferences (as characterized by the distribution function $F$) such that the upward inference from the decision to trade in is small while condition (ii) states that the used car is extremely dissimilar to the new car. If both (i) and (ii) hold, then the buyer can obtain a lower price on the new car by trading in.

To envision these conditions graphically, they would appear in Figure 1 with the two upward sloping curves close together (condition (i)) and the $\Phi_{TI}(p,t,k)$ curve lying everywhere below $\Phi_{NTI}(p)$ (condition (ii)).

2.5 Illustrative Example

It is possible to illustrate the workings of our general theory using a worked out example.

Suppose the distribution of $(V, T, C)$ on the unit cube $[0,1]^3$ is characterized simply by the conditional distribution function:
\[ \Pr[V > p \mid T = t, C = c] = \frac{1}{2}(1 - p + t + c). \] (8)

This distribution represents the purchase probability of the buyer conditional on the trade-in loyalty index being $t$ and the private cost being $c$. Note that this probability is decreasing in $p$ and increasing in $t$ and $c$ and the probability of purchase is 1 when $p = 0$, $t = 1$, and $c = 1$. If the buyer brings a trade-in, then (8) (after conditioning on $T = t$ and $C > s$) implies the expected profit for the dealer is $(p_{TI} - w)\left(1 - \frac{1}{2}(1 - p_{TI} + t - \frac{1}{2})\right)$, where $s$ is defined by (1). The seller’s first-order condition implies:
\[ (p_{TI} - w)[1 - \frac{1}{2}] = (1 - p_{TI} + t - \frac{1}{2}). \] (9)
It is instructive to compare this condition with its general counterpart in (4). The bracketed term on the LHS of (9) represents $\psi$ in the general model. In particular, the $-\frac{1}{2}$ appearing here is the (normalized) trade-in deterrent effect of price, or $(\partial \hat{\psi} / \partial \hat{p}_{TI}) (\partial \hat{F}_{p} / \partial \hat{F}_{s})$. Note also that the entire term is positive, $\psi > 0$, which ensures that the trade-in deterrent effect of price does not dominate the dealer’s direct margin-purchase trade-off. If the buyer does not bring a trade-in, then using (8), we write the dealer’s expected profit (conditional only on $C < \hat{s} = k + E_{s} (p_{TI} - p_{NTI})$) as $(p_{NTI} - w) \frac{1}{3}(\frac{3}{2} - p_{NTI} - \frac{1}{2})$. The first-order condition yields:

\[(p_{NTI} - w)[1 + \frac{1}{3}] = (\frac{3}{2} - p_{NTI} - \frac{1}{2}). \quad (10)\]

In contrast to the buyer with trade-in case in (9), the bracketed term is larger than unity since $(\partial \hat{s} / \partial \hat{p}_{NTI}) (\partial \hat{F}_{p} / \partial \hat{F}_{s}) > 0$. A marginal increase in the $NTI$ price encourages the buyer to sell the used car privately. Solving (9) and (10) simultaneously leads to the equilibrium pricing strategy of the dealer:

\[
p_{TI}^* = \frac{1}{13}(15 + 5k + 12t + 3w)\\
p_{NTI}^* = \frac{1}{13}(10 + 3k + 7w). \quad (11)\]

As indicated by (11) and established in Proposition 1, $p_{TI}^*$ is increasing in $t$ and $k$. Note as well that trade-in price is larger than the no trade-in price under the fairly weak conditions of Proposition 2, namely, as long as $t > \frac{1}{12}(4w - 5 - 2k)$, $p_{TI}^* - p_{NTI}^* > 0$. However, this example also shows that if wholesale price $w$ is large while $k$ and $t$ very small, then $p_{NTI}^*$ can, in fact, exceed $p_{TI}^*$. In other words, a buyer of an expensive new car (large $w$) may be able to get it at a lower price (relative to the no trade-in case), if she trades in a used car very dissimilar to the new one (very small $t$) and with a small private-sale premium (small $k$). As in the general case, this example suggests that the conditions under which the new car price will be lower when the buyer brings a trade-in are considerably more stringent than those for which the new car price will be higher with a trade-in.

3. Empirical Evidence

As illustrated above, if willingness to pay is correlated with the loyalty index of the trade-in and the cost of private selling, then dealers should, in theory, be using this information in the pricing
of the new car. In this section, we examine whether there is empirical evidence that dealers actually utilize this information. The model of section 2 aids our empirical strategy. Specifically, we use data on new car transactions to estimate a pricing equation to identify whether a trade-in effect exists and, if so, determine the factors affecting its magnitude and direction. Furthermore, if there is a systematic pattern of a trade-in effect, our theory provides specific conditions for its sign, with which we can compare the conditions in the data.

We first describe the data used. We then describe the formation of our empirical pricing model and how it is constructed to identify the presence of any trade-in effects. Finally, we present the estimated parameters of the pricing model and discuss how they relate to our theoretical predictions.

3.1. Data

Power Information Network (PIN), a division of J.D.Power and Associates, collects new vehicle transaction data from a large number of dealers. It acquires information on details of transactions from participating dealers electronically, and cleans the information, decodes it, and removes any confidential information. The data used in this study come from a transaction history of new car purchases in the premium midsize sedan category made by consumers in Southern California in 2002, 2003 and 2004. Our data set consists of a total of 124,499 new car transactions for one of the twelve top-selling models that together accounted for about 92% of transactions in this category. The data captures several details of each transaction including the price each individual consumer paid for the vehicle, the annual percentage rate (APR) for finance and lease contracts, the monthly payment amount, manufacturer rebate (if any) and the residual value of the vehicle if it was leased. Table 1 reports descriptive statistics for the data in our sample including market shares for each vehicle expressed as a fraction of the 93% total share of all the vehicles together. We also leverage U.S. census data by linking each of the transactions with census data at the census block level (Scott-Morton et al. 2001, Silva-Risso and Ionova 2008).

All statistics are based on the observations in our data set.
3.2. Model Variables

3.2.1. Dependent Variable. We define price as how much the consumer pays for the new vehicle, including manufacturer- and dealer-installed accessories and options. Conceptually, our dependent variable should represent the net monetary exchange of the entire transaction. We measure this by making two adjustments to the observed car prices. First, we subtract any cash rebate offered by the manufacturer, which represents a discount that a consumer can avail without investing additional effort. This may include loyalty cash rebates offered to customers who purchase the same make vehicle as they previously owned. Second, unlike previous research on trade-ins (e.g. Zhu et al. 2008) we adjust for any trade-in over- or under-allowance in the transaction, which represents the difference between the price that the dealer pays the consumer for the traded in car and its actual second-hand market or auction value (Scott-Morton et al. 2001). This adjustment controls for the possibility that dealers may pay consumers a higher [lower] price for the traded in vehicle and then charging them a lower [higher] price for the new car. Thus, our dependent variable is the net monetary exchange of the entire transaction, and enables us to examine the impact of both incidence and characteristics of trade-ins after controlling for behavioral explanations that have been studied in previous research.

Our objective is to test whether consumers who traded in a used vehicle paid a systematically different price for the same new car than those who did not, and whether the prices were affected by the similarity of trade-in, in make and model, relative to the new vehicle for those consumers who traded in. To this end, we include trade-in incidence and loyalty variables as well as other control variables that may impact new car transaction prices.

3.2.2. Trade-In Incidence and Loyalty Variables. Trade-in incidence and loyalty are characterized by indicator variables TRD_i, TMAKE_i, and TMODEL_i: TRD_i takes the value 1 if consumer i traded in her used car, 0 otherwise. The variable TMAKE_i (TMODEL_i) takes the value 1 if the traded in vehicle is the same make (model) as the new vehicle purchased by consumer i, 0 otherwise, thus capturing the loyalty between the traded in vehicle and the new one.

3.2.3. Control Variables. We include six sets of control variables to capture the impact of other new car characteristics on transaction prices. First, we define a vehicle as the interaction of make, model, model year (MY), body type, transmission, number of doors, number of cylinders, and displacement, and include fixed effects for each vehicle. For example, a Toyota Camry, MY2004,
sedan, with automatic transmission, 4 doors, 6 cylinders, and a 2.4 L engine would have its own fixed effect. It is possible that new car options and accessories, such as a navigation system for example, which are not directly observed in our data can also lead to different prices on otherwise similar vehicles. Therefore, because cars with more expensive options and accessories will also tend to have higher than average wholesale prices, we also include the variable CostDev, which is the amount by which the wholesale price of the car purchased by consumer i differs from the average wholesale price of all other cars in our dataset with the same observed vehicle characteristics, expressed as a percentage of the average wholesale price (Zettelmeyer et al. 2006).

Previous research has found that consumer demographics play a significant role in explaining bargaining power in new car price negotiations (Chen et al. 2008), consumer information search behavior on the internet (Ratchford et al. 2003), and, ultimately, the prices paid by consumers (Scott-Morton et al. 2003). Therefore, second, we also include consumer gender and census-block level demographic variables such as education, vocation, income, race distribution, housing, and household expenditure. Specifically, we include the variables Male, a fixed effect for male consumers, and Asian%, White%, Black%, and Hispanic%, the corresponding percentage of Asians, Whites, Blacks, and Hispanics in the census block, respectively. Education variables, NoHighSchool% and CollegeGrad%, the percentage of residents who did not finish high school and who graduated college, respectively, are also included. The variables HouseOwn% (percentage of households who own a home), MedianHouseValue, MedianAnnualIncome, and AnnualHouseholdExpenditure control for the impact of the consumer's wealth and income on the new car price. Squared values of these variables are also included to allow for nonlinear effects.

Third, as in previous research (Scott-Morton et al. 2003, Busse et al. 2006), we control for time-related factors by including year, month, and week fixed effects and two dummy variables for purchases made on the weekend or towards the end of the month. Specifically, Weekend equals 1 if the vehicle was sold on a Saturday or Sunday, and 0 otherwise, and EndOfMonth equals 1 if the vehicle was sold during the last five days of a month, 0 otherwise. These variables account for the fact that dealers may price vehicles more aggressively during these periods, to coincide with advertised specials or sales targets. The fixed effects of year, month, and week control for changes in manufacturer pricing and promotion schedule.
Fourth, we control for dealer-related factors by including dealer fixed effects for each one of the 262 dealers in our sample. We also include the variable $DaysInStock_i$, the number of days that have elapsed since the vehicle arrived at the dealer’s lot, which controls for the dealerships opportunity cost of keeping the car (not selling it) as well as its inventory carrying cost.

Fifth, it is important to consider the mode by which the new car was acquired, because each mode has unique acquisition costs and is supported by specific manufacturer and dealer promotions (Dasgupta et al. 2007). Three modes of acquisition are observed in the data: cash, finance, and lease. Cash transactions refer to those in which the consumer purchased the vehicle with funds from outside the dealer system, finance transactions are those purchased with dealer financing, while the remainders are transactions in which vehicles were not purchased outright, but leased through the dealer network. Therefore, our model controls for transaction type via dummy variables for Cash and Lease transactions, with Finance transactions being the default. We also include three dummy variables to capture variations in the Annual Percentage Rate (APR) of the lease and financing contracts: $APR1 (APR5, APR10)$ equals 1 if $APR<1 (1\leq APR <5, 10 \leq APR)$, 0 otherwise.

Finally, we also control for other characteristics of the traded in car that may be correlated with the new car price. Ray et al. (2005) find that trade-ins of a more recent vintage result in a lower price for the new good. We therefore include three indicator variables that represent the vintage of the traded in vehicle: $NewVintageTrade$ equals 1 if the traded in vehicle was less than one year old), 0 otherwise, and $RecentVintageTrade$ equals 1 if the traded in vehicle was more than one year old and less than five years old (the median vintage of trade-ins in our data), 0 otherwise. $OldVintageTrade$ equals 1 if the traded in vehicle was more than ten years old, 0 otherwise. We also include the variable $TradeACV$, the actual cash value of the traded in car because it is likely to be positively correlated with the price premium that a consumer can obtain in the private market and, therefore, be a source of inference for the dealer.

Table 2 reports summary statistics for the model variables. We note that the substantial variation in variable values supports our ability to identify their impact on vehicle transaction prices. The mean value of the $TRD_i$ variable indicates that 29.12% of consumers in our sample traded in a used car to the dealer when purchasing a new vehicle. The corresponding values of the $TMAKE_i (TMODEL_i)$ variables indicate that 11.80% (6.28%) of all consumers, or 40.52%
(21.57%) of those who traded in their old cars, also re-purchased a new car of the same make (model) as their old one.

3.3. Model Estimation and Results

We estimated a linear regression model to quantify how transaction characteristics affect new car prices. Specifically, the log of price consumer $i$ paid for a new vehicle, $p_i$, (adjusted as described in Section 3.2.1) is specified as:

$$\ln(p_i) = \alpha + X_i \beta + TRD_i (\lambda_1 + \lambda_2 TMAKE_i + \lambda_3 TMODEL_i) + \epsilon_i.$$  

(12)

The vector $X_i$ includes all the control variables described in the previous section. The first column in Table 3 [Model 1] reports the parameter estimates from the regression and shows that the coefficients of the trade-in incidence and loyalty variables (i.e., $TRD_i$, $TMAKE_i$ and $TMODEL_i$) are all positive and statistically significant. Thus, consumers who traded in their old vehicle to the dealer paid $\exp(0.01261) - 1 = 1.27\%$, or $276$ more, consumers trading in a vehicle of the same make as their new one paid $1.61\%$, or $351$ ($276 + 75$) more, and those who traded in the exact same vehicle model, paid $1.89\%$, or $411$ ($276 + 75 + 60$) more than consumers who did not trade in their used cars. Considering the fact that median dealer margin per car is $759$ in our data, we find that the trade-in premium plays a significant role in determining dealer profits. There are five ways in which these results support the notion that dealers use trade-in information to set new car prices and that the trade-in effects are not purely a result of the behavioral biases identified in previous research (e.g. Zhu et al. 2008).

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9 We conducted a Harrison-McCabe test (Harrison and McCabe 1979) to find that the variance of error terms are constant, that is, homoskedastic (p-value=1.00), and a Kolmogorov-Smirnov test (Bartlett 1978) to find that the error terms are not auto-correlated (p-value=0.92).
First, the finding that trade-in consumers pay more for a new car than non-trade-in consumers is consistent with the idea that dealers infer a high willingness to pay among consumers who bring a trade-in. Furthermore, according to our theory, a trade-in consumer who has a higher cost threshold, \( s \), also has a higher expected cost of selling privately, and this threshold is an increasing function of the private sale premium, \( k \). All else being equal, a dealer who observes a trade-in with a high resale value can infer that the buyer could have obtained a considerably better price for the trade-in than the dealer would offer. But because the buyer is trading in despite this, the dealer infers a high \( V \) and charges accordingly. The positive coefficient for the \( TradeACV \) variable supports the prediction in Proposition 1 regarding the positive impact of \( k \) on new car price.\(^{10}\)

Second, the regression results indicate that, among consumers who trade in their old vehicle, those who re-purchase the same make and model pay more than those who purchase a different vehicle. We interpret this as support for another key aspect of our dealer inference theory, i.e. that dealers use the traits of the buyer’s trade-in to assess the buyer’s preference for the new car. This result provides an answer to a question of whether sellers in automobile industry reward the company's previous customers. Although manufacturers or retailers sometimes offer cash rebates to the company's own customers, they still charge higher prices to the loyal consumers.

Third, we further examine the impact of the two loyalty variables (\( TMAKE_i \) and \( TMODEL_i \)) on new car prices. We estimated a nested version of our model after dropping the two loyalty variables. This model whose estimated parameters are shown under Model 2 in Table 3, is representative of how trade-in effects have been documented in existing research (e.g., Zhu et al. 2008). We compare the estimate for \( TRD_i \) in Model 2 (1.423, standard error = 0.077) to that from the proposed model (Model 1) using the approach of Clogg et al. (1995) and find that the two estimates are significantly different (t-statistic = 6.14). This shows that not accounting for the loyalty effect can significantly overestimate the trade-in premium.

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\(^{10}\) For formal illustration, let \( KBB \) be the private market used-car value and suppose that \( TRDACV = \gamma KBB \), where \( \gamma \in (0,1) \). If the dealer makes a fixed percentage margin \( m \) on each trade-in, the buyer’s trade-in premium is written as the proportional relationship: \( k = TRDACV \left( \frac{1}{\gamma} - \frac{1}{m+1} \right) \).
Fourth, we also investigate the extent to which ignoring the trade-in over- or under-
allowance impacts the estimate of the trade-in effect by replacing the dependent variable in
Model 1, with the unadjusted price and re-estimating the model. The parameter estimate of $TRD_i$
for this model [Model 3 in Table 1] is 2.978 (standard error = 0.085), which translates into a
trade-in premium of $658, 138% larger than the estimate from Model 1. We conclude that
ignoring the trade-in allowance (as done in previous research) can significantly bias the
estimated trade-in effect upward.

Finally, since the data reveal that trade-in buyers systematically pay more than non-trade-
in buyers, we can use Proposition 3 as a further check on our theory. Recall that Proposition 3
implies (by contraposition) that if $P_{TRI}^* > P_{NTI}^*$ then (i) the impact of the trade-in decision on the
new car price outweighs the impact of trade-in similarity; and (ii) trade-in vehicles tend to be
relatively similar to the new car. Indeed, the trade-in effect is significantly greater than the
similarity effect ($276 versus $75 + $60) and our data also indicate that 64% of trade-in vehicles
are the same country of origin, 59% have the same number of cylinders, and 58% have the same
body type as the new vehicle purchased, i.e. buyers tend to re-purchase similar cars. We find this
effect after controlling for the behavioral biases that have been examined in previous research.
Specifically, the data show that the net monetary exchange of the entire transaction is favorable
to consumers who do not trade in a used vehicle.

In summary, the empirical analysis lends support to the notion that by accepting trade-ins
dealers can differentiate between those who have a high cost of private selling from those who
do not, more accurately assess a buyer’s willingness to pay, and hence adjust their prices
accordingly. This implies that in a world in which dealers did not accept trade-ins they would
tend to charge a lower than optimal price to consumers with a trade-in, while charging a higher
than optimal price to those consumers who did not trade in.

4. Conclusion

The purpose of this research was to examine how the transacted price of a durable good can be
affected by the information contained in a buyer’s decision to trade in and the traits of the trade-in.
We developed a theoretical model, in which the seller could make inferences about the
buyer’s willingness to pay based on the presence of a trade-in. We used the model to determine
the conditions under which the transacted price of the new good will be positively or negatively affected by the presence of a trade-in. Using transaction data from new car purchases, we empirically identified a positive trade-in effect. That is, new car prices were higher for buyers who brought their old vehicle as a trade-in. Furthermore, the theoretical conditions for a positive trade-in effect matched the conditions of our data. Finally, the data also indicated that buyers with trade-ins that were more similar to the new car paid higher prices than buyers with less similar trade-ins. These regularities provide empirical support for the informational role of product trade-ins in the pricing of a new durable good. While previous research has discussed the role of trade-ins in the price of new products, we show that a retailer incorporates, not only the consumer’s decision whether or not to trade in a used product, but also the characteristics of the traded in product. Furthermore, we have established that a trade-in effect can be result of rational inferences instead of only behavioral factors identified in previous research.

This research leaves several future research directions to be explored. First, our theoretical model assumes that each consumer who purchases a new car currently owns a used car that she can either trade in or sell privately. To minimize the possibility that consumers in our sample consist mainly of first-time buyers, who may not have a used car that they could trade in, we chose to analyze data from the premium midsize sedan category, a category in which first-time buyers are rare. Future research, however, may extend our work by incorporating first time buyers in dealer inference and comparing that to the case of replacement buyers.

Second, our work shows the existence of trade-in premiums in new car pricing. Since new car prices are individually transacted, some consumers [dealers] may have a higher bargaining ability to pay a lower [charge a higher] trade-in premium. Future research may identify the characteristics of consumers with which the amount of trade-in premiums vary.

Third, our focus was on dealers’ reactions to the presence and the type of a trade-in in a buyer-seller dyad. Since the incidence and the type of trade-ins serve as a source of new car price variation, future research may examine whether and how dealers’ incorporation of consumer trade-in information in new car pricing impacts on dealer competitions.
REFERENCES


Table 1: Descriptive Statistics of New Vehicle Models in the Premium Midsize Segment

<table>
<thead>
<tr>
<th>Make and Model</th>
<th>Average Price ($)</th>
<th>Average Rebate ($)</th>
<th>Market Share</th>
</tr>
</thead>
<tbody>
<tr>
<td>Honda Accord</td>
<td>21,401</td>
<td>0</td>
<td>30.78 %</td>
</tr>
<tr>
<td>Nissan Altima</td>
<td>21,306</td>
<td>250</td>
<td>24.45 %</td>
</tr>
<tr>
<td>Toyota Camry</td>
<td>20,606</td>
<td>410</td>
<td>21.98 %</td>
</tr>
<tr>
<td>Nissan Maxima</td>
<td>28,377</td>
<td>340</td>
<td>5.38 %</td>
</tr>
<tr>
<td>Volkswagen Passat</td>
<td>25175</td>
<td>110</td>
<td>3.95 %</td>
</tr>
<tr>
<td>Volvo S40</td>
<td>24,174</td>
<td>30</td>
<td>2.20 %</td>
</tr>
<tr>
<td>Toyota Avalon</td>
<td>28,903</td>
<td>30</td>
<td>2.03 %</td>
</tr>
<tr>
<td>Mazda 6</td>
<td>21,928</td>
<td>1,250</td>
<td>1.84 %</td>
</tr>
<tr>
<td>Ford Taurus</td>
<td>20,659</td>
<td>2,160</td>
<td>1.61 %</td>
</tr>
<tr>
<td>Chevrolet Impala</td>
<td>23,044</td>
<td>2,580</td>
<td>1.58 %</td>
</tr>
<tr>
<td>Subaru Outback</td>
<td>25,588</td>
<td>250</td>
<td>1.47 %</td>
</tr>
<tr>
<td>Mitsubishi Galant</td>
<td>20,032</td>
<td>910</td>
<td>1.40 %</td>
</tr>
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</table>
Table 2: Summary Statistics for Model Variables Used in the Regression

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>Standard Error</th>
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</thead>
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<td>NoHigh School (%)</td>
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<tr>
<td>Model 1</td>
<td>Model 2</td>
<td>Model 3</td>
</tr>
<tr>
<td>---------</td>
<td>---------</td>
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</tr>
<tr>
<td><strong>Trade-In Allowance</strong></td>
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<td>Adjusted</td>
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<tr>
<td>TRD</td>
<td>1.261*</td>
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<tr>
<td></td>
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<td>(0.077)*</td>
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<td>-0.004</td>
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<td>(0.041)</td>
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<td>Asian (%)</td>
<td>-0.022</td>
<td>-0.022</td>
</tr>
<tr>
<td></td>
<td>(0.005)*</td>
<td>(0.005)*</td>
</tr>
<tr>
<td>White (%)</td>
<td>0.003</td>
<td>0.003</td>
</tr>
<tr>
<td></td>
<td>(0.005)</td>
<td>(0.005)</td>
</tr>
<tr>
<td>Black (%)</td>
<td>0.030</td>
<td>0.030</td>
</tr>
<tr>
<td></td>
<td>(0.006)*</td>
<td>(0.006)*</td>
</tr>
<tr>
<td>Hispanic (%)</td>
<td>0.012</td>
<td>0.012</td>
</tr>
<tr>
<td></td>
<td>(0.003)*</td>
<td>(0.003)*</td>
</tr>
<tr>
<td>NoHigh School (%)</td>
<td>0.003</td>
<td>0.004</td>
</tr>
<tr>
<td></td>
<td>(0.003)</td>
<td>(0.003)</td>
</tr>
<tr>
<td>College Grad (%)</td>
<td>-0.002</td>
<td>-0.002</td>
</tr>
<tr>
<td></td>
<td>(0.003)</td>
<td>(0.003)</td>
</tr>
<tr>
<td>BlueCollar (%)</td>
<td>0.002</td>
<td>0.002</td>
</tr>
<tr>
<td></td>
<td>(0.003)</td>
<td>(0.003)</td>
</tr>
<tr>
<td>MedianHouseValue</td>
<td>-0.037</td>
<td>-0.037</td>
</tr>
<tr>
<td></td>
<td>(0.017)*</td>
<td>(0.017)</td>
</tr>
<tr>
<td>HouseOwn (%)</td>
<td>0.491</td>
<td>0.497</td>
</tr>
<tr>
<td></td>
<td>(0.130)*</td>
<td>(0.130)*</td>
</tr>
<tr>
<td>MedianAnnualIncome</td>
<td>-1.102</td>
<td>-1.127</td>
</tr>
<tr>
<td></td>
<td>(0.333)*</td>
<td>(0.333)*</td>
</tr>
<tr>
<td>MedianAnnualIncome(^2)</td>
<td>0.409</td>
<td>0.416</td>
</tr>
<tr>
<td></td>
<td>(0.130)*</td>
<td>(0.130)</td>
</tr>
<tr>
<td>Variable</td>
<td>Coefficient 1</td>
<td>Coefficient 2</td>
</tr>
<tr>
<td>-------------------------------</td>
<td>---------------</td>
<td>---------------</td>
</tr>
<tr>
<td>AnnualHouseholdExpenditure</td>
<td>-0.171</td>
<td>-0.170</td>
</tr>
<tr>
<td></td>
<td>(0.127)</td>
<td>(0.127)</td>
</tr>
<tr>
<td>AnnualHouseholdExpenditure^2</td>
<td>-0.006</td>
<td>-0.008</td>
</tr>
<tr>
<td></td>
<td>(0.051)</td>
<td>(0.051)</td>
</tr>
<tr>
<td>Weekend</td>
<td>-0.090</td>
<td>-0.093</td>
</tr>
<tr>
<td></td>
<td>(0.083)</td>
<td>(0.083)</td>
</tr>
<tr>
<td>EndOfMonth</td>
<td>-0.134</td>
<td>-0.135</td>
</tr>
<tr>
<td></td>
<td>(0.081)</td>
<td>(0.081)*</td>
</tr>
<tr>
<td>DaysInStock</td>
<td>-0.006</td>
<td>-0.006</td>
</tr>
<tr>
<td></td>
<td>(0.000)*</td>
<td>(0.000)*</td>
</tr>
<tr>
<td>Cash</td>
<td>-1.799</td>
<td>-1.797</td>
</tr>
<tr>
<td></td>
<td>(0.066)*</td>
<td>(0.066)*</td>
</tr>
<tr>
<td>Lease</td>
<td>1.334</td>
<td>1.339</td>
</tr>
<tr>
<td></td>
<td>(0.059)*</td>
<td>(0.059)*</td>
</tr>
<tr>
<td>APR1</td>
<td>3.350</td>
<td>3.351</td>
</tr>
<tr>
<td></td>
<td>(0.124)*</td>
<td>(0.124)*</td>
</tr>
<tr>
<td>APR5</td>
<td>0.400</td>
<td>0.401</td>
</tr>
<tr>
<td></td>
<td>(0.053)*</td>
<td>(0.053)*</td>
</tr>
<tr>
<td>APR10</td>
<td>0.535</td>
<td>0.533</td>
</tr>
<tr>
<td></td>
<td>(0.076)*</td>
<td>(0.076)*</td>
</tr>
<tr>
<td>NewVintageTrade</td>
<td>-1.104</td>
<td>-1.113</td>
</tr>
<tr>
<td></td>
<td>(0.163)*</td>
<td>(0.162)*</td>
</tr>
<tr>
<td>RecentVintageTrade</td>
<td>-1.785</td>
<td>-1.720</td>
</tr>
<tr>
<td></td>
<td>(0.102)*</td>
<td>(0.101)*</td>
</tr>
<tr>
<td>OldVintageTrade</td>
<td>0.700</td>
<td>0.707</td>
</tr>
<tr>
<td></td>
<td>(0.118)*</td>
<td>(0.118)*</td>
</tr>
<tr>
<td>Adjust R^2</td>
<td>0.832</td>
<td>0.832</td>
</tr>
</tbody>
</table>

1. * significant at p= 0.05
2. MedianHouseValue, MedianAnnualIncome, AnnualHouseholdExpenditure are in units of hundred thousand, while TRADEACV is in 1000 dollar units.
3. All coefficients and standard errors are multiplied by 100.
4. For the sake of brevity, vehicle, year, month, week, and dealer fixed effects are not reported.
Figure 1: Graphical Representation of Equilibrium Prices with and without Trade-In

\[
(p_{NTI} - w) \left[ 1 + \left( \frac{\partial F_s / \partial s}{\partial s / p_{NTI}} \right) \right] \]

\[
(p_{TI} - w) \left[ 1 + \left( \frac{\partial F_s / \partial s}{\partial s / p_{TI}} \right) \right] \]

\[\Phi_{NTI}(p)\]

\[\Phi_{TI}(p, t, k)\]

\[t, k \uparrow\]
APPENDIX: PROOFS OF PROPOSITIONS 1-3

Proof of Proposition 1
Assumptions A1 and A2 ensure that there is a unique equilibrium price $p^*_{TI}$. Therefore, it is sufficient to establish the result by showing that $dp^*_{TI} / dt > 0$. This is done by implicitly differentiating (4) with respect to $t$ (after multiplying by $v > 0$):

$$\frac{dp^*_{TI}}{dt} \left[ -f_v - \frac{\partial F_v}{\partial s} \right] - (p^*_{TI} - w) \left[ \frac{\partial f_v}{\partial t} + \frac{\partial^2 F_v}{\partial p \partial s} \frac{dp^*_{TI}}{dt} + \frac{\partial^2 F_v}{\partial p^*_{TI} \partial s} \frac{dp^*_{TI}}{dt} \right] = \frac{\partial F_v}{\partial t} + \frac{\partial F_v}{\partial p} \frac{dp^*_{TI}}{dt}.$$

Solving the above equation for $dp^*_{TI} / dt$ gives the expression

$$\frac{dp^*_{TI}}{dt} = \frac{(p^*_{TI} - w) \left[ \frac{\partial f_v}{\partial t} + \frac{\partial^2 F_v}{\partial t \partial s} \right] + \frac{\partial F_v}{\partial t} - f_v}{-f_v - \frac{\partial F_v}{\partial s} - (p^*_{TI} - w) \left[ \frac{\partial f_v}{\partial p^*_{TI}} + \frac{\partial^2 F_v}{\partial p^*_{TI} \partial s} \right]}$$

the denominator of which is negative under the second-order condition of the maximization of (3). Hence, the sign of $dp^*_{TI} / dt$ is opposite the sign of the numerator, which is can be rewritten using (4) and the definition of $\psi$:

$$\left( p^*_{TI} - w \right) \left[ \frac{\partial f_v}{\partial t} + \frac{\partial^2 F_v}{\partial t \partial s} \right] + \frac{\partial F_v}{\partial t} = \frac{\frac{\partial f_v}{\partial t} + \frac{\partial^2 F_v}{\partial t \partial s}}{f + \frac{\partial F_v}{\partial s}} (1 - F_v) + \frac{\partial F_v}{\partial t}$$

$$= \frac{\partial \psi}{\partial t} (1 - F_v) + \frac{\partial F_v}{\partial t}.$$

The last expression is negative by proposition’s assumption. The same argument can be applied to the case of $k$. Q.E.D.

Proof of Proposition 2
An equilibrium pricing strategy for the dealer is a pair of prices simultaneously satisfying Equations (2), (4), (5), and (7). It was shown that $p^*_{TI}$ and $p^*_{NTI}$ satisfy (4) and (7). The pair of prices satisfy (2) and (5) if $p^*_{NTI} < p^*_{TI}$. This is now shown. Note that the inverse hazard function
\(\frac{1-F_v(p|C>s)}{f_v(p|C<s)}\), unconditional on \(T\), can be written as the expectation of the conditional over \(T\).

Therefore,
\[
\Phi_{NTI}(p) = \frac{1-F_v(p|C<s)}{f_v(p|C<s)} < \frac{1-F_v(p|C>s)}{f_v(p|C>s)} = E_{T_v}\left[\frac{1-F_v(p|T,C>s)}{f_v(p|T,C>s)}\right] \leq \frac{1-F_v(p|T=T, C>s)}{f_v(p|T=T, C>s)} \leq \frac{1-F_v(p|T=t, C>s)}{f_v(p|T=t, C>s)} = \Phi_{TI}(p,t,k)
\]

where the first inequality follows from A1, the second from Jensen’s inequality (\(\Phi_{TI}\) is assumed non-convex) and the third from the fact that \(t \geq T\) and A1.

Q.E.D.

Lemma A: Define \(\eta_2 = \frac{1-F_v(p|C>\hat{s})}{f_v(p|C>\hat{s})} - \Phi_{NTI}(p|C<\hat{s}) > 0\).

If (i) \(\Phi_{TI}(p,t,k)\) is non-concave in \(t\) and (ii) there exists \(\tilde{t} < \tilde{T}\) such that
\[
\Phi_{TI}(p,\tilde{T},k) - \Phi_{TI}(p,\tilde{t},k) > \eta_2 \text{ then } \Phi_{NTI}(p) > \Phi_{TI}(p,t,k) \text{ for all } p \text{ and } t < \tilde{t}.
\]

Proof: The definition of \(\eta_2\) implies
\[
\Phi_{NTI}(p) = \frac{1-F_v(p|C<\hat{s})}{f_v(p|C<\hat{s})} = \frac{1-F_v(p|C>\hat{s})}{f_v(p|C>\hat{s})} - \eta_2 = E_{T_v}\left[\frac{1-F_v(p|T,C>s)}{f_v(p|T,C>s)}\right] - \eta_2 \geq \frac{1-F_v(p|T=\tilde{T}, C>s)}{f_v(p|T=\tilde{T}, C>s)} - \eta_2 = \Phi_{TI}(p,\tilde{T},k) - \eta_2
\]

where the inequality follows from condition (i) and Jensen’s inequality. The claim follows from (A1) and condition (ii) since \(\Phi_{TI}(p,\tilde{T},k) - \eta_2 > \Phi_{TI}(p,t,k)\) for \(t < \tilde{t}\).

Q.E.D.
Proof of Proposition 3

Define

\[ \eta_1 = \inf_{p} \left| \Phi_{NTI}(p) - \Phi_{TI}(p) \right| \frac{p_{TI} - w}{p_{TI} - \Delta}, \]

which is positive from Lemma A. From Lemma A we also have

\[ 0 < \Phi_{NTI}(p_{NTI}^*) - \Phi_{TI}(p_{NTI}^*) = \Phi_{NTI}(p_{NTI}^*) - \Phi_{TI}(p_{TI}^*) - \Phi_{TI}(p_{NTI}^*) \]
\[ = (p_{NTI}^* - w)\left[ 1 + \frac{(\partial \Phi_{NTI} / \partial \Delta)(\Delta / \Delta_{NTI})}{f_s(p, t, k > s)} \right] - (p_{TI}^* - w)\left[ 1 + \frac{(\partial \Phi_{TI} / \partial \Delta)(\Delta / \Delta_{TI})}{f_s(p, t, k > s)} \right] + \Phi_{TI}(p_{TI}^*) - \Phi_{TI}(p_{NTI}^*) \]
\[ < (p_{NTI}^* - p_{TI}^*)\left[ 1 + \frac{(\partial \Phi_{NTI} / \partial \Delta)(\Delta / \Delta_{NTI})}{f_s(p, t, k > s)} \right] + (p_{TI}^* - w)\eta_1 + \Phi_{TI}(p_{TI}^*) - \Phi_{TI}(p_{NTI}^*) \]
\[ < (p_{NTI}^* - p_{TI}^*)\left[ 1 + \frac{(\partial \Phi_{NTI} / \partial \Delta)(\Delta / \Delta_{NTI})}{f_s(p, t, k > s)} \right] + \left[ \Phi_{NTI}(p_{NTI}^*) - \Phi_{TI}(p_{TI}^*) \right] + \left[ \Phi_{TI}(p_{TI}^*) - \Phi_{TI}(p_{NTI}^*) \right] \]

where the second inequality follows from (i) in the statement of the proposition and the third inequality utilizes the definition of \( \eta_1 \). Thus, we can rearrange the above as:

\[ 0 < (p_{NTI}^* - p_{TI}^*)\left[ 1 + \frac{(\partial \Phi_{NTI} / \partial \Delta)(\Delta / \Delta_{NTI})}{f_s(p, t, k > s)} \right] + \left[ \Phi_{TI}(p_{TI}^*) - \Phi_{TI}(p_{NTI}^*) \right]. \]

Recalling that \( \Phi_{TI}(p, t, k) \) is decreasing in \( p \) and \[ 0 < 1 + \frac{(\partial \Phi_{TI} / \partial \Delta)(\Delta / \Delta_{TI})}{f_s(p, t, k > s)}, \] the above can hold only if \( p_{TI}^* < p_{NTI}^* \). Q.E.D.