Might I Interest You in an Extended Warranty?*

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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 of the base warranties are a deterministic function of the vehicle exceeding certain pre-determined cutoffs (mileage cutoffs). We employ a regression discontinuity design by comparing extended-warranty purchase-incidence rates just below and above the expiry of manufacturer-backed warranties. We find that used-vehicle buyers do indeed adjust their likelihood of purchase of extended warranties in a statistically and economically significant way in response to the stock of residual base warranty still available in the vehicle purchased. We quantify the window of opportunity wherein auto dealers have the highest likelihood of success selling extended warranties and also quantify how this window of opportunity varies by country of origin of the automaker.

Keywords: Extended warranties, durable goods, retailing.

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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?

These questions of whether and how base warranties affect buyers' purchase of extended warranties are central to how and to whom extended warranties get marketed.

These aforementioned research questions are also relevant to policy makers, as the number of consumers who choose to insure against product failure has steadily increased. For example, in the U.S. auto industry, over the past fifteen years, the purchase rates for extended warranties has risen steadily from 20% to 42% (Warranty Week 2010). This has occurred despite concerns raised in the popular press that these extended warranties are not worth buying. Additionally, recessionary concerns in concert with automobiles becoming more reliable have owners and potential buyers holding on to their current vehicles longer than they have done in years past.[6] As buyers anticipate holding on to their vehicles longer and well past their vehicle's base warranty, extended warranties have continued to experience a healthy compound annual rate of 13.5% since 2009. As markets rebound and credit becomes more easily available to auto buyers, industry insiders anticipate that a flood of used vehicles will enter the secondary market as their previous owners trade these in for new (or used) vehicles. If the current owner of a soon-to-be-traded-in vehicle purchased an extended warranty, the residuals on the vehicle's extended and base warranty will get transferred, at no additional cost, to the subsequent buyer of her vehicle. In turn, for the reduced uncertainty she faces with the purchase of a warrantied used vehicle, the subsequent buyer may anticipate paying a higher sales price.[7] Correspondingly, should the base warranty be expired and the previous owner not have purchased an extended warranty, the subsequent

[5]Source: *Warranty Week*

[6]In fact, a recent study by Polk reports that the average age for vehicles in America has steadily climbed to an all-time high of 11.4 years in 2013 - up from 9 years in 2006. This upward trend in the age of existing vehicles is expected to continue for the next four to five years. Source: http://www.cnbc.com/id/100940923.

[7]These motivations have also led to a rapid growth in the market for certified pre-owned vehicles. Herein, automakers recondition the certified pre-owned vehicles through a comprehensive inspection and often bundle the extended bumper-to-bumper and power-train warranties (Source: AutoTrader.com 2013). In turn, consumers pay a price premium for this certification in exchange for alleviating the risk involved with the purchase of a used vehicle.

buyer may anticipate paying a lower price for this vehicle relative to a like vehicle with a residual base and/or extended warranty. The buyer of the used vehicle can also decide to purchase or forgo the extended warranty. She does so depending on her own intrinsic preferences and expectations about product quality and repair costs, and the presence and size of the residual warranty on her purchased vehicle.

This study investigates these aforementioned questions in the empirical context of used-vehicle sales. We focus on the used-vehicles market for several reasons. In the U.S., the volume of used-vehicle sales is larger than new-vehicle sales. Unlike new vehicles, not all used goods have residual base warranties. We exploit this rich and "pre-determined" variation in the availability and size of residual base warranty to quantify the tradeoff that buyers make between base and extended warranties. Herein, the terms of the base warranties are pre-determined and expire upon select vehicle characteristics exceeding a certain threshold value. Furthermore, the expiry terms of the base warranties: (i) cannot be manipulated by the buyer/seller, (ii) are pre-determined by the automobile manufacturer, and (iii) are a deterministic function of the vehicle exceeding certain pre-determined cutoffs (mileage cutoffs, in our case).

These unique institutional features of the secondary market for automobiles allow us to quantify how extended-warranty-purchase rates of otherwise identical vehicles vary pre- and post-expiry of the base warranty after controlling for other concomitant factors. However, the buyer's intrinsic risk preference – which drives her decision to purchase an extended warranty – also drives her decision to select a vehicle with/without a residual warranty. Identification in our setting 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 in the "local" region where our causal effect is estimated (McCrary 2008). Since manufacturer-backed warranties include both basic and power-train warranties, we recover estimates of the tradeoffs that buyers make for both of these manufacturer-bundled warranties.

Key findings are as follows:

1. The purchase rates for extended warranties rise gradually leading up to the expiry of the basic warranty.

2. Purchase rates drop by approximately 3 percent at the point when the basic warranty expires.

3. Thereafter, the purchase rates remain constant, and at a rate much higher than the pre-basic-

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). Padmanabhan and Rao (1993) show that the optimal combination of price and warranty can increase a manufacturer's profit in a market where (i) consumers exhibit a heterogeneous preference for risk-aversion, and (ii) there is room for consumer-side moral hazard. Padmanabhan (1995) considers the role of heterogeneity in consumers' usage of warranties and consumer moral hazard, which then creates variation in their willingness to pay for a price-warranty contract. Lutz and Padmanabhan (1998) show that manufacturer profits from the high-valuation consumers remain unchanged. The presence of an independent insurer causes the manufacturer to drop a product intended for low-valuation consumers, resulting in a reduction in the overall profits for the manufacturer.

In sum, sorting theory predicts that households with the same observed characteristics demand different levels of warranties depending on their inherent preference for risk. Understanding how sorting amongst buyers (through warranties and prices paid for these warranties) impacts purchase rates for extended warranties remains unexplored, and is key to how dealers price-discriminate across buyers.

2.5 Papers That Consider Base and Extended Warranties

Lastly, we identified four published papers that consider the interaction between base and extended warranties. Padmanabhan and Rao (1993) present a model that designs optimal warranty policy for manufacturers under the situation in which consumers are heterogeneous in their risk preference, and product failure depends on the level of consumers' maintenance effort and usage, both of which are unobserved to the firm. Lutz and Padmanabhan (1995) study why manufacturers offer minimal base-warranty contracts in the presence of consumer moral hazard in a competitive insurance market. They show that manufacturers' optimal strategy is to unbundle the base warranty from the product because bundling creates a cost disadvantage over an independent insurer. Lutz and Padmanabhan (1998) consider the same problem under conditions of producer moral hazard and the independent insurer. They find that the heterogeneity in risk preference significantly affects a menu of base warranties, and that the profitability from screening hinges on the degree of competition with the independent insurer. In the context of channel distribution, Jiang and Zhang (2011) show that a retailer's service plan and manufacturer-issued base warranty are substitutes. Jiang and Zhang (2011) assume that there is no consumer-side moral hazard. The primary goal of these papers is the development of a theoretical model to design an optimal base-warranty policy when the insurance market is competitive and consumers vary in their willingness to pay for warranties. In contrast, the objective of the current study is to examine how the presence of a residual base warranty affects the demand for an extended warranty.

Padmanabhan and Rao (1993) examine the effect of the duration of a base warranty on extended-warranty sales in the new-vehicle market. In their new-vehicle setting, when quality is unobservable, a high-quality automaker offers more comprehensive base warranty coverage than a lower-quality seller. Longer and more attractive base warranties reduce consumers' need for (optional) extended coverage. As a result, the authors estimate a negative correlation between the average length of the base warranty and the choice probability of an extended warranty.

In contrast, our analysis is conducted in the context of the used-car market. The distinction is substantively quite important. Since new vehicles have their entire base warranty intact, new-vehicle buyers face limited variation in the amount of base warranty that needs to be traded off against an extended warranty. Unlike new vehicles, not all used goods have residual base warranties. We exploit this rich and "pre-determined" variation in the availability and size of residual base warranties to quantify the tradeoff that buyers make between base and extended warranties. Herein, the terms of the base warranties are pre-determined and expire upon select vehicle characteristics exceeding a certain threshold value. Hence, our empirical setting lends itself nicely to an RD-based quasi-experimental design (Imbens and Lemieux 2008). Because of the quasi-experimental design, the empirical strategy permits reliable causal inference of the aforementioned tradeoffs made by used-vehicle buyers. Specifically, we provide estimates for the pooled "local" net effect, and also quantify how this net effect varies with vehicle 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 included an extended warranty (either purchased by the previous owner or if the vehicle came certified). We do so because for these vehicles, we cannot directly ascertain the warranty residuals (at the point of purchase) and/or the price paid for the inclusion of the extended warranty by the current buyer.

Since vehicle VINs do not directly contain information on the manufacturer-backed factory warranties, we augmented our sales-transactions database with auxiliary data obtained from Cars.com and companies' websites. We report the factory-warranty terms across key manufacturers and their brands

[10]Later in the paper, we discuss how our analysis is robust to threats from self-selection.

[11]Our non-disclosure agreement prevents us from disclosing the identity of our data source.

[12]We built our VIN-decoder using the yearly-vehicle-attribute details generously provided to us by our data source.

[13]The data released include all types of sales made at these dealerships. These include individual, fleet and B2B sales. Since the economic motives for these agents differ drastically from individual buyers, we left these out of our empirical analysis. Individual transactions were screened based on whether birth dates were included for the buyers.

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 warranties includes the 3-years/36,000 miles and 5-years/60,000 miles (35.29%) coverage plans.

In addition to manufacturer-backed factory warranties, buyers (of both new and used vehicles) have the option to extend the duration of their purchased vehicle's factory-warranty coverage by purchasing an extended warranty. Similar to the factory-warranty terms, auto manufacturers offer a fairly differentiated menu of extended-warranty plans. For example, Honda and Mazda sell one extended-warranty policy, while General Motors, Nissan, and Toyota present three varying coverages for the extended warranties they underwrite. Ford and Volkswagen provide the most differentiated extended-warranty plans, with four and five products, respectively. The specific terms of extended warranties also vary across automakers. The Ford-PremiumCARE plan covers 13 major auto parts with deductibles of $0 to $100 with varying year/mileage limits (1/12,000 to 5/75,000).[15] Toyota Certified Platinum VSA overlaps

[14]Usually, this happens when the vehicle is originally delivered to the dealer from the assembly plant.

[15]These include the engine, transmission, rear-wheel-drive axle, front-wheel-drive axle, steering, brakes, front and rear suspension, electrical, air conditioning and heating, high-tech, emissions, audio and the safety. These details were obtained

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. Collectively, these included brands account for 84.75% of all the used-vehicle sales in our sample. After applying the aforementioned screening criteria, our final estimation sample consists of 20,817 observations (or about 15.33% of the transactions originally contained in our database). Our estimation sample spans 41 dealers, covers 15 automakers and includes a total of 2,216 unique make-model-dealer combinations. Table 3 contains summary statistics for the key variables of interest.

4 Empirical Strategy

New vehicles (for the most part) have their entire factory-warranty coverage intact at the time of purchase. This leaves little variation to assess how buyers trade off factory warranties against optional extended warranties. However, used vehicles vary drastically in age and mileage. Correspondingly, this induces natural variation in factory-warranty residuals across transacted vehicles. Because factory-warranty terms are pre-determined (set at the time the vehicle was manufactured), these terms cannot be strategically manipulated by either the previous owner or the dealer. Herein, the factory warranties expire upon select vehicle characteristics exceeding a pre-determined set of threshold values. We exploit this rich and pre-determined variation in the availability and size of residual-factory warranties to quantify the tradeoff that buyers make between factory (basic and power-train) and extended warranties.

Our empirical setting, therefore, lends itself nicely to a regression-discontinuity-based quasi-experimental design, which also affords us a reliable causal inference. The regression-discontinuity (RD) approach is a quasi-experimental research design in which observational units are assigned to a treatment based on whether their value of an observed covariate is above or below a known cutoff. This discontinu-

from Ford's website.

[16]Ford does not offer zero deductibles for used vehicles.

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 respective base warranties. In the section below, we first discuss the RD design more generally, followed by a detailed exposition of the sharp RD approach that we take to our data.[17]

4.1 Overview of Regression-Discontinuity Design

Researchers are often interested in the causal effect of a binary intervention or treatment. Units may be individuals, firms, products (a unique vehicle in our setting), etc. Each of these units is either exposed or not exposed to a treatment. The effect of the treatment is potentially heterogenous across units. Let $Y_i(0)$, and $Y_i(1)$ denote the potential outcomes when observational unit $i = 1, 2, \ldots, n$, is not exposed and when it is exposed to a treatment, respectively. If we had access to panel data wherein every time the observational unit is observed, the unit is randomly assigned to either the treatment or no treatment condition, Then, we would simply focus on the differences $Y_i(1) - Y_i(0)$ to make a causal inference. Unfortunately, in most empirical settings, we never observe the pair $Y_i(0)$, and $Y_i(1)$ together. This problem arises because most often the researcher either has one observation per unit (as is the case in our empirical setting) or the unit is either in the exposed/not-exposed condition (in a panel setting). Causal inference, therefore, typically focuses on the average effects of the treatment $Y_i(1) - Y_i(0)$ across units, rather than on unit-level effects. For unit i, we observe the outcome corresponding to the treatment received. If $W_i \in \{0, 1\}$ denote the no treatment and the treatment condition of unit i respectively, then the observed outcome can be expressed as:

$$Y_i = (1 - W_i) * Y_i(0) + W_i * Y_i(1) = \begin{cases} Y_i(0) & \text{if } W_i = 0 \\ Y_i(1) & \text{if } W_i = 1 \end{cases}$$

[17]For a more expansive review of the technical details, the reader is referred to Lee and Lemieux (2010), Imbens and Lemieux (2008) and Van der Klaauw (2008).

The unique feature of the RD design is that assignment to the treatment is determined, either completely or partly, by the value of a predictor X_i (which has a continuous support, ex. mileage in our setting) being on either side of a fixed threshold. Additionally, predictor X_i itself can have a direct impact on the potential outcomes. Therefore, any discontinuity in the conditional distribution of the outcome $Y_i(\bullet)$ as a function of this covariate – at the cutoff value – is interpreted as evidence of a causal effect of the treatment.

Such treatment assignments often arise in practice. For example, in Thistlethwaite and Campbell's (1960) original application of the RD method, an award was made to students whose test score was higher than a minimum score on a scholarship examination. Hahn et al. (1999) study the effect of an anti-discrimination law that only applies to firms with at least 15 employees. In the seminal Card et al. (2008) study, eligibility for medical services through Medicare is pre-determined by age. In Ludwig and Miller (2007), the Head Start program funding rates are governed by Office of Economic Opportunity (OEO) cutoffs.[18] Matsudaira (2007) investigates the effect of a remedial summer-school program that is mandatory for students who score less than some cutoff level on a test. In our empirical setting, treatment occurs when the mileage on a vehicle reaches and/or exceeds a certain pre-determined mileage cutoff. Specifically, upon reaching this mileage cutoff, the manufacturer-issued basic and/or power-train warranty gets voided.

In the sharp RD setting (SRD), the assignment to the treatment W_i is a deterministic function of one (or many) covariates, each of which is observed and has continuous support. Let X denote the forcing variable (or treatment-assignment variable), then $W_i = \mathbf{1}(X_i \geq z)$. Herein, all units with a covariate value of at least z are assigned to the treatment group, and all units with a covariate value of less than z are assigned to the control group. In this design, the average causal effect of the treatment is the discontinuity in the conditional expectation of the outcome, given the covariate at the discontinuity point. Formally:

$$\tau_{\texttt{SRD}} = \mathbb{E}[Y_i(1) - Y_i(0)|X_i = z] = \lim_{x \downarrow z} \mathbb{E}[Y_i|X_i = z] - \lim_{x \uparrow z} \mathbb{E}[Y_i|X_i = z] \quad (1)$$

Recall that matching-type treatment-effect estimators are grounded in the "unconfoundedness" assumption (see Rosenbaum and Rubin 1983; Imbens, 2004). That is:

[18] The Head Start program was established in 1965 as part of the War on Poverty initiative. The federal program provides preschool, health and other social services to poor children age three to five and their families.

$$Y_i(0), Y_i(1) \perp W_i | X_i \tag{2}$$

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.

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

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, in large samples, the amount of extrapolation required to make inferences is arbitrarily small, as we only need to infer the conditional expectation of $Y(w)$ given the covariates ε away from where it can be estimated. So as to avoid non-trivial extrapolation, we focus on the average treatment effect at $X_i = z$. That is:

$$\tau_{\texttt{SRD}} = \mathbb{E}[Y_i(1) - Y_i(0) | X_i = z] = \mathbb{E}[Y_i(1) | X_i = z] - \mathbb{E}[Y_i(0) | X_i = z] \tag{4}$$

However, by design, there are no units with $X_i = z$ for which we observe $Y_i(0)$. We therefore exploit the fact that we observe units with covariate values arbitrarily close to z. However, in order to justify this averaging, one needs to assume smoothness, which is often formulated in terms of conditional expectations (Hahn et al. 2001).

Taking advantage of the local continuity condition enables us to make individual units in a neighborhood of $X_i = z$ comparable. Therefore, by comparing the average outcomes just above and below the threshold, now we can identify the average treatment effect for units close to the forcing variable/covariate cutoff value.[19] In the simplest case, flexible estimation of RD treatment effects approximates the regression function of the outcome near the cutoff value of the forcing/running variable for control and treated groups separately, and computes the estimated effect as the difference of the values of the regression functions at the cutoff for each group:

[19] Before employing the RD approach, researchers need to test the validity of these RD design requirements for their individual empirical settings (Lee 2008).

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

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

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

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 doing so, helps the researcher obtain more precise estimates of the treatment effect. However, a model applied to a large bandwidth is more likely to suffer predictive inaccuracy. Furthermore, if the underlying conditional expectation of the outcome is nonlinear, then a linear model may still be a good approximation within a narrow bandwidth. However, a linear parameterization may be unable to accurately approximate variation in the data over a wider bandwidth. Therefore, the key intuition for bandwidth selection is that one needs to trade off the bias and the variance of $\hat{\tau}_{\texttt{SRD}}(h_n)$. Heuristically:

$$\uparrow \mathsf{Bias}(\hat{\tau}_{\texttt{SRD}}) \quad \Longrightarrow \quad \downarrow \hat{h} \qquad \mathsf{and} \qquad \uparrow \mathsf{Var}(\hat{\tau}_{\texttt{SRD}}) \quad \Longrightarrow \quad \uparrow \hat{h}$$

There are two approaches for data-driven bandwidth selection: (i) cross-validation, and (ii) direct plug-in rules based on mean square error (MSE) expansions.[20] The direct plug-in (DPI) approach is based on a MSE expansion of the sharp RD estimators, leading to the MSE-optimal choice:

[20]See Lee and Lemieux (2010) for the application of cross-validation methods in RD settings.

$$\hat{h} = \hat{C} \cdot n^{-1/5} \tag{7}$$

where

$$\hat{C} = 3V \left(\frac{3V}{2B^2} \right)^{\frac{1}{5}} \tag{8}$$

In the expressions above, B and V are the leading asymptotic bias and variance of the RD estimator. In practice, one discards 50% of the observations on either side of the threshold (Imbens and Lemieux 2008). Ludwig and Miller (2007) implement their bandwidth-selection procedure by using only data within 5 percentage points of the threshold on either side. If the curvature of the density of the running variable is similar on both sides close to the cutoff point, then in large samples, the optimal bandwidth will be similar on both sides of the cutoff. In the case of the cross-validation-based approach to bandwidth selection:

$$\hat{h}_{\texttt{CV}} = \arg\min_{h} \sum_{i=1}^{n} w(X_i) \left(Y_i - \hat{\mu}_1(X_i, h) \right)^2 \tag{9}$$

The cross-validation approach boils down to selecting an optimal bandwidth h that minimizes the MSE between the predicted and actual Y. The limitation of cross-validation is that the bandwidth-selection criterion is evaluated over the entire support of X, as opposed to the distribution of the running variable only around the cutoff z. For this reason, in our empirical analysis, we limit our analysis to the direct plug-in bandwidth-selection estimators. Specifically, we run our analysis using the estimator proposed in Imbens and Kalyanaraman (2012) and Calonico et al. (2014).

4.2 Model specification

In much of the empirical literature focused on recovery of the treatment effects (including the difference-in-difference approach), the researcher will estimate a regression function across the entire sample of treated and control units of the form:

$$
\begin{aligned}
logit\left(Pr\left(Y_{djst}=1|Mileage_{djst},\, X_{djst}\right)\right) &= log\left(\frac{Pr\left(Y_{djst}=1|Mileage_{djst},\, X_{djst}\right)}{1-Pr\left(Y_{djst}=1|Mileage_{djst},\, X_{djst}\right)}\right) \\
&= \beta_0+\beta_1 * D_{djst}+\beta_2 * Mileage_{djst} \\
&\quad +\beta_3 * D_{djst}\cdot Mileage_{djst} \\
&\quad +\gamma * X_{djst}+\varepsilon_{djst}
\end{aligned}
$$

This approach has some undesirable properties. First, the resulting estimator puts uniform weight across all observational units when estimating the model. In our empirical setting, this would amount to not distinguishing between used vehicles whose mileage is far away from the cutoff from those whose mileage is very proximate to the cutoff. It is reasonable to assume that vehicles with odometer readings that are far away from the cutoff are qualitatively very different than those that are closer to the cutoff. These qualitative differences may stem from different levels of wear-and-tear, maintenance, number of previous owners, etc. Since these are unobservable to the econometrician, the recovered treatment effect may suffer bias. However, these qualitative differences, while not absent, are unlikely to be systematic or large when one limits the estimation to a “narrow” region around the cutoff.

So as to mitigate this concern, we use the SRD design outlined above. In our specific empirical setting, the running variable is the odometer mileage of the used vehicle being purchased. As discussed in the data section, manufacturer-backed factory warranties include basic and power-train warranties. Each of these factory warranties expires when the vehicle reaches or exceeds the pre-determined basic or power-train warranty terms (e.g., 3 years/36,000 miles or 5 years/60,000 miles). Because the expiry of a factory warranty is decided at pre-determined levels, the treatment assignment in our setting is deterministic in mileage (a requirement for SRD). Therefore, using the approach outlined above affords us the ability to answer the following question: By how much do purchase rates of extended warranties for used vehicles change at the point when the vehicle hits the pre-determined factory-warranty-expiry level?

But the demand for extended warranties can also depend on other covariates in addition to the forcing covariate that is the basis of the assignment mechanism in our RD design. Including other covariates can help eliminate sample biases present in the model specification outlined above and improve the precision of our treatment effect estimate $\hat{\tau}$. In addition, they can be useful for evaluating the plausibility of the identification strategy (more on this later). For example, vehicle characteristics such as the automobile 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:

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

where D_{djst} is an indicator variable that takes on value 1 when $z_{basic/power-train\,cutoff} \leq Mileage_{djst} \leq h_n$ 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, the net effect of the used-vehicle-transacted prices on purchase probability of the extended warranty remains an open empirical question.

To quantify this net effect in the region "local" to the expiry of the warranty, we also include the vehicle transacted price as an additional covariate. For the same reasons, we also include the price of the vehicle traded in (should there be a trade-in). Time-invariant dealer- and buyer-market unobservables are controlled via dealer- and buyer-market fixed effects. To control for aggregate time-varying unobservables (seasonality, weather, gas prices, etc.), we include year and month dummies. [21] Finally, ε_{djst} captures other drivers that impact buyers' extended warranty-purchase decisions but are unobserved to the econometrician, and that are specific to product and vary by dealer, state, transacted year and month. Our key parameters of interest are β_1 and β_3. β_1 estimates the average effect of the basic/power-train warranty expiry on the probability of choosing an extended warranty. β_3 allows a varying slope for the impact of vehicle mileage pre- and post-expiry of the basic warranty.

5 Threats to Identification

The most serious threat to identification in RD design is the strategic manipulation of the forcing/running variable (McCrary 2008). In our empirical setting, the vehicle mileage is hard to manipulate by either the auto buyer or dealer. Therefore, this concern about identification is mostly tempered by the institutional setting itself. To formally rule out this primary threat to identification, we perform the McCrary test. McCrary (2008) tests the continuity of the density of the running variable (that underlies the assignment at the discontinuity point) against the alternative of a jump in the density function at that point. Herein, the logarithm of the difference in the height of density functions on both sides of the cutoff is non-parametrically estimated and tested against its asymptotic normal distribution. We conduct this test on the running variable only on the observations identified as being local to the cutoff by the IK and CCT bandwidth estimators.

The results of the McCrary test on the running variable for the estimator suggested by IK and CCT is reported in Tables 4 and 5. A positive (negative) McCrary test statistic implies that the density of the running variable is higher (lower) post-expiry of the basic/power-train warranty than pre-expiry of these

[21] Copeland (2014) highlights seasonality in consumer mix. Since automakers frequently use cash-back rebates at the end of the model year to boost sales, consumers time their purchase decisions to avail of lower prices. Including month fixed-effects helps control for sorting/strategic timing of purchase by deal-prone buyers.

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 estimators.[22] We report key statistics for the bandwidth-limited sample for IK and CCT in Tables 8 and 9. The CCT-optimal bandwidths for the basic warranty and power-train-warranty cutoffs at 60,000 and 100,000 miles are 12,021; 18,320; and 43,981 miles.[23] On average, the CCT- based estimator yields a more compact bandwidth than the IK-based bandwidth estimator.

To examine the effect of the base warranty on purchasing an extended warranty, we begin by first graphing the relationship between the mileage of the used vehicle and the probability of buying the extended warranty at the base-warranty thresholds in Figure 7.2. Each panel illustrates the average attachment rate for an extended warranty within a mileage bin. The vertical line denotes the basic-warranty-cutoff mark. The 4th-order polynomial fitted lines without covariates (i.e., without X_{djst}) are overlaid in each plot. Figure 7.2 presents model-free evidence on discontinuous jumps at the basic mark and at the power-train cutoff of 60,000 miles, and a noticeable drop at the 100,000-miles cutoff. It highlights that the expiry of basic/power-train warranties has a *causal* influence on the probability of buying extended warranties. It is well known, however, that the simple comparison of pre- and post-expiry of the basic/power-train warranties does not necessarily suggest anything about the attachment rate of extended warranties. Thus, we estimate the proposed local linear regression with other covariates beyond the running variable. Tables 10 and 11 report estimates from the SRD with the transaction price and trade-in value, and a battery of fixed effects to control for plausible unobservables. These include manufacturer dummies, model dummies, dealer dummies, buyer state-of-residence dummies, and year and month dummies.

Our main finding is that there is a discontinuous change in the probability of purchasing extended warranties upon the expiry of the basic warranty. The RD estimates also confirm that the purchase rate for extended warranties rises gradually up to the cutoff point where the basic warranty expires. At the cutoff point, there is a discontinuous drop of 3%[24] in the attachment rate for extended warranties. However, post-expiry of the basic warranty, the attachment rate for extended warranties remains constant at a level higher than its pre-basic-warranty-expiry level. In fact, after expiry of the basic warranty, the attachment rate settles at the pre-expiry level of 35,200 miles. These findings suggest that buyers who purchase used vehicles that are 800 miles short of the expiry of the basic warranty are the ones who

[22]We select the optimal plug-in bandwidth because the conventional cross-validation approach yields a bandwidth that is optimal for fitting a curve over the entire support of the data, while we are interested in the best-fitting bandwidth around the cutoff point.

[23]The IK-optimal bandwidths for the basic- and power-train-warranty cutoffs are 14,848; 21,047; and 61,569 miles, respectively.

[24]$([\beta_0 + \beta_1 + (\beta_2 - \beta_3) * 36,000] - [\beta_0 + \beta_2 * 36,000])$

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 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.[25]

The discussion on the average effects of expiry of basic/power-train warranties raises the following question: To what extent do the pooled effects vary by the country of origin of the automaker? Sepa-

[25]Our inference procedure, given recovered estimates, is as follows: Using the estimates for the intercept, discontinuity, vehicle mileage, and the interaction of discontinuity and vehicle mileage in Table 11, we compute the log-of-the-odds ratio before and after the expiry of the basic warranty.

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*, buyers of expensive used vehicles are more likely to purchase extended warranties. This finding suggests that heterogeneity in buyers' risk preferences may be at work. Specifically, risk-averse consumers are willing to pay a price premium to reduce the risk. To mitigate risk, these consumers purchase more expensive vehicles than other buyers with a higher tolerance for risk. These high-risk-averse consumers are also more likely to purchase extended warranties and do so at a higher rate than buyers with a higher tolerance for risk. It is buyers' risk preferences that seed a positive correlation between the types of vehicles purchased and the corresponding attachment for extended warranties. The positive correlation generates the positive price coefficient. While studying the effect of heterogeneous risk preferences is not central to this essay, inclusion of the vehicle transacted prices helps us at least control for it.

[26] Domestic brands include Ford, GMC, Chevrolet, Jeep, Dodge, Pontiac, Chrysler and Mercury. Imported vehicles are Honda, Toyota, Nissan, Mazda, Volkswagen, Subaru and Scion.

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 a level higher than its pre-basic-warranty-expiry level. In fact, after expiry of the basic warranty, the attachment rate settles at the pre-expiry level of 35,200 miles. That is, *ceteris paribus*, the attachment rate for extended warranties post-expiry of the basic warranty remains steady at a level equal to the attachment rate for used vehicles that are 800 miles short of the expiry of their basic warranty. For the power-train warranty of 60,000 miles, following the sudden bump in the demand for extended warranties at the expiry, the attachment rates 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 where consumers choose the extended warranties the most. These findings have important managerial implications. First, buyers who purchase used vehicles that are 800 miles short of the expiry of the basic warranty are the ones who 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 fewer to go before their basic warranty expires. The next-most-attractive segment is buyers of vehicles with expired basic warranties. As for the power-train-warranty mark, 3,700 miles post-expiry of the power-train warranty is the most profitable consumer segment for auto dealers. The next-most-attractive segment is buyers who purchase used vehicles prior to the expiry of the power-train warranty. 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.

Although this study makes several contributions to the empirical literature on product warranties, it has some limitations. First, this is a descriptive study, albeit using a causal-inference approach. Therefore, we cannot currently examine how changes to manufacturer-backed factory warranties and/or the price of extended warranties will impact extended-warranty-adoption rates of individual buyers. Answering such normative questions requires a structural modeling framework to recover the structural primitives that drive buyers' choice of extended warranties.[27] Second, we limit our analysis to used vehicles alone in part because new vehicles have limited variation in residual base warranties. Hence, we cannot readily make any statements about the window of opportunity that auto dealers have to sell extended warranties to buyers of new vehicles. A few niche automakers' vehicles were intentionally left out of our analysis. These were excluded in part because they had very different base-warranty mileage cutoffs than those we have currently included in the analysis. However, the empirical framework we ad-

[27] Jindal (2015) proposes a framework to explore this in the context of new durable goods using stated-choice data. Extending Jindal's empirical framework to accomodate tradeoff buyers make between base and extended warranties using observational data alone is non trivial and is outside the scope of this study.

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.

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Table 1: A list of Manufacturer Warranties (years/miles)

Manufacturer	Brand	Basic warranty	Powertrain warranty
Audi	Audi	4/50,000	4/50,000
Bentley	Bentley	3/Unlimited	3/Unlimited
BMW	BMW, Mini	4/50,000	4/50,000
Chrysler	Chrysler, Dodge, Jeep	3/36,000	5/100,000
Ferrari	Ferrari	2/Unlimited	2/Unlimited
Ford	Ford, Mercury	3/36,000	5/60,000
	Lincoln	4/50,000	6/70,000
	Volvo	4/50,000	4/50,000
General Motors	Chevrolet, GMC, Pontiac	3/36,000	5/100,000
	Buick, Cadillac, Hummer	4/50,000	5/100,000
Honda	Honda	3/36,000	5/60,000
	Acura	4/50,000	6/70,000
Hyundai	Hyundai, Kia	5/60,000	10/100,000
Jaguar	Jaguar	4/50,000	4/50,000
Lamborghini	Lamborghini	3/Unlimited	3/Unlimited
Land Rover	Land Rover	4/50,000	4/50,000
Lotus	Lotus	3/36,000	3/36,000
Maserati	Maserati	4/50,000	4/50,000
Maybach	Maybach	4/50,000	4/50,000
Mazda	Mazda	3/36,000	5/60,000
Mercedes-Benz	Mercedes-Benz	4/50,000	4/50,000
Mitsubishi	Mitsubishi	5/60,000	10/100,000
Nissan	Nissan	3/36,000	5/60,000
	Infiniti	4/60,000	6/70,000
Porsche	Porsche	4/50,000	4/50,000
Rolls-Royce	Rolls-Royce	4/Unlimited	4/Unlimited
Subaru	Subaru	3/36,000	5/60,000
Suzuki	Suzuki	3/36,000	7/100,000
Toyota	Toyota, Scion	3/36,000	5/60,000
	Lexus	4/50,000	6/70,000
Volkswagen	Volkswagen	3/36,000	5/60,000

Table 2: Select Extended Warranties

Manufacturer	Providerr	Plans	Terms (Years/1k miles)	Deductibles ($)	Number of auto parts covered
Ford	Ford Credit	PowertrainCare	3/75 to 7/125	0/50/100/200	4
		BaseCare	3/48 to 7/125	0/50/100/200	9
		ExtraCare	3/48 to 7/125	0/50/100/200	10
		PremiumCare	3/48 to 7/125	0/50/100/200	13
General Motors	Ally Financial Inc.	Basic Guard	not specified	not specified	6
		Value Guard	not specified	not specified	11
		Major Guard	not specified	not specified	13
Honda	Honda Financial Services	Honda Care	not specified	not specified	11
Mazda	Mazda	Mazda Extended Confidence	1 year to 9/100	0 to 100	7
Nissan	Nissan	Powertrain Plan	2/24 to 7/100	0 to 100	4
		Deluxe Plan	2/24 to 7/100	0 to 100	10
		Supreme Plan	2/24 to 7/100	0 to 100	10
Subaru	Subaru	Added Security Classic	up to 7/100	not specified	10
		Added Security Gold Plus	up to 7/100	0/50/100	10
Toyota	Toyota Financial Services	Powertrain Protection	6/100	not specified	4
		Gold Protection	3/50 to 8/125	not specified	4
		Plantinum Protection	3/50 to 8/125	not specified	13
Volkswagen	Volkswagen Credit	Powertrain Plan	up to 100,000 miles	not specified	4
		Silver Plan	up to 100,000 miles	not specified	9
		Gold Plan	up to 100,000 miles	not specified	9
		Gold Plus Plan	up to 100,000 miles	not specified	10
		Plantinum Plan	up to 100,000 miles	not specified	10

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

Table 9: Summary Statistics of Post-CCT Bandwidth Sample

Basic Warranty Mark	Mean	SD	Minimum	Maximum
Extended warranty attachment rate	.557	.497	0	1
Odometer Mileage	35367.71	6700.14	23986	48015
Transacted Price of Used-Vehicle	20112.78	6939.68	3396.1	63225.24
Transacted Price of Trade-in Vehicle	3534.3	6051.8	0	54000

Powertrain Warranty Mark (60,000 miles)	Mean	SD	Minimum	Maximum
Extended warranty attachment rate	.562	.496	0	1
Odometer Mileage	57066.23	10420.61	41684	78318
Transacted Price of Used-Vehicle	17047.96	6067.37	2900	48900
Transacted Price of Trade-in Vehicle	3000.92	5493.33	0	44328.65

Powertrain Warranty Mark (100,000 miles)	Mean	SD	Minimum	Maximum
Extended warranty attachment rate	.436	.496	0	1
Odometer Mileage	82134.96	20134.51	56064	143962
Transacted Price of Used-Vehicle	15248.3	7095.55	100	55000
Transacted Price of Trade-in Vehicle	2938.89	5534.29	0	40782.55

Note: Standard errors in parentheses.

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.

Table 13: Regression Discontinuity Estimates by Domestic versus Imported Brands (Power-train warranty)

	Domestic except Ford (100k miles)	Imported (60k miles)
Intercept	-1.325 (1.692)	-2.798*** (.945)
Discontinuity	-1.421 (1.514)	2.071** (.842)
Discontinuity * Vehicle Mileage	.000011 (.000015)	-.000032** (.000013)
Vehicle Mileage	-.000013 (.000013)	.0000073 (.0000096)
Cash Price	.000041* (.000022)	.000099*** (.000015)
Trade-In Value	.0000074 (.000017)	-.000026*** (.0000093)
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	1143.1	3264.1
Observations	867	2,315
Bandwidth	(74296, 125704)	(39091, 80909)

Note: Standard errors in parentheses.

Figure 1: McCrary Test

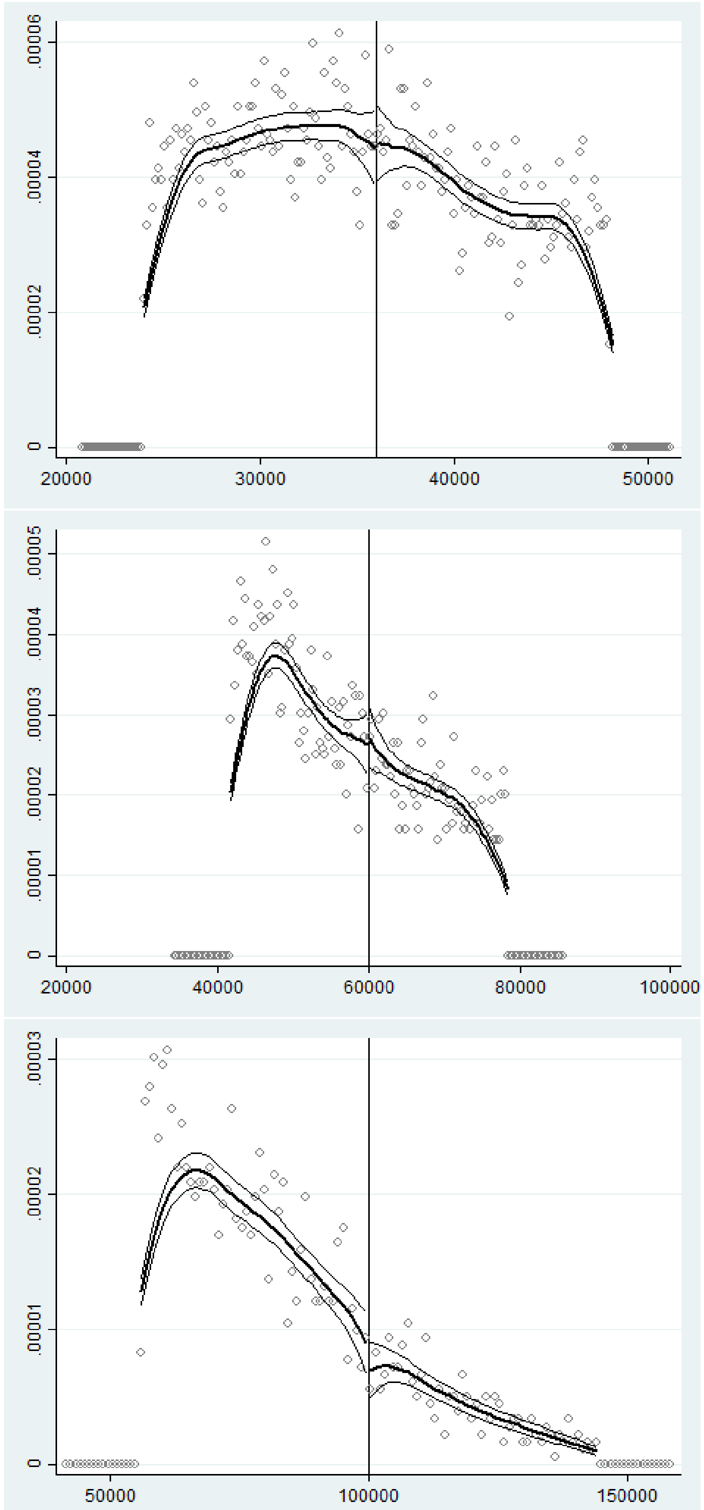
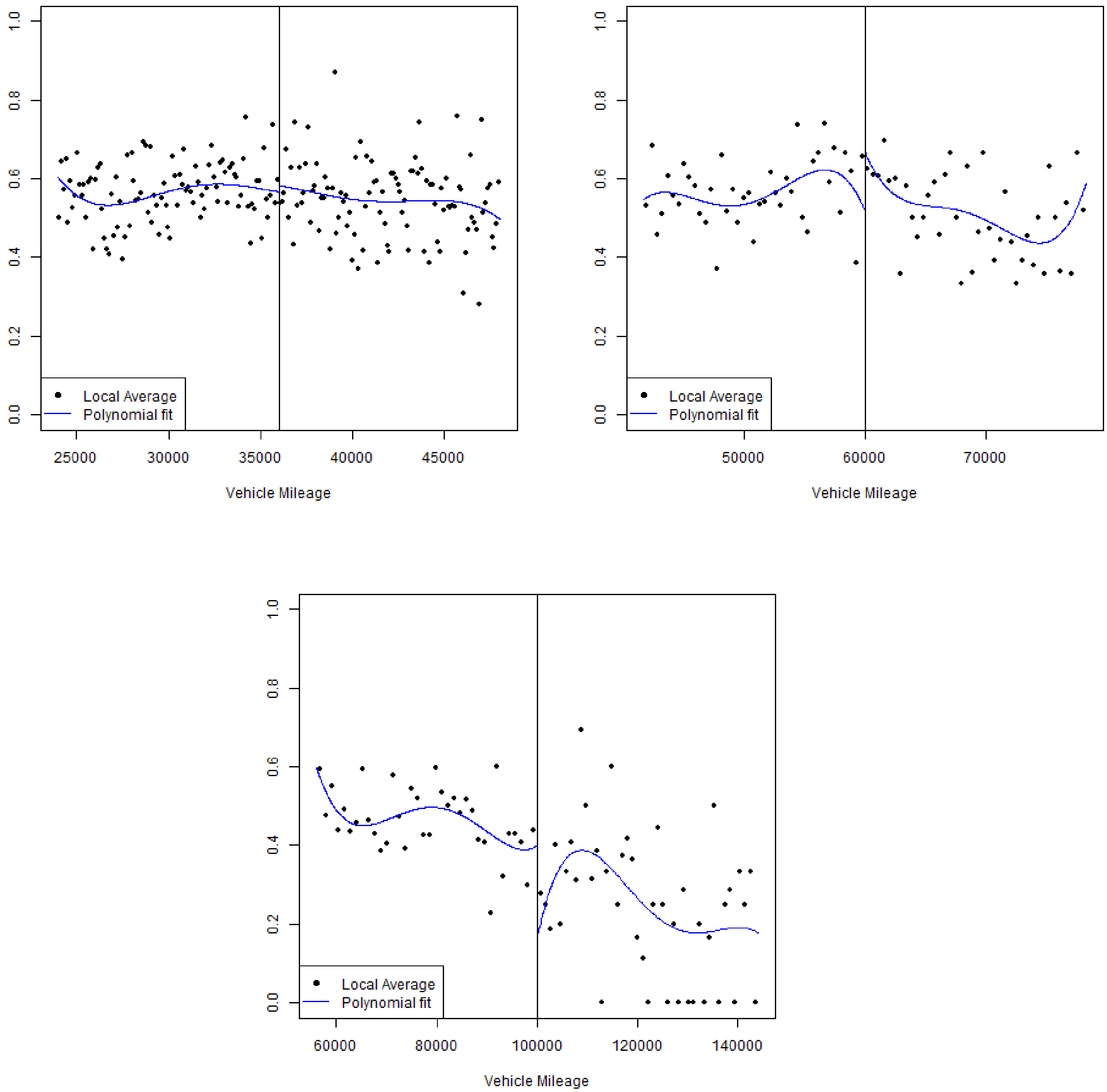


Figure 2: Impact of the Basic/Powertrain Warranty on Extended Warranty Purchase



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*** (.000035)	-.00009 (.00001)	.000021*** (.0000074)	.0000023 (.0000045)
Bandwidth	(7215, 12785)	(14612, 25388)	(18124, 41876)	(25620, 54380)	(29114, 70886)

Table 15: Robustness Check: Placebo Test Results (Power-train Warranty)

	40k miles	50k miles	60k miles	70k miles	80k miles	90k miles
Intercept	-1.73*** (.932)	-1.21 (.903)	-2.46** (1.01)	-2.74** (.854)	-1.01 (1.33)	-1.06 (1.25)
Discontinuity	-.332 (.832)	-.268 (.833)	1.90** (.937)	1.07 (.719)	-1.21 (1.24)	1.52 (1.26)
Discontinuity * Vehicle Mileage	.0000035 (.00002)	.0000086 (.000016)	-.000032** (.000015)	-.000021 (.00001)	.000015 (.000015)	-.0000142 (.000014)
Vehicle Mileage	.0000072 (.000014)	-.0000014 (.000011)	.000017 (.000011)	.000011* (.0000064)	-.000025* (.000013)	-.000024** (.00001)
Bandwidth	(26818, 53182)	(33373, 66627)	(41680, 78320)	(42466, 97534)	(61437, 98563)	(66754, 113246)

Table 16: Robustness Check: McCrary Test of The Effect of Product Availability

	Basic Warranty Mark (36k miles)	Powertrain Warranty Mark (60k mile)	Powertrain Warranty Mark (100k mile)
Log discontinuity estimate	.022 (.097)	-.012 (.124)	.144 (.253)
Observations	5,848	3,310	938

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)	.0097 (.016)
Cash Price	.000051*** (.000008)	.000075*** (.000014)	.000031 (.00002)
Trade-In Value	-.0000056 (.0000054)		.0000018 (.000016)
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	6870.8	2584.4	1190
Observations	5263	1819	937

Table 18: Non-parametric Regression Discontinuity Estimate in Extended Warranty Price

	Basic warranty mark (36k miles)	Powertrain warranty mark (60k miles)	Powertrain warranty mark (100k miles)
Vehicle Mileage	-6.875 (62.053)	12.204 (100.85)	-440.23** (205.19)
Observations	5340	2917	1613

Figure 3: Discontinuity in Transaction Price of Used Vehicles

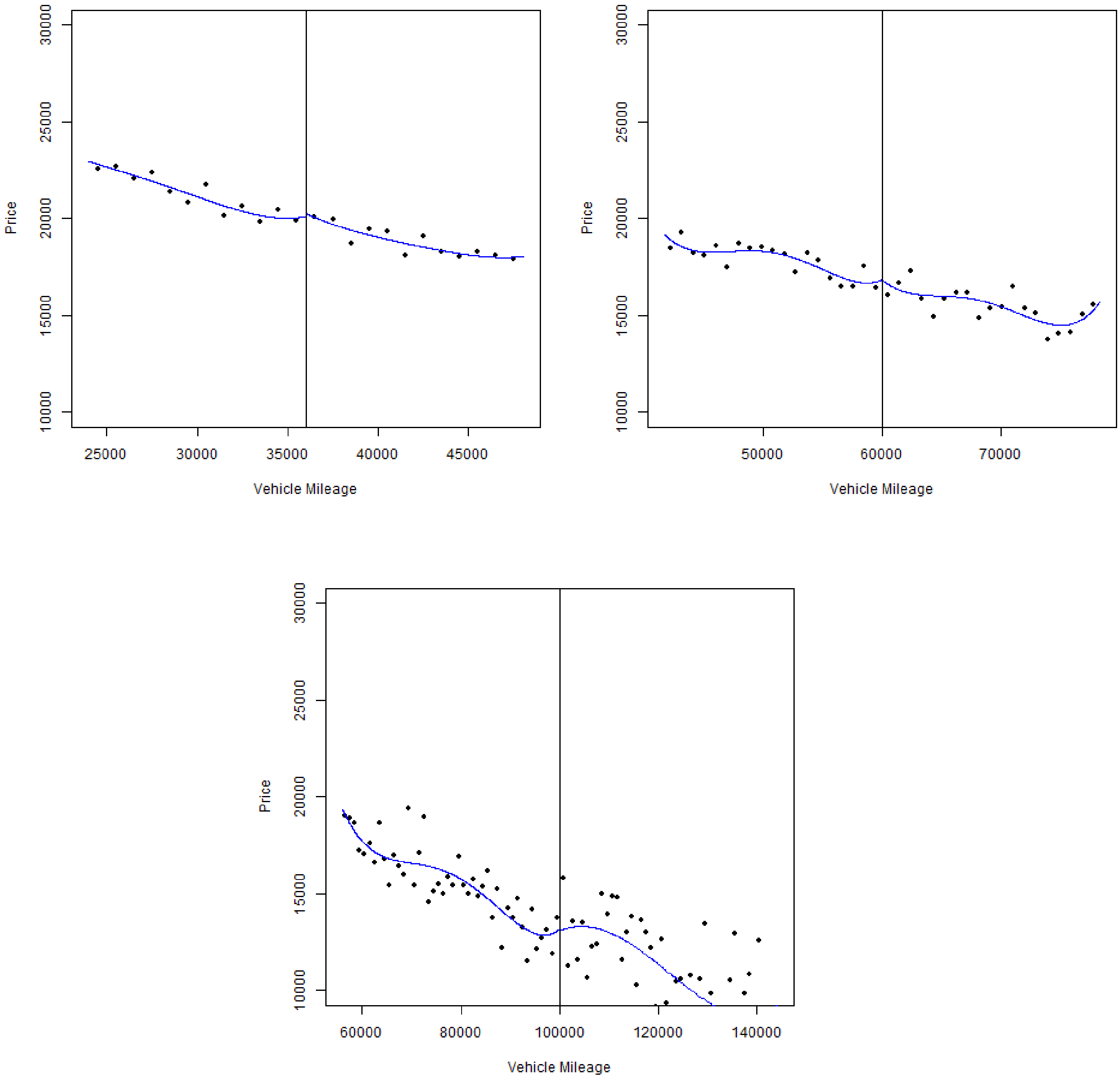


Figure 4: Discontinuity in Trade-In Value