Might I Interest You in an Extended Warranty?

Hyeong-Tak Lee
Kenan-Flagler Business School

Sriram Venkataraman
Kenan-Flagler Business School

July 1, 2016

Abstract

Retailers routinely market extended warranties to durable-goods buyers. Extended warranties are optional and need be purchased at an additional cost. However, manufacturer-backed base warranties come bundled with the product at no additional cost. The question of whether and how base warranties affect buyers' purchase of extended warranties remains central to how and to whom extended warranties get marketed. We test the impact of base warranties on the purchase-incidence rate of extended warranties in the used-vehicles market. In this market, two otherwise identical vehicles may only differ (marginally) in the amount of their residual base warranties. Additionally, the expiry terms

1 Introduction

The automobile industry is a vital part of the U.S. economy and contributes approximately 3.6%, or $500 billion, to the total GDP output (Bureau of Labor Statistics 2009). Given its economic significance and rich institutional features, the automobile industry has had natural appeal for academic inquiry in marketing and economics. The extant academic literature is rich in insights around pricing (Boyle and Hogarty 1975; Bresnahan 1981; Berry et al. 1995; Sudhir 2001), consumer-directed price promotions (Pauwels et al. 2004; Bruce et al. 2006), trade promotions (Bruce et al. 2005), channel pass-through (Busse et al. 2006), information search (Punj and Staelin 1983), leasing versus selling (Desai and Purohit 1998, 1999; Bhaskaran and Gilbert 2005), new- versus used-car competition (Purohit 1992), consumer-adoption decisions (Schiraldi 2011), dealer-consumer negotiations (Desai and Purohit 2004), product obsolescence (Levinthal and Purohit 1989), hybrid car adoption (Huang 2010; Gallagher and Muehlegger 2011), etc.

Amid the ongoing global economic crisis, the U.S. auto industry has experienced tremendous structural changes and garnered renewed interest among scholars to study how these changes impact auto buyers and sellers. This study investigates one such feature of the current marketplace, i.e, the aggressive marketing of extended warranties by auto dealers.[1] Extended warranties are marketed by dealers after the buyer commits to the purchase of the vehicle (new and used).[2] An extended warranty is an agreement between an administrator and a vehicle owner, wherein the administrator agrees to pay for the replacement or repair, for a specific coverage period, of vehicle parts in the event of a mechanical breakdown. Unlike base warranties, which are provided by manufacturers and come bundled with the product at no additional cost to the buyer (Soberman 2003), extended warranties are optional and can be purchased by the buyer separately at an additional cost (Chu and Chintagunta 2009, 2011; Desai and Padmanabhan 2004).[3] Extended warranties are purchased by buyers so as to insure themselves against the risk of product failure (after the base warranty expires). Extended warranties supplement manufacturers' original warranties and provide a broad array of coverage options, but do not usually cover routine maintenance or repairs due to excessive use.[4]

[1]While vehicle buyers can purchase extended warranties any time before the base warranty expires (albeit at a higher price), these are most often purchased at the point of purchase (Jindal 2015). Buyers of older used vehicles with expired base warranties can either purchase the extended warranty at the point of purchase or elect to forgo altogether the insurance benefits from having warranty coverage.

[2]Prices charged by the dealers for extended warranties are never advertised, which severely limits the ability of the buyer to engage in price comparisons.

[3]Extended warranties can be underwritten by either the manufacturer or independent third parties (Chu and Chintagunta 2011; Jindal 2015).

[4]Coverage of the extended warranty kicks in after the vehicle's bumper-to-bumper base warranty expires.

In 2012 alone, consumers spent $14.7 billion on extended service contracts.[5] Yet very little empirical research exists on this important topic. The few empirical studies that do exist either investigate the role of base warranties (Chu and Chintagunta 2009; 2011) or extended warranties (Chen et al. 2009; Jindal 2015), but not both. Therefore, key managerially relevant questions remain unanswered. For example,

1. Ceteris paribus, do purchase-incidence rates for extended warranties vary systematically before and after expiry of the base warranty?

2. Should extended warranties be marketed more aggressively to auto buyers before or after their manufacturer-issued base warranty expires?

warranty-expiry level.

Our empirics also reveal interesting new insights for managers when it comes to tradeoffs that buyers make between power-train and extended warranties. Contrary to the tradeoffs buyers make with basic warranties, purchase rates for extended warranties:

1. Remain constant leading up to the expiry of the power-train warranty.

2. Rise sharply by about 10.2 percent at the point when the power-train warranty expires.

3. Fall steadily to a rate well below their pre power-train-expiry level, after expiry of the power-train warranty.

These findings suggests that the most opportune time to market an extended warranty is shortly before the basic warranty expires, and then again at or just after the power-train warranty expires. Dealers can harvest many more opportunities within this window than outside of it.[8] These findings suggest that after controlling for the strategic sorting of buyers, when it comes to the purchase of extended warranties for used vehicles, insurance motivations dominate in the region around the expiry of the basic warranty. However, signaling motivations dominate in the region around expiry of the power-train warranty. We elaborate on this point later in the study.

Our net effects also differ by country of origin of the automaker. For example, the drop in purchase rates when the basic warranty expires is more precipitous for domestic vehicles (6.4% versus 3% across all vehicles). However, purchase-incidence rates do not change in the region pre- and post-expiry of the manufacturer-backed power-train warranty. These effects are reversed for foreign auto makers. Purchase-incidence rates rise by as much as 15% for foreign automakers at the point when their power-train warranties expire. However, the purchase rates remain unchanged at the point of expiry of their basic warranty.

Taken together, our net-effect findings have important implications for marketing managers (auto dealers and warranty underwriters), as they provide valuable guidance on how and to which consumers extended warranties should be marketed. The rest of the study is organized as follows: In Section 2, we briefly review the extant literature on warranties. In section 3, we describe our empirical setting and

[8]For one to generate normative recommendations for optimally targeting buyers, one would need to recover the underlying risk preferences of used-vehicle buyers. Jindal (2015) proposes a framework to explore this in the context of new durable goods using stated-choice data. Understanding how Jindal's empirical strategy can be extended to a used-goods setting using observational data alone is outside the scope of this study.

data. This is followed by a detailed review of the causal-inference-motivated empirical design. The last section concludes with a summary of our findings and directions for future research.

2 Related Literature

Scholarly inquiry on the provisioning of warranties is very rich in theory. The theoretical underpinnings can be broadly classified into distinct, yet related, research streams that differ primarily on the economic role played by warranties. In the following subsections, we review each of these economic motives.

2.1 Warranties as an Insurance Motive

Warranties are a binding contract made by a seller to a buyer wherein the seller assumes specific responsibilities if the purchased product fails to meet the specifications or legitimate contractual expectations of the buyer (Parisi 2004). Warranties often offer consumers compensation and / or replacement when the product fails. Under the assumption that consumers are risk-averse and firms are risk-neutral, warranties operate as a risk-sharing mechanism, where risk stems from uncertainty about product quality (Heal 1977). In settings where consumers are risk-neutral or risk-loving, they do not need any warranty protection because they willingly bear all the risk. However, as long as the consumers are risk-averse, warranties serve as an insurance against product failure under pre-determined conditions (Kelley and Conant 1991).

Thus, insurance motivations imply a positive correlation between consumers' degree of risk-aversion and their intrinsic preference towards warranty (base and / or extended). Therefore, all else being equal, we expect that higher-risk-averse consumers will more likely purchase extended warranties and, conditional on purchasing extended warranties, elect longer-term warranties. By virtue of being risk-averse, these consumers are also more likely to purchase used vehicles with higher residual base warranties than consumers with low risk-aversion. Hence, because of insurance motivations, *ceteris paribus*, theory would predict that the conditional likelihood of buyers purchasing extended warranties for used vehicles would be higher prior to the expiry of a base warranty than after expiry.

2.2 Warranties as a Signaling Motive

Spence (1973) was the first to theorize that the signaling mechanism could be used to realize information flow credibly amongst market agents. Herein, consumers treat the provisioning of a warranty as a credible indicator of product quality (Murthy and Blischke 2006). The seminal Spence (1977) study explores the quality signaling of price and warranties when the quality of the product is not readily observable to consumers. In equilibrium, the quality can be credibly signaled and suitably inferred from warranties under two conditions: i) the provision of warranties is costly to the seller, and ii) the production cost rises with product reliability. Grossman (1981) shows that when the quality of the product is *ex post* verifiable, high-quality sellers can distinguish themselves from low-quality sellers by offering warranties.

Predictions from these aforementioned signaling studies imply that warranty provisioning helps firms credibly signal higher product quality to consumers/buyers.[9] Correspondingly, we expect that a higher-quality seller will offer longer and more attractive warranties than a lower-quality-producing competitor. Predictions from these studies suggest that, *ceteris paribus*, buyers perceive the used vehicles with the residual warranty to be of better quality compared to a like vehicle without any residual warranty. Since these buyers associate residual warranties with higher quality, these buyers are less inclined to buy extended warranties on the used vehicles with residual warranties than like vehicles without any residual warranties. This prediction runs counter to the aforementioned insurance motives of warranties. Therefore, the net effect of these two countervailing motives remains an open research question and one that is critical to how and to whom extended warranties are marketed.

2.3 Warranties as an Incentive Motive

The incentive motive examines consumers' and firms' incentives as they pertain to the provision of warranties (Cooper and Ross 1985; Dybvig and Lutz 1993; Lutz 1989; Mann and Wissink 1989; Priest 1981). The firm faces two incentives to enhance product durability as a result of warranty provisioning. The first is to signal the product quality using the warranty, the same as the signaling motive. The difference is that, as the firm endogenously determines the quality level of the product, it encounters the tradeoff between product cost and warranty cost. When the product is sold with a warranty, the firm may cheat on quality to lower the production cost; at the same time, such firm behavior leads to a higher warranty cost. Hence, the warranty deters firms from deviating on quality (Spence 1977). Cooper and Ross (1985) and Lutz (1989) consider firms' signaling incentives to consumers who choose how much maintenance efforts to exert on their purchases. Both papers analyze a model in which the buyer and

[9] When a lower-quality firm offers warranty terms comparable to a higher-quality seller, it will incur very high costs to serve its warranty commitments. This deters a low-quality firm from providing the same warranty terms as a higher-quality firm. This is what makes the signaling via warranties credible (Chu and Chintagunta 2011; Kirmani and Rao 2000).

seller can influence the product performance. Lutz (1989) shows that a negative relationship between warranties and product quality is possible in the presence of consumer moral hazard. Here, when not all firms provide warranties, faced with quality uncertainty, consumers will opt out of firms that do not offer warranties. This will result in all firms providing warranties. Since low-quality products cannot bear the warranty costs, they will be driven out of the market. Taken together, the two countervailing incentive mechanisms of warranties explain the mixed empirical findings of the relationship between product reliability and warranty provisioning.

2.4 Warranties as a Sorting Motive

The sorting theory posits that warranties are a credible way for firms to screen consumers. Effective screening facilitates extraction of greater surplus by price-discriminating across these screened consumers (Kubo 1986; Matthews and Moore 1987; Lutz and Padmanabhan 1998; Padmanabhan and Rao 1993; Padmanabhan 1995). A key assumption of the sorting motive is the presence of a heterogeneous preference for risk-aversion amongst consumers (Grossman 1981; Lutz and Padmanabhan 1998). Pad-

hicle characteristics. We focus on recovering the variation in the attachment rate in the region very close to the expiry of the base warranty. Identification comes from the assumption that potential outcomes are smooth in the region around the expiry of the base warranty threshold after controlling for systematic variation in transacted prices pre- and post-expiry of the base warranty. Because the terms of the base warranty are pre-determined, concerns about strategic behavior by agents that pose a threat to causal inference are allayed (McCrary 2008).[10]

3 Data

We leverage a novel new database from a major auto-industry market-research firm.[11] The data provided to us include detailed transaction-level information for every vehicle purchased at 50 randomly selected dealerships across Georgia, North Carolina, South Carolina, Tennessee, and Virginia between July 2009 and July 2014. For each transaction, the data contain a VIN identifier of the vehicle purchased, date of purchase, age of the buyer, ZIP code of the buyer, odometer mileage, etc. We coded up a VIN-decoder that permits recovery of VIN-specific attributes, including vehicle make, model, trim, model-year, engine size, etc.[12] For each transaction, we know information on the transaction price for the vehicle purchased, whether or not the sale was accompanied by a trade-in, the price of the trade-in (if any), and the price paid for the extended warranty (if any). In addition, we observe whether the vehicle purchased was leased, financed or paid in full.

The full dataset contain 135,813 transactions spanning sales of both new and used vehicles. Given our research objectives, we limited our attention to only used-vehicle transactions made by individual buyers.[13] We also eliminated observations where the purchased vehicle already EMC / 1a Etended ourranty ifei
vee encet yer,

ThSin ecovt che -back -

in Table 1. As seen in Table 1 , there is rich variation in factory-warranty terms across manufacturers. Herein, the basic warranty or "bumper-to-bumper" policy covers the cost of most repairs except normal wear and tear (such as replacement of oil filters). A power-train warranty, on the other hand, covers major internal parts of the vehicle such as the engine and transmission. Basic warranties are in effect between two through five years from the date when the factory warranty is activated.[14] The most commonly occurring basic warranties are 3-years / 36,000 miles (41.46%), 4-years / 50,000 miles (39.02%), and 5-years / 60,000 miles (7.31%). Power-train warranties have more expansive coverage than basic warranties. They range anywhere from two to ten years. The 4-years / 50,000 miles (24.39%), 5-years / 60,000 miles and 5-years / 100,000 miles (21.95%) are the most commonly occurring power-train warranty terms.

Both the basic and power-train warranty terms vary across manufacturers. For example, Ford (brands include Ford and Mercury), Toyota (brands include Toyota and Scion), Nissan, Honda, Subaru, Mazda and Volkswagen provide a power-train warranty coverage for 5-years / 60,000 miles. In contrast, General Motors (brands include Chevrolet, GMC, and Pontiac) and Chrysler (with Chrysler and Dodge) offer 5-years / 100,000 miles coverage. Even within a manufacturer, warranty terms vary across brands. For example, General Motors, Honda, Nissan and Toyota offer two policies, and Ford provides three policies, across different brands within their product portfolios. However, warranty coverage remains the same across models within the same brand (for example, Hyundai Elentra and Hyundai Sonata both have 5-years / 60,000 miles and 6-years / 100,000 miles coverage). Amongst manufacturers with multiple warranty policies, the most widely offered combination of basic and power-train warrant -2.01 A el the most with Ford-PremiumCARE's coverage in terms of components, but differs along other dimensions (7-years / 100,000 miles versus 8-years / 125,000 miles). Extended warranties can be sold either by the manufacturer, the dealer or a third-party. Manufacturers sell extended warranties either direct-to-the-consumer or through their expansive franchised dealer-network. General Motors is the only exception. Ally Financial Inc. runs GM's extended warranty business. Additionally, well-established third-party warranty companies such as GE Capital, Lubrico, Global, and Pafco underwrite the extended warranty contracts sold by dealers (Soberman 2003). Table 2 presents details on the extended warranties offered by select manufacturers.[16]

For our empirical analysis, we limited the set of brands to the top 15 in terms of cumulative sales.

ous jump induces “variation” in the treatment assignment that may be regarded as being unrelated to potential confounders for observations near the cutoff or threshold. In our empirical setting, too, the likelihood of receiving a treatment (i.e. a vehicle with an expired base warranty) jumps sharply based on an observable covariate of the purchased vehicle (mileage of the vehicle). Using an RD-based-causal-inference-design approach, we estimate the average local effect (of the expiry of the base warranty on purchase rates of extended warranties). Specifically, we quantify the impact of the expiry of each type of base warranty on the purchase rates of extended warranties in the region “local” to the expiry of the

$$Y_i(0), Y_i(1) \ ? \ W_i j X_i \tag{2}$$

This assumption readily holds in SRD because conditional on the covariates, there is no variation in the treatment. Matching-type approaches also requires that for all values of the covariates, the data contain both treated and control units.

$$0 < Pr(W_i = 1 j X_i = z) < 1 \tag{3}$$

This assumption by construction does not hold in SRD design. Instead, in SRD, for all values of x, the probability of assignment is either 0 or 1, rather than always between 0 and 1. As a result, there are no values of x with overlap. Therefore, SRD warrants the unavoidable need for extrapolation. However, 3)

$$
\begin{array}{c|c}
-h_n \leq X_i < z: & z \leq X_i \leq h_n: \\
Y_i = \alpha_- + (X_i - z) \cdot \beta_- + \varepsilon_{-,i} & Y_i = \alpha_+ + (X_i - z) \cdot \beta_+ + \varepsilon_{+,i}
\end{array} \tag{5}
$$

Correspondingly, the treatment effect at the cutoff off the running variable is given by:

$$
\hat{\tau}_{SRD} = \hat{\alpha}_+ - \hat{\alpha}_- \tag{6}
$$

As noted above, RD design is predicated on comparing treated and untreated units in a region "near" the cutoff value of the running/forcing variable. Several approaches have been advanced to date to identify observations that constitute being sufficiently "near." These approaches vary from being completely ad hoc to methods that are grounded in exploiting the variation in the data. The latter are collectively referred to as bandwidth-selection estimators. Bandwidth-selection estimators help choose the optimal bandwidth h around $X_i = z$, i.e., the cutoff of the running variable. In the most general form, the bandwidth-selection estimator tries to strike a delicate balance between prediction accuracy and the precision of an estimator in the region around the cutoff. On the one hand, a larger bandwidth affords the researcher more observations, and in dma71nec7-oan9ar(ounded 0 0 8.3049 335.524 590.043 Tm()Tjtan)-

!

bile manufacturer, auto brand, and car model might systematically impact attachment rates for extended warranties. Attachment rates can also be impacted by non-vehicle-related factors such as characteristics of the auto dealership (aggressive sales force, franchised / non-franchised site, exclusive underwriter of extended warranties in the market, etc.) and characteristics of the auto buyer's local market (average road-driving conditions, number of repair shops and average cost of repairs, etc.).

To address these empirical issues, we estimate the SRD in the following steps. First, we employ the bandwidth-selection estimator advanced in Imbens and Kalyanaraman (2012) (henceforth IK) as well as in Calonico et al. (2014) (henceforth CCT). Both the bandwidth-selection estimators rely on non-parametric, local-polynomial approximation (see Calonico et al.2014). The resulting bandwidth permits us to exploit only the variation in the observations around the neighborhood where the basic / power-train warranty of the specific vehicle expires. Next, we calibrate a logistic regression where the dependent variable is a logit transformation of conditional probability of the buyer of a used vehicle j, buying an extended warranty for her vehicle from dealer d located in state s at time t, and parameterized as:

$$
\begin{aligned}
\text{logit}\ \Pr\ Y_{djst} = 1 \mid \text{Mileage}_{djst}, X_{djst} &= \log \frac{\Pr\ Y_{djst} = 1 \mid \text{Mileage}_{djst}, X_{djst}}{1 - \Pr\ Y_{djst} = 1 \mid \text{Mileage}_{djst}, X_{djst}} \\
&= \beta_0 + \beta_1\ D_{djst} + \beta_2\ \text{Mileage}_{djst} \\
&\quad + \beta_3\ D_{djst} \cdot \text{Mileage}_{djst} \\
&\quad + \gamma\ X_{djst} + \varepsilon_{djst}, \qquad h_n \leq \text{Mileage} \leq h_n
\end{aligned}
$$

where D_{djst} is an indicator variable that takes on value 1 when $z_{basic/power-train\,cutoff} \leq \text{Mileage}_{djst} \leq h_n$ and 0 otherwise. Mileage_{djst} is the odometer mileage of the used car, h_n is the bandwidth proposed by IK and / or CCT, and X_{djst} includes other vehicle, dealer and buyer-market characteristics.

Extended warranties are marketed only after the buyer commits to a specific vehicle. However, transacted prices on the vehicle purchased may still impact extended-warranty-purchase-probability. If transaction price proxies for vehicle unobservables, including product quality, then consumers may associate higher-quality products with greater reliability, which may therefore result in a reduced likelihood to purchase extended warranties. Another possibility is that a budget-constrained buyer, upon paying a higher transacted price on the vehicle, may have fewer additional resources to spare for purchasing extended warranties. This, too, would reduce the likelihood of a buyer purchasing extended warranties. However, if higher prices also translate to more expensive-to-maintain vehicles, then the buyer may be more likely to purchase extended warranties to insure against product failure. Therefore, warranties. However, none of these estimates is statistically significant. The estimate and corresponding confidence intervals are plotted in Figure 7.1. Taken together, these tests confirm that the strategic manipulation of the running variable is absent, and therefore does not pose any threat to identification.

The second threat to identification is discontinuity of the density of continuous covariates. Recall that we have two continuous covariates in the model, namely: the transacted price of the vehicle and the value of the vehicle traded in (should there be a trade-in). To test the discontinuity of these covariates, we first visually inspect the covariates. Figures 7.4 and 7.5 depict the RD for the transaction price and trade-in value. Each point is the average price of the corresponding covariate within the focal 1,000-mile bin. These plots reveal a noticeable discontinuity for trade-in values at the 60,000-miles power-train-warranty mark. No apparent graphical discontinuity is found at other mileage markers around the warranty cutoffs. Next, we formally assess the statistical significance of this discontinuity in the trade-in value at the power-train-warranty-mark. We do so by running a non-parameteric local polynomial RD-based regression separately for each covariate (including the used-vehicle transacted price). Here, we treat the covariates as the outcome variable. A statistically significant treatment effect would imply that the density of the covariate exhibits a discontinuity at the running-variable cutoff, which limits our ability to make causal claims on the recovered-treatment-effect estimate. The results for these tests are reported in Tables 6 and 7. They suggest that the trade-in value at the 60,000-mile mark turns out to be statistically significant, and so presents a threat to identification. Therefore, for the recovery of the treatment effect at the 60,000-mile power-train warranty cutoff, we restrict the estimation sample only to observations without trade-ins. The test does not reveal any discontinuity for the basic-warranty cutoff.

In summary, after careful review of the key threats to identification and employing the necessary safeguards, we are sufficiently confident that causal inference using RD design is credible and has strong internal validity.

6 Results

After allaying concerns about potential threats to identification, we conduct the statistical inference using a local linear regression. We do so after limiting the observations to those that lie within the optimal bandwidth around the threshold. We choose the bandwidth using the procedures suggested by IK and CCT, and assess whether substantive findings are sensitive to the choice of bandwidth estima-

are most likely to purchase extended warranties, relative to other buyers of pre-basic-warranty-expiry used vehicles. Therefore, dealers need to target extended warranties most aggressively to buyers of purchased vehicles that have 800 miles or less to go before their basic warranty expires. The next-most-attractive segment is buyers of vehicles with expired basic warranties. Taken together, dealerships have a very small window of opportunity to win a sale before expiry of the basic warranty, and a much wider window of opportunity to market extended warranties after expiry of the basic warranty.

On the contrary, to the left of the power-train warranty mark of 60,000 miles, the attachment rate for extended warranties remains constant. As soon as the power-train warranty runs out, the purchase probability discontinuously jumps by 10%, and then steadily decreases with mileage. In this case, the region from 60,000 to 63,700 miles, i.e., 3,700 miles post expiry of the power-train warranty – is the most attractive "sweet spot" for dealerships to market extended warranties. The next-most-attractive segment is the buyers of used vehicles who purchase vehicles before the expiry of the power-train warranty. In sum, results show that there is a statistically significant effect of warranty expiry on purchase rates for extended warranties on used vehicles. Given the high profit margins that dealerships realize on the sale of extended warranties, the recovered effects can have an economically significant impact on dealers' revenues from the marketing of extended warranties.

Earlier in the article, we discussed the insurance and signaling roles of warranties. Recall that each of these motives has polar-opposite predictions on the demand for extended warranties. According to the insurance motive, we expect the likelihood of purchasing extended warranties to be higher for the used vehicles prior to the expiry of the base warranty than post-expiry. In contrast, signaling theory predicts that buyers perceive used vehicles with residual warranties to be of better quality compared to those without, and will therefore be less prone to buying the extended warranty on the vehicles that have remaining base warranties than those that do not. Our "net-effect" findings suggest that the net effect of these two countervailing motives for basic warranties is negative. This implies that in the local region around the expiry of the basic warranty, insurance motives and sorting motives dominate rately running local linear regressions of basic / power-train-warranty marks for domestic and imported brands in our data allows one to answer that question.[26] These findings suggest that the treatment effect of the basic-warranty mark is driven by domestic vehicles, while non-domestic brands exhibit discontinuity at the power-trainwarranty mark (Tables 12 and 13). On one hand, compared to the average drop of 3% in the attachment rate at the cutoff of the basic warranty, domestic brands show a discontinuous decrease of 6%. On the other hand, the purchase probability discontinuously jumps by 15% for the imported vehicles once the power-train warranty expires, while the pooled effect is estimated to be a 10% increase. We interpret these results as follows. The fact that domestic brands exhibit a larger drop in attachment rate than the average change implies that the basic warranties serve insurance and sorting roles more for the U.S. automakers than non-domestic brands. The empirical evidence is consistent with trade-publication reports that consistently rank the domestic brands lower than their Japanese rivals in terms of reliability (Consumer Reports 2014). Hence, by providing manufacturer-backed warranties, the degree to which insurance and sorting motives dominate other economic roles is greater for less durable U.S. automakers than imported brands. In the case of a power-train warranty that covers major internal parts of the vehicle such as the engine and transmission, consumers are likely to encounter more expensive repairs for imported vehicles than domestic cars when engine parts fail. Moreover, replacing these parts in the aftermarket can be less available and more expensive for the non-domestic brands, which leads to a higher jump at the threshold of the power-train warranty than the pooled average.

Lastly, the the positive coefficient for the used-vehicle transacted price indicates that, *ceteris paribus*,

6.1 Robustness Checks and Alternative Explanations

In this section, we address a number of alternative explanations and factors that might affect our findings.

Placebo Test. Do discontinuities occur at mileage marks other than the vehicle's basic and powertrain-warranty marks? Evidence of such discontinuities can call into question the causal mechanism we posit. To rule out this legitimate concern, we perform the aforementioned local linear regression for every 10,000-mile threshold. Nine out of ten times, we do not find any discontinuity in the demand for extended warranties around the local region of the cutoffs. The only exception is the 40,000-mile marker, where we find significant discontinuity. However, this is not surprising, since 93.2% of the bandwidth around the 40,000-mile mark overlaps with the expiry of the basic warranty at the 36,000-mile mark. The bandwidth and results are shown in the Online Appendix Tables 14 and 15.

Product Availability. Another concern is that the expiry of the base warranty can be confounded with the product availability. This could manifest in two ways. First, reduced availability very likely increases the transacted price of the used vehicle. Higher transaction prices, in turn, will lead consumers to protect their vehicles (consistent with insurance motivations) and result in higher purchase rates of extended warranties. Second, in the market where auto dealers maintain a low inventory level or offer a narrow range of products, consumers can purchase extended warranties in lieu of limited access to aftermarket parts and more expensive repairs, should the vehicle parts need replacements. If this is the case, product availability can be a source of unobserved heterogeneity around the warranty thresholds and be correlated with the recovered treatment effect. To address this concern, we create a measure of product availability by counting the number of similar vehicles (i.e., of the same make-model as the focal vehicle) offered by the same auto dealer in the particular year-month when the focal vehicle was sold. Then we perform a battery of tests. First, the McCrary test is conducted to check if product availability exhibits discontinuity before and after the warranty marks. The Online Appendix Table 16 shows that the McCrary test rejects the null hypothesis, which implies that there is no systematic difference between the densities of product availability measures pre- and post-expiry of basic / powertrain-warranty thresholds. Second, we run a local linear regression that directly allows the product availability to impact extended-warranty-purchase rates. As seen in the Online Appendix Table 17, this analysis also yields statistically insignificant estimates of product availability, which further allays treatment-effect bias that might stem from product availability.

Endogenous Choice of Extended-Warranty Terms. Consumers pre- and post-expiry of basic / power-train-warranty marks may choose the different terms of extended warranties. If consumers to the left of the cutoff systematically purchase the shorter period of extended warranties than those to the right, or vice versa, it can be evidence of self-sorting due to their risk preferences. Under the assumption that extended-warranty premiums reflect the terms of warranties, we estimate an non-parametric RD on the extended-warranty prices. As can be seen in the Online Appendix Table 18, the extended-warranty price does not show any discontinuity pattern at the 36,000-mile or the 60,000-mile marks, where we obtain significant RD estimates on the attachment rates for extended warranties. At the 100,000-mile mark, we find a significant negative RD estimate of the extended-warranty premium, meaning that consumers tend to buy cheaper or less comprehensive extended-warranty products post-expiry of the power-train warranty. Since our main findings rest on the basic warranty mark of 36,000-miles and the power-train warranty of 60,000-miles, our treatment-effect estimates are also robust to the concern of endogenous choice of extended-warranty terms.

7 Conclusion

Thus far, we have studied the interaction between manufacturer-backed factory warranties (that come bundled with the product at no additional cost) and optional extended warranties (that need to be purchased separately) in the used-vehicle market. Our empirical context is a preferred setting to investigate the interaction because it provides a unique opportunity to test the net effect of insurance, signaling and sorting roles on the tradeoff that buyers make between manufacturer-backed factory warranties and extended warranties. We employ an RD design and show how the demand for extended warranties drops / increases as the manufacturer-backed basic / power-train warranty expires. Our "net-effect" findings suggest that the net effect of these two countervailing motives for basic warranties is negative. This implies that in the local region around the expiry of the basic warranty, insurance motives and sorting motives dominate all other motives. The positive net effect for power-train warranties suggests that in the local region around the expiry of the power-train warranty, signaling motives are dominant.

Taken together, our findings highlight potential complementarities between manufacturer-backed factory warranties and extended warranties. Specifically, as soon as the basic warranty expires, there is a discontinuous drop of 3% in the attachment rate for extended warranties, while the purchase probability discontinuously jumps by 10% upon passing the power-train-warranty mark of 60,000 miles. In addition, post-expiry of the basic warranty, the attachment rate for extended warranties remains constant at

vance in this study can be readily extended to quantify the sales-opportunity window for these vehicles and assess how it varies relative to the ones we currently include in the study. We hope this study and its findings help garner greater interest amongst marketing scholars to advance more research in the area of product warranties and assess if the economic benefits these products accrue justify the premiums consumers pay to protect themselves from modest levels of product failure.

References

1. Autotrader.com (2013) "Certified Pre-Owned: Understanding the Customer," (November, 2013), (accessed February 16, 2015), [available at http://digitalsolutions.autotrader.com/wp-content/uploads/2014/01/2013-AutoTrader.com-CPO-Study-Results-Full-Report.pdf]
2. Berry, Steven, James Levinsohn, and Ariel Pakes (1995), "Automobile Prices in Market Equilibrium," Econometrica, 63(4), 841-90.
3. Bhaskaran, Sreekumar R. and Stephen M. Gilbert (2005), "Selling and Leasing Strategies for Durable Goods with Complementary Products," Management Science, 51(8), 1278-90.
4. Boyle, Stanley E. and Thomas F. Hogarty (1975), "Pricing Behavior in the American Automobile Industry, 1957-71," Journal of Industrial Economics, 24(2), 81-95.
5. Bresnahan, Timothy F. (1981), "Duopoly Models with Consistent Conjectures," American Economic Review, 71(5), 934-45.
6. Bruce, Norris, Preyas S. Desai and Richard Staelin (2005), "The Better They Are, the More They Give: Trade Promotions of Consumer Durables," Journal of Marketing Research, 42(1), 54-66.
7. Bruce, Norris, Preyas S. Desai and Richard Staelin (2006), "Enabling the Willing: Consumer Rebates for Durable Goods," Marketing Science, 25(4), 350-66.
8. Busse, Meghan, Jorge Silva-Risso, and Florian Zettelmeyer (2006), "$1,000 Cash Back: The Pass-Through of Auto Manufacturer Promotions," American Economic Review, 96(4), 1253-70.
9. Calonico, Sebastian, Matias D. Cattaneo, and Rocio Titiunik (2014), "Robust Nonparametric Confidence Intervals for Regression-Discontinuity Designs," Econometrica, 82(6), 2295-2326.
10. Card, David, Carlos Dobkin, and Nicole Maestas (2008), "he Impact of Nearly Universal Insurance Coverage on Health Care Utilization: Evidence from Medicare," American Economic Review

16.

37. Ludwig, Jens and Douglas L. Miller (2007), "Does Head Start Improve Children's Life Chances? Evidence from a Regression Discontinuity Design," Quarterly Journal of Economics, 122(1), 159-208.

38. Lutz, Nancy A. (1989), "Warranties As Signals Under Consumer Moral Hazard," RAND Journal of Economics, 20(2), 239-55.

39.

58. Thistlethwaite, Donald L. and Donald T. Campbell (1960), "Regression-Discontinuity Analysis: An Alternative to the Ex Post Facto Experiment," Journal of Educational Psychology, 51(6), 309-17.

59.

Table 3: Summary Statistics

	Mean	SD	Minimum	Maximum
Extended warranty attachment rate	.533	.499	0	1
Mileage	48528.99	33901.52	10	298,736
Cash price	19059.124	8235.71	1	165,000
Trade-in values	3598.4	6279.97	0	58000

Table 4: McCrary Density Test (Post-IK Bandwidth Sample)

	Basic warranty mark (36k miles)	Powertrain warranty mark (60k miles)	Powertrain warranty mark (100k miles)
Log discontinuity estimate	.006 (.072)	.047 (.107)	-.183 (.161)
Observations	9,556	5,232	3,399

Note: Standard errors in parentheses.

Table 5: McCrary Density Test (Post-CCT Bandwidth Sample)

	Basic warranty mark (36k miles)	Powertrain warranty mark (60k miles)	Powertrain warranty mark (100k miles)
Log discontinuity estimate	.019 (.093)	.042 (.104)	-.235 (.21)
Observations	7,882	4,482	2048

Note: Standard errors in parentheses.

Table 6: Nonparametric Estimate of Discontinuity in Transacted Price and Trade-In Value (Post-IK Bandwidth Sample)

	Basic warranty mark (36k miles)	Powertrain warranty mark (60k miles)	Powertrain warranty mark (100k miles)
Transacted Price	190.77 (467.26)	-12.878 (696.13)	641.58 (1315.1)
Trade-In Value	-366.24 (484.29)	-1612.6** (670.53)	1076.6 (1101.3)
Observations	9,556	5,232	3,399

Note: Standard errors in parentheses.

Table 7: Nonparametric Estimate of Discontinuity in Transacted Price and Trade-In Value (Post-CCT Bandwidth Sample)

	Basic warranty mark (36k miles)	Powertrain warranty mark (60k miles)	Powertrain warranty mark (100k miles)
Transacted Price	210.35 (493.75)	41.64 (611.16)	632.94 (1353.6)
Trade-In Value	-389.41 (506.39)	-1640.2** (703.38)	690.4 (1277.3)
Observations	7,882	4,482	2,048

Note: Standard errors in parentheses.

Table 8: Summary Statistics of Post-IK Bandwidth Sample

Basic Warranty Mark	Mean	SD	Minimum	Maximum
Extended warranty attachment rate	.558	.497	0	1
Mileage	35190.26	8272.9	21160	50848
Cash price	20239.45	7009.61	3396.1	69995
Trade-in values	3589.5	6078.94	0	54000

Powertrain Warranty Mark (60,000 miles)	Mean	SD	Minimum	Maximum
Extended warranty attachment rate	.557	.497	0	1
Mileage	56248.65	11920.15	38954	81045
Cash price	17167.27	6114.75	2900	48900
Trade-in values	2990.32	5482.59	0	44328.65

Powertrain Warranty Mark (100,000 miles)	Mean	SD	Minimum	Maximum
Extended warranty attachment rate	.469	.499	0	1
Mileage	69052.63	25116.98	38434	161452
Cash price	20239.45	7009.61	3396.1	69995
Trade-in values	3002.53	5514.99	0	44451

0 5514.

Table 10: Regression Discontinuity Estimates (Post-IK Bandwidth Sample)

	Basic warranty mark (36k miles)	Powertrain warranty mark (60k miles)	Powertrain warranty mark (100k miles)
Intercept	-2.944*** (.606)	-2.465*** (.890)	-1.008 (.814)
Discontinuity	.774** (.378)	2.372*** (.800)	.543 (0.972)
Discontinuity * Vehicle Mileage	-.00002** (0.00001)	-.00004*** (0.00001)	-.000008 (0.000008)
Odometer Mileage	.00002*** (.000007)	.000012 (0.000009)	-.000006** (0.000003)
Transacted Price of Used-Vehicle	.00005*** (0.000006)	.00008*** (0.00001)	.00005*** (0.00001)
Transacted Price of Trade-in Vehicle	-.00001*** (0.000004)		-.0000006 (0.000008)
Make Dummy	yes	yes	yes
Model Dummy	yes	yes	yes
Dealer Dummy	yes	yes	yes
Buyer-State Dummy	yes	yes	yes
Year Dummy	yes	yes	yes
Month Dummy	yes	yes	yes
AIC	12,589	3760.9	4,224
Observations	9,556	2,918	3,399

Note: Standard errors in parentheses.

Table 11: Regression Discontinuity Estimates (Post-CCT Bandwidth Sample)

	Basic warranty mark (36k miles)	Powertrain warranty mark (60k miles)	Powertrain warranty mark (100k miles)
Intercept	-3.092*** (0.668)	-2.46** (1.006)	-1.267 (0.981)
Discontinuity	1.057** (0.500)	1.902** (0.937)	.605 (1.155)
Discontinuity * Vehicle Mileage	-.00003** (0.00001)	-.00003** (0.00002)	-.00001 (0.00001)
Vehicle Mileage	.00003*** (0.00001)	.00002 (0.00001)	-.000005 (0.000005)
Cash Price	.00006*** (0.000007)	.00008*** (.00001)	.00005*** (0.00001)
Trade-In Value	-.000008* (0.000004)		-.000007 (0.00001)
Make Dummy	yes	yes	yes
Model Dummy	yes	yes	yes
Dealer Dummy	yes	yes	yes
State Dummy	yes	yes	yes
Year Dummy	yes	yes	yes
Month Dummy	yes	yes	yes
AIC	10,385	3245.4	2540.5
Observations	7,882	2,494	2,048

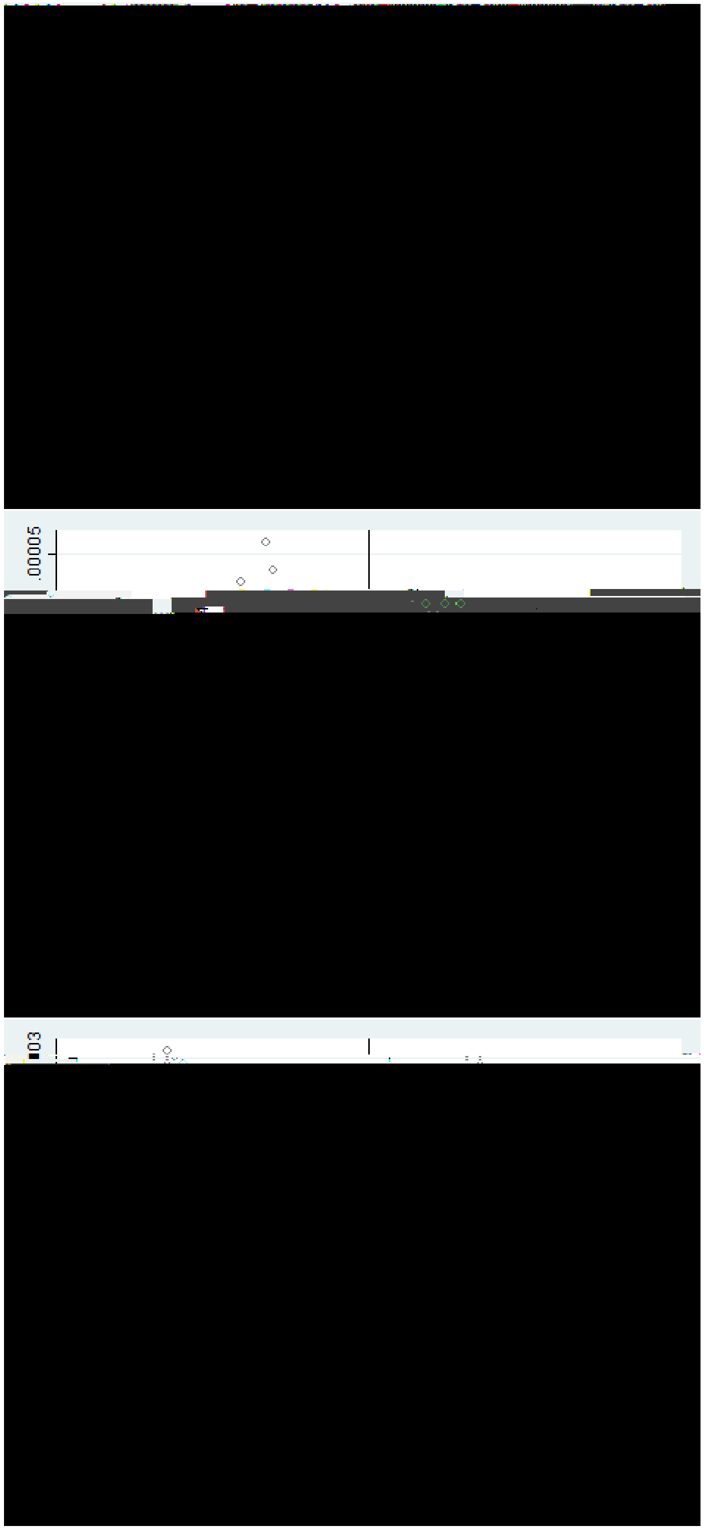
Note: Standard errors in parentheses.

Table 12: Regression Discontinuity Estimates by Domestic versus Imported Brands (Basic warranty 36k miles)

	Domestic	Imported
Intercept	-1.902** (.818)	-1.139 (1.194)
Discontinuity	.908* (.557)	1.076 (.955)
Discontinuity * Vehicle Mileage	-.000027* (.000015)	-.000028 (.000026)
Vehicle Mileage	.00002** (.00001)	.000016 (.00002)
Cash Price	.000035*** (.0000085)	.000079*** (.000017)
Trade-In Value	-.0000081*** (.0000055)	-.0000026 (.000001)
Make Dummy	yes	yes
Model Dummy	yes	yes
Dealer Dummy	yes	yes
State Dummy	yes	yes
Year Dummy	yes	yes
Month Dummy	yes	yes
AIC	5711.2	2654.7
Observations	4,340	1,969
Bandwidth	(21268, 50732)	(24981, 47019)

Note: Standard errors in parentheses.

Figure 1: McCrary Test



Online Appendix

Table 14: Robustness Check: Placebo Test Results (Basic Warranty)

	10k miles	20k miles	30k miles	40k miles	50k miles
Intercept	.285 (1.531)	-.321*** (1.03)	-1.54** (.682)	-3.15*** (.62)	-1.73** (.932)
Discontinuity	-1.316 (1.272)	.665 (.862)	.151 (.423)	.752* (.466)	.208 (.387)
Discontinuity * Vehicle Mileage	.0002 (.0001)	-.000054 (.000043)	.0000032 (.00014)	-.00002 (.000011)	-.000004 (.0000072)
Vehicle Mileage	-.00022** (.00012)	.00011***	-.000004 (.0000072) .0000032		

Table 17: Robustness Check: Regression Discontinuity allowing The Effect of Product Availability

	Basic warranty mark (36k miles)	Powertrain warranty mark (60k miles)	Powertrain warranty mark (100k miles)
Intercept	-.741 (.854)	-2.854** (1.130)	-1.626 (1.502)
Discontinuity	1.295** (.658)	1.865* (1.013)	-1.179 (1.539)
Discontinuity * Vehicle Mileage	-.000036** (.000018)	-.00003* (.000016)	.0000067 (.000014)
Vehicle Mileage	.000023* (.000013)	.000015 (.000013)	-.000008 (.000011)
Product Availability	-.000032 (.0006)	.000049 (.0011) .0000067	(.000016) va8T5)

Figure 3: Discontinuity in Transaction Price of Used Vehicles

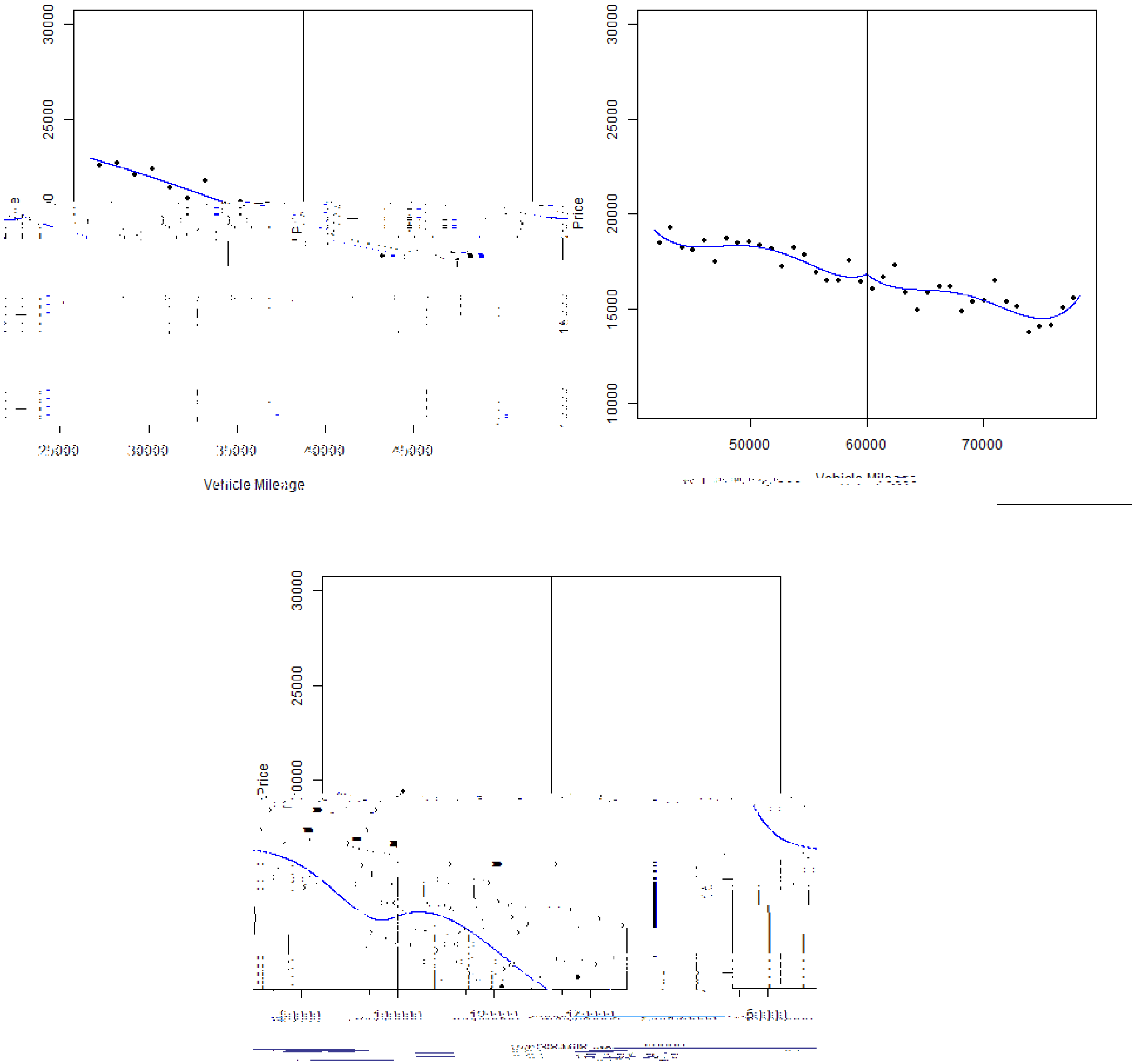


Figure 4: Discontinuity in Trade-In Value