# Risk Preferences and Demand Drivers of Extended Warranties*

Pranav Jindal

*Booth School of Business*

*University of Chicago*

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**Abstract**

The objective of this paper is to understand what drives consumers to buy extended warranties and pay high premia for them. We primarily focus on the role of risk preferences and disentangle and study their relative importance. Empirical and behavioral research on insurance is at odds with whether diminishing returns (curvature of the utility function), or loss aversion and non-linear probability weighting lead to the observed consumer behavior. This is primarily due to the inability of standard choice data to separate curvature of the utility function, loss aversion and non-linear probability weights, and the need to rely on strong parametric assumptions. We design two conjoint studies (consistent with simultaneous and sequential decision making) with choices over washing machines (with and without extended warranty) where failure probabilities and repair costs are given to subjects. Using stated choice data from the survey, consumer preferences, degree of curvature, loss aversion and probability weights can be non-parametrically identified. We find that loss aversion is significantly more important than curvature and probability weights in explaining extended warranty choices. These findings are robust to different specifications of the utility function and risk preferences. Importantly, failure to decompose risk averse behavior into that arising from curvature, loss aversion and probability weighting leads to lower washer and warranty prices, and under predicts the rate of change of warranty prices with varying repair costs. We test theory on complementary good pricing and find that estimates from the sequential choice survey rationalize the high premium consumers pay for extended warranties. Finally, forcing different retailers to sell washers and extended warranties increases (decreases) the washer (warranty) price, and makes consumers worse-off. A 5% discount on the washer price makes consumers indifferent to the proposed policy intervention.

*Keywords:* Extended warranties, product insurance, prospect theory, loss aversion, risk aversion, insurance pricing

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# 1 Introduction

Consumers pay a high premium when purchasing extended warranties (protection plans) and service contracts to insure product purchases[1]. As researchers, it is important for us to understand what drives consumers to pay such high premia to insure against moderate risks. This has managerial implications for both, product and warranty pricing, and policy implications on how extended warranties should be sold. In this paper, we focus on the role of different preferences in explaining extended warranty purchases and the premium paid. Specifically, we disentangle different risk and product preferences and quantify their relative importance in driving warranty choices. We use the demand estimates to draw managerial implications for product and warranty pricing, and shed light on retailers' pricing incentives when selling complementary goods such as products and extended warranties.

Unlike manufacturers' base warranties which are bundled with the product, extended warranties are optional and consumers purchase them depending on their intrinsic preferences and expectations about product quality[2]. While extended warranties can be purchased for a product purchased in the past, most extended warranties are purchased simultaneously with the product and thus, we focus on extended warranties purchased at the time of product purchase[3]. As per the trade publication Warranty Week, extended warranties worth $15 billion were sold in 2004 and the industry is growing 7% per year. As compared to an average contribution margin of 15%-20% on home appliances and electronics goods, the contribution margin on warranties is approximately 50%-60%[4]. These high margins, coupled with the attention warranties have received in the media warrants a better understanding of the factors which lead consumers to pay high risk premia for warranties, and the impact of their pricing on consumer demand and firm profitability.

Table 1 provides data on insurance price and claims from different papers, and from a large mid-western retailer of home appliances. We consistently find that firms enjoy a contribution margin upwards of 40% (corresponding to mark-up of around 65%). Researchers argue that these margins are driven by consumers' aversion to risk, which is operationalized by a concave utility function. Rabin and Thaler (2001), however, claim that consumers have to demonstrate extreme degrees of risk aversion (concavity) to justify warranty and other product insurance purchases. Using data from the home appliance retailer, we calibrate the degree of risk aversion required to rationalize warranty choices. Details of the calibration exercise are present in Appendix A. We find that consumers choices imply risk aversion such that they will reject a gamble which has an equal chance of winning $100 and losing $5 or less. In the economics literature, researchers have consistently found risk aversion estimates such that consumers reject a gamble which has an equal chance of

[1]Henceforth, we will be using the words warranties and service contracts interchangeably. If not mentioned otherwise, warranties refer to extended warranties. Any reference to base warranties or any other type of warranties will be explicit.

[2]Extended warranties differ from base warranties in that they are additional SKUs retailers sell which consumers could buy with products. Extended warranty contracts are underwritten and serviced either by the retailer or by third party insurers. For example, extended warranties sold at Best Buy are serviced by Geek Squad while those sold at Circuit City are serviced by BWG. The Home Depot and Lowes have their own specialists who repair products purchased with protection plans.

[3]Warranty Week (2007), "Extended Warranty Solution", July 25, 2007.

[4]See for example http://www.bbb.org/us/article/know-the-deal-on-extended-warranties-and-service-contracts-2443 and http://www.cbsnews.com/stories/2007/08/10/earlyshow/contributors/raymartin/main3156565.shtml

winning \$100 and losing around \$90-\$95. Thus, share of warranty choices and the premia paid for them are not justified by risk aversion (curvature) alone[5].

We consider three different dimensions leading to risk averse behavior, namely, risk aversion which is equivalent to diminishing returns in utility, loss aversion where losses loom larger than gains of similar magnitude, and non-linear weighting of failure probabilities (also known as probability or probability weighting). Kahneman and Tversky (1979) show that consumers are not equally sensitive to small changes in probabilities at different probability levels, which leads them to account for probabilities non-linearly and leads to possibility and certainty effects. Rabin and Thaler (2001) rationalize warranty purchases through loss aversion, and through the non-linear weights consumers assign to failure probabilities (as in the probabilistic insurance example discussed in Wakker, Thaler, and Tversky (1997))[6]. While risk aversion and loss aversion can co-exist, it is important to note that loss aversion exists only when the consumer incurs possible losses. On the contrary, risk aversion just refers to the concavity of the utility function and exists even in the absence of losses.

Panel data on warranty purchases and repairs do not provide information about failure beliefs; thus, requiring researchers to assume rational expectations and make functional form assumptions. In the insurance literature, where claims are generally observed, researchers assume rational expectations to model claim rates (for example, Cohen and Einav (2007), Barseghyan, Molinari, O'Donoghue, and Teitelbaum (2010)). In the case of extended warranties, where researchers typically do not observe product failure, they model the failure probability and expected repair costs as a function of product prices and other characteristics (see for example, Chen, Kalra, and Sun (2009), Chen and Sun (2010)). Estimation of probability weights is thus, contingent on the assumptions researchers make about failure beliefs. Experiments and surveys are ideally suited for such a problem. They not only allow researchers to overcome the assumptions of rational expectations and functional forms, but also give researchers the ability to manipulate beliefs within subjects, which facilitates estimation of probability weights (or function).

In this research, we design two conjoint studies to understand what drives consumers to purchase washing machines (washers) and an optional extended warranty. Economic theory does not provide any guidance on whether products and warranties are purchased simultaneously or sequentially. In practice, firms such as Best Buy first focus on selling products and then try and up sell warranties at the check out counter (consistent with a sequential decision making process). In contrast, some firms display price tags for both products and warranties and do no push consumers to purchase warranties during check-out (consistent with simultaneous decision making). Thus, we design studies with simultaneous and sequential product and warranty choice and compare our results. By explicitly providing subjects the beliefs about product failure and repair costs, we do not rely on functional form assumptions about belief formation[7]. The key advantage

[5]In a related context, Sydnor (2010) shows that a standard model of decision making (based on expected utility theory) requires triple-digit coefficients of relative risk aversion to explain deductible choices in homeowners insurance.

[6]Henceforth, we will refer to risk aversion stemming from a concave utility function as risk aversion and that stemming from greater sensitivity to losses as loss aversion. Thus, the term risk aversion is used in the sense of expected utility theory while loss aversion (which also leads to risk aversion) is used based on prospect theory.

[7]Consumers may not know the exact probability of failure and repair costs at the time of buying the product. An alternate

of this approach lies in the researchers' ability to manipulate the beliefs about product failure and repair costs to non-parametrically separate risk aversion from loss aversion and probability weights. Beliefs about product failure and repair costs are not observed in panel data and thus, methods based on panel data rely on parametric assumptions about risk aversion, loss aversion and the weights consumers assign to probabilities to separately identify these.

In the first study, subjects simultaneously choose between two leading brands of washing machines (with or without warranty) and the outside option of not purchasing. In the conjoint tasks, the subjects are provided with washer prices and characteristics, prices of an extended warranty, probability that the washer fails during the three years after the first year (which is covered by the manufacturer warranty), and the repair costs in case the washer fails. Across different tasks, we vary these characteristics to get within subject variation which aides non-parametric identification. In the second study, subjects first choose between two leading brands of washing machines and the outside option of not purchasing. Conditional on product choice, they are shown the failure probability, repair costs and warranty prices and asked whether they would choose an extended warranty for the washer purchased. In the second stage, they also have the choice of not purchasing the washing machine after learning about the failure characteristics.

Based on our assumption of reference points, we find that subjects are on average risk neutral but there exists substantial heterogeneity in risk aversion (curvature of the utility/value function). We also find evidence in support of probability weighting but contrary to the literature, we find an S-shaped weighting function (as opposed to inverted S-shaped) on average. Subjects are found to be extremely loss averse. While the average loss aversion is estimated to be around 2.05, there exists substantial heterogeneity in how averse different subjects are to losses. This finding is consistent with the vast behavioral literature which estimates a mean loss aversion parameter of 2.25. Not accounting for loss aversion, we estimate a simultaneous choice model consistent with expected utility theory and find that subjects seem to be more price sensitive, and buy warranties because of both; aversion to risk (diminishing returns), and intrinsic preference for warranties. *Based on the out of sample predictions, and after accounting for product and price preferences, loss aversion explains warranty choices substantially better than risk aversion and weights assigned to failure probabilities.* These findings are robust to alternate functional form assumptions.

We use the demand estimates to run pricing simulations and find that the optimal warranty and product price are lower if we assume that consumers are expected utility maximizers (profits decrease by around 9%), as compared to a model accounting for loss aversion and probability weighting. Failure to separate diminishing returns from loss aversion and probability (decision) weights under-predicts the rate at which warranty prices should adjust when repair costs change. Interestingly, comparing optimal warranty and product prices from the simultaneous and sequential studies, we find that under sequential choice, retailers have an incentive to price discriminate by charging high mark-ups on extended warranties (as observed in

approach would be to elicit these beliefs and integrate over them to calculate expected utility. This substantially complicates the separate identification of risk aversion, loss aversion and probability weights which is one of the objectives of this paper. We discuss this issue in more detail in Section 10.

practice). In contrast, estimates from the simultaneous choice study imply charging a higher mark-up on the washing machine and selling warranties at marginal cost. These results are consistent with the theory predictions on two-part pricing as shown in Oi (1971) and Rosen and Rosenfield (1997). We find that risk preferences explain part of the premium paid for extended warranties. Not allowing for loss aversion and preference for warranties, the optimal warranty price reduces by around 25%. If we implement a policy where the same retailer cannot sell both, washers and extended warranties, then, consistent with intuition, the washer price increases by 8% and the warranty price decreases by 18%. Having separate retailers sell washers and warranties makes the subjects worse off. On average, subjects would have to be given a discount of $46 (around 5% of washer price) on the washer to make them indifferent to the policy change.

We contribute to the literature in several different ways. First, we make a methodological contribution through the survey design which allows us to non-parametrically estimate risk and product preferences. Most of the previous research is done with monetary gambles where utility is defined over a single construct (money), and an outcome is known to be a gain or a loss. In contrast, utility over consumption is a multi-dimensional construct, which depends on unobserved preferences. Standard approaches to identification used in the previous literature cannot be simply extended to the context of consumption. Second, we quantify the relative importance of different risk preferences in explaining warranty choices. The extant literature finds incidence of different risk preferences but does not elaborate on their relative importance in making choices. Third, we test the retailers' incentives to price discriminate and understand the role of risk preferences in explaining the high premium consumers routinely pay for extended warranties. To the best of our knowledge, there is no prior research which empirically explores the complementary goods nature of products and warranties, and it's impact on pricing. This also provides managerial implications on how to price products and extended warranties. Finally, we study the effect of forcing different retailers to sell products and warranties on consumer welfare.

The rest of the paper is organized as follows. Section 2 sheds light on the related literature on warranties, price discrimination, insurance and prospect theory. Section 3 outlines the model and identification strategy. Sections 4, 5 and 6 discuss the survey design, describe the data and present reduced form evidence of loss aversion/reference dependent preferences and non-linear probability weighting. Estimation details and results are discussed in Section 7. We discuss the pricing implications in Section 8 and do robustness checks around our modeling assumptions in Section 9. Section 10 concludes by summarizing our findings, highlighting limitations of current research and providing directions for future work.

## 2 Related Literature

Researchers have studied extended warranties from many different perspectives, partly due to the attention this topic has received across multiple disciplines. Below we briefly discuss the literature on warranties and reference dependence in the fields of marketing and economics.

**Warranty Theories**

In the economics literature, researchers have proposed several different theories for the existence of warranties. Warranties act as a risk sharing mechanism by providing insurance to consumers (Stiglitz (1977)), extended warranties are a sorting mechanism and can be used to discriminate among customers with different risk preferences (Mussa and Rosen (1978); Cooper and Ross (1985); Emons (1988) etc.), base warranties can signal product quality under informational asymmetry (Akerlof (1970); Emons (1988, 1989); Soberman (2003)) and can be used as incentive or commitment devices for firms by revealing and improving product quality (Grossman (1981); Dybvig and Lutz (1993))[8].

Chu and Chintagunta (2011) empirically test between different theories in the US computer server market. While they find support for the insurance and sorting theories, they rule out that base warranties signal quality or provide incentives to the manufacturer in this industry. Chen, Kalra, and Sun (2009) conduct a similar exercise aimed at understanding why consumers purchase extended service contracts. Their analysis, however, primarily focuses on understanding the impact of product characteristics, consumer demographics and retailer actions on the sales of service contracts[9].

**Empirical Literature on Warranties**

The empirical literature on extended warranties is fairly limited; largely due to lack of comprehensive data. Padmanabhan and Rao (1993) and Padmanabhan (1995) prove that it is optimal for a firm to offer partial coverage when consumers differ in risk aversion or exerted effort. They further show how these characteristics are related to consumer demographics and use survey data on automobile insurance to test their predictions. Soberman (2003) builds a model of consumer behavior explicitly allowing warranties to signal and screen simultaneously, and uses survey data to test his predictions. None of these papers, however, estimate demand for warranties. Bryant and Gerner (1982) use survey data to estimate demand for service contracts using a model which accounts for the costs of servicing. This is probably the first paper to explicitly account for product failure and claims in the decision to purchase warranties. Their analysis, however, is in reduced form and does not provide any guidance on how consumers will behave if the firm pricing changes. More recently, Chu and Chintagunta (2009) structurally estimate demand for warranties in the server market. They however, assume a concave utility function with diminishing returns and focus on quantifying the economic value of base warranties (as opposed to extended warranties) to channel intermediaries. Chen and Sun (2010) estimate demand for service contracts when firms engage in inter-temporal price discrimination. Like Chu and Chintagunta (2009), they assume that warranty purchases are driven by risk aversion. Further, they do not account for the possibility of endogenous failure rate. While understanding the inter-temporal nature of the problem is important and relevant in the context of technology products, there exists no empirical work which estimates demand for warranties associated with durable goods while non-parametrically accounting

[8]For a detailed overview of the different theories proposed for warranties, please see Emons (1989)

[9]Unlike Chu and Chintagunta (2011), Chen, Kalra, and Sun (2009) assume warranties provide insurance and that their purchase is driven by the perceived probability and the magnitude of loss, risk aversion and the insurance premium.

for consumer beliefs. Further, as mentioned before, the empirical literature largely rests on the assumption that risk aversion drives the demand for warranties, which is at odds with the behavioral economics literature on prospect theory.

Huysentruyt and Read (2010) study the factors which drive consumers to buy warranties and pay a substantially high premium. They find that consumers vastly over-predict failure probability and repair costs, but failure beliefs do not drive the high risk premium. Consumers do, however, account for the failure probability as seen from its correlation with the elicited market prices. Further, they find that emotional benefits (as measured on a Likert scale) are important in predicting the willingness to buy a warranty but not its fair price, as elicited from consumers. In this paper, we study the role of risk preferences in driving warranty purchases and risk premiums. We account for the possibility of emotional benefits (operationalized as preference for warranties), but deterministically provide the failure beliefs to subjects. In future work, we plan to integrate the failure beliefs with risk preferences.

**Reference Prices and Reference Dependent Preferences**

Accounting for reference dependent preferences and loss aversion has become widespread in the marketing literature over the past decade. Winer (1986) outlines the role of reference prices in consumer choice. Building on this, several researchers (see for example, Hardie, Johnson, and Fader (1993); Bell and Bucklin (1999); Bell and Lattin (2000); Klapper, Ebling, and Temme (2005); Erdem, Mayhew, and Sun (2001); Bronnenberg and Wathieu (1996)) have studied the role of reference prices, promotion and quality on consumer choices within and across different product categories. Kalyanaram and Winer (1995) and Meyer and Johnson (1995) summarize the empirical findings on reference prices and discrete choice modeling. Ho and Zhang (2008) show that loss aversion and reference dependence justify the discrepancy between theoretical and empirical findings on two-part pricing in vertical channels. Ho, Lim, and Camerer (2006) account for psychology in modeling consumer behavior and stress on the importance of understanding why consumers buy extended warranties.

Other research (Novemsky and Kahneman (2005); Ariely, Huber, and Wertenbroch (2005)) explores the conditions under which consumers exhibit loss aversion, and the role of emotional attachment and cognitive perspective in loss aversion. Dhar and Wertenbroch (2000) provide evidence for reference dependent preference asymmetries under either acquisition or forfeiture conditions for hedonic and utilitarian items. Gächter, Johnson, and Herrmann (2007) run experiments based on endowment effect to provide evidence of loss aversion in risk less and risky choices. Additionally, Jarnebrant, Toubia, and Johnson (2009) study the conditions under which consumers integrate versus segregate gains and losses. Finally, Camerer (2005) argues whether loss aversion is an emotional reaction, a mistake or a part of preferences. This research complements the extant literature on reference points and loss aversion, and integrates these concepts with choices under risk.

**Prospect Theory**

Cicchetti and Dubin (1994) study consumers decision to purchase protection against having to pay for repairs for internal telephone wiring. They find that people were paying 45 cents a month to insure against a "risk" that will average 28 cents per month, with a small risk of having to pay $55, and a minuscule risk of having to pay more, and justify this using expected utility theory. Rabin and Thaler (2001) attribute this behavior to loss aversion as opposed to risk aversion. Loss aversion was introduced in the seminal work by Kahneman and Tversky (1979) who hypothesized that consumers care about relative changes in utility with regards to a reference point (as opposed to the final utility state), and that losses loom larger than gains. Tversky and Kahneman (1992) and Wakker and Tversky (1993) provide an axiomatization of prospect theory where in addition to diminishing returns, behavior under risk can either be attributed to loss aversion or to the probability weights a consumer implicitly assigns to probabilities. Using monetary trade-offs, Tversky and Kahneman (1992) find that most of the behavior under risk can be explained by loss aversion (subjects weigh losses almost 2.25 times the similar gains) and probability weighting, and only a small part of the behavior is explained through the concavity in utility function arising due to diminishing returns (risk aversion). Schoemaker and Kunreuther (1979) show that insurance choices involving monetary gambles are more consistent with prospect theory (than with expected utility theory), but prospect theory alone does not rationalize the choices completely[10].

Building on this, several researchers have estimated the shape of the utility function to provide evidence of loss aversion. These include Abdellaoui, Bleichrodt, and Paraschiv (2007), Abdellaoui (2000), Booij and van de Kuilen (2009) and Wakker and Deneffe (1996) among others. While researchers have found evidence of the utility function being concave in gains and convex in losses, the finding is not robust in the literature. For example, Abdellaoui, Bleichrodt, and Paraschiv (2007) finds evidence of a concave function in gains but a convex function in losses only at the aggregate level. In contrast, Tversky and Kahneman (1992) find that the degree of concavity and convexity is similar. While loss aversion implies that losses loom larger than gains, researchers do not agree on a single definition of loss aversion. Kahneman and Tversky (1979) and Wakker and Tversky (1993) define loss aversion as a ratio of the marginal utility at any point in the gains domain and the marginal utility of the corresponding point in the losses domain. Neilson (2002) defines weak loss aversion using a chord joining the origin to a relevant gain on the value function[11] and comparing it with any loss on the value function. Bowman, Minehart, and Rabin (1999) define loss aversion in the sense that the marginal disutility from any loss is greater than the marginal utility from even a small gain. Finally, Köbberling and Wakker (2005) define loss aversion as the ratio of marginal utility from gains and losses around the reference point[12].

[10]Kunreuther and Pauly (2006) discuss the anomalies observed in the demand and supply of insurance and provide possible explanations, which are accounted for and not accounted for by prospect theory.

[11]Kahneman and Tversky (1979) use the word value function as opposed to utility function to highlight the fact that only the relative changes (gains or losses) from the reference point matter. Under expected utility theory, the utility from the final state matters and thus, utility function is defined over the final state as opposed to gains and losses.

[12]For a more detailed discussion on the treatment and definitions of loss aversion, please refer to Abdellaoui, Bleichrodt, and Paraschiv (2007)

Unlike expected utility theory, where risk aversion is the same as diminishing returns, prospect theory allows for risk aversion even for a linear value function. The key is that under prospect theory, in addition to a concave value function, risk aversion can either be attributed to loss aversion or to the probability weights a consumer attaches to probabilities. Kahneman and Tversky (1979) show that consumers may not be able to distinguish between small changes in probability (for example, 33% versus 34%). However, they might have strong preferences for certainty and possibility, and thus, are most sensitive to probabilistic changes around 0% and 100%. Probability weights assigned to probabilities then, lead to a non-linear weighting function which, together with even a convex value function, can lead to risk averse behavior. We shed more light on this in our discussion on the importance of accounting for probability weights in Section 3.3.

The behavioral economics literature has taken different approaches to estimating individual and aggregate level risk aversion and loss aversion. Recent work by Bruhin, Fehr-Duda, and Epper (2010) elicits certainty equivalents from subjects in 3 different regions and consistently finds that only 20% of the subjects behave consistent with expected utility theory while the remaining 80% show deviations from linear probability weighting. They, however, do not account for loss aversion in their analysis. Conte, Hey, and Moffatt (2011) ask subjects to choose between pairs of 500 lotteries and account for unobserved heterogeneity in their analysis. They fit a mixture of normal distributions where subjects could either behave consistent with expected utility (EU) theory or with rank dependent expected utility (RDEU) theory; thus, not accounting for loss aversion. Consistent with Bruhin, Fehr-Duda, and Epper (2010), they find that around 80% of the population behaves consistent with RDEU while 20% of the subjects are EU maximizers. von Gaudecker, van Soest, and Wengstrom (2011) use a variation of the price list experiment to estimate a distribution of risk aversion, loss aversion, timing of uncertainty resolution and the subjects' propensity to choose randomly. They find that subjects are on average, slightly risk averse but there is substantial heterogeneity in risk preferences. Additionally, the average loss aversion parameter is estimated to be around 2.4 but again, subjects vary in degree of loss aversion.

Most of the research on eliciting value functions has been done using monetary trade-offs and eliciting certainty equivalents from subjects. Identification of risk (and product) preferences in consumption contexts requires us to think about the problem very differently, and is not a direct extension of the above approaches. We discuss our methodology and approach in Sections 3 and 4, respectively.

**Price Discrimination**

Products and extended warranties are tied goods where warranties are purchased conditional on product ownership. Retailers, thus, have an incentive to meter extended warranties by selling products at lower prices and charging a high mark-up for extended warranties. Oi (1971) and Rosen and Rosenfield (1997) outline theoretical models of consumer behavior and derive the relationship between the willingness to pay for the product and the per unit demand of the aftermarket good (warranties in our case) under which, it would be profitable for firms to meter extended warranties. This is commonly known as the single crossing property. In the marketing literature, empirical test of the single crossing property is extremely limited. Gil and Hartmann (2009) test this property for the sales of concession goods at movie theaters. More generally, Hartmann and Nair (2010) discuss the implications of retail competition and tied goods nature of razors and blades on product pricing.

**Other Related Research**

Duration of warranties and extent of coverage have been extensively studied in the operations literature. Researchers have been interested in warranties primarily because of the costs they entail to the manufacturer. For example, Chun and Tang (1995) derive the optimal warranty prices when consumers differ in their risk preferences. They however, assume constant failure rates and constant costs throughout the warranty period. Hartman and Laksana (2009) study the dynamic problem of designing and pricing a menu of warranties but do not account for the possibility of individual level beliefs. Most of the literature in this area provides cost based arguments for the design of warranty contracts without accounting for heterogeneity in risk and product preferences.

Lastly, researchers have studied the role of asymmetric information (adverse selection and moral hazard) in consumers' decision to purchase insurance. Cardon and Hendel (2001) do not find any evidence of asymmetric information in the market for health insurance. Cohen and Einav (2007) use auto insurance contracts to jointly estimate the distribution of risk aversion and risk (accident probability), thus account for adverse selection. In contrast to Cardon and Hendel (2001), Cohen and Einav (2007) find evidence for the presence of informational asymmetries in the insurance market. While adverse selection and moral hazard might affect the demand for warranties, we do not account for this in the current paper. Instead, we explicitly provide subjects the beliefs about product failure.

# 3 Methodology Overview

In this section, we present a model of consumers' purchase decisions for durable goods which have an associated probability of failure. While we apply our model in the context of washing machines, the model is extremely general and can be easily extended to other durable goods and insurance. We will outline two different models - one consistent with simultaneous decision making and another consistent with sequential decision making (warranty purchase conditional on product purchase). Washing machines are a relevant application to understand the drivers of warranty purchases given that the likelihood of break-down and warranty attachment rate for such products is high. Further, unlike electronic goods, we do not see inter-temporal price discrimination for washing machines and thus, the decision to not buy does not hinge on expectations about future product prices and characteristics. A key feature of the survey simplifies the consumers' decision process: in contrast to the empirical literature where probability of failure is modeled as a function of product and warranty characteristics; in our survey, the probability of product failure is provided to the subjects. Given the importance of estimating probability weights, we do not elicit the entire distribution of beliefs about product failure.

### 3.1 Simultaneous Choice Model

Subjects simultaneously choose between 2 different washing machines, with or without warranty, and the outside option of no purchase. Let $x_j = (p_j, \omega_j, c_j, X_j, \pi_j)$ be a vector including the product price $p_j$, warranty price $\omega_j$, repair cost $c_j$, a vector of product attributes $X_j$, and the failure probability $\pi_j$ for washer $j$, respectively. The deterministic portion of utility a risk neutral subject $i$ gets from buying brand $j$ or paying a repair cost is given by an index $y(x_j \mid \theta_i)$ where $\theta_i$ are the subject specific utility parameters. Further, let $r$ denote the reference point from which gains and losses are measured. We define a value function $v(y, r)$ which accounts for the risk a subject faces given the reference point $r$[13]. More specifically, $v(.)$ can be written out as

$$v(y,r) = \begin{cases} v_g(y-r) + z(r) & ; \quad y \geq r \\ v_l(y-r) + z(r) & ; \quad y < r \end{cases} \tag{1}$$

where $v_g(.)$ and $v_l(.)$ are the value functions in gains and losses, respectively, and $z(r)$ is the value from consumption of $r$.

The value subject $i$ gets from buying brand $j$ without a warranty can now be written as

$$u_{ij,nw} = \delta_i(\pi_j)\, v(y_{ij,nw}, r \mid failure) + (1 - \delta_i(\pi_j))\, v(y_{ij,nw}, r \mid no\, failure) + \epsilon_{ij,nw} \tag{2}$$

where $\delta_i(\pi_j)$ is the weight subject $i$ assigns to failure probability $\pi_j$[14]. $\epsilon_{ij.nw}$ represents the mistakes subjects make in their choices which are unobserved to the researcher.

Note that the utility from the reference point $(z(r))$ is common to all alternatives and hence, is not relevant to decision making. We assume that the reference point of a subject before making any decision is the utility from no purchase. Thus, the value subjects get from no purchase is $v(0)$, which is normalized to 0 i.e. $v(0) = 0$. Köszegi and Rabin (2006, 2007) outline a theory for reference point formation where the reference point is endogenous in the sense that it depends on the subjects' preferences and expected outcome. While we acknowledge the presence of this work; apriori, there is no reason to believe that subjects use endogenous reference points in our application. This is a commonly made assumption in the extant behavioral literature (see for example, Conte, Hey, and Moffatt (2011); von Gaudecker, van Soest, and Wengstrom (2011); Bruhin, Fehr-Duda, and Epper (2010)). Once the subject decides to purchase the product, the reference point shifts to the expected utility from buying the product. As shown by Novemsky

[13] Kahneman and Tversky (1979) use the word value function (as opposed to utility function) to highlight the fact that the argument is a gain (loss) measured with respect to a reference point. The utility function commonly referred to when using expected utility theory has the final consumption state as its' argument (as opposed to gains or losses).

[14] Under prospect theory, probability weights could be different in the gains and losses domain. The model outlined here assumes the same probability weighting function in both, gains and losses. This assumption is not critical to model identification, rather it is made for ease of estimation. Model outline and discussion on identification with separate probability weights can be requested from the author.

and Kahneman (2005), the price paid to acquire a product is not considered a loss. However, consistent with mental accounting (see Thaler (1985)), if the consumer has to pay the repair cost, then relative to the utility from consumption, the cost is perceived as a loss and weighs more than a gain of comparable magnitude. This is analogous to how a retailer measures gains and losses in Ho and Zhang (2008). Conditional on the product failing, the value subject $i$ gets from purchasing brand $j$ without warranty can now be written as $v\left(y_{ij,nw}, r \mid failure\right) = v\left(y_{ij,nw}\right) + v_l\left(y^c_{ij,nw}\right)$ where $v_l\left(y^c_{ij,nw}\right)$ represents the negative value (considered a loss) a subject gets from paying repair costs and is measured with respect to the expected utility from consumption[15]. Similarly, the value subject $i$ gets from purchasing brand $j$ without warranty (conditional on no failure) is given by $v\left(y_{ij,nw}, r \mid no\,failure\right) = v\left(y_{ij,nw}\right)$. Combining these, equation 12 can be re-written as[16]

$$\begin{aligned} u_{ij,nw} &= v\left(y_{ij,nw}\right) + \delta_i\left(\pi_j\right) v_l\left(y^c_{ij,nw}\right) + \epsilon_{ij,nw} \\ &= v^*_{i,nw}\left(x_j\right) + \epsilon_{ij,nw} \end{aligned} \tag{3}$$

If the subject chooses to buy a warranty, then she does not incur any costs in case the product fails. Given the reference point assumption, the value subject $i$ gets from buying brand $j$ with warranty is given by

$$\begin{aligned} u_{ij,w} &= v\left(y_{ij,w}\right) + \epsilon_{ij,w} \\ &= v^*_{i,w}\left(x_j\right) + \epsilon_{ij,w} \end{aligned} \tag{4}$$

and is independent of the failure probability and repair costs. Finally, the value subject $i$ gets from no purchase is given by $u_{i,0} = \epsilon_{i,0}$. In the survey, the subjects are told that in case they decide to not purchase a washer, the outside option is to use their current method of doing laundry (laundry mat or using the current washer etc.). Thus, the utility subjects get from not purchasing does not depend on their beliefs about future product characteristics or product characteristics at other stores, and hence on the vector of current state variables. A subject adopts product $j$ (with or without warranty) if and only if $v^*_{i,k}\left(x_j\right) + \epsilon_{ij,k} \geq v^*_{i,k'}\left(x_{j'}\right) + \epsilon_{ij',k'}$ for all $j, j' \in \{1, 2, 0\}$, $j \neq j'$ and $k, k' \in \{w, nw\}$ and $k \neq k'$. We assume that the mistakes subjects make are type I extreme value distributed. For each subject $i$, we observe the adoption choice $d_{ij,k}$. $d_{ij,k} = 1$ if subject $i$ chooses product $j$ with $k \in \{w, nw\}$ and $d_{ij,k} = 0$ otherwise. The probability that consumer $i$ chooses product $j$ with (without) warranty is then given by a multinomial logit model of the form:

$$\Pr\{d_{ij,k} = 1\} = \frac{\exp\left(v^*_{i,k}\left(x_j\right)\right)}{1 + \sum_{j' \in \{1,2\}} \sum_{k' \in \{w,nw\}} \exp\left(v^*_{i,k'}\left(x_{j'}\right)\right)} \tag{5}$$

[15] If we do not account for reference dependent preferences, then consistent with expected utility theory, this will be given by $v\left(y_{ij,nw}, r \mid failure\right) = v\left(y_{ij,nw} + y^c_{ij,nw}\right)$

[16] Under expected utility theory, the utility a consumer gets from purchasing the product without warranty will be given by $u_{ij,nw} = \pi_j v\left(y_{ij,nw} + y^c_{ij,nw}\right) + (1 - \pi_j) v\left(y_{ij,nw}\right) + \epsilon_{ij,nw}$

### 3.1.1 Identification

The value a subject gets from not purchasing a warranty is similar to the value subjects get from gambles (as studied in the behavioral literature) where $u = \delta(\pi)v(m) + (1 - \delta(\pi))v(n)$. $m$ and $n$ are pay-offs measured with respect to an exogenous reference point which is usually assumed to be the status quo and is normalized to 0. $\delta(.)$ and $v(.)$ are multiplicative and are not identified (non-parametrically) by varying $\pi$, $m$ and $n$. The behavioral literature takes different approaches to estimating risk aversion, loss aversion and probability weighting. Typically, the literature has adopted functional forms for the probability weights and value functions, basing identification primarily on parametric assumptions (for e.g., Abdellaoui, Bleichrodt, and L'Haridon (2008), Bruhin, Fehr-Duda, and Epper (2010), Booij and van de Kuilen (2009) and Conte, Hey, and Moffatt (2011) etc.). Abdellaoui (2000) uses a trade-off design to elicit outcomes which make subjects indifferent between two gambles. The specific design allows them to estimate probability weights, and utility in the gains and losses domain separately. Abdellaoui, Bleichrodt, and Paraschiv (2007) and Abdellaoui, Bleichrodt, and L'Haridon (2008) use specific chained designs to non-parametrically estimate loss aversion but not the probability weighting function[17]. In contrast to these elicitation based approaches, Gonzalez and Wu (1999) outline an iterative algorithm to step by step estimate probability weights and value function at various design points. It is important to point out that *identification in all these papers (i) relies on prior knowledge of whether an outcome is a gain or a loss, and (ii) works only when the utility is defined over a single characteristic (for example, money).* In contrast, utility from consumption is a multi-dimensional construct, which depends on individual specific unobserved preferences. Further, a prospect cannot be apriori, classified as a gain or a loss.

We now sketch the empirical identification of our model from Section 3.1. This discussion shows that the empirical distinction between different risk and product preferences in a consumption context relies on subtle aspects of the data that are not observed in previous studies. Suppressing the individual and brand subscripts, we first define the deterministic utility index from product purchase and paying for repairs as

$$y_w = h(X_w) - (p + \omega) \tag{6}$$

$$y_{nw} = h(X_{nw}) - p \tag{7}$$

$$y^c_{nw} = -c \tag{8}$$

where $h(X_k)$ is some arbitrary function of product characteristics and preferences[18]. For discussion on identification, let us ignore the $k$ subscript and consider one function $h(X)$. The price (and cost) coefficient in the utility index has been normalized to 1 since it is not separately identified unless we make a parametric assumption about $v(.)$ or include a normalization.

[17] The design adopted by Abdellaoui, Bleichrodt, and L'Haridon (2008) can in theory, be extended to estimating probability weights but that would require substantially more elicitations from each subject.

[18] We allow subjects to have different preference for the product with (without) warranty and thus, $h(X_k)$ has a subscript where $k \in \{w, nw\}$. The identification of this, is based on the assumption of mental accounting where value from product purchase and repair costs are additively separable.

Given an substantially large data set, we can observe the conditional choice probabilities of different alternatives. Given these choice probabilities, and the type 1 extreme value distribution on the error term, the choice specific value ($v_w^*(x)$ and $v_{nw}^*(x)$) differences can be inferred by a simple inversion of choice probabilities as follows[19]:

$$v_w^*(x) - v(0) = \log(\Pr\{d_w = 1\}) - \log(\Pr\{d_0 = 1\}) \tag{9}$$

Let $\mathbb{X}$ be the support of $x$. Assume that the support of $\mathbb{X}$ is large enough such that for any $X'$ there is an $x' \in \mathbb{X}$ such that (i) $X'$ is the $X$-component of $x'$ and (ii) $v_w^*(x') = v(h(X') - (p' + \omega')) = 0$. Thus, for any product and warranty price, we can find a corresponding $h(X)$ such that $h(X) - (p + \omega) = 0$. Varying product or warranty prices then, non-parametrically identifies $h(X)$. If $h(X) \geq 0$, i.e. if the value of the product is always weakly desirable over not having the product if the price is zero (apart from idiosyncratic reasons captured by the latent utility term), the assumption on the support of $\mathbb{X}$ can be achieved by varying the price $p$ (or $\omega$) sufficiently for any $X$ value. To identify $v(y)$ on a suitable range, say $[y_L, y_U]$, we now only need a sufficiently large support $\mathbb{X}$ such that for any $y \in [y_L, y_U]$ there is an $x$ such that $y = h(X) - (p + \omega)$ and hence $v(y) = v_w^*(x)$. Having identified $v(y)$ (and $v_l(y)$) and the parameters of $h(X)$, we can then infer the probability weighting function $\delta(\pi)$ directly from the right hand side of the equation 3 which defines $v_{nw}^*(x)$.

Under expected utility theory, risk aversion is a measure of the curvature of the value (utility) function. Thus, conditional on (non-parametrically) estimating the value function in gains and losses, we can get an estimate of value function curvature in gains and losses separately. This then, provides a measure of risk aversion. The estimation of loss aversion is less straight forward given that the literature does not agree on one single definition of loss aversion. As discussed in Section 2, researchers have defined loss aversion based on the ratio of absolute, marginal and average utilities in gains and losses. Having said this, if we know the shape of the value function in gains and losses, we can estimate loss aversion subject to any particular definition. Broadly speaking, the identification of loss aversion rests on the difference in the shape of the value function in gains and losses.

Field data on consumer choices do not allow us to separate risk aversion from loss aversion non-parametrically. To see this, note that beliefs about product failure and repair costs are unobserved in field data and researchers are forced to make specific assumptions. $\pi_j$ is then modeled as a function of repairs (claim rates) or product characteristics and does not vary for any given consumer. Thus, a researcher would be forced to exploit the parametric assumption about the probability weighting function and pool probabilities across consumers to estimate it. Any inference about loss aversion then, relies on the chosen parametric form for the probability weighting function (and vice versa). The presence of probability weighting function compli-

[19] Hotz and Miller (1993) show that a similar inversion exists for more general distributions, $p(\epsilon)$, of the error terms but they may not have a convenient closed form. While we make an assumption about the distribution of error terms, it is rather innocuous given that a more general distribution can be used, and the distributional assumption is less important once we allow for unobserved heterogeneity in our estimation.

cates the identification of model parameters due to the confound with value function (and loss aversion). In the absence of a probability weighting function, variation in repair costs and product (and/or warranty) prices would be sufficient to nail down loss aversion. We discuss the importance of accounting for probability weights in Section 3.3.

## 3.2 Sequential Choice Model

The sequential choice model differs from the simultaneous model in that the subjects first choose whether or not to buy a washing machine. Conditional on washing machine purchase, the subjects learn about the failure characteristics of the chosen washer and decide whether or not to purchase an extended warranty. In the second stage, subjects can also choose to not purchase the washer altogether. In the first stage, the value subjects get from purchasing brand $j$ is given by $u_{ij} = v(y_{ij}) + \epsilon_{ij}$. Assuming that $\epsilon_{ij}$ follow a type 1 extreme value distribution, the unconditional probability of choosing brand $j$ in the first stage is given by

$$\Pr\{y_{ij} = 1\} = \frac{\exp(v(y_{ij}))}{1 + \sum_{k \in \{1,2\}} \exp(v(y_{ik}))} \tag{10}$$

In the second stage, the subjects learn about the failure probability, repair cost and warranty price, and decide between buying a warranty or not, and not buying the washer altogether. The value subjects get from buying the washer with warranty can be written out as

$$u_{ij,w} = v(y_{ij}) + v\left(y_{ij}^{w}\right) + \epsilon_{ij,w} \tag{11}$$

where $y_{ij}^{w}$ is the utility index from buying a warranty. Note that in the second stage, subjects can also choose to not buy the washer. Thus, the value subjects get from buying the washer with (without) warranty includes the value from washer purchase only. Unlike the simultaneous choice model, the value from buying the washer and the warranty is calculated separately with respect to the reference point. In the second stage, if the subject decides to not purchase the warranty, then the value from buying the product alone is given by

$$u_{ij,nw} = v(y_{ij}) + \delta_i(\pi_j)\, v\left(y_{ij}^{c}\right) + \epsilon_{ij,nw} \tag{12}$$

Assuming that $\epsilon_{ij,k}$ follow a type 1 extreme value distribution, the probability of warranty purchase conditional on product purchase (in the first stage) is given by[20]

$$\Pr\{w_{ij} = 1 \mid y_{ij} = 1\} = \frac{\exp\left(v(y_{ij}) + v\left(y_{ij}^{w}\right)\right)}{1 + \exp\left(v(y_{ij}) + v\left(y_{ij}^{w}\right)\right) + \exp\left(v(y_{ij}) + \delta_i(\pi_j)\, v\left(y_{ij}^{c}\right)\right)} \tag{13}$$

[20]Utility from product adoption could be correlated with utility from warranty purchase due to correlation between some unobserved factors captured in the error terms. To account for this in our estimation, we allow the preferences parameters between the first and second stage to be correlated.

Compared to simultaneous choice, the decision to purchase a warranty is independent of the competing brands washer and warranty price, and repair costs. Further, washer choice is independent of warranty price and repair costs of all competing brands. The unconditional probability of purchasing a washer with warranty can simply be written out as

$$\Pr\{w_{ij} = 1\} = \Pr\{w_{ij} = 1 \mid y_{ij} = 1\} \Pr\{y_{ij} = 1\} \tag{14}$$

Unlike the simultaneous choice model, subjects can choose to not purchase a washer in either of the stages. We account for this by calculating the unconditional and conditional probability of no purchase is each stage and including them directly in the likelihood function. Note that this specification assumes that subjects are "myopic" in that they do not account for warranty choice while making the washer choice. We do robustness checks around this assumption in Section 9.6.

#### 3.2.1 Identification

The identification of the model primitives in the sequential model is very similar to the simultaneous choice model. Intuitively speaking, variation in washer prices and characteristics in the first stage allows us to identify the utility index and the shape of the value function in gains and losses. Using equation 10, we can infer the choice specific value differences from data. These value differences are independent of the failure probability and the probability weighting function. The identification of the utility index and the shape of the value function is exactly the same as outlined in Section 3.1.1. Again, the underlying assumption is that the utility index includes some positively valued characteristic (such as utility from wearing clean clothes) such that variation in other characteristics allows us to cover the entire support of the utility index. Conditional on the identification of the utility index and the value function in gains and losses, the probability weighting function can be inferred from the within-subject variation in failure probabilities from the second stage.

### 3.3 Importance of Probability Weights

Recall that under prospect theory, in addition to curvature and loss aversion, risk aversion could also stem from the probability weights a consumer assigns to different probabilities. Researchers have consistently found evidence that the weighting function is an inverse S-shaped function. As we discuss below, failure to account for the probability weights could lead to over (under) predicting the curvature of the utility function.

Figure 5 (taken from Abdellaoui, Bleichrodt, and L'Haridon (2008)) provides an intuitive explanation for the importance of accounting for probability weights when estimating risk aversion. Let the utility at points $x_i$ and $y_i$ be fixed. Now, if $G_i$ is the certainty equivalent for a gamble between $x_i$ and $y_i$ with probability $p$, we have $u(G_i) = \delta^+ (u(x_i) - u(y_i)) + u(y_i)$ where $\delta^+$ is the probability weight associated with a probability $p$. As per expected utility theory, this should be $u(G_i) = p\,(u(x_i) - u(y_i)) + u(y_i)$. If $p > \delta^+$, i.e. the probabilities are under weighted, then we will predict less curvature than is actually present. In fact, a concave value function might appear linear or even convex. On the contrary, if $p < \delta^+$, then we will over predict curvature and a linear or convex value function might appear concave. In the context of insurance, probability $p$ is typically small, and as Kahneman and Tversky (1979) show, for small probabilities $\delta^+ > p$. Thus, not accounting for the probability weights might make a researcher conclude that the utility function is concave, when it might actually be linear. Two points are important to note here. First, it is important to account for probability weights $\delta^+$ to get a consistent estimate of curvature (risk aversion). Second, due to the presence of $\delta^+$, risk aversion can co-exist with a linear or even convex value function; unlike in expected utility theory where risk aversion implies concavity in the utility function and a convex utility function is associated with risk seeking behavior.

## 4 Survey Design

We design two online surveys to separately identify risk due to diminishing returns from risk due to loss aversion and probability weighting. In both surveys, several introductory screens provide subjects an overview of the washing machines under consideration and possible benefits of buying an extended warranty. The subjects were told that they do not incur any repair, parts or replacement costs if they buy the warranty and that the product is repaired next business day. Subjects were then presented with several conjoint choice tasks where they choose between two competing washing machines (with or without warranty) and not buying the product. To make the product choices realistic, we included the loading type (front versus top) as a washer characteristic in addition to the washer brand.

Figure 1 shows a screen in the simultaneous choice survey. The screen provides subjects with information about different product characteristics they see in each choice task. Figure 2 shows a standard simultaneous choice task in the survey where subjects are presented with prices of both washers, prices of the extended warranty, repair costs and the probability of failure for each washer. We ask the subjects whether they will buy a washer (with or without warranty) or not. Subjects can choose the “None” option which indicates that they will continue using their current method of doing laundry. On each screen, subjects have the option of seeing the other characteristics common to both the washers and the characteristics of the warranty being offered. Product characteristics common to both washers and warranty characteristics are included in Figure 27 in Appendix B.

Each subject completes a total of 3 *blocks* of questions where each block consists of 8-10 choice tasks, resulting in a total of 24-30 choices per subject. Subjects and blocks are randomly matched. Within each block, we randomly vary the brand, loading type, product and warranty prices and the cost of repair. Additionally, we randomize the failure probabilities such that within each block, there are 2-3 screens with a 100% failure probability (Figure 28 in Appendix) and 2-3 screens with 0% failure probability (Figure 29 in Appendix). The remaining screens in a block have failure probabilities varying between 5% and 80%. While we do not need to vary the failure probability to as high as 80%, we include higher failure rates so as to have better data for the estimation of probability weights.

Figure 3 shows the first stage of a sequential survey. As compared to the simultaneous study, subjects are only provided with washer characteristics (brand, loading type and price) and asked about their decision. If the subjects choose to purchase either washer, the next screen (as shown in Figure 4) provides them information about failure probability, warranty price and repair costs specific to the chosen washer. The subjects have a choice to either buy a warranty or not, or to not buy the washer, altogether. Each subject completes 2 *blocks* of questions where each block consists of 8-10 choice tasks, resulting in a total of 16-20 choices per subject. As before, subjects and blocks are randomly matched and within each block, we randomly vary the brand, loading type, product and warranty prices, failure probability and cost of repair.

One possible critique of the surveys may be that we are making subjects focus on characteristics which might not be otherwise important in their decision making. For example, consumers may not explicitly think about repair costs or might not think about probabilities in terms of numbers when deciding to purchase a warranty or not. Williamson, Ranyardy, and Cuthbertz (2000) allow consumers to ask questions important in their decision to purchase a washer. They find that majority of the consumers think about washer prices and repair costs, and ask questions to infer about product quality and characteristics. Huysentruyt and Read (2010) find some evidence for probability neglect in that failure probability does not affect the actuarially fair warranty price. They, however, show that consumers do know how to account for failure probabilities and they are correlated with the elicited market price of warranties. Thus, there is some evidence in the literature that the characteristics shown to subjects are indeed important in their decision to purchase warranties.

## 5 Data Description

The data for the two studies was collected from 235 MBA students at a large mid-western university, and 77 under-graduates from two US universities, respectively. The simultaneous survey was done with MBA students and resulted in 6,317 choices, while the sequential survey was carried out with under-graduates and resulted in 1,422 choices. The survey demonstrates the application of our approach and robustness of the methodology[21].

Table 15 in the Appendix summarizes the purchasing habits and familiarity with warranties and washing machines. Focusing on the simultaneous survey, 70% of the subjects were familiar with extended warranties before they took the survey and over half of the subjects have purchased warranties for either home appliances or electronics goods in the past. 50% of the subjects have either purchased or considered purchasing a washer in the past and 78% use the washer at least once a week or more. Lastly, 94% of the subjects mentioned that the survey questions were clear and 81% believed that the prices and characteristics shown were realistic. This provides some external validity of the choices made by subjects and their prior experience with such purchase occasions.

[21] We are currently working on conducting the surveys with a more representative sample of the US population.

We vary the failure probabilities substantially across choice tasks so it is important to ensure that subjects account for failure probabilities in their decision making. Figure 6 shows the warranty attachment rate for different product failure probabilities from the simultaneous survey. The shaded area shows the 95% credibility region around the attachment rate. As expected, subjects are more likely to purchase warranties for their products as the failure rate increases. Also, the attachment rate is somewhat concave in the failure probability; the attachment rate does not increase once the failure probability exceeds around 60%. This is consistent with our finding that the likelihood of product purchase does not change much until a failure probability of 60%; after which, the likelihood of product purchase decreases with failure probability. Figure 7 shows the distribution of product choices (across all subjects) classified by the type of probability task. We classify all choice tasks into three groups - with failure probability equal 1, failure probability equal 0 or failure probability strictly between 0 and 1. When the product does not fail with certainty, only 8% of the product choices are made with warranty. For product failure with certainty, this number increases to 62% and for intermediate failure probabilities, 33% of products are chosen with warranty. Also, the relative share of the outside option of "None" is highest when the product fails with certainty and lowest when the product does not fail with certainty. These findings are evident of the fact that subjects account for the failure probabilities in their choices and that the choices are not chosen randomly[22]. Further, we find evidence of subjects choosing actuarially unfair warranties, and choice variation within subject allows us to estimate the model parameters. Data from the sequentially survey is qualitatively very similar and can be obtained from the author on request.

Figure 8 shows the distribution of the modal choices across subjects. Only 13% of the subjects choose the "None" option as their modal choice. While we observe subjects with modes for all products, the modal choices are concentrated towards buying the products without warranty. Figure 9 shows the distribution of number of times the model choice was chosen by a subject within a block. Majority of the subjects chose the modal choice 3-5 times, thus, providing evidence of substantial variation in choices within a subject. Figure 10 shows the distribution of the number of distinct choices made by subjects. For example, if a subject chooses product 1 twice and product 3 on all other choice occasions, the number of distinct choices made by that subject is two. The highest possible number of distinct choices is 5 (4 product options - 2 brands with and without warranty, and the "None" option). We find that 87% of the subjects make 4-5 distinct choices. Thus, there is substantial evidence for switching across different products when product and warranty characteristics change. This within subject variation is crucial to estimating heterogeneous product and risk preferences.

[22] von Gaudecker, van Soest, and Wengstrom (2011) allow for subjects to make random choices in their analysis. While we acknowledge that this might be a possibility, we do not explore it further in our analysis.

# 6 Reduced Form Results

Table 2 summarizes the results from different logistic regressions run using the simultaneous survey data. The dependent variable indicates the subjects' choice between buying either of the brands (with or without warranty) and the outside option of no purchase. Standard errors on the estimates are reported in parenthesis (all coefficients are significant at the 95% confidence level). Subjects have an intrinsic preference for front loading washing machines and are sensitive to the total product price. The coefficient on product price is robust to the addition of repair costs and failure probabilities. From column 2, we can see that expected repair costs have a negative and significant impact on the purchase probability. Subjects are twice as sensitive to expected repair costs as compared to product price. Even after accounting for higher order terms of product and warranty prices (thus, controlling for curvature), we find that subjects are more sensitive to expected repair costs than to product price. If repair costs and product prices are measured from different (same) reference points, then this provides evidence for reference dependent preferences (loss aversion). Without imposing more structure on the utility function, we cannot conclude whether these results are driven by loss aversion or reference dependent preferences.

Under expected utility theory, the higher order terms of failure probability should not be significant conditional on controlling for repair costs. In the last column of Table 2, we include an interaction between the higher order terms of failure probability and repair cost. The coefficients show a non-linear effect of failure probability on product (and warranty) purchase.

Table 3 provides estimates from logistic regressions for the sequential survey. Again, we find that subjects are substantially more sensitive to expected repair costs as compared to washer prices, thus, providing some support for loss averse behavior. In contrast to the simultaneous survey, we find that subjects sensitivity to warranty prices is the same order of magnitude as their sensitivity to washer prices. As with the simultaneous survey, in our model specification, we allow subjects to get some intrinsic utility from purchasing warranties. As expected, product prices show up insignificant in the second stage where subjects make a warranty choice. Also, we do not find any evidence of non-linear weighting of failure probabilities.

# 7 Estimation and Results

We now discuss the estimation and empirical results from the survey. Recall that if we have a substantially large sample, we can in theory, estimate the shape of the value function in gains and losses without imposing any functional form restrictions. However, given the small sample size and for ease of interpretation, we now make functional form assumptions which aide estimation. *The functional form assumptions are same across both the surveys.* We conduct several checks around these functional form assumptions using the simultaneous choice data in Section 9.

We use a power value function which, subject to our assumption about the exogenous reference point, is given by

$$v(y_{ij,k}) = \begin{cases} (y_{ij,k})^{\gamma_i} & ; y_{ij,k} \geq 0 \\ -\lambda_i \left(-y_{ij,k}\right)^{\gamma_i} & ; y_{ij,k} < 0 \end{cases} \tag{15}$$

where gains and losses are measured with respect to the normalized reference point. Additionally, we assume that the value function is symmetric around the reference point, and has the same curvature in gains and losses[23]. While we do not need this assumption, it imposes less burden on the model estimation and is consistent with findings in the behavioral literature (Tversky and Kahneman (1992)). We relax this assumption and estimate a model with different curvature in gains and losses in Section 9.4. In equation 15, we use the most widely accepted definition of loss aversion - the ratio of the absolute value at $y = 1$ in gains and losses, which is also consistent with the index of loss aversion in Köbberling and Wakker (2005)[24]. Finally, we assume that the weighting function follows a flexible parametric form (suggested by Tversky and Kahneman (1992)) given by $\delta_i(\pi_j) = \frac{\pi_j^{\mu_i}}{\left(\pi_j^{\mu_i} + (1-\pi_j)^{\mu_i}\right)^{1/\mu_i}}$ where $\mu_i$ is a model parameter we estimate.

To operationalize the value function, we define the utility index as follows

$$y_{ij,w} = \alpha_{ij,w} + X_j \kappa_i - \beta_i \left(p_j + \omega_j\right) \tag{16}$$

$$y_{ij,nw} = \alpha_{ij,nw} + X_j \kappa_i - \beta_i p_j \tag{17}$$

$$y_{ij,nw}^{c} = -\beta_i c_j \tag{18}$$

where $\alpha_{ij,w}$ ($\alpha_{ij,nw}$) is the intrinsic consumption utility subject $i$ gets from purchasing brand $j$ with (without) warranty. The survey data allows us to separately estimate the consumption utility from a brand with warranty and without warranty which provides a direct test of whether or not subjects get consumption utility (disutility) from buying warranties. $\kappa_i$ is subject $i's$ preference for washer characteristic $X$ (loading type) and $\beta_i$ is subject $i's$ sensitivity to prices. The power value function provides an implicit normalization ($v(1) = 1$) which allows us to estimate $\beta_i$. However, as discussed in Section 3.1.1, $\beta_i$ is not identified in a non-parametric sense without this normalization.

The model outlined in Sections 3.1 and 3.2 are static in the sense that they do not account for discounting over time. Product and warranty costs are incurred in the current period while repair costs are (possibly) incurred between the second and fourth years of service[25]. This leads to a temporal aspect in risk incurred by a subject. Not accounting for discounting, we estimate a lower bound on loss aversion. If the subjects have a linear value function and their beliefs about when the product fails between the second and fourth years of service do not change across choice tasks, then for a homogeneous annual discount factor of 0.95, we under predict loss aversion by roughly 10%.

In addition to the base model, we use the simultaneous survey data to estimate and draw comparison

[23]The empirical literature on prospect theory commonly makes this assumption (for e.g., Post, van den Assem, Baltussen, and Thaler (2008); Tanaka, Camerer, and Nguyen (2010)).

[24]For a value function with same curvature in gains and losses, loss aversion is the ratio of absolute value at in point in gains and losses.

[25]The first year of service is covered by the manufacturer warranty.

between four other models. The first two models are special cases of the model outlined in Section 3.1 where we restrict the risk aversion (loss aversion) parameter to be 1. Restricting the risk aversion parameter ($\gamma$) to be 1 gives a linear utility model with a kink at the reference point. As mentioned earlier, not accounting for loss aversion, we estimate a model consistent with reference dependent preferences while accounting for rank dependent probability weights. We estimate a third model consistent with expected utility theory where only the final states (as opposed to gains and losses) matter and we do not account for loss aversion and probability weights. Finally, we estimate a linear utility model using the product characteristics shown to subjects. This model is analogous to the standard model researchers and industry experts run using conjoint data. Robustness checks around the nature of risk preferences, and assumption of reference point are present in the web appendix.

For each model, we report results for both homogeneous and heterogeneous (normally distributed random coefficients) specifications. In each case, we report quantiles of the posterior distribution of the population hyper parameters to assess the parameter magnitudes and precisions. We also report the log marginal density (computed using the Newton and Raftery (1994) approach) as well as a trimmed log marginal density where we trim the upper and lower 2 percentile posterior draws to correct for outlier effects. Comparing log marginal densities across models is roughly equivalent to computing a Bayes' Factor to assess relative posterior model fit. For more details on the estimation of log marginal densities and Bayes' Factor, please refer to Rossi, Allenby, and McCulloch (2005) (Chapter 6).

We call the baseline model consistent with equations 1 through 15 the "Full" model and estimate the curvature of the utility function subject to the restriction $\gamma \geq 0$ which ensures that value is monotonically increasing in $y$. Additionally, we restrict $\mu \geq 0$. We impose these restrictions by expressing the curvature and the weighting function parameter using an exponential transformation based on unrestricted parameters $\Gamma$ and $\rho$ such that $\gamma = \exp(\Gamma)$ and $\mu = \exp(\rho)$[26]. To simplify notation, we use the vector $\theta_i$ to denote the subjects' taste parameters, $(\alpha_{ij,k}, \beta_i, \kappa_i, \Gamma_i, \rho_i, \lambda_i)$. We then allow for heterogeneity by assuming that the subjects' parameters are drawn from a common population normal distribution: $\theta_i \sim N(\overline{\theta}, V_\theta)$. Priors on the population hyper-parameters, $\overline{\theta}$ and $V_\theta$, are specified as follows:

$$\overline{\theta}|V_\theta \sim N(0, a^{-1}V_\theta) \tag{19}$$

$$V_\theta \sim IW(\nu, \nu I) \tag{20}$$

where $a = 1/16$ and $\nu = \dim(\theta_i)+3$, which are proper but very diffuse prior settings. The model is estimated using a hybrid MCMC approach with a customized Random Walk Metropolis step as discussed in Rossi, Allenby, and McCulloch (2005) (Chapter 5) and applied in Dubé, Hitsch, and Jindal (2011).

For the "EU" model consistent with expected utility theory, we define the utility subject $i$ gets from

[26]The value function curvature ($\gamma$) and the probability weighting parameter ($\mu$) are thus, lognormally distributed.

choosing brand $j$ with or without warranty is given by

$$u_{ij,w} = f(y_{ij,w}) + \epsilon_{ij,w} \tag{21}$$

$$u_{ij,nw} = \pi_j f\left(y_{ij,nw} + y^c_{ij,nw}\right) + (1-\pi_j) f(y_{ij,nw}) + \epsilon_{ij,nw} \tag{22}$$

$$u_{i0} = \epsilon_{i0} \tag{23}$$

where $f(.)$ is a function that mirrors the utility function around the origin such that

$$f(y_{ij,k}) = \begin{cases} (y_{ij,k})^{\gamma_i} & ; y_{ij,k} \geq 0 \\ -(-y_{ij,k})^{\gamma_i} & ; y_{ij,k} < 0 \end{cases} \tag{24}$$

Note that the expected utility model is not "embedded" in the baseline specification due to the presence of reference dependent preferences (consistent with mental accounting).

## 7.1 Simultaneous Survey

We summarize the trimmed log marginal density (excluding 2% outliers) from the 5 models outlined above in Table 4. As expected, accounting for unobserved heterogeneity improves the model fit. The "Full" baseline model fits the data substantially better than the expected utility model and the linear conjoint model. Recall that the expected utility model does not account for loss aversion. The two special cases nested in the baseline specification - the "Risk only" model (same as the reference dependent model with rank dependent probability weights) and the "Loss only" model fit the data worse than the baseline model; thus, providing strong evidence against the restrictions $\gamma_i = 1$ and $\lambda_i = 1$. Both these models outperform the expected utility model. This highlights the importance of accounting for both, reference dependent preferences and loss aversion. Further, the "Loss only" model outperforms the "Risk only" model pointing to the relative importance of accounting for loss aversion as opposed to risk aversion (curvature). We shed more light on this in the next section.

Tables 5 through 9 present the demand estimates from the 5 models outlined above. We focus our discussion on the estimates of risk aversion, probability weighting function and loss aversion. Recall that both probability weighting parameter and risk aversion parameter are estimated subject to the exponential transformation ($\gamma = \exp(\Gamma)$ and $\mu = \exp(\rho)$). In the baseline model (Table 5), we find that subjects are on average risk neutral (based on the curvature) but there exists substantial heterogeneity in the curvature of the value function. The most important finding is the average loss aversion estimate of 2.05. This finding is consistent with the literature where the average loss aversion is estimated between 2 and 2.25. Further, we find substantial heterogeneity in the degree of loss aversion across subjects which is consistent with the findings of von Gaudecker, van Soest, and Wengstrom (2011).

The average probability weighting parameter in the population is 1.33 which implies an S-shaped probability weighting function. While we find substantial heterogeneity in the weights different subjects assign to probabilities, the S shape is at odds with findings in the behavioral economics literature which consistently finds an inverted S-shaped probability weighting function. Estimates of probability weights are very sensitive to the specification of the value function curvature. We thus, estimate the model on data excluding extreme failure probabilities of 0 and 1 to see if these choice tasks are driving the results, and do not find substantial differences in the risk preferences and probability weights as compared to the baseline model. Thus, the probability weight estimates do not seem to be driven by choices at the extreme failure probabilities. Additionally, we eliminate some of the choice tasks where warranties are actuarially fair. If subjects do not buy actuarially fair warranties, then this could be justified through under-weighting of smaller probabilities which will make the weighting function look S-shaped. Again, eliminating actuarially fair warranty choice tasks does not change the shape of the probability weighting function.

Another possible concern is the parametric form used for the probability weighting function. It is well known that the probability weighting function suggested by Quiggin (1982) is non-monotonic in probabilities for $\mu < 0.27$. As per our estimates, the posterior distribution of probability weighting parameter does have some mass in this region. Thus, we use an alternate one parameter probability weighting function proposed by Prelec (1998) and do not find any substantial differences in the distribution of the probability weights. The results from this model are presented in Section 9.2. Thus, while the shape of the probability weighting function does not conform to intuition, we do not find any systematic inconsistencies in the data which might lead to the probability weights we get. Finally, as we show in Section 7.3, probability weights do not have any predictive power in explaining warranty choices. In contrast to our findings, Barseghyan, Molinari, O'Donoghue, and Teitelbaum (2010) attribute most of risk aversion to an inverted S-shaped probability weighting function. We estimate an analogous model where warranty choice is modeled conditional on product purchase and find that estimates of the weighting function without unobserved heterogeneity are consistent with Barseghyan, Molinari, O'Donoghue, and Teitelbaum (2010)[27]. Incorporating unobserved heterogeneity, however, reverses the shape of the weighting function.

Figure 11 plots the marginal density and the 90% credibility region of the value function curvature ($\gamma$) for the baseline model and the model assuming $\lambda_i = 1$. Assuming that subjects do not exhibit loss aversion, we find that product and warranty purchases are explained by a higher degree of risk aversion (as can also be seen in Table 6). From Figure 12, we see that assuming consumers have a linear value function does not affect the sample distribution of loss aversion. We do, however, note that assuming that subjects have a linear value function reduces the average curvature of the probability weighting function in favor of an inverted S-shaped function. Table 8 reports the parameter estimates from the expected utility model. It is surprising that on average, subjects seem to be risk seeking (average $\gamma = 1.30$) under the expected utility model. While this model fits the data worse that the other models incorporating loss aversion or reference dependent preferences, we provide some possible explanations for this in Section 9.3. Compared to the "Full"

[27]Please see web appendix for the outline of this model and the estimates.

model, we find that subjects get slightly higher utility from buying warranties. The difference is however, statistically insignificant.

Table 10 presents the correlation (and the 95% confidence interval bounds) between all the model parameters. Subjects with higher product and warranty preference are also more price sensitive. We do not find significant correlations between the weighting function, risk aversion and loss aversion. More price sensitive subjects do seem to be less loss averse on average.

Finally, we look at the importance of accounting for loss aversion on the dollar willingness to pay (based on consumption utility) for the washer and extended warranties[28]. Correlation between GE and Whirlpool brands is 1.0; thus, we only focus on the dollar willingness to pay for GE and the warranty associated with GE. Figure 13 presents the distribution of a proxy of the dollar willingness to pay for GE (based on the posterior distribution) under different model specifications. Computed as the ratio of intrinsic preference for warranty normalized by the price coefficient, we call it a proxy since in our model, subjects do not have a constant marginal utility of income. Not accounting for risk aversion or restricting the consumption utility from warranties to be zero does not have a substantial effect on the willingness to pay for GE as compared to the baseline "Full" model. However, assuming the subjects are expected utility maximizers, we find that they have a slightly lower willingness to pay for GE. Figure 14 shows the same distribution for the willingness to pay for an extended warranty with GE. While we find substantial heterogeneity in the WTP for warranties, subjects on average, get disutility from buying warranties. Failure to separate risk averse behavior into that arising from curvature and aversion to losses will lead us to conclude that subjects get additional utility from buying warranties.

## 7.2 Sequential Survey

Table 11 reports the parameter estimates from the homogeneous and heterogeneous models using the sequential survey data. Qualitatively, the estimates of risk preferences are very similar to those from the simultaneous survey. We find substantial heterogeneity in risk preferences, but on average, subjects have a loss aversion parameter estimate of 1.77. Compared to the simultaneous survey, subjects on average, have a slightly convex value function.

To draw a direct comparison between the estimates of risk preferences, we plot the posterior marginal density and the 90% credibility region of the value function curvature ($\gamma$), and loss aversion ($\lambda$) for the simultaneous and sequential surveys in Figures 15 and 16, respectively. We find substantial more heterogeneity in the estimate of the value function curvature using the sequential survey. This is not surprising given the difficulty in measuring curvature and the relatively small sample size of the sequential survey. In comparison, the distribution of loss aversion from the two surveys are comparable, with loss aversion being slightly higher in the simultaneous survey.

[28]Note that the model we outlined in Section 3.1 does not have a constant marginal utility of income. What we report here are the consumption utilities normalized by the price coefficient which can be seen as a proxy for willingness to pay. Further, this analysis is reduced form in the sense that we do not account for income effects.

The importance of the sequential survey is highlighted when we compare the dollar willingness to pay for a warranty from the different surveys. Figure 17 plots the posterior density of the "dollar willingness to pay" for a GE warranty under the different surveys. On average, subjects in the sequential survey are willing to pay $50 more for a warranty as compared to those in the simultaneous survey. Recall that in the sequential survey, subjects first decide to buy a washer and then a warranty. In contrast, in the simultaneous survey, subjects simultaneously choose a washer and a warranty. As pointed out by Peck and Shu (2009), the two stage choices in the sequential survey could lead to a sense of ownership of the washer in the second stage, which consistent with endowment effect, could lead to a higher willingness to pay for the warranty.

### 7.3 Relative Importance of Risk Preferences in Warranty Choices

We now seek to understand the relative importance of different risk preferences in explaining choices. For this, we again focus our attention to the simultaneous choice survey[29]. From Table 4, we see that a model incorporating only loss aversion fits the data better (based on log marginal density) than models incorporating only risk aversion (i.e. expected utility model and the reference dependent model with rank dependent probability weights). We provide 2 additional tests which get at the relative importance of risk aversion, loss aversion and probability weights. For both these tests, we estimate different models on a subset of the data and randomly select 6 choices for each subject for the holdout sample. We then use demand estimates based on the sub-sample to test out of sample fit.

First, we estimate the "Risk only" and "Loss only" models on the estimation sample and make out of sample predictions. The results are reported in the top 2 panels of Table 12. In addition to reporting hit rate on the overall sample, we split the hit rate based on whether a warranty was purchased or not[30]. Using the demand estimates, we accurately predict 74% of the choices in the holdout sample based on both, the "Risk only" and the "Loss only" models. If we now assume that there exists no risk aversion and probability weighting in the "Risk only" model i.e. $\gamma_i = 1$ and $\mu_i = 1$, then using only the product and price preferences, we are able to correctly predict 71% of the choices. Conditional on warranty purchase, there is a 7% drop (from 65% to 58%) in hit rate. Thus, risk aversion and probability weighting play little role in predicting warranty choices in the holdout sample. However, if we assume that $\lambda_i = 1$ and $\mu_i = 1$ in the "Loss only" model, then the out of sample prediction for all choices (warranty purchases) drops to 62% (30%), pointing to the importance of accounting for loss aversion in out of sample prediction. One may argue that the correct approach will be to use the demand estimates after marginalizing out the distributions of risk and loss aversion. To this end, we note that the correlations between these parameters, and the product and price preferences is extremely small and thus, we do not expect the out of sample predictions to change substantially.

While the first test studies the relative importance of risk and loss aversion, and probability weights,

[29]We did the same analysis for the sequential survey and found qualitatively similar results.

[30]Hit rate is defined as the percentage of choices correctly predicted using the demand estimates.

estimating separate models allows product and price preferences to have a differential impact on warranty choices. To overcome this limitation, we estimate the "Full" base model and use the demand estimates to do out of sample predictions. We then assume that $\gamma_i = \lambda_i = \mu_i = 1$, and use only the product and price preferences to make out of sample prediction. Intuitively, the difference in accuracy between these two predictions can be attributed to risk aversion, loss aversion and probability weights. We then take turns "switching on" each of these parameters one at a time and report the out of sample predictions. Finally, we "switch on" both loss aversion and probability weights and keep $\gamma_i = 1$. In addition to the whole sample, we report the hit rates split by whether a warranty was purchased or not. The results are reported in the bottom panel of Table 12. The full model correctly predicts 73% of the choices in the holdout sample. Product and price preferences explain 61% of these predictions. Adding risk aversion (probability weights) to the product and price preferences, out of sample prediction increases to 62% (61%) but adding loss aversion improves the out of sample prediction to 70%. Risk preferences have little bearing on out of sample predictions when a warranty is not purchased. However, when warranties are purchased, risk preferences are as important as product and price preferences in explaining choices (hit rate drops from 64% to 31% when we includes only product and price preferences). Further, accounting for risk aversion improves the hit rate from 31% to 35% but accounting for loss aversion improves it to 62%. This provides sufficient evidence to conclude that loss aversion is substantially more important than risk aversion and probability weighting in explaining warranty choices.

# 8 Pricing Implications

In this section, we address three key questions. First, we wish to understand how firm pricing decisions are affected if they do not account for the fact that consumers are loss averse. If repair costs are treated as a loss, then failure to account for this will mislead the analyst into concluding that consumers are more price sensitive; and thus, the analyst will set lower equilibrium prices. Intuitively, warranty prices should increase with increasing repair costs. However, not accounting for loss aversion, we will under-predict the rate of change of warranty prices. Second, we try and understand whether risk preferences rationalize the high premium consumers routinely pay for extended warranties. As mentioned earlier, extended warranties can be used as a sorting device to price discriminate among consumers. We use data and parameter estimates from the two surveys to test economic theory on price discrimination and understand the role of risk preferences in explaining the high premia. Finally, in Section 8.3, we provide a rough estimate of the change in consumer welfare from a policy intervention. Specifically, we calculate the compensating variation from a regime change where different retailers sell products and extended warranties.

## 8.1 Loss Aversion and Washer and Warranty Pricing

To understand the impact of risk preferences on product and warranty pricing, we focus on the simultaneous survey and use the demand estimates from the "Full" model and the "EU" model to calculate a monopolists' profit maximizing equilibrium prices for the washer and extended warranty[31]. We assume that the firm sells only the GE washing machine with the front loading option and consumers have the option of purchasing it with or without warranty, or choosing to make no purchase.

Firms can vary the washer and warranty prices, and repair costs (to the consumer) such that the optimal profits remain unchanged. Thus, we cannot jointly maximize profits over these simultaneously. We first assume that the firm does not make any money on product repair and calculate the optimal washer and warranty prices for different washer costs, repair costs and failure probabilities. Figures 18 and 19 show how the optimal washer and warranty prices vary with washer costs and repair costs (for a fixed failure probability of 25%). As expected, failure to account for loss aversion leads to lower equilibrium washer prices and under predicts the rate of change of warranty prices with varying repair costs. Together, these translate to roughly 9% lower profits.

Figure 20 shows how optimal repair prices (to consumers) vary with varying repair costs and washer costs. To calculate these, we assume that the firm charges a fixed 20% markup over washer costs, and then calculate the optimal warranty prices and repair prices given this markup. Repair prices charged to the consumer increase in both repair costs and the washer costs (and price). As compared to the expected utility model, accounting for loss aversion leads to higher repair prices to consumers.

## 8.2 Risk Preferences and Price Discrimination

From the above analysis, we find that in the simultaneous study, while warranty prices are higher when we account for loss aversion, the optimal warranty price is roughly equal to the expected repair cost. Thus, it is optimal to sell warranties at marginal cost and charge a high mark-up on the washing machine. Oi (1971) and Rosen and Rosenfield (1997) show that subject to certain conditions, it is optimal for firms to charge a premium on aftermarket goods (extended warranties in our case) if the aftermarket demand of the marginal consumer is less than the per unit average aftermarket demand of all the primary good (washers) consumers. For this to be true, either the income effects are small or are not correlated with the demand for the aftermarket good. This is satisfied by assuming away income effects as is standard in the discrete choice literature.

Gil and Hartmann (2009) use this to derive specific correlations to test in data from movie ticket and concession sales.In the context of extended warranties, we define the per unit aftermarket demand as the likelihood of a consumer purchasing an extended warranty. Let $\theta$ be a vector of product and risk preferences, and $\theta^*$ denote the marginal consumer who is indifferent between buying and not buying the washer at any

[31] Subjects do not have a constant marginal utility of income. Thus, we do not account for income effects in the pricing analysis which makes this analysis somewhat reduced form.

price $p$. Mathematically, the above condition can be written out as

$$\Pr\left(\mathbb{I}\left(warranty\right) = 1 \mid \theta^*\right) < \mathbb{E}\left[\Pr\left(\mathbb{I}\left(warranty\right) = 1 \mid \theta\right) \mid v\left(p;\theta\right) > v\left(p;\theta^*\right)\right] \tag{25}$$

where $v(p;\theta)$ is the value a subject with preference vector $\theta$ gets from buying the washer at price $p$. Equation 25, also known as the single crossing property implies that a firm should charge a high mark-up on extended warranties if at any given washer and warranty price, the probability that the marginal washing machine consumer buys the warranty is lower than the average probability of warranty purchase of all the consumers who buy the washing machine at that price. To simplify notation, let $z^* = \Pr\left(\mathbb{I}\left(warranty\right) = 1 \mid \theta^*\right)$ and $\bar{z} = \mathbb{E}\left[\Pr\left(\mathbb{I}\left(warranty\right) = 1 \mid \theta\right) \mid v\left(p;\theta\right) > v\left(p;\theta^*\right)\right]$. Conversely, if $z^* = \bar{z}$, firms should charge a premium on the washing machine and sell warranties at marginal cost.

The left panel of Table 13 reports the quantiles for the distribution of $\bar{z}$, $z^*$ and $\bar{z} - z^*$ from the simultaneous survey. These estimates are calculated by integrating out over the distributions of the error terms ($\epsilon$) and preferences. We find that the distribution of the $\bar{z} - z^*$ is centered around 0. Thus, the probability that the marginal washer consumer buys the warranty is the same as the average probability of all the consumers who buy the washer, implying selling warranties at marginal cost. Our findings from the monopolist profit maximization are consistent with this; however, are somewhat at odds with what we observe in practice. The right panel of Table 13 reports the quantiles for the distribution of $\bar{z}$, $z^*$ and $\bar{z} - z^*$ from the sequential survey. In contrast to the sequential survey, we see that the distribution of $\bar{z} - z^*$ has a median value of 13% is lies to the right of 0. Theoretically, this implies that firms should sell extended warranties at a high premium. Re-calculating the monopolist profit maximizing prices using the sequential data, we find that it is optimal for firms to sell extended warranties at a contribution margin of 62%. As observed in practice, the optimal warranty prices are predicted to be 16% of product price.

Consumers purchase extended warranties due to several different factors. These include over predicting failure probability or repair costs, risk preferences, intrinsic preference for warranties (peace of mind). *While warranty purchase can be rationalized by the estimates of these parameters, rationalizing the high premium paid for warranties requires us to look at the correlations between the parameter estimates.* The single crossing property from equation 25 provides a test of this. In both surveys, failure probabilities and repair costs are given to subjects. Note that we find similar estimates for risk preferences in both surveys but they do not drive the premium for extended warranties in the simultaneous choice survey. To test whether the model specification implicitly drives the high premia in the sequential study, we re-estimated the sequential choice model on data from the simultaneous survey. Profit maximization from the demand estimates indicate only a slight increase in the mark-up for extended warranties. Thus, the high optimal mark-up we observe in the sequential survey are not driven only by the model specification.

We next understand the importance of risk preferences in explaining the high premia we find in the sequential survey. To do this, we do not allow subjects to be loss averse or have any intrinsic preference for extended warranties. We re-estimate the optimal profits for a monopolist and find that the optimal warranty price reduces by around 25% on average. This corresponds to a contribution margin of around 49%. Thus, while risk and intrinsic warranty preference (endowment effect) explain part of the premium, they do not rationalize the high premium entirely. Intuitively speaking, these results are driven by the correlations between parameter estimates which exist in the sequential survey but are missing in the simultaneous survey.

### 8.3 Welfare Changes from Policy Intervention

Kunreuther and Pauly (2006) and Schoemaker and Kunreuther (1979) argue that insurance decisions and premiums paid for them are more complex and may not be entirely explained by risk preferences. Retailers generally carry warranties from only one source (third party insurer) and act as monopolists over extended warranties. Since it is unlikely that consumers search over warranty prices when buying a product, retailers are able to charge higher mark-ups on warranties. This has important consequences for insurance pricing and how insurance is sold. In a world where the high premia are driven by retailers acting as monopolists over extended warranties (as opposed to risk preferences), forcing retailers to carry extended warranties from multiple insurers will make extended warranties market more competitive and help reduce warranty prices. If however, high risk premiums are (partly) driven by risk preferences, then firms benefit by metering extended warranties. Thus, any normative statement about warranty pricing should account for not only risk preferences and consumer beliefs, but also, other possible factors such as role of information and competition which could drive warranty prices and purchases.

To the extent that washers and warranties are complementary goods (as shown in Section 8.2), forcing different retailers to carry washers and warranties will not only lead to lower warranty prices, but will also increase the prices of the washers. The net effect on consumer surplus is ambiguous. We now estimate the discount on the washer price (measure of compensating variation), which would make subjects indifferent between the current policy where a retailer sells both washers and warranties, and a policy where different retailers sell washers and warranties[32]. We first calculate the optimal washer price for a retailer selling only the washer (warranty price is irrelevant to this pricing decision). Given the optimal washer price, and some assumed repair costs and failure probability, we then maximize the retailer profit with respect to the warranty price. The washer price determines the distribution of preferences faced by the retailer selling warranties, and is thus, relevant to warranty pricing. Compensating variation is calculated by equating the expected maximum utility based on the new optimal prices with the expected maximum utility based on the prices calculated from joint profit maximization in Section 8.1.

For the assumed washer cost ($400), repair cost ($200) and failure probability (25%), forcing separate retailers to sell washers and warranties increases the washer price by approximately 8% and reduces the warranty price by 18%. 74 out of the 77 subjects are worse off after the policy intervention and need to be

[32]In our model, we do not have income effects and utility is non-linear in product and warranty prices. Further, the marginal utility with respect to product price and warranty price can be different. Thus, we calculate the discount in washer price which would make consumers indifferent to the policy change.

positively compensated. On average, subjects need to be given a \$46 discount on the washer price to make them indifferent between buying a washer (and optionally, a warranty) from one retailer versus separate retailers. This translates to around 5% discount on the washer price. We also calculated the compensating variation on the warranty price. In order to make the subjects indifferent to the policy change, subjects would have to be given on average, \$100 off the warranty price. This translates to about 75% discount on the extended warranty. Compared to the discount on washers, this is substantially higher and makes intuitive sense given that the likelihood of warranty purchase is substantially lower than the likelihood of washer purchase. Thus, forcing separate retailers to sell washers and warranties reduces the warranty price, but makes the consumers worse off due to the increase in washer price, which more than off-sets the benefit from lower warranty prices.

# 9 Robustness Checks

The survey data provides us enough flexibility to estimate alternate model specifications. In this section, we detail some of the robustness checks we do around the model specification and parametric assumptions to understand their impact on estimated preferences. We only report robustness checks done around parametric assumptions using the simultaneous survey. While we expect different models to give different estimates of preferences, we focus on understanding how the distribution of risk aversion and loss aversion changes when we change one or more underlying assumptions. For each of the cases below, we report the the quantiles from the homogeneous and the heterogeneous models (as was done in Section 7.1) but limit our discussion to the distribution of risk and loss aversion, and probability weights. For the sequential survey, we test the assumption that subjects do not account for the warranty price and repair costs in their washer purchase decision.

## 9.1 Intrinsic preference for warranties

In the model outlined in Section 3.1, we allow subjects to have some intrinsic preference for warranties. However, one may argue that this will only be true when the washer has a possibility of failure. Thus, for a failure probability of 0, subjects should not get any (dis)utility from buying the warranty. Given that 8% of the choices include warranty purchases when failure rate is 0, it is possible that these choices are driving the higher preference for warranties under the EU model. To account for this, we estimate a model where the deterministic portion of linear utility a risk neutral subject $i$ gets from buying brand $j$ with a warranty is given by

$$y_{ij,w} = \begin{cases} \alpha_{ij,w} + X_j\kappa_i - \beta_i p_j & ; \pi_j > 0 \\ \alpha_{ij,nw} + X_j\kappa_i - \beta_i p_j & ; \pi_j = 0 \end{cases} \tag{26}$$

As per equation 26, subjects get a different consumption utility from purchasing a warranty only when there is a non-zero probability of product failure. The estimates from the revised specification for both, the "Full" and the "EU" model are presented in Tables 16 and 17 in Appendix C.1. The results are very qualitatively the same as in the baseline specification. We find that subjects get slight disutility (utility) from buying warranties when we account (do not account) for loss aversion. As in the base model, we find subjects have an almost linear value function on average and are substantially more averse to losses.

## 9.2 Probability weighting Function

The baseline model presents the demand estimates assuming a probability weighting function outlined by Quiggin (1982). As mentioned in Section 7, this function is non-monotonic in failure probabilities for lower values of $\mu$. To correct for this, we use a probability weighting function $\delta_i(\pi_j) = \exp(-(-\log(\pi_j))^{\mu_i})$ proposed by Prelec (1998). Intuitively speaking, due to the non-monotonicity of the weighting function in the baseline model, lower weights are assigned to probabilities for lower parameter values. Thus, eliminating the non-monotonicity of the weighting function will affect the value function. Our primary interest is in understanding if this has a substantial impact on the value function curvature and the estimate of loss aversion. The results from this model are presented in Table 18.

The homogeneous estimates from this model are almost identical to those from the baseline model. This is not surprising given that the probability weighting parameter in the baseline homogeneous model is substantially higher than 0.27. Turning to the heterogeneous estimates, consistent with intuition, we find that the product and price preferences are different from the baseline model. However, we still find that on average, subjects have a linear value function and exhibit substantial loss aversion (average loss aversion in the population decreases slightly from 2.05 to 1.76). As before, we find substantial heterogeneity in the risk preferences across subjects. We used these parameter estimates to study the relative importance of risk aversion and loss aversion in explaining warranty choices (similar to the exercise done in Section 12). While the importance of risk aversion in explaining warranty choices increases slightly (by around 2%), we still find that warranty purchases are by and large explained by loss aversion and probability weights do not affect subjects' choices.

## 9.3 Risk aversion and intrinsic warranty preference

The specifications outlined till now allow subjects to get different intrinsic consumption utility from buying the product with warranty and without warranty. While we find that subjects get slight disutility (utility) from buying warranties under the "Full" ("EU") model, the difference is not statistically significant. Thus, in the "Full" and the "EU" model, we restrict the subject to get the same consumption utility from brand $j$ irrespective of whether she buys the brand with warranty or without warranty. Intuitively, this does not allow subjects to get a higher (lower) consumption value from buying warranties and thus, warranty purchases will be justified by a higher (lower) degree of risk aversion or a lower degree of loss aversion. The demand estimates from this restricted model are present in Table 19 in Appendix C.3. We do not see any differences in the distribution of risk aversion in the restricted baseline specification. Figure 23 shows the distribution of loss aversion (along with the 90% confidence interval) for the "Full" model with and without this restriction. As can be seen, restricting subjects to get the same utility from product purchase with and without warranty (thus, getting higher utility from buying warranties as compared to the "Full" model) reduces the degree of loss aversion, which intuitively makes sense. The difference in the distribution though is not statistically significant.

In Figure 24, we provide the distribution of risk aversion from the restricted and unrestricted versions of the "EU" model. As expected, the distribution of risk aversion shifts to the left (higher degree of risk aversion) when we do not allow subjects to get any additional intrinsic consumption utility from buying warranties. Recall that in our survey, we have several choice tasks where the product fails with certainty ($\pi = 1$). To keep the repair costs realistic, we did not reduce the repair costs and thus, in some of these choice tasks, warranties prices are lower than the expected repair costs. For these choice tasks, warranties are actuarially fair and do not require risk aversion to justify their purchase. To understand the impact of these choices on degree of risk aversion, in Figure 24, we also show the distribution of risk aversion estimated on data excluding choice tasks with $\pi = 1$. As can be seen, subjects seem to be more risk averse when we retain data only for choice tasks where warranties are actuarially unfair. The demand estimates from these two models with intrinsic consumption utility from warranties restricted to 0 are presented in Tables 20 and 21 in Appendix C.3.

### 9.4 Separate curvature parameters for gains and losses

In this section, we get back to our assumption about the same utility curvature in gains and losses. Recall that we use variation in costs to estimate the value function in losses ($v_l(.)$). However, we restrict the disutility from losses to have the same curvature as the utility from buying the product (gains). We can use the variation in repair costs to independently estimate the curvature of the value function in losses. Thus, we re-estimate the "Full" model subject to the value function

$$v(y_{ij,k}) = \begin{cases} (y_{ij,k})^{\gamma_i} & ; y_{ij,k} \geq 0 \\ -\lambda_i \left(-y_{ij,k}\right)^{\phi_i} & ; y_{ij,k} < 0 \end{cases} \tag{27}$$

and restrict $\phi_i > 0$ by using the transformation $\phi_i = \exp(\Phi_i)$, where $\Phi_i$ is another parameter we estimate. Demand estimates from this model are summarized in Table 22. Understandably, a model allowing for different curvature in gains and losses fits the data better than the base model which restricts the curvature to be same. Figure 25 shows the distribution of risk aversion (curvature) from the base model and from this model (for both gains and losses). Allowing for different degree of curvature in gains and losses, we find that on average, the value function is convex in losses, which is consistent with the findings in the behavioral literature. In contrast to the literature, we find that the average degree of curvature is higher in losses domain than in gains. Further, subjects are substantially more heterogeneous in the degree of curvature in the losses domain, than they are in the gains domain. Allowing for the curvature of the utility function to be different makes the subjects slightly more loss averse as can be seen in Figure 26. Finally, subjects have a lower price sensitivity as compared to the baseline specification.

We detail some additional robustness checks around warranty price being treated as a loss, CARA utility specification, utility from the outside option and probability weighting function in the web appendix.

## 9.5 Utility specification

In the baseline "Full" model, we assume that the subject faces risk over the entire utility from product purchase. However, one may argue that the product price is paid with certainty (if the product is purchased), and thus, risk exists only on the consumption utility derived from the product and characteristics. To account for this, we estimate an alternate model where the value a subject gets from different alternatives is given by

$$u_{ij,w} = v\left(y'_{ij,w}\right) - \beta_i(p_j + \omega_j) + \epsilon_{ij,w} \tag{28}$$

$$u_{ij,nw} = v\left(y'_{ij,nw}\right) + \delta_i\left(\pi_j\right) v\left(y^c_{ij,nw}\right) - \beta_i p_j + \epsilon_{ij,nw} \tag{29}$$

$$u_{i0} = \epsilon_{i0} \tag{30}$$

where $y'_{ij,k} = \alpha_{ij,k} + X_j \kappa_i$ for $k \in \{w, nw\}$ and the remaining parameters are as before. As compared to the baseline specification in equations 12 and 11, the curvature only exists on the consumption utility from product purchase and not on the price paid to acquire the product/warranty. The identification of this model follows along similar lines as discussed in Section 3.1.1.

Table 23 in Appendix C.5 summarizes the demand estimates from this model. Based on log marginal density, this model fits the data worse than the "Full" model. Comparing the parameter estimates with those from the baseline model (present in Table 5), we find that subjects have a lower intrinsic product preference if we assume that risk exists only over the consumption utility. As compared to the "Full" model, we do not find any substantial difference in the distribution of price sensitivity[33]. For ease of comparison, we plot the posterior marginal densities of risk aversion and loss aversion from this model and the baseline specification (along with the 90% credibility region) in Figures 21 and 22, respectively. If we believe that subjects do not incur any risk over the prices they pay for the product, then on average, they seem to be slightly more risk seeking (convex curvature). We see a similar trend for loss aversion where assuming that risk is only over the consumption utility, subjects seem to be less loss averse.

[33] In the baseline model, subjects do not have a constant marginal utility of income. However, in this model, the price coefficient can be interpreted as the constant marginal utility of income.

### 9.6 Accounting for Warranty Choice in Sequential Survey

The model outlined in Section 3.2 does not allow warranty and repair characteristics to affect washer choice in the first stage. Thus, the subjects are assumed to be somewhat myopic. While this is consistent with the survey design, in reality, consumers may have some beliefs about the warranty characteristics, which they account for while making a washer purchase decision. Also, in our survey, subjects can go back and forth between pages and thus, might have information about warranty price and repair costs while making washer choice. To check for this, we treat the decision making as a "dynamic" problem where we allow subjects to account for the expected maximum utility from warranty choice in the first stage washer decision.

We assume that in the first stage, the subject has information about warranty price, failure probability and repair costs in addition to brand, loading type and washer price. In the first stage, the subject decides which washer to buy. Conditional on washer purchase, the subject decides whether to buy a warranty or not (or not buy the washer at all) in the second stage. In the first stage, we include a "continuation value", which is the expected maximum utility from the second stage choice and test whether the consumer accounts for this in the first stage or not, through an accounting factor. The accounting factor here is similar to a discount factor in dynamic choice model, but rather, it captures whether the subject accounts for the warranty price and repair costs in the first stage or not. The value from different choices in the second (warranty choice) stage are

$$\begin{aligned} u_{ij,nw} &= v\left(y_{ij}\right) + \delta\left(\pi_j\right) v_l\left(y_{ij}^c\right) + \epsilon_{ij,nw} \\ &= v_{ij,nw}^* + \epsilon_{ij,nw} \\ u_{ij,w} &= v\left(y_{ij}\right) + v\left(y_{ij}^w\right) + \epsilon_{ij,nw} \\ &= v_{ij,w}^* + \epsilon_{ij,w} \\ u_{i0} &= \epsilon_{i0} \end{aligned}$$

In the first stage, the value from adopting washer $j$ can be written as

$$u_{ij} = v\left(y_{ij}\right) + \zeta_i \mathbb{E}\left[\max\left\{u_{ij,w}, u_{ij,nw}, u_{i0}\right\}\right] + \epsilon_{ij}$$

where $\zeta_i$ is the individual specific accounting factor. If $\zeta_i = 0$, then the subject doesn't account for continuation value in the first stage. If $\zeta_i = 1$, then the subject accounts for the continuation value perfectly. Assuming that the $\epsilon_{ij,k}$ from the second stage are type 1 extreme value distributed, the value from choosing brand $j$ in the first stage can be written as

$$u_{ij} = v\left(y_{ij}\right) + \zeta_i \log\left[\exp\left(v_{ij,nw}^*\right) + \exp\left(v_{ij,w}^*\right) + 1\right] + \epsilon_{ij}$$

If the subject decides to not buy in the first stage, then there is no continuation value since the subject doesn't get an option to purchase the warranty. Finally, assuming the $\epsilon_{ij}$ from the first stage are type 1 extreme value distributed, we get the logit specification for the conditional and unconditional probabilities, similar to equations 10, 13 and 14.

Table 24 in Appendix C.6 summarizes the demand estimates from this model. Qualitatively, the parameter estimates are similar to those from the full sequential model. Based on trimmed log marginal density, this model fits the data better than the sequential model outlined in Section 3.2. However, we find that on average, the accounting factor is almost 0. The standard deviation of the distribution of the accounting factor is also relatively small, indicating that in general, subjects do not account for the warranty price and repair costs in their decision to purchase the washer. This is consistent with the survey design and provides validity to the sequential choice model. Note that if information related to warranty price and repair costs are provided to the subjects upfront, then the results could be different. However, we stress that in actual buying conditions, retailers only stress on warranty price and repair costs once the consumer has decided to buy the product.

# 10 Discussion, Limitations and Future Research

This paper contributes to the growing stream of research on product insurance and inference using stated preference data. From the two surveys, we find overwhelming evidence that warranty purchases are explained by loss aversion substantially more than risk aversion (stemming from diminishing returns in utility) and non-linear probability weights. We find that on average, subjects have a linear value function and are almost twice as sensitive to losses as they are to gains but there exists substantial heterogeneity in risk preferences. These findings are robust to different specifications of the utility function, probability weighting function and reference point. A Bayesian model selection test based on the demand estimates rejects a model which does not account for loss aversion and reference dependent preferences.

Based on the profit maximization using the demand estimates, we find that not accounting for loss aversion, we under predict the washer and warranty prices and the rate at which warranty prices should adjust to changing repair costs. Both these lead to lower firm profits. This provides managerial implications on how firms should price products and warranties. Using data from the sequential survey, we find that risk preferences rationalize part of the premium consumers routinely pay when buying extended warranties. These results are not driven by the model choice or the parameter estimates; rather, they are driven more by the correlation between the parameter estimates which satisfy the single crossing property required for price discrimination. Finally, forcing different retailers to sell washers and warranties leads to an increase (decrease) in the washer (warranty) price, overall, making the subjects worse off.

We contribute to the literature by empirically analyzing the factors which drive warranty choices and explain the high premium paid for them. To do this, we design two conjoint surveys which allow us to non-parametrically separate risk aversion, loss aversion, product preferences and probability weights. We quantify the relative magnitude of different risk preferences in explaining warranty choice and their role in the high premium paid for warranties. Additionally, we study the change in consumer welfare from a policy intervention which doesn't allow retailers to sell both, products and warranties.

We see several directions for future research based on the findings herein. First, we deterministically provide the failure probability and repair costs to subjects. Thus, apriori, the subjects' beliefs about these are known to the researcher. In practice, warranty purchases are based on (and possibly driven by) the beliefs consumers have about product failure and repair costs. A possible extension would be to build on the current analysis by non-parametrically eliciting the consumers' beliefs about these and integrating over their distribution to study warranty choice. In this survey, we offer the subjects a single warranty which acts as a sorting device. In practice, consumers have access to a menu of warranties varying not only in duration but also in the intensity of coverage. Another interesting extension would be to study the price discrimination incentives by incorporating a menu of warranties and using the elicited distributions to optimize the insurance contracts a firm should offer. In contrast to the economics literature, in our application, we find a slightly S-shaped weighting function, on average. While we do our best to ensure that this is not driven by inconsistent choices; ex-ante, we do not know whether subjects exhibit an S shaped weighting function or if the shape is due to the deterministic beliefs we incorporate in our analysis. Eliciting subjects' beliefs will not only address this concern but will also allow us to dig deeper into why subjects are more sensitive to warranty prices as compared to the washer prices, as we found in the simultaneous survey.

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Table 1: Contribution margins in insurance

| **Context** | **Data Source** | **Insurance Price**[a] | **Actuarially Fair Price**[b] | **Contribution margin** |
|---|---|---|---|---|
| Regular vs. High Deductible and Premium choice | | | | |
| Home | Sydnor (2010) | $100 | $21 | 79% |
| Comprehensive Auto | Barseghyan, Molinari, O'Donoghue, and Teitelbaum (2010) | $23 | $10.50 | 54% |
| Home | Barseghyan, Molinari, O'Donoghue, and Teitelbaum (2010) | $74 | $44.50 | 40% |
| Auto | Cohen and Einav (2007) | NIS 399 | NIS 208 | 48% |
| Product Insurance | | | | |
| Extended Warranties | Mid-western retailer | $118[c] | $53[d] | 55% |

[a]For home and auto insurance, insurance price is calculated as the increase in premium required to reduce the deductible from the most frequently bought level to one lower level.

[b]Actuarially fair price for home and auto insurance is calculated based on the claims made by the consumers. Specifically, this is the ex-post probability of making a claim multiplied by the deductible amount.

[c]The insurance price for extended warranties is the average price of a 3 year warranty across 13 different product categories.

[d]The actuarially fair price for extended warranties is the average cost of making claims for all the claims across 13 different product categories as observed in the data.

Table 2: Simultaneous Survey - Logistic Regressions

| | **1** | **2** | **3** | **4** |
|---|---|---|---|---|
| GE | 6.103 | 8.646 | 8.346 | 8.382 |
| | (0.181) | (0.203) | (0.207) | (0.208) |
| GE + Warranty | 6.893 | 7.707 | 8.329 | 8.354 |
| | (0.214) | (0.23) | (0.251) | (0.251) |
| Whirlpool | 6.054 | 8.685 | 8.383 | 8.411 |
| | (0.179) | (0.203) | (0.207) | (0.208) |
| Whirlpool + Warranty | 6.967 | 7.742 | 8.363 | 8.397 |
| | (0.212) | (0.227) | (0.248) | (0.249) |
| Front loading | 0.15 | 0.167 | 0.183 | 0.183 |
| | (0.039) | (0.040) | (0.040) | (0.040) |
| Total price $(p + \omega)$ | -0.9 | -0.998 | | |
| | (0.028) | (0.030) | | |
| Product price $(p)$ | | | -0.937 | -0.939 |
| | | | (0.031) | (0.031) |
| Warranty price $(\omega)$ | | | -1.786 | -1.801 |
| | | | (0.133) | (0.134) |
| $c * \pi$ | | -2.112 | -2.164 | -1.834 |
| | | (0.048) | (0.049) | (0.278) |
| $c * \pi^2$ | | | | -1.942 |
| | | | | (0.840) |
| $c * \pi^3$ | | | | 1.664 |
| | | | | (0.603) |
| Log-Likelihood | -9334 | -8012 | -7993 | -7985 |
| AIC | 18680 | 16037 | 16002 | 15990 |
| No. of observations | 6317 | 6317 | 6317 | 6317 |
| Schwarz Criterion | 18720 | 16084 | 16056 | 16057 |

Table 3: Sequential Survey - Logistic Regressions

| | | **Stage 2** | |
|---|---|---|---|
| | **Stage 1** | 1 | 2 |
| GE | 5.273 | 2.842 | 2.874 |
| | (0.362) | (0.731) | (0.730) |
| GE + Warranty | | -0.265 | -0.285 |
| | | (0.412) | (0.413) |
| Whirlpool | 5.090 | 2.428 | 2.459 |
| | (0.356) | (0.705) | (0.704) |
| Whirlpool + Warranty | | -0.313 | -0.330 |
| | | (0.407) | (0.409) |
| Front loading | 0.226 | -0.337 | -0.329 |
| | (0.077) | (0.229) | (0.229) |
| Product price ($p$) | -0.758 | 0.104 | 0.111 |
| | (0.058) | (0.122) | (0.122) |
| Warranty price ($\omega$) | | -0.683 | -0.727 |
| | | (0.335) | (0.337) |
| $c * \pi$ | | -1.623 | -2.034 |
| | | (0.112) | (0.672) |
| $c * \pi^2$ | | | 0.334 |
| | | | (2.073) |
| $c * \pi^3$ | | | 0.099 |
| | | | (1.485) |
| Log-Likelihood | -1327 | -888 | -887 |
| AIC | 2662 | 1793 | 1794 |
| Schwarz Criterion | 2683 | 1833 | 1845 |
| No. of observations | 1374 | 1124 | 1124 |

Table 4: Simultaneous Survey - Model comparison based on trimmed log marginal densities

| **Model** | **Homogeneous** | **Heterogeneous** |
|---|---|---|
| Conjoint Linear | -9,117.61 | -5,802.31 |
| Full baseline | -8,069.51 | -4,211.51 |
| Full "Risk only" | -8,232.49 | -4,471.80 |
| Full "Loss only" | -8,089.83 | -4,335.71 |
| Expected Utility | -8,231.88 | -4,500.87 |

Table 5: Simultaneous Survey - "Full" baseline model

| | Homogeneous Tastes | | | Heterogeneous Tastes | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Pop. mean | | | Pop. SD | | |
| | 2.5% | 50% | 97.5% | 2.5% | 50% | 97.5% | 2.5% | 50% | 97.5% |
| $\alpha_{GE}$ | 6.30 | 6.79 | 7.39 | 21.77 | 24.81 | 28.06 | 11.50 | 13.65 | 16.20 |
| $\alpha_{GE,w}$ | 5.70 | 6.21 | 6.79 | 20.84 | 23.97 | 27.21 | 11.45 | 13.67 | 16.32 |
| $\alpha_{Wh}$ | 6.32 | 6.81 | 7.43 | 21.90 | 24.96 | 28.25 | 11.53 | 13.72 | 16.25 |
| $\alpha_{Wh,w}$ | 5.72 | 6.24 | 6.83 | 20.90 | 24.05 | 27.27 | 11.41 | 13.66 | 16.28 |
| Price($\beta$) | 0.69 | 0.76 | 0.84 | 2.27 | 2.64 | 3.00 | 1.15 | 1.40 | 1.66 |
| Front loading ($\kappa$) | 0.04 | 0.10 | 0.17 | 0.02 | 0.38 | 0.75 | 2.11 | 2.46 | 2.91 |
| Probability weight ($\mu$) | 1.08 | 1.18 | 1.29 | 1.18 | 1.33 | 1.51 | 0.57 | 0.72 | 0.91 |
| Curvature/risk ($\gamma$) | 1.11 | 1.17 | 1.23 | 0.98 | 1.05 | 1.13 | 0.34 | 0.40 | 0.47 |
| Loss aversion ($\lambda$) | 2.16 | 2.43 | 2.75 | 1.82 | 2.05 | 2.30 | 0.84 | 0.99 | 1.16 |
| Log marginal density | | -8073.77 | | | | -4259.09 | | | |
| Trimmed log m.d. | | -8069.51 | | | | -4211.51 | | | |

Table 6: Simultaneous Survey - "Risk only" model

| | Homogeneous Tastes | | | Heterogeneous Tastes | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Pop. mean | | | Pop. SD | | |
| | 2.5% | 50% | 97.5% | 2.5% | 50% | 97.5% | 2.5% | 50% | 97.5% |
| $\alpha_{GE}$ | 9.72 | 10.34 | 11.00 | 37.79 | 42.47 | 48.02 | 21.89 | 25.20 | 29.53 |
| $\alpha_{GE,w}$ | 9.89 | 10.51 | 11.16 | 38.21 | 42.91 | 48.37 | 22.49 | 25.96 | 30.40 |
| $\alpha_{Wh}$ | 9.69 | 10.32 | 10.98 | 37.88 | 42.60 | 48.17 | 21.99 | 25.32 | 29.61 |
| $\alpha_{Wh,w}$ | 9.91 | 10.53 | 11.19 | 38.23 | 42.92 | 48.39 | 22.46 | 25.95 | 30.37 |
| Price($\beta$) | 1.29 | 1.37 | 1.45 | 4.29 | 4.76 | 5.32 | 2.14 | 2.47 | 2.88 |
| Front loading ($\kappa$) | 0.10 | 0.18 | 0.27 | -0.08 | 0.53 | 1.14 | 3.54 | 4.14 | 4.84 |
| Probability weight ($\mu$) | 1.13 | 1.23 | 1.35 | 1.13 | 1.26 | 1.41 | 0.50 | 0.61 | 0.78 |
| Curvature/risk ($\gamma$) | 0.95 | 0.99 | 1.03 | 0.83 | 0.89 | 0.95 | 0.30 | 0.35 | 0.41 |
| Log marginal density | | -8234.42 | | | | -4504.73 | | | |
| Trimmed log m.d. | | -8232.49 | | | | -4471.80 | | | |

Table 7: Simultaneous Survey - "Loss only" model

| | Homogeneous Tastes | | | Heterogeneous Tastes | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Pop. mean | | | Pop. SD | | |
| | 2.5% | 50% | 97.5% | 2.5% | 50% | 97.5% | 2.5% | 50% | 97.5% |
| $\alpha_{GE}$ | 7.89 | 8.31 | 8.72 | 21.84 | 24.41 | 27.05 | 12.30 | 14.42 | 16.73 |
| $\alpha_{GE,w}$ | 7.16 | 7.62 | 8.11 | 20.77 | 23.34 | 26.05 | 11.70 | 13.80 | 16.19 |
| $\alpha_{Wh}$ | 7.94 | 8.34 | 8.76 | 21.99 | 24.57 | 27.25 | 12.39 | 14.50 | 16.81 |
| $\alpha_{Wh,w}$ | 7.20 | 7.66 | 8.14 | 20.82 | 23.39 | 26.07 | 11.72 | 13.82 | 16.18 |
| Price($\beta$) | 0.90 | 0.96 | 1.03 | 2.29 | 2.55 | 2.81 | 1.21 | 1.42 | 1.65 |
| Front loading ($\kappa$) | 0.08 | 0.15 | 0.22 | 0.08 | 0.42 | 0.77 | 2.13 | 2.43 | 2.77 |
| Probability weight ($\mu$) | 1.01 | 1.09 | 1.19 | 1.09 | 1.22 | 1.37 | 0.50 | 0.61 | 0.78 |
| Loss aversion ($\lambda$) | 1.80 | 1.95 | 2.12 | 1.79 | 1.98 | 2.20 | 0.82 | 0.96 | 1.13 |
| Log marginal density | | -8092.20 | | | | -4376.35 | | | |
| Trimmed log m.d. | | -8089.83 | | | | -4335.71 | | | |

Table 8: Simultaneous Survey - Expected Utility "EU" model

| | Homogeneous Tastes | | | Heterogeneous Tastes | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Pop. mean | | | Pop. SD | | |
| | 2.5% | 50% | 97.5% | 2.5% | 50% | 97.5% | 2.5% | 50% | 97.5% |
| $\alpha_{GE}$ | 8.53 | 9.07 | 9.65 | 17.12 | 19.48 | 21.45 | 8.96 | 10.74 | 12.41 |
| $\alpha_{GE,w}$ | 8.67 | 9.21 | 9.82 | 17.42 | 19.80 | 21.79 | 9.07 | 10.93 | 12.64 |
| $\alpha_{Wh}$ | 8.51 | 9.04 | 9.64 | 17.17 | 19.51 | 21.48 | 9.01 | 10.79 | 12.45 |
| $\alpha_{Wh,w}$ | 8.68 | 9.23 | 9.82 | 17.44 | 19.82 | 21.83 | 9.06 | 10.93 | 12.65 |
| Price($\beta$) | 1.12 | 1.19 | 1.28 | 1.97 | 2.23 | 2.46 | 1.02 | 1.20 | 1.39 |
| Front loading ($\kappa$) | 0.07 | 0.15 | 0.22 | -0.06 | 0.24 | 0.53 | 1.78 | 2.03 | 2.31 |
| Curvature/risk ($\gamma$) | 1.07 | 1.13 | 1.19 | 1.21 | 1.30 | 1.40 | 0.50 | 0.58 | 0.69 |
| Log marginal density | | -8234.85 | | | | -4548.80 | | | |
| Trimmed log m.d. | | -8231.88 | | | | -4500.87 | | | |

Table 9: Simultaneous Survey - Linear Conjoint Model

| | Homogeneous Tastes | | | Heterogeneous Tastes | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Pop. mean | | | Pop. SD | | |
| | 2.5% | 50% | 97.5% | 2.5% | 50% | 97.5% | 2.5% | 50% | 97.5% |
| $\alpha_{GE}$ | 7.06 | 7.50 | 7.96 | 24.21 | 27.16 | 30.28 | 14.76 | 17.20 | 20.06 |
| $\alpha_{GE,w}$ | 7.14 | 7.64 | 8.11 | 24.63 | 27.60 | 30.73 | 14.51 | 16.98 | 19.86 |
| $\alpha_{Wh}$ | 7.03 | 7.47 | 7.92 | 24.31 | 27.27 | 30.38 | 14.86 | 17.31 | 20.15 |
| $\alpha_{Wh,w}$ | 7.22 | 7.72 | 8.19 | 24.83 | 27.84 | 30.99 | 14.67 | 17.12 | 20.01 |
| Product Price($\beta_1$) | -1.06 | -1.00 | -0.94 | -3.03 | -2.71 | -2.42 | 1.47 | 1.73 | 2.02 |
| Warranty Price ($\beta_2$) | -0.31 | -0.09 | 0.15 | -0.58 | -0.24 | 0.09 | 0.79 | 1.01 | 1.27 |
| Repair Cost ($\beta_3$) | 0.10 | 0.17 | 0.23 | 0.18 | 0.30 | 0.42 | 0.54 | 0.64 | 0.74 |
| Failure probability ($\nu$) | -1.92 | -1.73 | -1.55 | -8.49 | -7.36 | -6.37 | 4.78 | 5.74 | 6.88 |
| Front loading ($\eta$) | 0.05 | 0.13 | 0.21 | -0.02 | 0.32 | 0.67 | 2.19 | 2.50 | 2.85 |
| Log marginal density | | -9119.82 | | | | -5851.08 | | | |
| Trimmed log m.d. | | -9117.61 | | | | -5802.31 | | | |

Table 10: Simultaneous Survey - Correlation Matrix for Population Distribution of Tastes ("Full" Model)

| | $\alpha_{GE}$ | $\alpha_{GE,w}$ | $\alpha_{Wh}$ | $\alpha_{Wh,w}$ | Price($\beta$) | Front loading ($\kappa$) | Probability weight ($\mu$) | Curvature/risk ($\gamma$) | Loss aversion ($\lambda$) |
|---|---|---|---|---|---|---|---|---|---|
| $\alpha_{GE}$ | 1 | | | | | | | | |
| $\alpha_{GE,w}$ | 0.98 (0.97,0.99) | 1 | | | | | | | |
| $\alpha_{Wh}$ | 1 (1,1) | 0.98 (0.97,0.99) | 1 | | | | | | |
| $\alpha_{Wh,w}$ | 0.98 (0.97,0.99) | 1 (1,1) | 0.98 (0.97,0.99) | 1 | | | | | |
| Price($\beta$) | 0.87 (0.82,0.92) | 0.89 (0.84,0.93) | 0.87 (0.82,0.92) | 0.89 (0.84,0.93) | 1 | | | | |
| Front loading ($\kappa$) | -0.08 (-0.25,0.08) | -0.07 (-0.23,0.09) | -0.09 (-0.25,0.08) | -0.08 (-0.24,0.09) | -0.01 (-0.17,0.15) | 1 | | | |
| Probability weight ($\mu$) | 0.01 (-0.22,0.24) | -0.01 (-0.24,0.21) | 0 (-0.23,0.23) | -0.01 (-0.23,0.21) | 0.03 (-0.19,0.25) | 0.05 (-0.17,0.27) | 1 | | |
| Curvature/risk ($\gamma$) | -0.01 (-0.18,0.15) | 0.01 (-0.15,0.18) | -0.01 (-0.17,0.15) | 0.01 (-0.15,0.18) | -0.03 (-0.19,0.13) | 0.07 (-0.08,0.22) | 0.06 (-0.1,0.22) | 1 | |
| Loss aversion ($\lambda$) | -0.06 (-0.26,0.15) | -0.14 (-0.34,0.06) | -0.06 (-0.26,0.15) | -0.14 (-0.33,0.06) | -0.29 (-0.47,-0.08) | -0.06 (-0.25,0.14) | -0.03 (-0.25,0.19) | 0.03 (-0.14,0.2) | 1 |

Table 11: Sequential Survey - "Full" baseline model

| | Homogeneous Tastes | | | Heterogeneous Tastes | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Pop. mean | | | Pop. SD | | |
| | 2.5% | 50% | 97.5% | 2.5% | 50% | 97.5% | 2.5% | 50% | 97.5% |
| $\alpha_{GE}$ | 2.80 | 3.41 | 4.34 | 9.95 | 12.42 | 15.56 | 5.76 | 7.25 | 9.19 |
| $\alpha_{GE,w}$ | 0.25 | 0.46 | 0.66 | 0.90 | 1.60 | 2.38 | 1.71 | 2.38 | 3.19 |
| $\alpha_{Wh}$ | 2.68 | 3.30 | 4.20 | 9.57 | 11.99 | 15.15 | 5.90 | 7.40 | 9.40 |
| $\alpha_{Wh,w}$ | 0.27 | 0.48 | 0.70 | 0.94 | 1.51 | 2.17 | 1.45 | 2.01 | 2.70 |
| Price($\beta$) | 0.29 | 0.38 | 0.52 | 1.21 | 1.57 | 1.99 | 0.66 | 0.85 | 1.13 |
| Front loading ($\kappa$) | 0.02 | 0.10 | 0.18 | -0.55 | 0.43 | 1.37 | 2.34 | 3.57 | 4.63 |
| Probability weight ($\mu$) | 1.50 | 2.12 | 3.08 | 1.37 | 2.12 | 3.64 | 1.24 | 2.40 | 6.33 |
| Curvature/risk ($\gamma$) | 1.15 | 1.47 | 1.86 | 1.02 | 1.27 | 1.68 | 0.72 | 1.04 | 1.69 |
| Loss aversion ($\lambda$) | 1.38 | 2.45 | 4.40 | 1.36 | 1.77 | 2.26 | 0.87 | 1.12 | 1.45 |
| Log marginal density | | -2336.03 | | | | -1191.98 | | | |
| Trimmed log m.d. | | -2333.70 | | | | -1166.27 | | | |

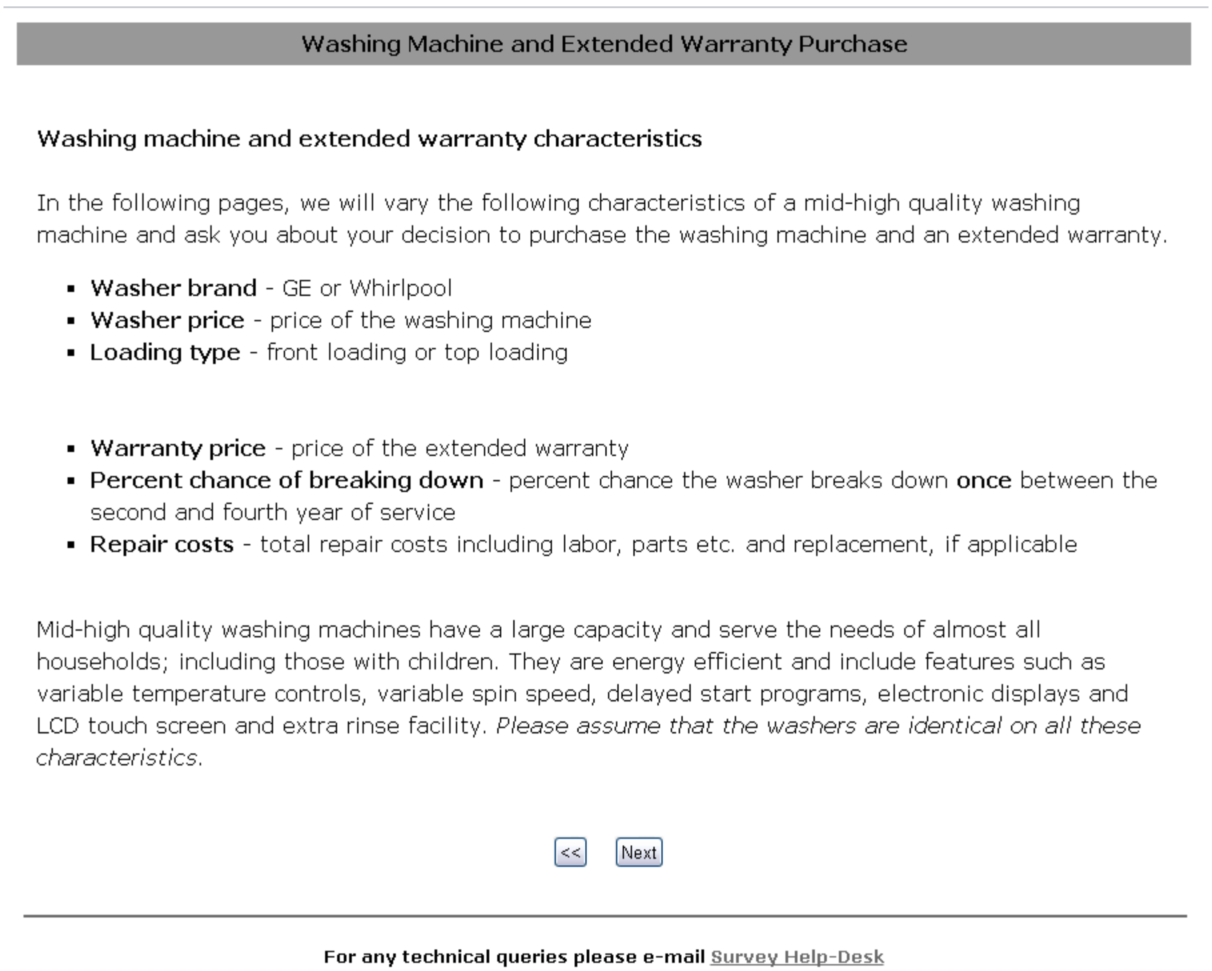
Table 12: Relative importance of risk and loss aversion in out of sample predictions

| **Hit Rate (% choices correctly predicted)** | **All choices** | **No warranty purchase** | **Warranty purchase** |
|---|---|---|---|
| **"Risk only" model** | | | |
| All preferences | 74% | 79% | 65% |
| Product and Price preferences only | 71% | 78% | 58% |
| **"Loss only" model** | | | |
| All preferences | 74% | 79% | 63% |
| Product and Price preferences only | 62% | 80% | 30% |
| **Full baseline model** | | | |
| All preferences | 73% | 78% | 64% |
| Product and Price preferences only | 61% | 78% | 31% |
| ***Additional preferences*** | | | |
| Risk aversion only | 62% | 77% | 35% |
| Loss aversion only | 70% | 74% | 62% |
| Probability weights only | 61% | 78% | 30% |
| Loss aversion and Probability weights | 70% | 75% | 60% |

Table 13: Test for price discrimination incentives (single crossing property)

| | **Simultaneous Survey** | | | **Sequential Survey** | | |
|---|---|---|---|---|---|---|
| | **2.5%** | **50%** | **97.5%** | **2.5%** | **50%** | **97.5%** |
| Marginal demand ($z^*$)[a] | 30% | 34% | 38% | 28% | 37% | 48% |
| Average demand ($\bar{z}$) | 32% | 34% | 36% | 47% | 51% | 55% |
| Difference ($\bar{z} - z^*$) | -3% | 0% | 3% | 2% | 13% | 22% |

[a] Assumes washer price of $599, warranty price of $99, repair costs of $249 and failure probability of 25%. These numbers are consistent with the average failure rate and prices as per Consumer Reports, and observed in practice.



**Washing Machine and Extended Warranty Purchase**

**Washing machine and extended warranty characteristics**

In the following pages, we will vary the following characteristics of a mid-high quality washing machine and ask you about your decision to purchase the washing machine and an extended warranty.

- **Washer brand** - GE or Whirlpool
- **Washer price** - price of the washing machine
- **Loading type** - front loading or top loading

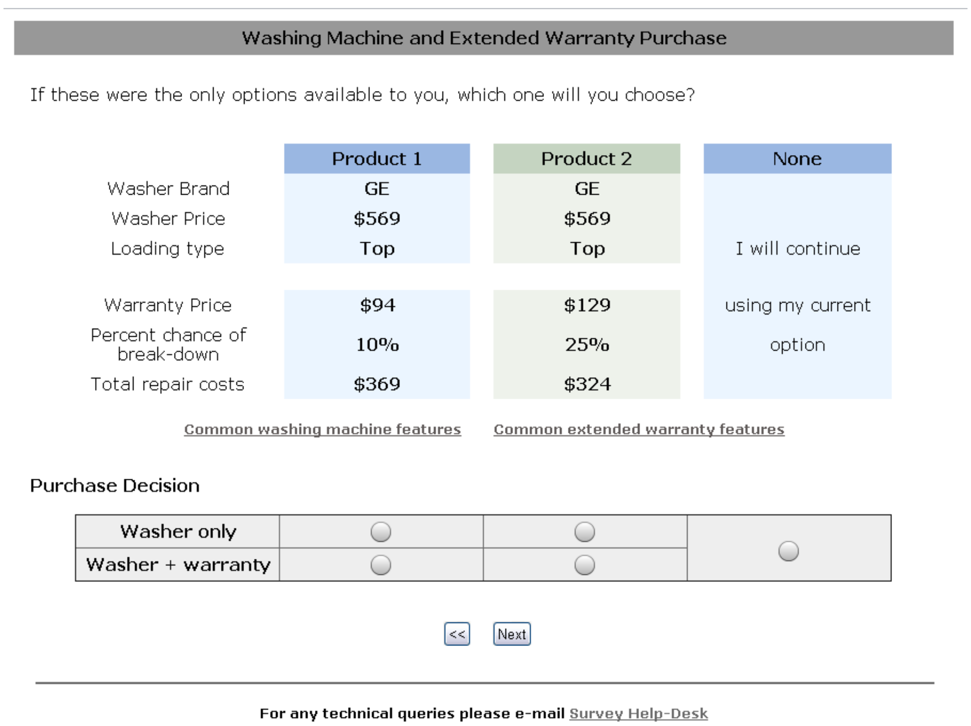
- **Warranty price** - price of the extended warranty
- **Percent chance of breaking down** - percent chance the washer breaks down **once** between the second and fourth year of service
- **Repair costs** - total repair costs including labor, parts etc. and replacement, if applicable

Mid-high quality washing machines have a large capacity and serve the needs of almost all households; including those with children. They are energy efficient and include features such as variable temperature controls, variable spin speed, delayed start programs, electronic displays and LCD touch screen and extra rinse facility. *Please assume that the washers are identical on all these characteristics.*

<< Next

**For any technical queries please e-mail** Survey Help-Desk

Figure 1: Survey Snapshot - Washer and Warranties characteristics presented



Washing Machine and Extended Warranty Purchase

If these were the only options available to you, which one will you choose?

| | Product 1 | Product 2 | None |
|---|---|---|---|
| Washer Brand | GE | GE | |
| Washer Price | $569 | $569 | |
| Loading type | Top | Top | I will continue |
| Warranty Price | $94 | $129 | using my current |
| Percent chance of break-down | 10% | 25% | option |
| Total repair costs | $369 | $324 | |

Common washing machine features Common extended warranty features

Purchase Decision

| | | | |
|---|---|---|---|
| Washer only | ○ | ○ | ○ |
| Washer + warranty | ○ | ○ | |

<< Next

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Figure 2: Simultaneous Survey - Sample choice task

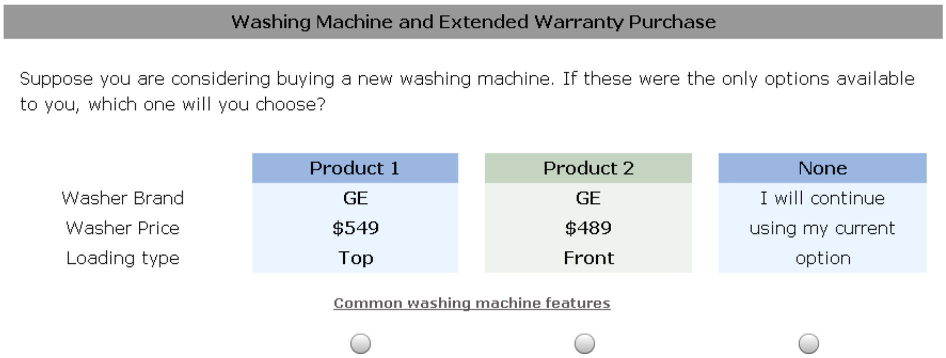



Figure 3: Sequential Survey - Stage 1 choice task

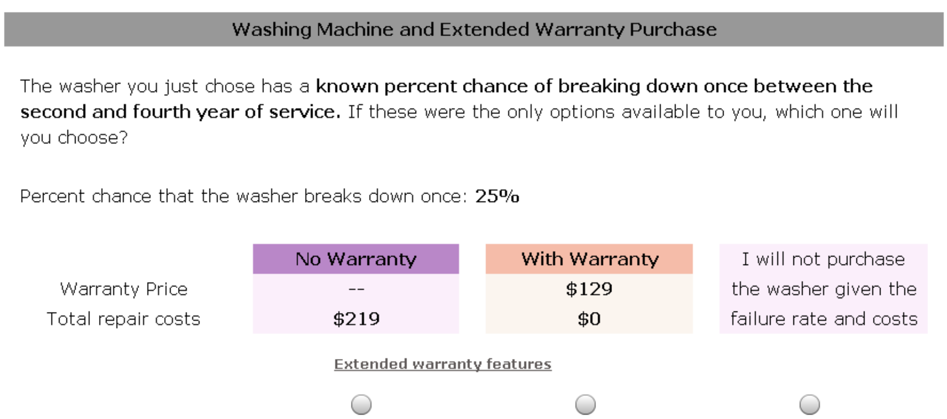



Figure 4: Sequential Survey - Stage 2 choice task

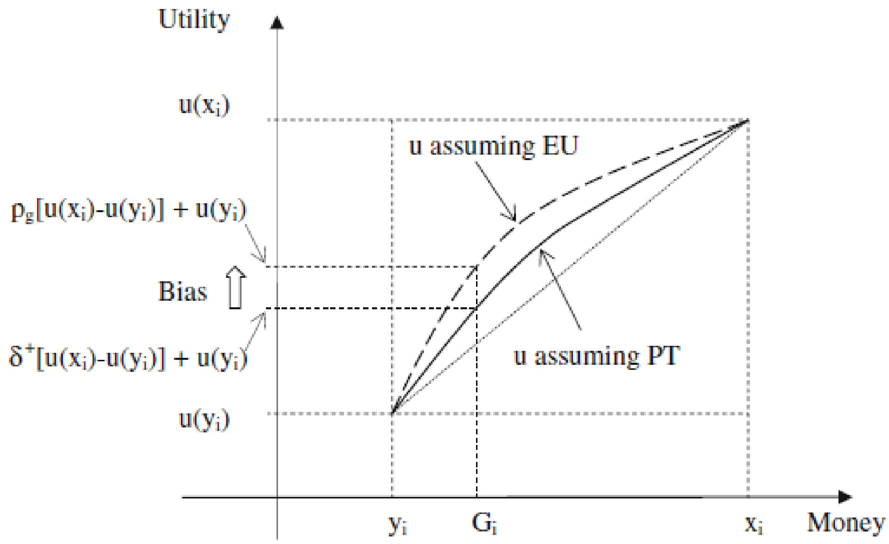



Figure 5: Probability Weights and Utility Function

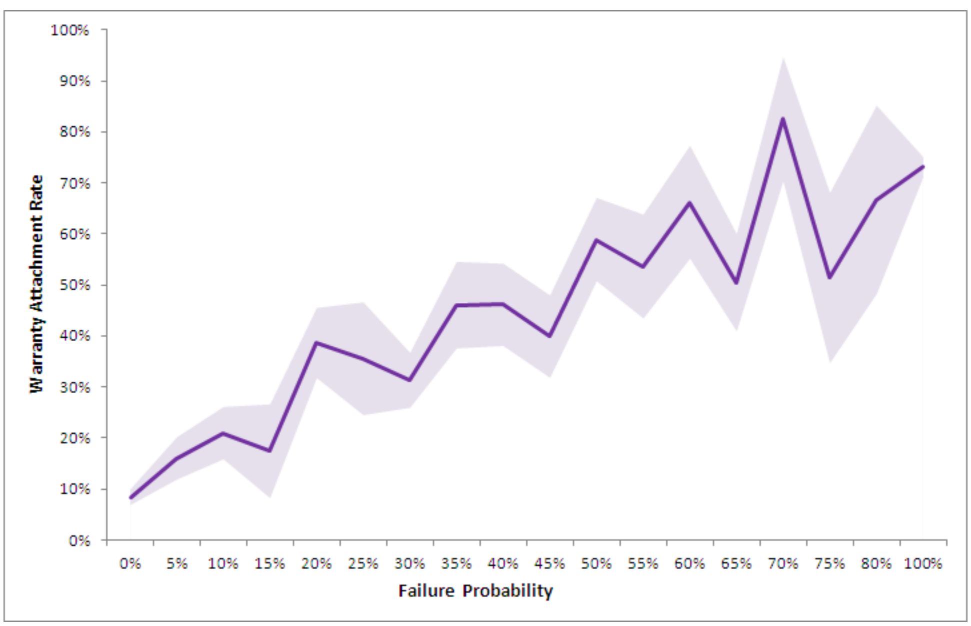



Figure 6: Warranty attachment rate by failure probability

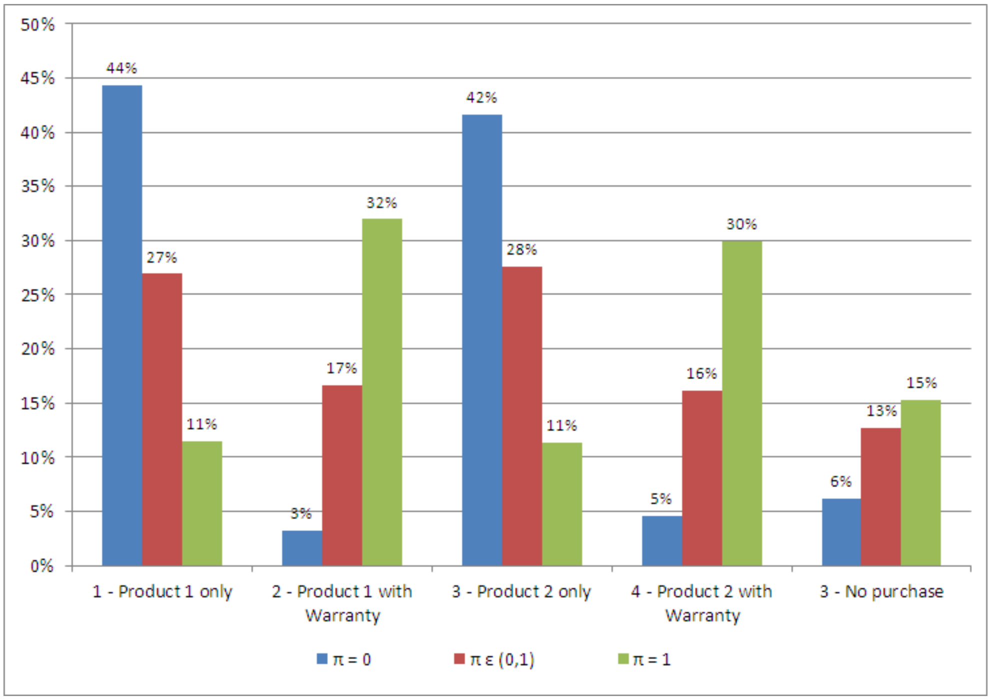



Figure 7: Distribution of choices by probability type

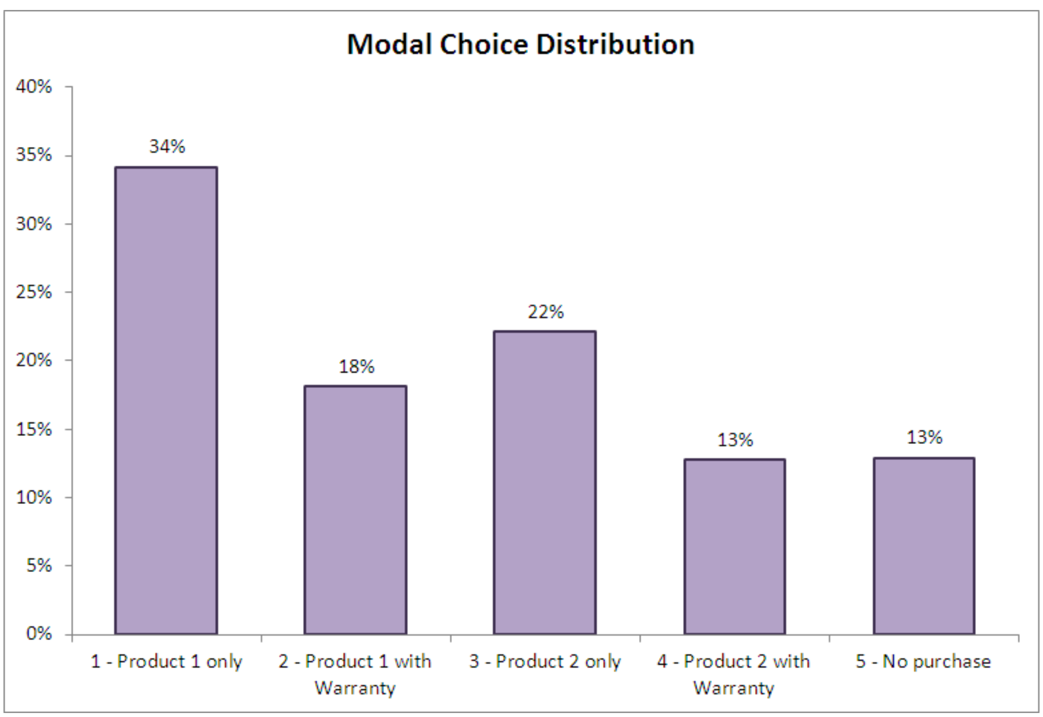



Figure 8: Distribution of modal choice across subjects and blocks

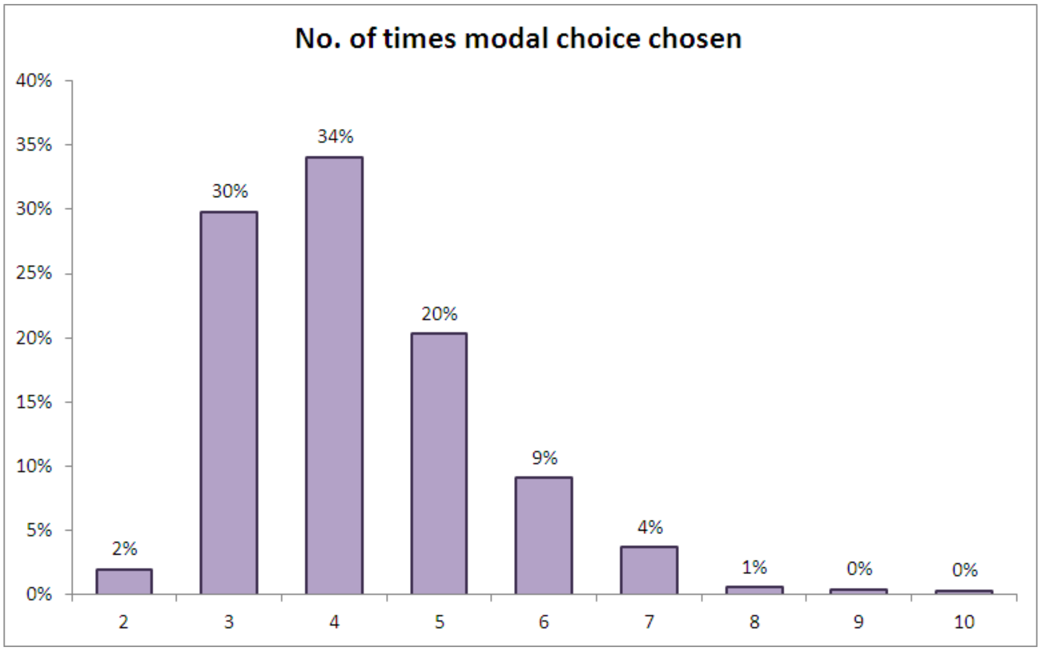



Figure 9: Distribution of number of times modal choice chosen

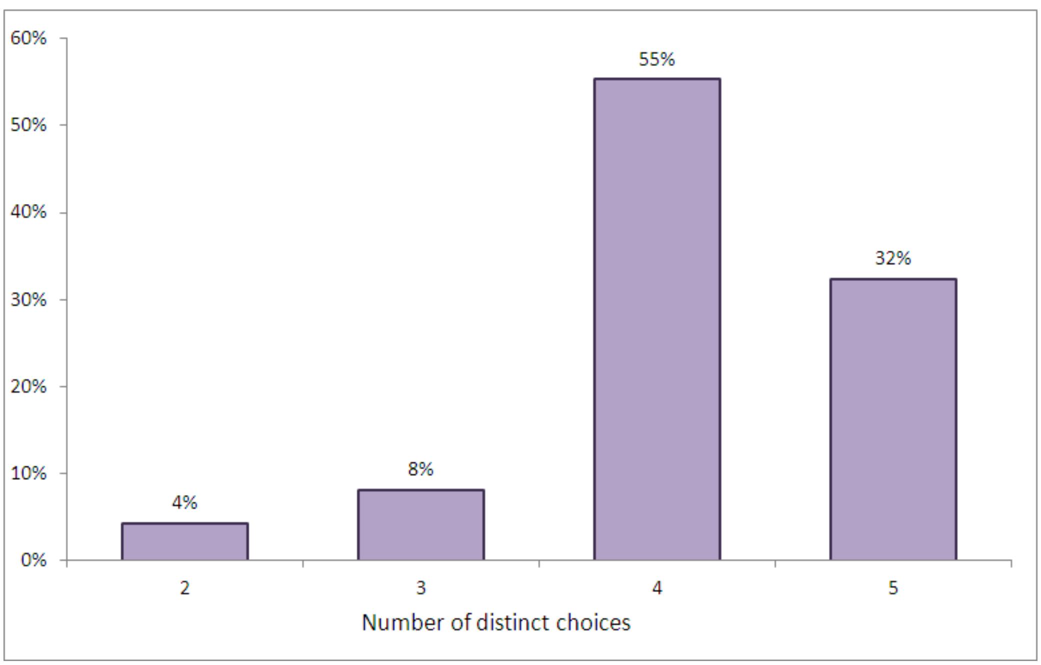



Figure 10: Distribution of number of distinct choices across subjects

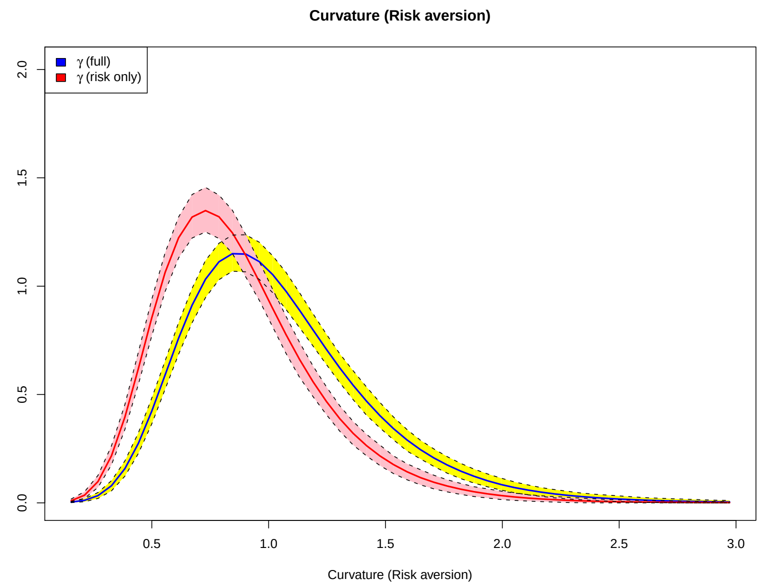



Figure 11: Distribution of utility function curvature under “Full” and “Risk only” models

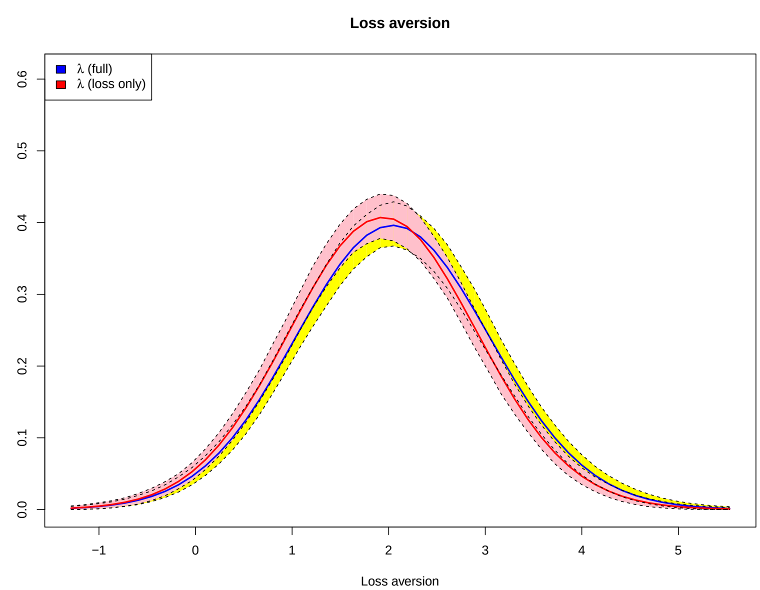



Figure 12: Distribution of loss aversion under “Full” and “Loss only” models

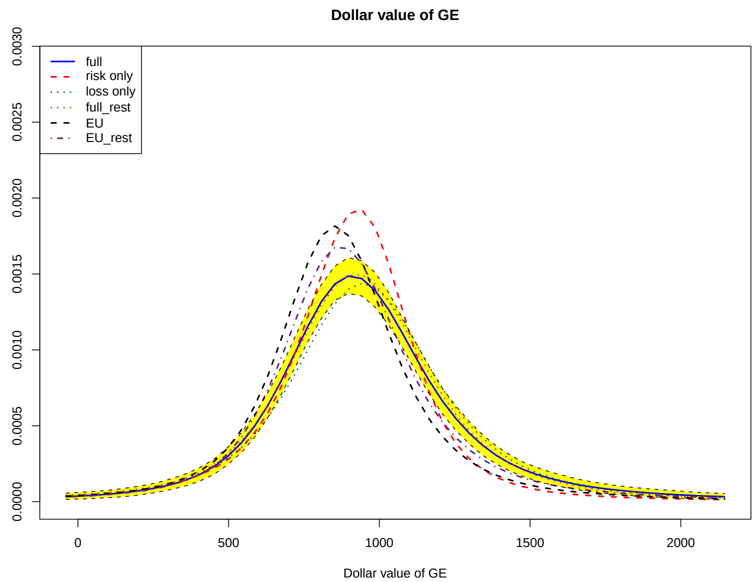



Figure 13: Distribution of willingness to pay for GE ($) under alternate model specifications

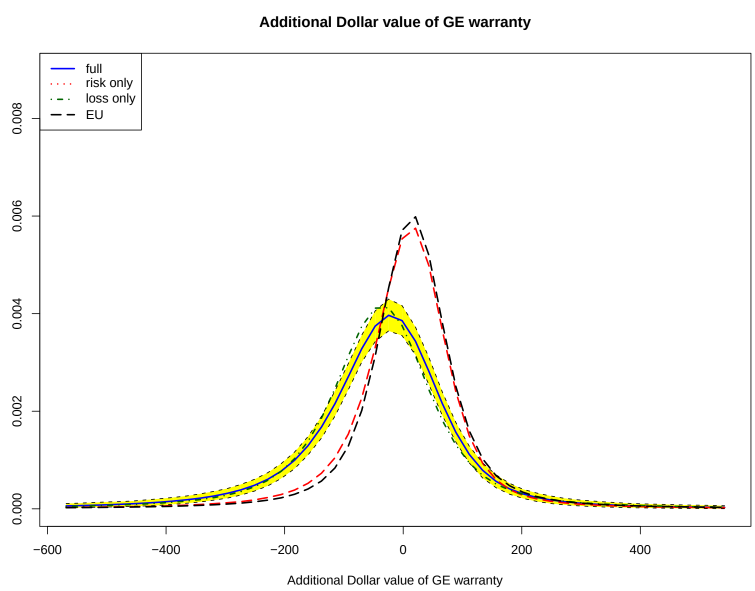



Figure 14: Distribution of willingness to pay for warranty with GE ($) under alternate model specifications

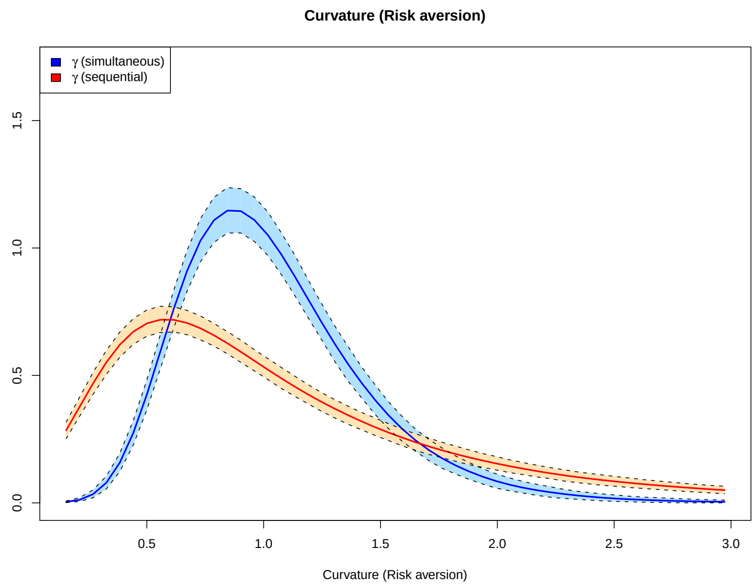



Figure 15: Distribution of value function curvature under simultaneous and sequential survey

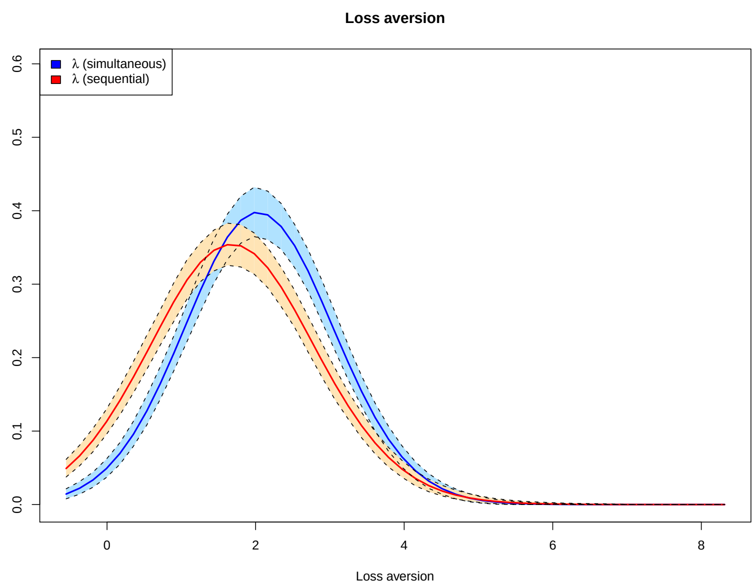



Figure 16: Distribution of loss aversion under simultaneous and sequential survey

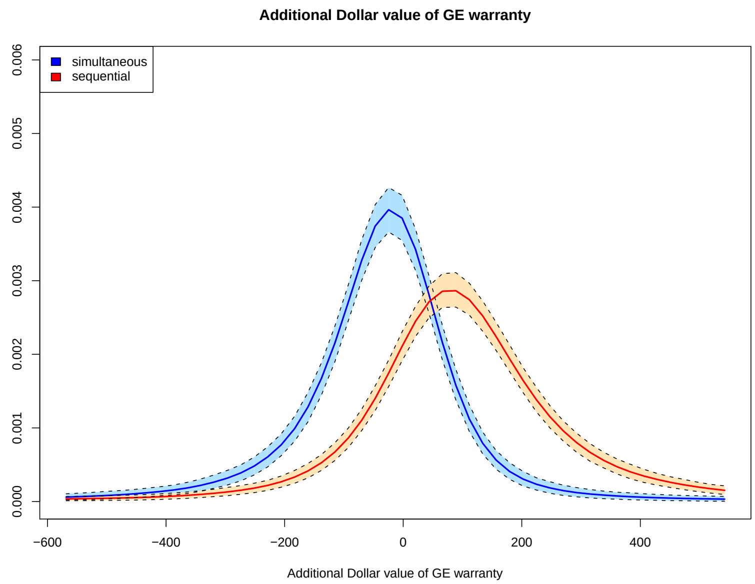



Figure 17: Distribution of willingness to pay for warranty with GE ($) from simultaneous and sequential survey

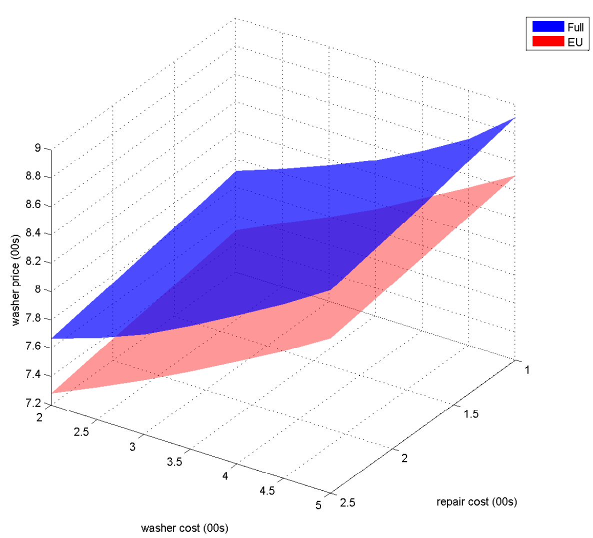



Figure 18: Optimal washer prices (GE) for different washer costs and repair costs

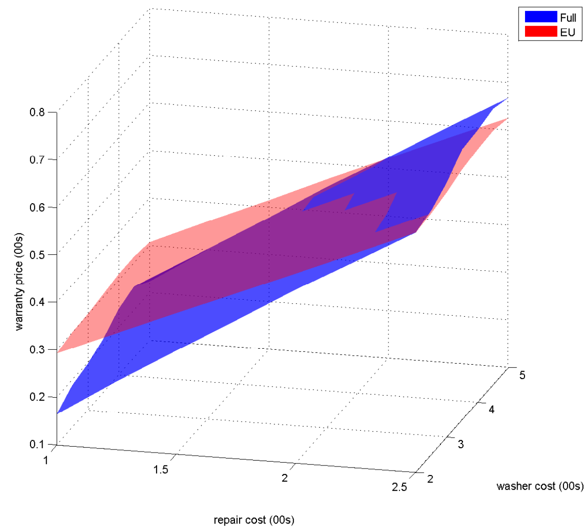



Figure 19: Optimal warranty prices (for GE) for different washer costs and repair costs

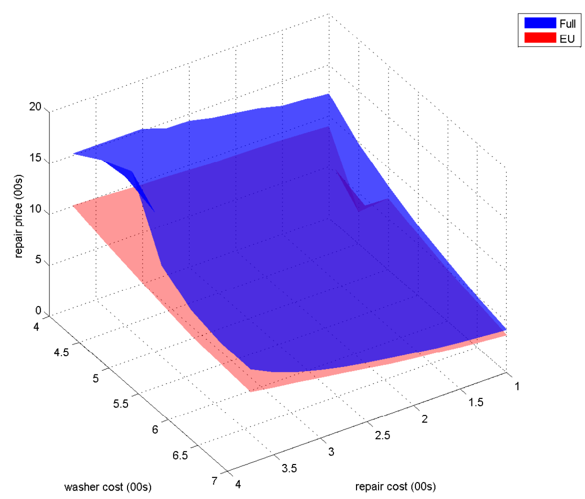



Figure 20: Optimal repair prices (to consumers) for different washer costs and repair costs

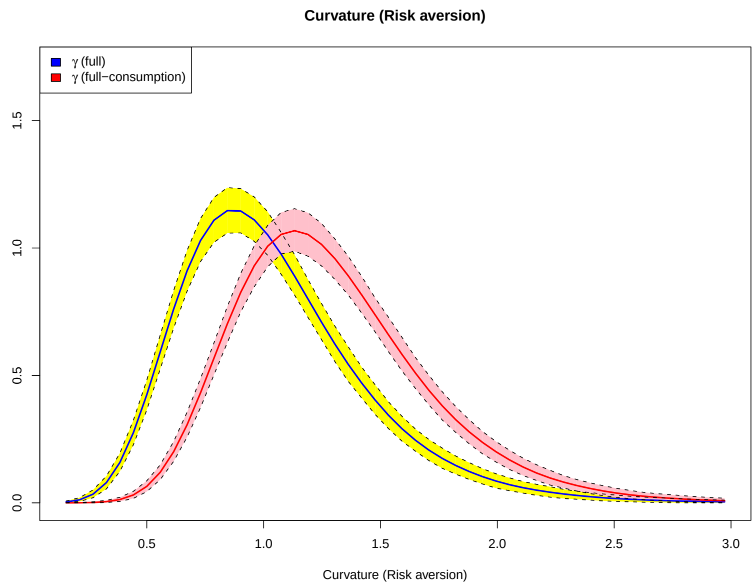



Figure 21: Distribution of utility function curvature under alternate utility function specifications

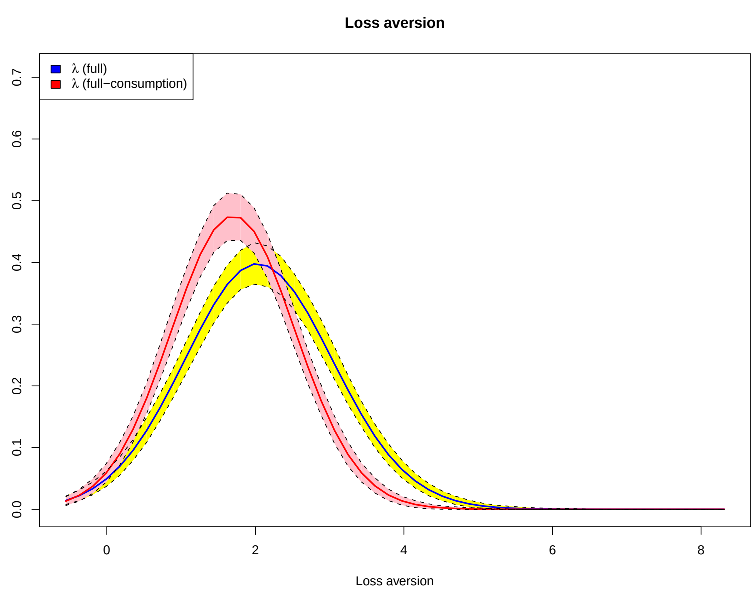



Figure 22: Distribution of loss aversion under alternate utility function specifications

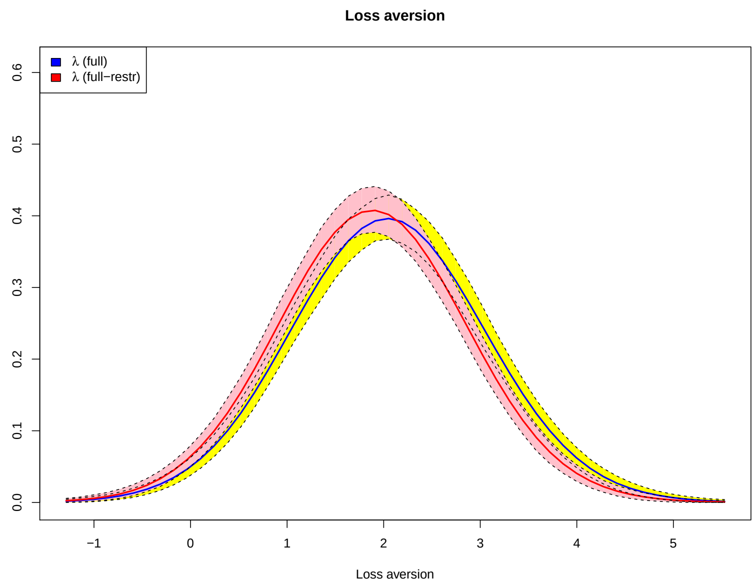



Figure 23: Distribution of loss aversion under “Full” and restricted models

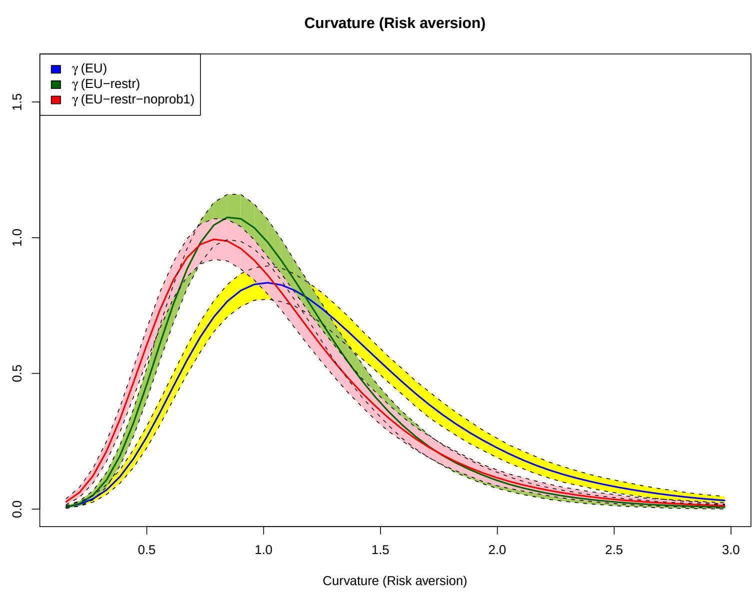



Figure 24: Distribution of utility function curvature under alternate “EU” models

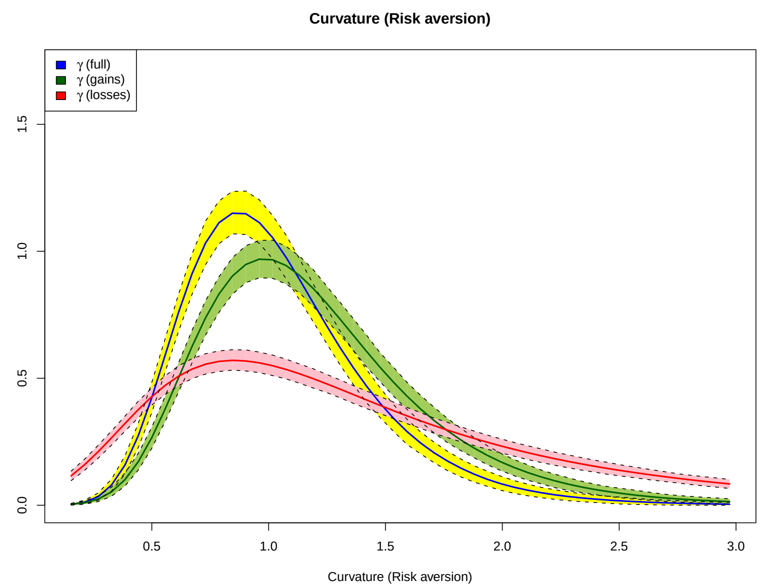



Figure 25: Distribution of utility function curvature under "Full" model and model with unrestricted curvature

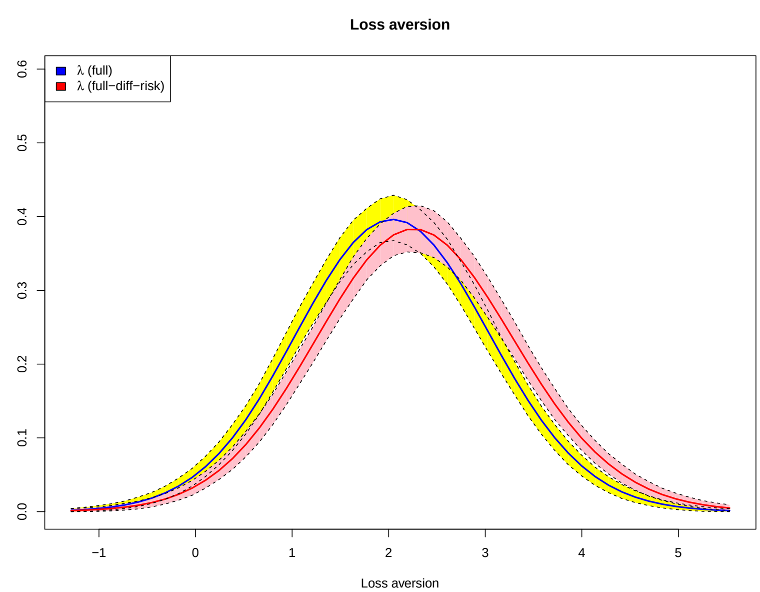



Figure 26: Distribution of loss aversion under "Full" model and model with unrestricted curvature

# Appendix

## A Calibration of Risk Aversion

We use sales data for 13 different product categories of home appliances from a large retailer in the mid-west. We have data on product and warranty sales and prices at the individual level, and product repair costs at an aggregate level (across categories). The average price of a standard 4 year warranty across all product categories is $118 while the average costs of repair are $125. The retailer also services products not sold by him. Thus, while we cannot find the actual failure rate, we calculate the number of products repaired as a percentage of those sold and get 77%. This number is abnormally high but even with such high failure rate, warranties are actuarially unfair. The maximum average failure rate (across different categories) from the Consumer Reports is around 40% over the first 3-4 years of service[34]. Using this failure rate, and the warranty price and repair costs calculated above, we find that the retailer has a contribution margin of around 55% from the sales of warranties as compared to an average contribution margin of 15%-20% from product sales.

The data we have access to includes a small number of purchases for many different models within each product category. Thus, given the lack of price variation, any attempt at doing a calibration exercise which incorporates product and price preferences with this data seems futile. Instead, we use just the aggregate warranty prices, repair costs and failure probabilities from the data to calibrate the degree of risk aversion required to explain the warranty attachment rate commonly observed for such products[35]. Let's suppose that the consumer has already purchased the product and is deciding between buying a warranty or not. Further, let the warranty price be $\omega$, repair costs be $c$ and the failure probability be given by $\pi$. Assuming a constant relative risk aversion utility specification mirrored around the origin, the utility the consumer gets can be written out as

$$u = \begin{cases} -(\omega)^\gamma + \epsilon_w & ; \quad \mathbb{I}(warranty) = 1 \\ -\pi(c)^\gamma + \epsilon_{nw} & ; \quad \mathbb{I}(warranty) = 0 \end{cases}$$

Assuming that the random taste shocks ($\epsilon$) are type 1 extreme value distributed, the probability a consumer purchases warranty is given by

$$\Pr(\mathbb{I}(warranty) = 1) = \frac{\exp\left(-(\omega)^\gamma\right)}{\exp\left(-(\omega)^\gamma\right) + \exp\left(-\pi(c)^\gamma\right)}$$

In our data, we observe an average attachment warranty rate of around 10%. Table 14 summarizes the different values of $\gamma$ required (for different failure probabilities) to justify the observed warranty attachment rate given the observed warranty price and repair costs. We calculate the risk aversion coefficient for an

[34]http://www.warrantyweek.com/archive/ww20061121.html

[35]Attachment rate is defined as the percentage of product purchases which are also accompanied with a warranty purchase.

attachment rate of 10% (as observed in our data), and also for an attachment rate of 2% as claimed in the media for some products. The top panel reports the coefficients for the average warranty price and repair cost as found in our data. For an average washing machine failure rate of 20% (as per the Consumer Reports), $\gamma = 0.21$ justifies an attachment rate of 10%. Even for an abysmally high failure rate of 77% and an attachment rate of only 2%, consumers need to exhibit risk aversion such that $\gamma = 0.62$. Several researchers, including Tversky and Kahneman (1992) estimate the curvature ($\gamma$) to be 0.88 when analyzing utility over money. Thus, both these estimates of $\gamma$ imply an extremely concave utility function and hence, implausible degree of risk aversion.

To get a better sense of the magnitude of risk aversion, we additionally provide the risk aversion coefficients assuming that consumers have a constant absolute risk aversion (CARA) utility function mirrored around the origin. To interpret these coefficients, we report the dollar value ($x$) such that the consumer is indifferent between accepting and rejecting a gamble in which she has an equal chance of winning \$100 and losing \$$x$. As can be seen, for any given failure probability, implausible degrees of risk aversion are required to justify commonly observed warranty attachment rates.

The bottom panel reports the risk aversion coefficients for more plausible warranty prices and repair costs. We use a warranty price of \$89 (15% of a washer priced at \$600) and a repair cost of \$250 (slightly above 40% of the washer price). Using failure probabilities from Consumer Reports, we again find that improbable degree of risk aversion is required to justify warranty purchases.

Table 14: Risk Aversion Calibration

| **Failure Probability**[a] | **Attachment Rate**[b] | $\gamma$ **(CRRA)** | $\gamma$ **(CARA)** | **Dollar Value ($x$)** |
|---|---|---|---|---|
| | **Warranty Price = \$118, Repair costs = \$125**[c] | | | |
| 11% | 2% | 0.31 | 0.23 | 3.01 |
| 11% | 10% | 0.19 | 0.41 | 1.69 |
| 20% | 2% | 0.33 | 0.21 | 3.30 |
| 20% | 10% | 0.21 | 0.36 | 1.93 |
| 40% | 2% | 0.40 | 0.15 | 4.62 |
| 40% | 10% | 0.28 | 0.28 | 2.48 |
| 77% | 2% | 0.62 | 0.06 | 11.53 |
| 77% | 10% | 0.49 | 0.11 | 6.30 |
| | **Warranty Price = \$89, Repair costs = \$250**[d] | | | |
| 20% | 2% | 0.38 | 0.21 | 3.30 |
| 20% | 10% | 0.24 | 0.37 | 1.87 |

[a] Failure probability numbers are the commonly observed failure probabilities from Consumer Reports for the big ticket categories

[b] Attachment rate is defined as the percentage of product purchases associated with a warranty purchase.

[c] Average warranty price and repair costs across all product categories as observed in the data

[d] Warranty price and repair costs calculated for a washing machine priced at \$600 using average warranty price and repair cost numbers from Consumer Reports.

In this exercise, we implicitly normalize the variance of the error shocks to $\pi^2/6$. It is well known that in discrete choice modeling, the model parameters are only identified up to the scale of the error term.

While this does not pose a substantial concern in linear utility models, in our case, increasing the variance of the error term reduces the degree of risk aversion (curvature) required to explain warranty choice. For any plausible increase in the variance of the error shocks, we still find that extreme degree of risk aversion is required to justify warranty purchases[36]. This exercise provides evidence that consumers need to be extremely risk averse to justify warranty purchase, but the exercise is based on several assumptions about warranty prices, repair costs and failure probabilities. Further, it does not account for product and price preferences, and heterogeneity in risk preferences. Lack of research on home appliances and the absence of demand data is a limitation in conducting calibration exercises of this nature. To summarize, we show that a moderate degree of risk aversion (concave utility function) does not justify the premia paid for extended warranties and this warrants a better understanding of what drives consumers to pay high premia for product insurance.

[36]To get plausible degree of risk aversion given the warranty prices, repair costs, attachment rate and failure probabilities, we had to increase the variance of the error term to roughly $150\pi^2 - 200\pi^2$.

# B Survey Snapshots and Summary

**Washing machine features common to both products:**

- Large washer capacity (4.5 - 5.0 cu. ft.)
- Energy star rating with automatic temperature control
- LED display with variable spin wash cycle options such as hand wash, delicate, delayed start etc.
- Stainless steel drum with powder coated exterior available in multiple colors
- Expected life of 10 years

**Extended warranty features common to both products:**

- Single standard 3 year warranty serviced by the retailer
- The warranty is valid starting end of the first year up to 4 years from the date of purchase (first year is covered by the base warranty)
- Next day on-site repair
- Covers all repair and replacement costs such as parts, labor etc. if the washing machine fails i.e. consumer doesn't pay anything additional
- Guarantees performance at par with pre-failure state

Figure 27: Washer and warranty characteristics common to both products

**Washing Machine and Extended Warranty Purchase**

Still suppose that you are considering buying a new washing machine. The washers available are known to **break down once with certainty between the second and fourth year of service.** If these were the only options available to you, which one will you choose?

| | Product 1 | Product 2 | None |
|---|---|---|---|
| Washer Brand | **Whirlpool** | GE | |
| Washer Price | $499 | $669 | |
| Loading type | **Top** | Front | I will continue |
| Warranty Price | $139 | $149 | using my current |
| Percent chance of break-down | 100% | 100% | option |
| Total repair costs | $179 | $154 | |

Common washing machine features    Common extended warranty features

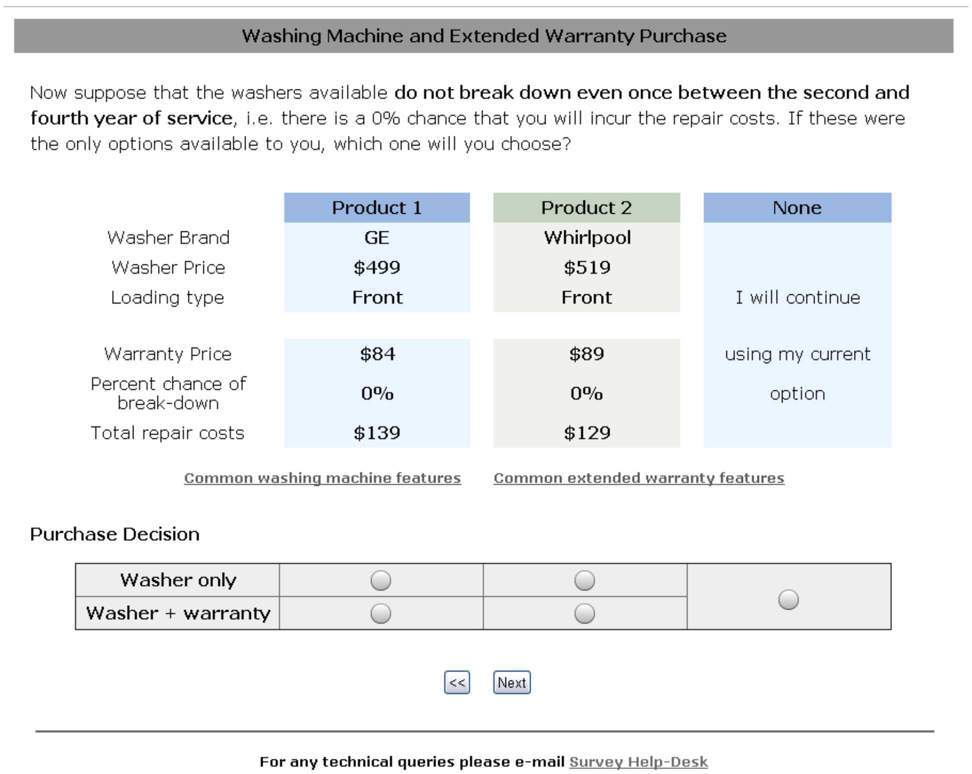
Purchase Decision

| | | | |
|---|---|---|---|
| Washer only | ○ | ○ | ○ |
| Washer + warranty | ○ | ○ | |

<< Next

For any technical queries please e-mail Survey Help-Desk

Figure 28: Simultaneous survey - sample choice task with $\pi = 1$



Washing Machine and Extended Warranty Purchase

Now suppose that the washers available **do not break down even once between the second and fourth year of service**, i.e. there is a 0% chance that you will incur the repair costs. If these were the only options available to you, which one will you choose?

| | Product 1 | Product 2 | None |
|---|---|---|---|
| Washer Brand | GE | Whirlpool | |
| Washer Price | $499 | $519 | |
| Loading type | Front | Front | I will continue |
| Warranty Price | $84 | $89 | using my current |
| Percent chance of break-down | 0% | 0% | option |
| Total repair costs | $139 | $129 | |

Common washing machine features    Common extended warranty features

Purchase Decision

| | | | |
|---|---|---|---|
| Washer only | ○ | ○ | ○ |
| Washer + warranty | ○ | ○ | |

<< Next

**For any technical queries please e-mail** Survey Help-Desk

Figure 29: Simultaneous survey - sample choice task with $\pi = 0$

Table 15: Survey Summary - familiarity and purchase behavior for washers and warranties

| Warranty familiarity | Simultaneous Survey | | Sequential Survey | |
|---|---|---|---|---|
| | **N** | **Percent** | **N** | **Percent** |
| Not at all familiar (1) | 9 | 4% | 10 | 13% |
| Somewhat familiar (2) | 61 | 26% | 24 | 31% |
| Familiar (3) | 96 | 41% | 11 | 27% |
| Very familiar (4) | 60 | 26% | 16 | 21% |
| Extremely familiar (5) | 9 | 4% | 6 | 8% |
| **Warranty purchase** | **N** | **Percent** | **N** | **Percent** |
| Yes, home appliances only | 18 | 8% | 2 | 3% |
| Yes, electronics only | 80 | 34% | 27 | 35% |
| Yes, for both home appliances and electronics | 31 | 13% | 24 | 31% |
| Never | 106 | 45% | 24 | 31% |
| **Washer purchase** | **N** | **Percent** | **N** | **Percent** |
| Yes, I have purchased a new washing machine before | 85 | 36% | 24 | 36% |
| Yes, I have considered but never purchased a new washing machine before | 34 | 14% | 16 | 24% |
| No, I have never purchased a new washing machine | 116 | 49% | 27 | 40% |
| **Washing machine usage** | **N** | **Percent** | **N** | **Percent** |
| Once a week or more | 184 | 78% | 60 | 78% |
| Once in 2 weeks | 37 | 16% | 12 | 16% |
| Once in 3 weeks | 12 | 5% | 3 | 4% |
| Once a month or less | 2 | 1% | 2 | 3% |
| **Questions clear?** | **N** | **Percent** | **N** | **Percent** |
| Yes | 221 | 94% | 76 | 99% |
| No (please elaborate) | 14 | 6% | 1 | 1% |
| **Prices and costs realistic?** | **N** | **Percent** | **N** | **Percent** |
| Yes, the prices and repair costs were realistic | 190 | 81% | 61 | 79% |
| The washer and warranty prices were realistic but repair costs were not believable | 32 | 14% | 12 | 16% |
| No, the prices and repair costs were not realistic | 13 | 6% | 4 | 5% |

# C Robustness Check Tables

## C.1 Intrinsic preference for warranties

The tables below corresponds to the robustness check around preference for warranty conducted in Section 9.1. In the tables, we report results for both homogeneous and heterogeneous (normally distributed random coefficients) specifications. In each case, we report quantiles (corresponding to the 95% confidence interval) of the posterior distribution of the population hyper parameters to assess the parameter magnitudes and precisions.

Table 16: "Full" model with preference for warranty only for non-zero failure probability

| | Homogeneous Tastes | | | Heterogeneous Tastes | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Pop. mean | | | Pop. SD | | |
| | 2.5% | 50% | 97.5% | 2.5% | 50% | 97.5% | 2.5% | 50% | 97.5% |
| $\alpha_{GE}$ | 7.05 | 7.66 | 8.26 | 20.32 | 23.55 | 26.23 | 9.61 | 12.24 | 14.20 |
| $\alpha_{GE,w}$ | 6.98 | 7.62 | 8.24 | 20.09 | 23.27 | 25.99 | 9.71 | 12.23 | 14.23 |
| $\alpha_{Wh}$ | 7.03 | 7.66 | 8.27 | 20.41 | 23.66 | 26.35 | 9.63 | 12.27 | 14.28 |
| $\alpha_{Wh,w}$ | 6.98 | 7.63 | 8.27 | 20.16 | 23.31 | 26.03 | 9.70 | 12.19 | 14.20 |
| Price($\beta$) | 0.86 | 0.96 | 1.04 | 2.18 | 2.52 | 2.80 | 0.95 | 1.19 | 1.42 |
| Front loading ($\kappa$) | 0.05 | 0.12 | 0.19 | -0.05 | 0.30 | 0.67 | 2.03 | 2.46 | 2.85 |
| Probability weight ($\mu$) | 1.24 | 1.36 | 1.49 | 1.31 | 1.47 | 1.68 | 0.65 | 0.82 | 1.06 |
| Curvature/risk ($\gamma$) | 1.12 | 1.17 | 1.25 | 1.02 | 1.09 | 1.17 | 0.37 | 0.43 | 0.52 |
| Loss aversion ($\lambda$) | 1.45 | 1.61 | 1.83 | 1.62 | 1.83 | 2.06 | 0.79 | 0.93 | 1.10 |
| Log marginal density | | -8133.52 | | | | -4327.40 | | | |
| Trimmed log m.d. | | -8130.59 | | | | -4283.43 | | | |

Table 17: "EU" model with preference for warranty only for non-zero failure probability

| | Homogeneous Tastes | | | Heterogeneous Tastes | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Pop. mean | | | Pop. SD | | |
| | 2.5% | 50% | 97.5% | 2.5% | 50% | 97.5% | 2.5% | 50% | 97.5% |
| $\alpha_{GE}$ | 8.32 | 8.89 | 9.49 | 17.08 | 18.99 | 21.07 | 8.81 | 10.25 | 11.78 |
| $\alpha_{GE,w}$ | 8.62 | 9.19 | 9.80 | 17.52 | 19.46 | 21.57 | 8.83 | 10.34 | 11.91 |
| $\alpha_{Wh}$ | 8.30 | 8.87 | 9.46 | 17.13 | 19.04 | 21.14 | 8.83 | 10.26 | 11.81 |
| $\alpha_{Wh,w}$ | 8.61 | 9.20 | 9.80 | 17.55 | 19.47 | 21.58 | 8.82 | 10.33 | 11.90 |
| Price($\beta$) | 1.10 | 1.18 | 1.26 | 1.95 | 2.17 | 2.41 | 0.98 | 1.13 | 1.30 |
| Front loading ($\kappa$) | 0.07 | 0.14 | 0.21 | -0.05 | 0.24 | 0.54 | 1.77 | 2.05 | 2.36 |
| Curvature/risk ($\gamma$) | 1.08 | 1.14 | 1.20 | 1.17 | 1.27 | 1.37 | 0.47 | 0.55 | 0.66 |
| Log marginal density | | -8192.98 | | | | -4558.07 | | | |
| Trimmed log m.d. | | -8189.95 | | | | -4503.63 | | | |

## C.2 Probability Weighting Function

The table below corresponds to the robustness check conducted in Section 9.2. In the table, we report results for both homogeneous and heterogeneous (normally distributed random coefficients) specifications. In each case, we report quantiles (corresponding to the 95% confidence interval) of the posterior distribution of the population hyper parameters to assess the parameter magnitudes and precisions.

Table 18: "Full" model with Prelec (1998) one parameter weighting function

| | Homogeneous Tastes | | | Heterogeneous Tastes | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Pop. mean | | | Pop. SD | | |
| | 2.5% | 50% | 97.5% | 2.5% | 50% | 97.5% | 2.5% | 50% | 97.5% |
| $\alpha_{GE}$ | 6.50 | 6.97 | 7.55 | 24.88 | 30.33 | 35.51 | 12.82 | 16.62 | 20.62 |
| $\alpha_{GE,w}$ | 5.90 | 6.39 | 7.00 | 23.28 | 28.83 | 33.84 | 12.05 | 16.15 | 19.97 |
| $\alpha_{Wh}$ | 6.52 | 6.99 | 7.54 | 25.01 | 30.49 | 35.67 | 12.97 | 16.74 | 20.66 |
| $\alpha_{Wh,w}$ | 5.95 | 6.43 | 7.04 | 23.39 | 28.90 | 33.88 | 12.07 | 16.14 | 19.97 |
| Price($\beta$) | 0.72 | 0.79 | 0.88 | 2.60 | 3.21 | 3.75 | 1.21 | 1.62 | 1.99 |
| Front loading ($\kappa$) | 0.04 | 0.11 | 0.18 | 0.03 | 0.48 | 0.95 | 2.53 | 3.06 | 3.67 |
| Probability weight ($\mu$) | 1.16 | 1.29 | 1.44 | 1.13 | 1.30 | 1.52 | 0.64 | 0.84 | 1.15 |
| Curvature/risk ($\gamma$) | 1.10 | 1.15 | 1.21 | 0.90 | 0.97 | 1.05 | 0.32 | 0.37 | 0.43 |
| Loss aversion ($\lambda$) | 1.99 | 2.28 | 2.55 | 1.57 | 1.76 | 2.01 | 0.69 | 0.81 | 0.96 |
| Log marginal density | | -8069.08 | | | | -4309.25 | | | |
| Trimmed log m.d. | | -8065.43 | | | | -4228.44 | | | |

### C.3 Risk aversion and intrinsic warranty preference

The tables below correspond to the robustness checks conducted in Section 9.3. In each table, we report results for both homogeneous and heterogeneous (normally distributed random coefficients) specifications. In each case, we report quantiles (corresponding to the 95% confidence interval) of the posterior distribution of the population hyper parameters to assess the parameter magnitudes and precisions.

Table 19: "Full" model with restricted intercept

| | Homogeneous Tastes | | | Heterogeneous Tastes | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Pop. mean | | | Pop. SD | | |
| | 2.5% | 50% | 97.5% | 2.5% | 50% | 97.5% | 2.5% | 50% | 97.5% |
| $\alpha_{GE}$ | 7.07 | 7.67 | 8.27 | 19.80 | 22.77 | 26.11 | 10.32 | 12.37 | 14.79 |
| $\alpha_{Wh}$ | 7.09 | 7.68 | 8.28 | 19.86 | 22.84 | 26.19 | 10.31 | 12.40 | 14.81 |
| Price($\beta$) | 0.87 | 0.96 | 1.05 | 2.11 | 2.45 | 2.82 | 1.00 | 1.22 | 1.48 |
| Front loading ($\kappa$) | 0.06 | 0.12 | 0.19 | -0.03 | 0.31 | 0.67 | 1.86 | 2.24 | 2.69 |
| Probability weight ($\mu$) | 1.27 | 1.39 | 1.50 | 1.36 | 1.52 | 1.71 | 0.70 | 0.87 | 1.12 |
| Curvature/risk ($\gamma$) | 1.12 | 1.18 | 1.25 | 1.01 | 1.09 | 1.18 | 0.36 | 0.42 | 0.50 |
| Loss aversion ($\lambda$) | 1.46 | 1.58 | 1.74 | 1.61 | 1.81 | 2.03 | 0.77 | 0.92 | 1.09 |
| Log marginal density | | -8131.60 | | | | -4587.78 | | | |
| Trimmed log m.d. | | -8129.25 | | | | -4548.11 | | | |

Table 20: Expected Utility "EU" model with restricted intercept

| | Homogeneous Tastes | | | Heterogeneous Tastes | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Pop. mean | | | Pop. SD | | |
| | 2.5% | 50% | 97.5% | 2.5% | 50% | 97.5% | 2.5% | 50% | 97.5% |
| $\alpha_{GE}$ | 8.54 | 9.10 | 9.69 | 21.22 | 24.00 | 27.51 | 10.99 | 13.16 | 15.89 |
| $\alpha_{Wh}$ | 8.52 | 9.09 | 9.69 | 21.27 | 24.07 | 27.57 | 11.03 | 13.21 | 15.87 |
| Price($\beta$) | 1.11 | 1.19 | 1.27 | 2.35 | 2.66 | 3.04 | 1.18 | 1.41 | 1.71 |
| Front loading ($\kappa$) | 0.07 | 0.15 | 0.22 | -0.11 | 0.25 | 0.61 | 2.03 | 2.37 | 2.81 |
| Curvature/risk ($\gamma$) | 1.05 | 1.10 | 1.16 | 0.98 | 1.05 | 1.13 | 0.37 | 0.43 | 0.52 |
| Log marginal density | | -8251.11 | | | | -5525.76 | | | |
| Trimmed log m.d. | | -8249.55 | | | | -5473.11 | | | |

Table 21: Expected Utility "EU" model with restricted intercept (excluding cases where $\pi = 1$)

| | Homogeneous Tastes | | | Heterogeneous Tastes | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Pop. mean | | | Pop. SD | | |
| | 2.5% | 50% | 97.5% | 2.5% | 50% | 97.5% | 2.5% | 50% | 97.5% |
| $\alpha_{GE}$ | 8.15 | 8.81 | 9.56 | 21.04 | 25.66 | 28.68 | 11.00 | 14.00 | 16.55 |
| $\alpha_{Wh}$ | 8.13 | 8.77 | 9.51 | 21.01 | 25.65 | 28.66 | 10.92 | 13.96 | 16.53 |
| Price($\beta$) | 1.08 | 1.17 | 1.27 | 2.37 | 2.93 | 3.29 | 1.20 | 1.53 | 1.85 |
| Front loading ($\kappa$) | 0.05 | 0.15 | 0.24 | -0.06 | 0.39 | 0.85 | 2.28 | 2.82 | 3.40 |
| Curvature/risk ($\gamma$) | 1.08 | 1.14 | 1.21 | 0.99 | 1.08 | 1.20 | 0.43 | 0.52 | 0.65 |
| Log marginal density | | -4840.29 | | | | -3085.38 | | | |
| Trimmed log m.d. | | -4838.79 | | | | -3034.25 | | | |

## C.4 Separate curvature parameters for gains and losses

The tables below correspond to the robustness checks conducted in Section 9.4. In each table, we report results for both homogeneous and heterogeneous (normally distributed random coefficients) specifications. In each case, we report quantiles (corresponding to the 95% confidence interval) of the posterior distribution of the population hyper parameters to assess the parameter magnitudes and precisions.

Table 22: "Full" model with different curvature

| | Homogeneous Tastes | | | Heterogeneous Tastes | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Pop. mean | | | Pop. SD | | |
| | 2.5% | 50% | 97.5% | 2.5% | 50% | 97.5% | 2.5% | 50% | 97.5% |
| $\alpha_{GE}$ | 6.12 | 6.67 | 7.20 | 13.58 | 16.64 | 18.91 | 6.22 | 7.76 | 9.64 |
| $\alpha_{GE,w}$ | 5.55 | 6.09 | 6.64 | 12.92 | 15.81 | 18.05 | 6.08 | 7.55 | 9.37 |
| $\alpha_{Wh}$ | 6.14 | 6.68 | 7.24 | 13.65 | 16.73 | 18.99 | 6.29 | 7.82 | 9.70 |
| $\alpha_{Wh,w}$ | 5.58 | 6.12 | 6.66 | 13.01 | 15.90 | 18.15 | 6.09 | 7.55 | 9.41 |
| Price($\beta$) | 0.67 | 0.75 | 0.82 | 1.36 | 1.70 | 1.97 | 0.65 | 0.79 | 0.99 |
| Front loading ($\kappa$) | 0.04 | 0.10 | 0.16 | 0.03 | 0.28 | 0.55 | 1.49 | 1.83 | 2.20 |
| Curvature/risk (gain)($\gamma$) | 1.12 | 1.19 | 1.26 | 1.12 | 1.22 | 1.36 | 0.41 | 0.49 | 0.59 |
| Curvature/risk(loss) ($\phi$) | 1.03 | 1.13 | 1.25 | 1.36 | 1.60 | 1.91 | 0.91 | 1.21 | 1.75 |
| Probability weight ($\mu$) | 1.06 | 1.16 | 1.28 | 1.47 | 1.69 | 1.96 | 0.79 | 1.03 | 1.35 |
| Loss aversion ($\lambda$) | 2.17 | 2.52 | 2.90 | 1.95 | 2.36 | 3.19 | 0.81 | 1.02 | 1.39 |
| Log marginal density | | -8072.73 | | | | -4218.67 | | | |
| Trimmed log m.d. | | -8069.79 | | | | -4171.76 | | | |

## C.5 Utility specification

The table below corresponds to the robustness check conducted in Section 9.5. In the table, we report results for both homogeneous and heterogeneous (normally distributed random coefficients) specifications. In each case, we report quantiles (corresponding to the 95% confidence interval) of the posterior distribution of the population hyper parameters to assess the parameter magnitudes and precisions.

Table 23: "Full" model - Risk only over consumption utility

| | Homogeneous Tastes | | | Heterogeneous Tastes | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Pop. mean | | | Pop. SD | | |
| | 2.5% | 50% | 97.5% | 2.5% | 50% | 97.5% | 2.5% | 50% | 97.5% |
| $\alpha_{GE}$ | 4.09 | 4.83 | 5.18 | 10.99 | 12.47 | 14.51 | 6.02 | 6.93 | 8.20 |
| $\alpha_{GE,w}$ | 3.88 | 4.59 | 4.91 | 10.56 | 11.94 | 13.89 | 5.82 | 6.69 | 7.95 |
| $\alpha_{Wh}$ | 4.08 | 4.84 | 5.19 | 11.05 | 12.53 | 14.62 | 6.05 | 6.97 | 8.23 |
| $\alpha_{Wh,w}$ | 3.90 | 4.61 | 4.92 | 10.59 | 11.97 | 13.92 | 5.83 | 6.70 | 7.94 |
| Price($\beta$) | 0.98 | 1.06 | 1.10 | 2.03 | 2.23 | 2.48 | 0.95 | 1.11 | 1.34 |
| Front loading ($\kappa$) | 0.04 | 0.05 | 0.09 | 0.04 | 0.18 | 0.33 | 0.76 | 0.94 | 1.12 |
| Probability weight ($\mu$) | 1.20 | 1.32 | 1.42 | 1.34 | 1.50 | 1.70 | 0.71 | 0.87 | 1.11 |
| Curvature/risk ($\gamma$) | 1.33 | 1.37 | 1.54 | 1.26 | 1.36 | 1.48 | 0.37 | 0.43 | 0.51 |
| Loss aversion ($\lambda$) | 1.27 | 1.48 | 1.57 | 1.33 | 1.58 | 1.83 | 0.65 | 0.79 | 0.94 |
| Log marginal density | | -8063.19 | | | | -4305.82 | | | |
| Trimmed log m.d. | | -8061.46 | | | | -4273.34 | | | |

## C.6 Accounting for Warranty Choice in Sequential Survey

The table below corresponds to the robustness check conducted in Section 9.6. In the table, we report results for both homogeneous and heterogeneous (normally distributed random coefficients) specifications. In each case, we report quantiles (corresponding to the 95% confidence interval) of the posterior distribution of the population hyper parameters to assess the parameter magnitudes and precisions.

Table 24: Sequential Model with Continuation Value

| | Homogeneous Tastes | | | Heterogeneous Tastes | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Pop. mean | | | Pop. SD | | |
| | 2.5% | 50% | 97.5% | 2.5% | 50% | 97.5% | 2.5% | 50% | 97.5% |
| $\alpha_{GE}$ | 2.97 | 3.54 | 4.65 | 5.95 | 8.03 | 10.11 | 3.91 | 5.36 | 7.36 |
| $\alpha_{GE,w}$ | 0.24 | 0.46 | 0.64 | 0.53 | 0.94 | 1.41 | 1.17 | 1.56 | 2.08 |
| $\alpha_{Wh}$ | 2.85 | 3.42 | 4.45 | 5.75 | 7.76 | 9.76 | 3.89 | 5.33 | 7.17 |
| $\alpha_{Wh,w}$ | 0.28 | 0.5 | 0.72 | 0.58 | 0.93 | 1.33 | 1.01 | 1.31 | 1.74 |
| Price($\beta$) | 0.31 | 0.41 | 0.56 | 0.7 | 0.96 | 1.19 | 0.56 | 0.71 | 0.91 |
| Front loading ($\kappa$) | 0.02 | 0.11 | 0.22 | -0.14 | 0.47 | 1.09 | 1.79 | 2.32 | 3.01 |
| Probability weight ($\mu$) | 0.35 | 0.73 | 1.04 | 1.78 | 2.78 | 4.59 | 1.74 | 3.27 | 7.94 |
| Curvature/risk ($\gamma$) | 0.06 | 0.35 | 0.54 | 1.74 | 2.34 | 3.42 | 1.66 | 2.61 | 4.91 |
| Loss aversion ($\lambda$) | 1.39 | 2.24 | 3.66 | 2.37 | 2.91 | 3.51 | 1.16 | 1.5 | 1.95 |
| Accounting Factor ($\zeta$) | 0.00 | 0.00 | 0.01 | 0.00 | 0.00 | 0.03 | 0.00 | 0.01 | 0.09 |
| Log marginal density | | -2336.11 | | | | -1152.35 | | | |
| Trimmed log m.d. | | -2334.07 | | | | -1126.42 | | | |