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Abstract

The paper investigates the validity of individuals' perceptions of heart disease risks, and examines how information and risk perceptions affect marginal willingness to pay (MWTP) to reduce risk, using data from a stated preference survey. Results indicate that risk perceptions individuals held before receiving risk information are plausibly related to objective risk factors and reflect individual-specific information not found in aggregate measures of objective risk. After receiving information, individuals' updates of prior risk assessments are broadly consistent with Bayesian learning. Perceived heart disease risks thus satisfy construct validity and provide a valid basis for inferring MWTP to reduce risk. Estimating MWTP based on objective rather than subjective risks causes misleading inferences about benefits of risk reduction. An empirical case study shows that benefits are 36% to 62% higher when estimated using objective rather than subjective risks, showing the importance of employing risk perception information to improve validity of benefit measures.

Keywords: risk perception, willingness to pay, subjective probability, information, Bayesian, heart disease.

JEL Codes: D61, I12, I38, J13, Q51, Q58

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1. Introduction

Information on individual preferences for reducing risks to health is critical for economic evaluation of policies meant to mitigate risks. But identifying preferences for reduced health risk may be difficult without knowledge of subjective perceptions of risk. For example, if an individual's marginal willingness to pay (MWTP) to reduce health risk depends on the level of risk faced, evaluating MWTP at an objective risk measure that differs from the risk she perceives would lead to inaccurate inferences about her marginal valuation of reduced risk.[1] When MWTP to reduce health risk depends on the level of risk, information on perceived risks and their influence on MWTP becomes central to the accurate and valid estimation of benefits of policies that affect risks to health.[2] Before using subjective risk perceptions for benefit estimation, however, it is important to establish whether they represent valid measures of risk.

This paper investigates parents' subjective perceptions of their own and their children's risks of future heart disease, and the relationship between parents' risk perceptions and their MWTP to reduce risk. The paper assesses whether perceived risks provide a valid foundation for estimating MWTP by examining the construct validity of parents' perceived risks. The assessment of construct validity examines two questions: (1) Are the risk perceptions parents held before receipt of information plausibly related to objective risk information? (2) After receiving information, do parents update their subjective probability assessments consistently

[1] More generally, MWTP is inferred from actual or hypothetical choices between alternatives that differ in amount of health risk and in cost or income. Choices depend on preferences, constraints and subjective probability distributions of health outcomes (Hurd 2009). Controlling for constraints, variation in choices and MWTP could be explained by differences in preferences or subjective probabilities. Inferences about preferences thus depend on assumptions or data on subjective probability (Manski 2004).

[2] Understanding subjective risk perceptions also is important for examining the effects of hazard warnings (Viscusi and O'Connor 1984, Smith and Johnson 1988) and designing efficient policies when consumption choices depend on perceptions of risk (Johanson-Stenman 2008, Salanié and Treich 2009).

with predictions of Bayesian learning? The paper then investigates parents' marginal valuations of reduced risk in order to quantify the difference between MWTP estimates computed from aggregate measures of objective risks and estimates computed from individual measures of perceived risk. The main contributions include assessing the validity of risk perceptions and the updating of these perceptions, and the importance of employing risk perception information for accurate benefit measurement.

The case of heart disease, the leading cause of death worldwide (World Health Organization 2017), is relevant because prior research indicates that MWTP to reduce risk of the disease depends on the level of risk (Gerking et al. 2017). Additionally, heart disease risk varies with known risk factors including personal characteristics such as gender and behavioral choices such as smoking. This feature makes it possible to compare subjective risks to objective risk measures estimates and known risk factors, and to examine how parents update their subjective probability assessments in response to information about objective risk and risk factors. Children are included in the analysis because health risks faced by children may be influenced by parental choices that depend on parents' perceptions of their children's risks, yet little is known about parents' subjective probability assessments of their children's health outcomes.

The analysis relies on data from a nationally representative stated preference survey. Survey methods featured careful elicitation of parents' perceptions of their own and their children's risk of future heart disease, both before and after systematic provision of extensive information about the risk. Individual data also were collected on numerous risk factors known to be related to the probability of contracting heart disease.

The validity of subjective risk perceptions, their response to new information, and their relationship to MWTP to reduce health risk remain incompletely resolved despite related prior research. Available evidence on valuation of reduced health risk comes mainly from studies of MWTP to reduce objective rather than subjective risks. Research on perceived risks includes numerous studies demonstrating that people make systematic errors in assessing probabilities (Tversky and Kahneman 1974, Lichtenstein et al. 1978). But other research shows that subjective probabilities of some future economic and health outcomes are similar to objective probability estimates and are related to factors that influence probability (Dominitz and Manski 1997, Hurd and McGarry 2002).[3] Several studies find that provision of risk information leads to revision of risk perceptions in the direction of the new information (*e.g.*, Viscusi and O'Connor 1984, Smith and Johnson 1988, Dickie and Gerking 1996), although there may be departures from rational Bayesian learning including alarmist reactions to conflicting information (Viscusi and Magat 1992) or overreaction to high-risk information (Viscusi 1997).

In a study focused on climate change rather than health risks, Cameron (2005) found that responses to information were close to predictions of Bayesian learning for expectations of future temperature but not for variances. In a recent study of French consumers' perceived risks of contracting food-borne illness before and after receiving information, Rheinberger and Hammitt (2018) found that most consumers revised their perceptions of risk consistently with Bayesian learning, but 16% of consumers responded to information in unexpected ways. Linn and Sloan (2015) reported that information – in the form of a lung cancer diagnosis of a cigarette-smoking neighbor – increased Chinese smokers' beliefs that smoking causes lung cancer, and that changes in beliefs affected smoking behavior and quit intentions. Zhao et al. (2013) also found that information affected health-related behavior (individuals in China reduced

[3] For example, prior research indicates that subjective expectations of survival to a given age are broadly consistent with life tables, are correlated with factors that predict mortality, and are predictive of actual mortality (Hurd and McGarry 1995, Smith et al. 2001, Manski 2004).

fat intake following a hypertension diagnosis), but did not investigate risk beliefs. None of these studies examined how information or subjective beliefs influence willingness to pay to reduce risk of climate change or of illness. We know of no other literature that examines updating of parents' beliefs about risks to their children.

Empirical findings in this paper indicate that parents' risk perceptions held prior to receipt of information are qualitatively consistent with current knowledge about heart disease risk and its risk factors. Parents' updates of risk perceptions in response to information are broadly consistent with Bayesian learning. Thus, subjective perceptions of heart disease risk satisfy important conditions for construct validity. Using objective risks to estimate MWTP for risk reduction misstates parents' MWTP to reduce heart disease risks, because MWTP depends on risk, and parents' subjective assessments of risks differ from objective risks. Additionally, information influences the amount parents are willing to pay at the margin to reduce risk, because learning affects perceived risk and MWTP depends on risk.

Results also indicate that substantial heterogeneity in valuation of reduced heart disease risk arises from variation in risk perceptions alone. Estimating MWTP with aggregate objective risk masks this heterogeneity. Previous researchers have documented heterogeneity in subjective probability assessments (Viscusi and Hakes 2008, Manski 2004, Hurd 2009, Gerking et al. 2014) and in valuations of reduced health risk (*e.g.,* Cameron and DeShazo 2013, Bosworth et al. 2015), but not the possible connection between the two types of heterogeneity.

The remainder of the paper is organized around the idea that if marginal valuations of health risk depend on the level of risk, then estimates of MWTP will reflect individual preferences more accurately when based on valid measures of perceived risk rather than on measures of objective risk. Section 2 describes the data, and Sections 3 and 4 assess the construct validity of parents' perceptions of heart disease risks. Section 5 examines how MWTP to reduce heart disease risk depends on the level of risk, and compares MWTP estimates based on objective and subjective risk estimates. Section 6 concludes.

2. Data

Data consist of a subsample of 2204 parents who completed a survey administered in 2011 to 3155 parents drawn from Knowledge Networks, Inc.'s nationally representative online research panel.[4] All participants were parents aged 18 to 55 years that had at least one biological child aged 6 to 16 years living in the home and had not previously been diagnosed with heart disease or experienced a heart attack.[5] For the 74% of parents with two or more children living at home, one child was randomly selected and designated as the sample child.

The survey consisted of four main sections on (1) elicitation of parents' initial or prior perceptions of heart disease risks, held before receiving information about risk; (2) the provision of information about heart disease risk and collection of data on risk factors; (3) elicitation of parents' revised or posterior risk estimates, made after receiving information; and (4) collection of data to support estimation of MWTP to reduce risk.

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[4] The panel was recruited by probability sampling methods, and the sample used here was selected from the panel using probability sampling. Research methods and data are described in Dickie and Gerking (2011).The sample of 3155 included 505 parents used in a pretest and 434 matched pairs of spouses (868 parents) living together in the same household. Parents used in the pretest are excluded because the final version of the survey instrument differed from the pretest. The second of the parents recruited for each of the matched pairs was excluded because the matched pairs subsample is not congruent with the subsample of parents living in different households: In the latter subsample, parents are queried about a child living in their household, whereas in the matched pairs subsample, two parents are queried about the same child. Data from the matched pairs were analyzed in Adamowicz et al. (2014). Retaining the first parent recruited from each matched pair plus the 1782 parents living in different households gives a sample of n=2216. Twelve parents were excluded because they did not answer all survey questions.

[5] Parents with a prior history of heart disease were excluded to focus on *ex ante* perception and valuation of risk. Older teenagers were excluded because they are more likely than younger children to earn income and make independent consumption decisions. Children under age 6 years were excluded because in focus groups conducted prior to administering the survey parents expressed difficulty assessing and valuing heart disease risk for very young children.

2.1 *Initial Risk Perceptions*

Parents assessed risk of contracting coronary artery disease before age 75 years using an interactive grid (Gerking et al. 2017).[6] Computerized, self-administered surveys are well suited to eliciting subjective probabilities (Manski 2004), and grids have been used successfully to provide or elicit probabilities in previous studies (Dickie and Gerking 2007, Viscusi and Huber 2012, Alberini and Ščasný 2018, Hammitt and Herrera-Araujo 2018). The grid depicted 100 numbered squares to measure risk as a number of chances in 100. Parents completed a tutorial about risk before using the scale to estimate the risk of getting coronary artery disease before age 75, first for themselves and then for the sample child. Parents' initial risk assessments, summarized in Table 1, are positively skewed and widely dispersed. Means exceed medians by about 5 percentage points, and standard deviations are about 60% to 70% as large as means.

2.2 *Risk Information and Data on Risk Factors*

After making initial assessments of risk of future heart disease, parents were given both quantitative and qualitative information about the risk.[7] Quantitative information was based on estimates of risk of contracting heart disease before age 75 years obtained from Framingham Heart Study data by Lloyd-Jones et al. (2006).[8] Qualitative risk information was based on other sources using the Framingham data (Lloyd-Jones et al. 1999 and Wilson et al. 1998) as well as on information from the U.S. government (US Department of Health and Human Services 2005, 2008) and the American Heart Association (Lichtenstein et al. 2006).

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[6] Parents were told that the terms "heart disease" and "coronary artery disease" would be used interchangeably in the survey.

[7] Parents in focus groups had indicated a preference for quantitative risk information. The final version of the survey reflected information obtained from 25 parents in two focus groups in addition to the 505 parents in two pre-tests.

[8] The Framingham Heart Study is an ongoing effort begun in 1948 with the goal of identifying factors that contribute to cardiovascular disease, by following a large group of participants over time. Over 2000 articles have been published in peer-reviewed medical journals using data from the study.

Average Risk. Parents first were advised that the average person in the US has about 27 chances in 100 of being diagnosed with coronary artery disease before age 75. The average risk was illustrated using a risk scale showing the 27% risk level next to the risk scales that parents had marked for themselves and their children.

Risk Factors. Parents then were told that an individual's risk could differ from average because chances of getting heart disease depend on risk factors that differ for everyone: gender, smoking, health status, family history, exercise, and diet.[9] The survey elicited information about each risk factor and advised parents how the factors affect risk. After inquiring whether a given risk factor was present for the parent and the child, the survey advised parents that heart disease risk is higher in the presence of the risk factor.[10] If quantitative estimates of objective risk were available, the survey displayed two risks scales to illustrate the risk with/without the risk factor.[11]

The survey presented quantitative estimates of objective risk for presence/absence of current cigarette smoking, diabetes, high blood pressure, and high cholesterol, and for body mass index (BMI) in the normal, overweight and obese range for adults. It provided qualitative risk information for BMI for children, and for family history of heart disease, exercise, and diet.[12]

2.3 Revised Risk Assessments

After reviewing risk information, parents were shown their initial assessments on the risk scales and could revise their assessments if desired. Revised risk assessments are summarized in

[9] Findings in Linn and Sloan (2015) support the importance of providing health information that fits individuals' personal circumstances.
[10] The one exception is that parents were not asked about their children's cigarette smoking.
[11] Objective risk estimates were computed as midpoints of gender-specific risks reported by Lloyd-Jones et al. (2006), to avoid providing four separate risk estimates for each risk factor (2 genders x presence/absence of each risk factor), because about half of parents (1106 parents) were answering on their own behalf and on behalf of a child of the opposite gender.
[12] In this section of the survey parents also were asked for overall subjective evaluations of their own health and their children's health using the standard "Excellent-Very Good-Good-Fair- Poor" rating scale.

Table 1. About 47% of parents revised their own assessments and 49% revised their assessments of their children's risk.[13] Parents on average reduced their own risk by about two percentage points and their children's risk by about four percentage points.[14]

2.4 Willingness to Pay

The final section of the survey elicited stated preferences for vaccines to reduce risk of coronary artery disease. Stated-preference methods have been used frequently to evaluate health-related preferences and behavior (e.g., Kesternich et al. 2013, Bosworth et al. 2015, Gyrd-Hansen et al. 2016, Fischer et al. 2018). Parents were asked about purchase intentions for each of two hypothetical vaccines, presented one at a time in random order. One vaccine reduced the parent's risk and the other reduced the child's risk. The vaccines are treated as new private goods that yield no direct utility and provide incremental reductions in heart disease risk.

The preference elicitation procedure, described fully in Gerking et al. (2017), had five main features.[15] First, parents were told about symptoms of heart disease and the need for medical treatment and were shown individualized hazard functions indicating how cumulative risk would increase until age 75, given the parents' revised risk assessments. Second, vaccine effectiveness was varied randomly: parents were assigned risk reductions of either 10% or 70% of their updated risk assessment, and children were assigned risk reductions of either 20% or

[13] Prior studies of parents' responses to risk information reported that 40% of parents revised perceptions of their own and their children's risks of future skin cancer (Dickie and Gerking 2007), and 57% revised perceptions of their own and their children's risks of future leukemia (Gerking et al. 2014). Rheinberger and Hammit (2018) found that 83% of French consumers revised assessments of the conditional risk of contracting a foodborne illness from eating fish, given that a foodborne illness was contracted.
[14] In the cited studies of skin cancer and leukemia, and the present study of heart disease, revised assessments are less widely dispersed than initial estimates, for both parents and children, as indicated by standard deviations and interquartile ranges.
[15] The survey approach follows most of the stated preference guidelines outlined by Johnston et al. (2017) such as the implementation of pretesting, pilots, the inclusion of reminders on substitutes, questions verifying the understanding of the purchase scenario, and the use of debriefing questions.

80%.[16] Third, risk scales based on the parents' revised risks showed: (1) the absolute risk reduction offered by the vaccine and (2) the amount of risk that would remain if the vaccine was purchased. Revised hazard functions illustrated the risk reductions in each year through age 75.

Fourth, parents were asked whether they would be willing to pay a randomly assigned price (chosen from the values of $10, $20, $40, $80, $160 that were selected on the basis of focus groups and pretests) for the first year of vaccination. Prices varied only between households; the same price was presented for the parent's and the child's vaccines. Parents were reminded of the budget constraint and that the vaccination program could be continued in future years. Fifth, parents indicating that they were willing to pay for a vaccine were asked how certain they were that they would really purchase the vaccine if it actually were available. About 13 percent of parents stating that they would purchase the vaccine indicated that they were uncertain about their intentions, and these parents are classified as not being willing to pay for the vaccine. Prior research (see Gerking et al. 2017) shows that hypothetical bias can be reduced by treating respondents stating uncertain purchase intentions as non-purchasers.

3. Comparing Subjective and Objective Estimates of Heart Disease Risk

As noted previously, when MWTP for health risk reduction depends on the level of risk, computing an individual's MWTP based on an objective risk measure that differs from her perception of risk will misstate her marginal valuation of risk. Using valid measures of individual risk perceptions to estimate MWTP will better reflect individual preferences than using aggregate measures of objective risk.

[16] Parents were told that risk reductions would materialize only for those who continued to receive the vaccinations annually through age 75 and would be larger for children because the vaccination program would be initiated earlier in life.

This section and the next assess the construct validity of parents' subjective perceptions of risk of getting coronary heart disease before age 75 years. The purpose is to establish whether parents' risk assessments provide a sound basis for investigating properties of MWTP to reduce risk. This section investigates validity by comparing initial assessments of risk, made before receiving information, to clinical and epidemiological evidence about risk. The comparison indicates whether subjective probability assessments are reasonably related to available information about heart disease risk, including information on individual risk factors. The following section examines validity by investigating whether parents revise their risk assessments in a consistent fashion in response to information, and whether the revisions are consistent with restrictions imposed by a model of Bayesian learning.

Two aspects of comparing subjective and objective risk estimates should be noted. First, objective risk estimates usually are provided as average risks for large groups with no information on dispersion, whereas subjective risk assessments are measured individually. To compare the two types of risk estimates in this section, subjective assessments are averaged within groups. But information is lost in this aggregation, because the probability of a future health outcome may be influenced by behavioral, genetic or environmental risk factors unobserved by experts but known to individuals (Smith et al. 2001, Perozek 2008, Hurd 2009). Second, objective risk estimates are in fact estimates, not known constants, and thus a statistical test for differences between subjective and objective risks is not feasible due to the lack of information on dispersion in the objective estimates.

3.1 Heart disease risk by gender

Table 1 presents estimates of objective probability of contracting coronary artery disease before age 75 years along with sample statistics of parents' subjective probability assessments, by gender of parent and child. Two results in Table 1 are worth noting. First, both mothers and fathers believe that they face higher risks than their children. The differences are significant at the 1% level.[17] This outcome is consistent with prior research showing that parents assess their own risks as higher than their children's risks, for skin cancer and for leukemia (Dickie and Gerking 2007, Gerking et al. 2014).[18]

Second, the gender difference in perceived risk of heart disease is far smaller than the difference in objective risk. Fathers' assessments of their own risks closely match epidemiological estimates on average, whereas the average mother's initial risk estimate exceeds the objective risk for females by 16 percentage points. This outcome is consistent with previous research showing that women are more pessimistic than men about survival probabilities (Hurd 2009, Elder 2013) and about health, environmental and other risks (Slovic 2000, Hakes and Viscusi 2004, Andersson and Lundborg 2007).[19]

3.2 Heart disease risk by risk factors

Table 2 compares objective and initial subjective risks by other risk factors for which quantitative estimates of objective probability were given to parents. For each risk factor, the table displays the objective risk estimates provided in the survey and the means and medians of

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[17] The null hypothesis that mean initial risk assessments made by mothers are equal between themselves and their sons is rejected at 1% in a matched-samples test. The corresponding hypotheses that mean risk assessments are equal between mothers and daughters, between fathers and daughters, and between fathers and sons also are rejected at 1% significance in separate matched-samples tests. Each of these hypotheses also would be rejected at 1% when applied to revised assessments.

[18] Parents' assessments also are more widely dispersed relative to means for children's than for parents' risks, as indicated by coefficients of variation. This outcome occurred for skin cancer but not leukemia.

[19] A somewhat similar outcome arises in comparing parents' risk assessments for children of different gender, in that the differences in the risks parents perceive for boys and girls are much smaller than objective estimates of risk differences between men and women. Parents on average believe that their sons face lower risk than objective estimates for men while believing that their daughters face higher risk than objective risks for women. Mean risk assessments made by mothers are higher for sons than for daughters at the 1% level for both initial and revised assessments, but fathers' mean risk assessments are statistically indistinguishable between sons and daughters ($p = 0.36$ and $p = 0.11$, respectively, for initial and revised assessments).

parents' initial risk perceptions by gender. Attention is limited to parents in Table 2 because very few children were reported to have diabetes, high blood pressure, or high cholesterol; BMI levels of 25 and 30 are not used to define overweight and obesity for children, and parents were not asked about children's cigarette smoking.

Results indicate that the qualitative relationship between heart disease risk and risk factors is the same for subjective and objective assessments of risk. For both mothers and fathers, mean subjective probability of contracting coronary artery disease increases at the 1% level with cigarette smoking, diabetes, high blood pressure, high cholesterol, and with being overweight or obese.[20] Previously, Carmen and Koorenen (2014) found that neither gender perceived increased heart disease risk with smoking, both genders perceived higher risk with blood pressure and BMI, and only women perceived an increase in risk with diabetes or cholesterol.

Although parents appear to understand the qualitative relationship between risk factors and chances of heart disease, mean subjective probabilities differ from objective probabilities. For example, both smokers and non-smokers on average overestimate risks of heart disease. The higher risk estimates made by smokers are broadly consistent with prior research showing that smokers hold lower subjective probabilities of survival to a given age than do nonsmokers (Smith et al. 2001, Rappange et al. 2016); the overestimation of risk by smokers is consistent with prior evidence that smokers overestimate risks of adverse smoking-related health outcomes (Viscusi and Hakes 2008). In contrast, persons with diabetes appear to underestimate their risks. The increase in mean (median) perceived risk associated with diabetes of about 10 (20) chances in 100 falls well short of the increase in objective risk of almost 40 percentage points.

[20] Equality of mean subjective risk between smokers and non-smokers is rejected at 1%, as is the parallel hypothesis that mean risk is equal for persons with and without diabetes. The null hypothesis that mean subjective probability is constant across the three blood pressure categories is rejected at the 1% level in an *F*-test, as are the parallel hypotheses for cholesterol and BMI categories.

Table 3 summarizes parents' initial risk assessments for both parents and children by additional risks factors for which objective risk estimates were not available to present to respondents in the survey. Risk assessments made for children are pooled over parent gender to simplify the exposition.[21] Parents believe that having a family history of heart disease, consuming too little exercise or fruits and vegetables, having a generally unhealthy diet, or being in poor health is associated with higher risk for both parents and children.[22] Table 3 results thus provide additional evidence that parents understand the qualitative relationship between heart disease risk and risk factors, and that parents' initial risk assessments contain individual-specific information not found in an objective risk estimate for the population as a whole.[23] In summary, the qualitative relationship between subjective assessments of risk and each of 11 risk factors considered accurately reflects scientific and medical knowledge.

4. Information and Learning about Heart Disease Risk

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[21] Fathers and mothers make similar assessments of risks faced by daughters, but mothers see sons as facing higher risks of heart disease than do fathers. The null hypothesis that mean subjective probability for daughters is equal between mothers and fathers is not rejected ($p = 0.36$), whereas the corresponding hypothesis for sons is rejected at the 1% level.

[22] The null hypotheses that mean risk assessments are equal regardless of family history, of exercise sufficiency, of fruit and vegetable consumption, of healthiness of diet, and of subjective health status, are each rejected at the 1% level in separate tests for mothers, fathers, sons and daughters.

[23] Comparisons in Tables 1-3 examine each risk factor in isolation, without controlling for presence of other risk factors, because that is how the objective probability estimates are computed and presented in the previously cited sources of risk information. A regression analysis of the association of initial risk assessments with risk factors and demographic indicators is available from the authors on request. Estimates for the parent and the child pooled over gender were computed using generalized least squares for seemingly unrelated regressions. For both parents and children and with the exception of gender, regression estimates of effects of risk factors on initial risk assessments are smaller than the estimated effects that do not control for presence of other risk factors reported in Tables 2 and 3. Hurd and McGarry (1995) report a similar outcome in their analysis of subjective survival probabilities. Nonetheless, parents' initial assessments of their own risks are significantly associated at the 5% level or less with their own gender and with presence of each risk factor in Tables 2 and 3, with the exception of diabetes. Similarly, parents' initial assessments of their children's risks are significantly associated at 1% with their children's gender, BMI, and each risk factor in Table 3 except fruit/vegetable consumption.

This section examines parents' risk updating in response to information by specifying and estimating a model of Bayesian learning. As in Section 3, the purpose is to assess whether parents' subjective risk perceptions provide a valid basis for estimating MWTP to reduce risk.

4.1 Overview of parents' revisions of heart disease risk assessments

Table 4 presents summary tabulations of parents' revisions of their initial risk assessments. Data are pooled over gender because differences between the sexes are insubstantial. Panel A tabulates mean prior risks and updates by the direction of updating. Means of initial risk assessments are largest (smallest) for parents who revise risk downward (upward). Despite the small overall average revision, absolute magnitudes of non-zero revisions are sizeable. Upward updates average10-11, and downward updates average 18-19, chances in 100.

Panel B of Table 4 cross-tabulates the direction of updating (reducing, not changing, or increasing the prior) by the level of risk initially perceived relative to objective risk by gender. Chi-square statistics indicate that the direction of updating is related systematically at the 1% level to information provided on objective risk by gender.

If population average risk by gender had been the only risk information provided, a Bayesian parent would reduce, not change, or increase her prior risk assessment according to whether the prior was greater than, equal to, or less than objective risk. About 40% of parents revised their initial assessments in the direction of objective risk by gender (39% for parents' own risks and 42% for their children's risks; see Panel B of Table 4). About one-half of parents did not update their initial risk assessment when it differed from objective risk by gender (52% for parent risk and 50% for child risk), and 8% of parents making non-zero revisions updated their assessments in the opposite direction of objective risk by gender. Thus, about 80% of non-zero revisions (82% for parents and 83% for children) are in the direction of population risk by gender. For comparison, Rheinberger and Hammitt (2018) found that 66% of the French consumers in their sample, and 80% of those making non-zero revisions of prior assessments, updated their beliefs in the direction of information provided about population average risk.[24]

To examine risk updating in relation to all the information provided to parents, the following subsection specifies a model of Bayesian learning. Estimation of the model supports testing whether parents' use of each piece of risk information, net of effects of other risk information provided, is consistent with Bayesian learning.

4.2 Specification of risk updating model

Initially the parent (*p*) believes that her risk of contracting heart disease equals R_{p0}, and that the risk of her child (*k*) equals R_{ko}, $0 \le R_{io} \le 1$, $i = p, k$. She then receives *J* estimates of objective risk, denoted S_j, $j = 1, \ldots, J$. The parent updates her prior probability beliefs according to the Bayesian updating rule

$$R_{i1} = \gamma_i R_{i0} + \sum_{j=1}^{J} \eta_{ij} S_j, \quad i = p, k, \tag{1}$$

where R_{i1} denotes the parent's revised or posterior risk belief.[25] In equation (1), the γ_i and η_{ij} parameters respectively denote the relative precision or information content of the prior and the j^{th} risk estimate.[26] The relative precision parameters lie between zero and one and sum to unity:

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[24] After accounting for individual differences in behaviors that increase or decrease risk, about 84% of respondents in the Rheinberger and Hammitt (2018) study updated in the expected direction.

[25] Equation (1) gives the mean of the posterior distribution of risk when perceived risks follow a beta distribution. See Pratt et al. (1975).

[26] The relative precision parameters are defined as $\gamma_i = \overline{\gamma}_i / D_i$, $\eta_{ij} = \overline{\eta}_{ij} / D_i$, where $\overline{\gamma}_i$ and $\overline{\eta}_{ij}$ denote precision of the prior and the j^{th} risk estimate, and $D_i = \overline{\gamma}_i + \sum_j \overline{\eta}_{ij}$. The parent acts as if her prior assessment were derived from $\overline{\gamma}_i$ Bernoulli trials in which $\overline{\gamma}_i R_{io}$ indicated presence of heart disease, and as if each risk estimate were derived from $\overline{\eta}_{ij}$ Bernoulli trials in which $\overline{\eta}_{ij} S_j$ indicated heart disease.

$0 \le \gamma_i, \eta_{ij} \le 1,\ \gamma_i + \sum_{j=1}^{J} \eta_{ij} = 1,\ i = p,k,\ j = 1,\ldots,J$. In the empirical analysis below, it is convenient to use the latter constraint to rewrite the updating rule as equation (2).[27]

$$R_{i1} - R_{i0} = \sum_{j=1}^{J} \eta_{ij} \left(S_j - R_{i0} \right), \quad i = p,k. \tag{2}$$

According to equation (2), the parent updates her risk perceptions by comparing each new risk estimate to her prior belief, and weighting the difference by the relative precision of the new information. Positive values for the η_{ij} that are less than unity imply that perceived risk adjusts to each new piece of information by moving toward, but not beyond, the new risk estimate. Negative values for any η_{ij} or values in excess of unity would be inconsistent with this logic and with Bayesian learning.

Before presenting estimates of the Bayesian learning model in equation (2), there are three issues to address concerning its empirical specification and estimation. First, the weight given to new information may reflect its applicability to individual circumstances as well as well as its information content (Viscusi 1989). To account for individual relevance of information, assume that when updating her prior risk for herself or her child, the parent uses only the information that corresponds to her own or her child's risk factors. For example, assume that smoking parents use the objective risk of smokers but not the objective risk of nonsmokers when updating their prior assessments; nonsmoking parents do the reverse. Thus if $S_j,\ j = 1,\ldots,4$

[27] The preceding discussion assumes the new risk estimates S_j are independent. If instead they are drawn from overlapping information (for example, if parents believe that the estimates rely in part on common data), the η_{ij} are adjusted for overlapping information, so that they represent the information content that is unique to each risk estimate. However, the mean posterior risk remains a weighted average of the prior risk and the new risk estimates and equation (2) remains valid, although with a somewhat modified interpretation of the weights. See Viscusi (1997) and Zeckhauser (1971).

denote objective risk estimates for females, males, non-smokers and smokers, then the first four terms on the right-hand-side of equation (2) are shown in equation (3).

$$\begin{aligned}\sum_{j=1}^{4}\eta_{pj}\left(S_j - R_{p0}\right) = \xi_{p1}(\text{Female})\left(S_1 - R_{p0}\right) + \xi_{p2}(\text{Male})\left(S_2 - R_{p0}\right) \\ +\xi_{p3}(\text{Nonsmoker})\left(S_3 - R_{p0}\right) + \xi_{p4}(\text{Smoker})\left(S_4 - R_{p0}\right),\end{aligned} \tag{3}$$

where Female, Male, Nonsmoker and Smoker denote (0,1) indicators for gender and smoking status, and ξ_{pj} reflect the relative precision of the corresponding objective risk estimates.[28]

Second, information gap variables for parents' risk factors for which objective risk estimates were available (gender, smoking, diabetes, BMI, blood pressure and cholesterol) were constructed as differences between the objective risk estimate given to parents in the survey (shown in Tables 1 and 2) and the parent's prior assessment of risk.[29] Information gap variables for risk factors for which only qualitative risk information was available (family history, exercise, fruit/vegetable consumption, healthiness of diet and children's BMI) were constructed so that their weights are expected to be positive.[30]

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[28] The only information gap variables reflecting quantitative estimates of objective risk for children are for risk by gender, because as mentioned previously few children had diabetes, high blood pressure or high cholesterol, the survey did not assess child smoking, and objective risk estimates by BMI category were not available for children.

[29] For blood pressure and cholesterol, information gap measures were constructed assuming that the objective risk estimate applicable to parents who have not been told to do something about the condition equals the risk in the lowest-risk category, whereas the risk estimate for parents who have the condition equals the risk in the highest risk category. Lloyd-Jones et al. (2006) reported estimates of objective risk for quantitative measures of blood pressure and cholesterol. Because parents would not be expected to know their blood pressure or cholesterol readings, the survey therefore inquired only if a medical professional had said to do something to lower blood pressure or cholesterol and if so whether medication was being taken for this purpose.

[30] For example, suppose S_j and S_{j+1} represent the unknown objective risks with and without a family history of heart disease, History/Nohistory are indicators for presence/absence of this risk factor, S_0 denotes the overall population risk estimate of 27 chances in 100, and $I\left(\bullet\right)$ equals 1 if the condition in parentheses is true and 0 if it is false. Then the associated terms in equation (2) are $\eta_{ij}\left(S_j - R_{i0}\right) = \xi_{ij}(\text{History})\left(S_0 - R_{i0}\right) I\left(S_0 > R_{i0}\right)$ when there is a family history and

Third, estimates are computed by ordered probit and by ordinary least squares. The ordered probit model is applied to an indicator variable for whether the update in risk was negative, zero, or positive, because of the large proportion of observations with zero revisions and the presence of some large nonzero revisions (see Table 4). Ordered probit supports a test for whether the direction of updating is consistent with predictions of Bayesian learning in that larger values of information gap variables should be associated with a greater (smaller) probability of revising perceived risk upward (downward). The ordered probit model does not support tests of quantitative predictions of Bayesian learning, due to the normalization of coefficients by the scale factor. Tests of quantitative predictions are based on least squares.

4.3 Empirical estimates of risk updating model

Table 5 displays results of the ordered probit analysis of the direction of parents' revisions in risk assessments. The table presents marginal effects (multiplied by 100) of each covariate on the probability of negative, zero, and positive updates in response to information. Covariates include information gap variables and indicators for economic/demographic characteristics and parents' prior knowledge of heart disease.[31] Estimates (pooled over gender for the sake of brevity) are presented in columns 2-4 for parents and columns 5-7 for children.

$\eta_{ij+1}\left(S_{j+1} - R_{i0}\right) = \xi_{ij+1}(\text{Nohistory})\left(S_0 \quad R_{i0}\right) I\left(S_0 \quad R_{i0}\right)$ when there is no family history. If $\xi_{ij} > 0$, then a parent increases the risk assessment for the parent or child when there is a family history, if and only if the prior assessment lies below overall objective risk. If $\xi_{ij+1} > 0,$ then a parent decreases the risk assessment for one without a family history, if and only if the prior assessment exceeds the overall objective risk. In each case the absolute size of the update increases with the absolute size of the gap between the prior risk assessment and overall objective risk.

[31] The estimating equation also included a constant term. The Bayesian learning model includes only the information gap variables with no constant and no other covariates (see equation (2)). The constant and the additional covariates, included to examine personal characteristics associated with risk updating, will be excluded from the least squares estimates used to test quantitative restrictions of Bayesian learning.

For parents' updates of their own risks, marginal effects for information gaps for gender take expected signs but are not statistically significant at conventional levels. For parents' updates of their children's risks, larger information gaps for gender are associated at the 1% level with a larger (smaller) probability of revising upward (downward), suggesting consistent use of information about risks by gender for children. Parents' updates of their own risks are consistent with rational use of objective risk information about diabetes and BMI. Estimated marginal effects of objective information about risks for smokers and nonsmokers are inconsistent with expectations. Parents appear to have used some information about risk levels according to exercise, fruit and vegetable consumption, and family history in a manner qualitatively consistent with Bayesian learning for both their own and their children's risks.[32]

Table 6 presents least-squares estimates of the Bayesian updating equation (2). Estimates are presented for the full sample (column 2 for parents and column 4 for children) because limiting the sample to observations with nonzero updates would be expected to cause overestimation of absolute magnitudes of information weights. Owing to the large proportion of zero revisions, however, Table 6 also presents estimates for the subsample with nonzero revisions (columns 3 and 5 for parents and children). Results are qualitatively similar in the full sample and the subsamples with nonzero updates. With few exceptions, estimated coefficients take the same signs and are absolutely larger when parents making zero revision are excluded.[33]

[32] Concerning marginal effects for prior knowledge and demographic indicators, higher education and income are associated with downward revisions of initial risk assessments. African-American parents are more likely than are whites to revise their assessment of their own risks upward. A parent who prior to the survey had thought about the chance that she might develop heart disease is more likely to revise her own risk upward and her child's risk downward.

[33] Estimates in Table 6 impose the Bayesian restriction of a zero intercept in equation (2). When constant terms are added to column 2 and 3 regressions, the coefficients are not significant at the 10% level. When constant terms are added to columns 4 and 5, the coefficients are negative and significant at 1%.

Slope coefficients in Table 6 are interpreted as weights parents applied to objective risk information when updating their priors and indicate the number of chances in 100 by which parents increased their risk assessments per 1-chance-in-100 increase in each information gap variable. Bayesian updating predicts that each weight lies between zero and one.

For parents' updates of their own risks, no estimated weight is greater than one; the largest in the full sample is 0.399 and is significantly less than unity at the 1% level. Weights on information about risk by gender are not significantly different from zero, suggesting that parents did not use this information when updating. Estimated weights on objective risk information for smoking are negative and significant at 1%, contrary to expectations. A partial explanation for this result and the corresponding finding in Table 5 may be that parents dismissed the smoking risk information because the risk estimate for smokers seemed implausibly low relative to their prior beliefs about health hazards of smoking, and parents may not have considered differences in competing risks of death before age 75 years between smokers and non-smokers.[34]

Estimated weights on objective risks by presence/absence of diabetes, overweight and obesity in Table 6 are positive and significant at 1%. Results for objective risks by blood pressure and cholesterol status, and for qualitative risk information, differ somewhat between the full sample and the subsamples of parents with nonzero updates. Few of the associated information weights are positive and significant at the 5% level in the full sample, but most are in the subsample of parents who revised initial assessments.

[34] As shown in Table 1, the mean initial risk assessment for non-smokers exceeds the objective risk estimate for smokers. For no other risk factor does the mean prior risk in the absence of the risk factor exceed the objective risk estimate in its presence. As reported in the source of the objective risks (Lloyd-Jones et al. 2006, 792-793), smokers experience cardiovascular disease at earlier ages than nonsmokers, but as years progress the differential between risks of smokers and nonsmokers shrinks because the competing risk of death from other smoking-related diseases reduces survival among smokers, thus limiting their heart disease risk.

Turning to parents' updates of their assessments of their children's risks, no estimated information weight is significantly less than zero or greater than one. The weight on objective risk by gender is positive and significant at 1%. Several weights pertaining to BMI, exercise, diet and family history are positive and significant at 5% or less, suggesting that parents used this information consistently for their children.

Using equations (2) and (3) and results in Table 6, the estimated sum of weights on new risk information, $\sum_{j=1}^{J} \eta_{ij}, i = p, k,$ can be computed at the means of risk factors. The implied weight on the prior assessment then is recovered as this sum subtracted from unity. For the full sample, the sum of weights on new information for parents is 0.504 (s.e. = 0.039), implying a weight on the prior assessment of 0.496. For children's risks, the weights are 0.784 (s.e. = 0.036) on new information and thus 0.216 on the prior. Parents may have placed a larger weight on the prior assessment when updating their own risks as compared to their children's risks, because of greater confidence in their ability to estimate risk for themselves than for their children. Parents have had a longer time to observe their own health, and their shorter time horizon until age 75 years relative to their children leaves less opportunity for unexpected future developments.[35]

4.4 Validity of subjective risk perceptions

Results in Section 3 indicate that parents' initial risk assessments are related plausibly to objective risk estimates and to their own and their children's risk factors, and contain individual-specific information. Results in Section 4 suggest that updates of prior risk assessments reflect

[35] In the subsample with nonzero revisions, estimated weights are 0.931 (s.e. = 0.045) on new information and thus 0.069 on the prior for parents, and 1.183 (s.e. = 0.036) on new information, which is significantly greater than unity at the 1% level, and thus -0.183 on the prior assessment for children. Weights outside the unit interval violate Bayesian learning. However, the subsample is obtained by removing the 50% of parents who made no revision and who thus placed the greatest weight on their prior assessments. Under-estimation of weights on prior risks and thus over-estimation of weights on new information would be expected in this subsample.

sensible use of information and are broadly consistent with Bayesian learning. Parents' subjective risk assessments therefore would appear to meet standards of construct validity and to provide a valid alternative to objective risk estimates for inferring MWTP to reduce risk.

5. Risk Perception, Information and Parents' MWTP to Reduce Risks

The analysis of parents' MWTP to reduce their own and their children's risks of future heart disease is divided into three subsections. Subsection 5.1 demonstrates that parents' MWTP depends on the level of risk. The dependence of MWTP on risk implies that estimated MWTP will more accurately reflect individual preferences when based on valid measures of perceived rather than objective risk. To explore this idea empirically, Subsection 5.2 compares MWTP estimates computed from objective and mean subjective risk estimates. It also examines how learning affects the marginal valuation of reduced risk and illustrates the heterogeneity in MWTP that arises from variation in individual risk perceptions. Information on this heterogeneity is lost when MWTP is estimated using aggregate objective risk estimates. Subsection 5.3 provides a policy example showing how estimated national benefits of heart disease risk reductions might differ depending on the use of objective or subjective risk estimates.

5.1 Estimates of parents' MWTP to reduce heart disease risks

Methods used to estimate parents' MWTP for reductions in heart disease risk build on the approach of Gerking et al. (2017).[36] Parents' purchase intentions for vaccines to reduce heart disease risk are modeled as depending on mean-centered measures of the risk reduction the vaccine provides, levels of posterior risk, and the vaccine price. The risk change and level of risk

[36] A key element of the model is treating the possible discrepancy between true and stated MWTP as a parent-specific random effect with non-zero mean that reflects systematic misstatement of willingness to pay. This feature, along with counting parents expressing an intention to purchase a vaccine as purchasers only if they also indicated they would definitely or probably make this decision if the vaccine were actually available and the random assignment of proportionate risk reductions and prices, was taken to minimize potential errors in inference arising from parental misstatement of purchase intentions.

are measured as chances in 100 and the price is measured in dollars per year. Bivariate probit estimates of equations describing parents' purchase intentions for the vaccine to reduce their own risks and the vaccine to reduce their children's risks are presented in Table 7.[37]

As shown in the second and third columns of Table 7, estimated coefficients of risk reduction are positive and significantly different from zero at the 1% level, and estimated coefficients of price are negative and significant at the 1% level, in both child and parent equations.[38] These estimates don not allow parents' MWTP for risk reduction to vary with subjective probability.[39] Gerking et al. (2017), however, present evidence from multiple functional forms indicating that parents' MWTP decreases as the level of perceived risk rises.[40] To allow MWTP to depend on the level of posterior risk, estimates presented in the fourth and fifth columns of Table 7 treat MWTP for risk reduction as a piecewise linear function of posterior risk. The specification allows effects of risk reduction and of vaccine price to depend linearly on the level of posterior risk within each tercile of the posterior risk distribution.[41]

Estimated effects of risk reduction are positive, and estimated effects of price are negative, in each tercile of the posterior risk distribution in both the parent and child equations

[37] Estimates of the correlation between disturbances in the equations for the parent and the child vaccines exceed 0.88 and are significant at the 1% level, indicating that joint estimation of the two equations with bivariate probit yields an efficiency gain over separate estimation of each equation with binomial probit.
[38] The estimated coefficient of the parent's posterior perception of her own risk is positive and significant at the 1% level, but the coefficient of the parent's posterior perception of her child's risk is not significant at conventional levels.
[39] Dividing the coefficient of risk reduction by the negative of the coefficient of vaccine price yields the MWTP to reduce risk (see Cameron and James 1987). The estimates imply that a representative parent's MWTP to reduce heart disease risk by 1 chance in 100 before age 75 years is $4.83 for her own risk and about 22% more, or $5.88, for her child's risk; these values are not significantly different in a Wald test ($p = 0.26$).In prior studies, estimates of parents' MWTP for risk reduction for one of their children is usually greater than parents' MWTP for an equal absolute risk reductions for themselves (Gerking and Dickie 2013).
[40] Diminishing MWTP with increases in baseline risk is not unexpected for health risks influenced by individual behavior. See Gerking et al. (2017) and Liu and Neilson (2006).
[41] The terciles of the uncentered distribution of posterior risk are 25 and 38 chances in 100 for the parent and 18 and 25 chances in 100 for the child.

presented in columns 4 and 5 of Table 7. The null hypothesis that risk reduction has no effect on purchase intentions is rejected at the 1% level in Wald tests for both parent ($\chi_4^2 = 121.06$) and child ($\chi_4^2 = 102.57$) equations, as is the hypothesis that price has no effect ($\chi_4^2 = 60.92$ and $\chi_4^2 = 52.34$ in parent and child equations, respectively). Interactions of risk reduction and posterior risk perception are significant at the 1% level ($\chi_3^2 = 39.58$ for parents and $\chi_3^2 = 26.08$ for children in Wald tests), but interactions of vaccine price with posterior risk perception are not significant at 10% (χ_3^2 statistics are 1.23 and 4.70 for the parent and child). Additional Wald tests reject the null hypothesis that coefficients of the interactions of risk reduction and posterior risk are equal across the three terciles, at 1% in the parent equation ($\chi_2^2 = 11.04$) and at 5% in the child equation ($\chi_2^2 = 6.54$)[42]. These estimates imply that parents' MWTP to reduce heart disease risk by 1 chance in 100 is diminishing in the level of risk.

Three implications follow when MWTP to reduce health risk depends on the level of risk perceived. First, to the extent that subjective risk assessments differ from objective risk estimates, evaluating MWTP for risk reduction using objective risk would misstate the individual's valuation, because her MWTP depends on the risk she perceives. Second, to the extent that providing information affects subjective risk assessments, learning will affect MWTP to reduce risk. Third, to the extent that subjective risk assessments are heterogeneous, MWTP to

[42] Additional specifications of equations for vaccine purchase intentions were estimated that allowed effects of risk reduction and price to depend on posterior risk linearly, as well as piecewise linearly with 2, 4, and 5 linear segments (with "knots" defined respectively at the median, quartiles and quintiles of posterior risk distributions). Results of estimating each of these specifications imply that MWTP to reduce risk declines in the level of posterior risk. The model with MWTP constant in posterior risk in columns 2 and 3 of Table 7 is rejected at the 1% in favor of the model with MWTP linear in posterior risk, as well as by each of the models with MWTP piece-wise linear in posterior risk. Additionally, the model with MWTP linear in posterior risk is rejected at the 1% level in favor of the model in columns 4 and 5 of Table 7, and at the 5% level by each of the other piecewise-linear models. The piecewise-linear models are not nested.

reduce risk will differ between persons with different perceptions of risk, even if they have the same preferences. The next subsection investigates these implications empirically.

5.2 Effects of subjective risks and information on MWTP to reduce risk

Table 8 presents estimates of parents' annual MWTP to reduce heart disease risk by 1 chance in 100, evaluated at given levels of risk.[43] Estimates are presented for parents and children overall and by gender, using the piecewise-linear specification of MWTP in Table 7.[44]

Estimates in Table 8 illustrate the misstatement of MWTP when it is evaluated using given levels of objective rather than subjective risk. The difference between MWTP evaluated using objective risk vs. mean posterior risk is significant at 10% for parents and 5% for children. Parents' MWTP to reduce their own heart disease risk is larger when evaluated using objective risk, because the objective risk estimate exceeds the mean of parents' posterior risk assessment. But the opposite is true for children when pooling over gender. Parents' MWTP to reduce their children's risk is smaller when evaluated using objective rather than mean posterior risk, because the objective risk estimate exceeds parents' mean posterior assessments of children's risk. When examining daughters separately, however, MWTP estimated using objective risk exceeds MWTP based on mean posterior risk because parents' revised risk assessments for daughters exceed the

[43] The MWTP estimates in the remainder of the paper use the jointly significant interactions of posterior risk and risk reduction by tercile, but ignore the insignificant interactions of posterior risk and price.
[44] MWTP to reduce risk differs by gender only because MWTP depends on the level of risk, which differs by gender. Wald tests detected no significant differences in MWTP parameters by gender. To test effects of parent gender on MWTP to reduce risk, an indicator for parent gender was entered in the vaccine equations for parent and child, along with interactions of parent gender and all other covariates. The hypothesis that all parameters affecting MWTP for reduced risk (coefficients of risk reduction, price and the interactions of these variables with posterior risk) are equal for mothers and fathers is not rejected in either the parent equation ($\chi_8^2 = 3.91$) or the child equation ($\chi_8^2 = 6.01$). Effects of child gender were tested similarly, except that the indicator for child gender and interactions with other covariates were entered only in the child vaccine equation. The hypothesis that parameters affecting parents' MWTP to reduce children's heart disease risk are equal for sons and daughters is not rejected ($\chi_8^2 = 5.47$).

objective risk estimate for females. The gap between MWTP based on objective and mean posterior risk is large for mothers (89%) and daughters (85%), because of the relatively large difference between objective and subjective risks for females.[45]

Comparing estimates of MWTP evaluated at the means of parents' posterior and prior risk beliefs in Table 8 illustrates how learning influences parents' willingness to pay to reduce heart disease risk. Parents are willing to pay about 20% more to reduce their own risk of heart disease by 1 chance in 100 when MWTP is evaluated at the mean of posterior risk relative to the mean of prior risk; the difference is significant at the 10% level.[46] Parents are willing to pay about 15% more at the margin to reduce risk for children after receiving information about the risk; the difference is significant at 5%. Parents are willing to pay more at the margin to reduce heart disease risk after learning about the risk because parents on average revised their perception of risk downward after receiving information, and MWTP to reduce risk is diminishing in the level of risk perceived.[47]

Table 9 presents evidence on heterogeneity in MWTP arising from heterogeneity in risk beliefs. It summarizes estimates of parents' annual MWTP to reduce heart disease risk by 1 chance in 100, computed by individual using the piecewise-linear specification of MWTP in

[45] Additionally, estimates in Table 8 illustrate how using objective rather than subjective risk assessments to estimate parents' MWTP to reduce heart disease risk leads to misstatement of gender differences in MWTP. Based on objective risk estimates, mothers appear willing to pay 39% more than fathers to reduce risk by 1 chance in 100, whereas this difference is only 22% when MWTP estimates are based on means of parents' own posterior subjective risks. Parents appear to be willing to pay twice as much at the margin to reduce risk for daughters than for sons based on objective risk estimates, but this difference is only 28% when based on means of parents' posterior risk assessments.
[46] Although the 90% confidence intervals of the two MWTP estimates overlap, the estimated difference of $1.44 has a standard error of $0.79. Each MWTP estimate is a ratio including several estimated parameters, but the difference is a ratio of only two estimated parameters because the mean prior and posterior assessments lie on the same segment of the piecewise linear MWTP function.
[47] The gap between MWTP based on posterior and prior risk assessments for children is larger for daughters (31%) than for sons (7%) because the means of posterior and prior risk assessments lie on the same segment of the piecewise linear MWTP function for sons, but on different segments for daughters.

Table 7 along with each parent's posterior assessment of her own and her child's risk. Estimates are pooled over gender because differences between males and females are small. The distributions of MWTP are widely dispersed, with coefficients of variation of 57 for parents and 44 for children. MWTP at the third quartile is over three times as large as at the first quartile for parents, and over twice as large for children. This dispersion, which is based solely on heterogeneity in subjective perceptions of risk, is larger than the dispersion Cameron and DeShazo (2013) report for MWTP to reduce risk of immediate death, which varied by as much as a factor of 3 between the 5th and 95th percentiles of the distribution.

Table 9 also reveals that the mean of individual parents' MWTP to reduce posterior assessments of heart disease risk exceeds MWTP evaluated at the mean of posterior risk by about 37% for both parents and children, reflecting the convexity of MWTP in posterior risk and the wide dispersion in posterior risk assessments.[48] For parents' own risk, the mean of MWTP lies within 5% of MWTP evaluated at a constant level of objective risk, whereas for children, mean of MWTP exceeds MWTP evaluated at objective risk by 53%.

Table 10 provides additional insight on the difference between MWTP estimates computed using objective and subjective risk estimates and on the heterogeneity of estimated MWTP to reduce heart disease risk. The table restricts attention to risk factors with objective risk estimates and thus includes only parents' MWTP to reduce their own risk. Table 10 shows three measures of MWTP for each risk factor category: MWTP evaluated at objective risk and at the mean of parents' posterior perceived risk, and the mean of MWTP evaluated at each individual parent's posterior risk perception. Results in Table 10 underline the misstatement of MWTP when it is estimated based on objective risk. For more than half of the risk factor categories,

[48] Crainich and Eeckhoudt (2017) establish theoretically that MWTP is convex in risk.

MWTP based on objective risk exceeds MWTP based on perceived risk by more than 50%, with particularly large percentage differences by smoking status and for persons without high blood pressure or high cholesterol. Although point estimates based on either objective risk or mean posterior risk reflect the heterogeneity in MWTP between risk factor categories, they fail to reveal the heterogeneity among individuals within a risk factor category. As shown, standard deviations of individual MWTP estimates range from 43% to 74% as large as means.

5.3 Policy illustration: Economic benefits of reducing heart disease risk

For a simple illustration of how accounting for information and subjective risk assessments might affect estimated economic benefits of policy, consider the “Healthy People 2020” goal in the US of reducing the death rate from coronary heart disease by 20% from its 2007 level. Suppose policies to achieve this goal aimed to reduce the overall population objective risk of coronary heart disease by 20% of 27 chances in 100, or 5.4 chances in 100.

Policy analysts rarely have access to individual-specific estimates of willingness to pay and typically estimate benefits of health risk reductions by multiplying a single estimate of the marginal value of reduced risk by the assumed risk change. This procedure is applied using MWTP estimates in Table 8, pooled over gender and inflated to 2019 USD. Employing MWTP computed from parents’ mean prior risk beliefs implies that the representative parent would be willing to pay $44.52 annually to reduce her own future heart disease risk by 5.4 chances in 100; she would be willing to pay $33.47 to reduce her child’s risk by the same amount. Being based on parents’ prior risk assessments, these values are taken to represent amounts that parents who had not received the heart disease information would be willing to pay. Assuming for purposes of illustration that these values apply to all adults and to all children, respectively, in the US

2018 population,[49] estimated annual benefits would be $13.8 billion in total ($11.3 billion for adults and $2.5 billion for children). Estimated benefits would be 19% higher ($16.4 billion) using MWTP estimates computed from parents' mean posterior risk assessments, illustrating how provision of risk information affects estimated benefits. For comparison, evaluating MWTP at the aggregate objective risk level yields $22.2 billion in estimated benefits. The benefit estimate based on objective risk overstates benefits by 62% relative to estimates based on prior subjective risks and by 36% relative to estimates based on posterior risks.

None of the benefit estimates just described fully accounts for heterogeneity in MWTP arising from individual variation in perceived risk. To retain this information, each parent's individual MWTP to reduce risk by 1 chance in 100 (i.e., the values summarized in Table 9) can be multiplied by the assumed risk reduction of 5.4 chances per 100. Inflating to 2019 USD, averaging over the sample, and scaling by the population of adults and children yields a national benefit estimate of $22.6 billion. This benefit estimate exceeds by 38% the estimate based on the mean of parents' posterior risk assessment, reflecting again the convexity of estimated MWTP in risk and the dispersion in subjective risk perceptions. Coincidentally, this benefit estimate lies within 2% of the estimate based on a constant level of objective risk.

6. Conclusion

This paper has explored the idea that if marginal valuations of health risk depend on the level of risk, estimates of marginal willingness to pay (MWTP) to reduce risk will reflect individual preferences more accurately when based on valid measures of perceived rather than objective risks. The paper investigated the construct validity of health risk perceptions and their

[49] US population figures for 2018 were obtained from the Census Bureau at https://www.census.gov/quickfacts/fact/table/US/PST045218.

effect on MWTP, by examining parents' MWTP to reduce their subjectively assessed risks of future heart disease for themselves and their children. Five main results were obtained.

First, parents' initial risk assessments are related plausibly to risk factors and contain individual-specific information not found in objective risk estimates. Second, parents' updates of their prior risks are broadly consistent with Bayesian learning. These results support the construct validity of subjective risk assessments as a basis for estimating MWTP to reduce risk.

Third, estimating MWTP for risk reduction based on objective rather than subjective risk misstates benefits, because parents' MWTP depends on the level of perceived risk, and objective risks differ from subjective perceptions of risk. The validity of MWTP measures is improved when based on valid measures of subjective risk, in cases where MWTP is a function of risk. Fourth, parents are willing to pay more at the margin to reduce heart disease risk after learning about risk because parents on average reduced their perception of risk after receiving information, and MWTP to reduce heart disease risk is diminishing in risk. Finally, heterogeneity in risk perceptions implies that MWTP differs widely between persons with different perceptions of risk, even if they have the same preferences.

These results have implications for benefit-cost analysis of policy to reduce heart disease risk. An empirical example shows that using objective risk measures could overstate benefits by 62% relative to estimates based on prior subjective risks and by 36% relative to estimates based on posterior risks.

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Table 1. Objective and Subjective Assessments of Risk of Coronary Artery Disease Diagnosis before Age 75 (chances in 100).

Objective Risks			Fathers' Risk Perception for:						Mothers' Risk Perception for:					
			Self (n=746)		Sons (n=388)		Daughters (n=358)		Self (n=1458)		Sons (n=748)		Daughters (n=710)	
Male	Female		Initial	Revised	Initial	Revised	Initial	Revised	Initial	Revised	Initial	Revised	Initial	Revised
35	19	Mean	37.42	35.40	27.76	23.75	26.51	22.11	35.24	32.69	31.14	26.40	27.67	23.47
		Std. Dev.	23.18	20.14	18.96	14.41	19.04	13.98	22.19	19.02	20.60	15.88	19.66	14.74
		Min	0	1	1	1	1	1	0	0	1	1	0	0
		25th %tile	20	21	10	15	10	13.5	20	20	10.5	15	10	15
		Median	33	30	25	20	25	20	30	28	26.5	25	25	20
		75th %tile	50	50	45	30	40	25	50	45	50	33	40	30
		Max	100	100	90	90	100	83	100	100	100	100	100	98

Table 2. Objective and Initial Subjective Risk Estimates by Risk Factor (chances in 100).

	Objective Probability Estimates			Parents' Subjective Probabilities: Initial Estimates				
					Fathers		Mothers	
					Mean	Median	Mean	Median
Current Smoker?			Current Smoker?					
	No	21		No	37	31	34	30
	Yes	28		Yes	44	33	44	50
Diagnosed with diabetes?			Diagnosed with diabetes?					
	No	23		No	37	33	35	30
	Yes	62		Yes	47	50	46	50
Blood pressure, mm Hg								
Diastolic	Systolic		Told by physician to lower blood pressure?					
< 80	< 120	18		No	34	30	33	30
>= 100	>= 160	43		Yes	46	50	44	50
or treated				Yes, on medication	42	40	47	50
Total cholesterol, mg/dL			Told by physician to lower cholesterol?					
	< 180	18		No	34	29	33	30
	>= 240	37		Yes	43	46	44	50
				Yes, on medication	44	45	48	50
Body Mass Index			Body Mass Index					
	< 25	21		BMI < 25	29	25	28	25
	25 - < 30	24		25<= BMI < 30	33	35	35	30
	>= 30	32		30<= BMI	43	49	42	40

Table 3. Initial Subjective Risks by Family History, Exercise, Diet and Health Status (chances in 100).

	Fathers		Mothers		Sons		Daughters	
	Mean	Median	Mean	Median	Mean	Median	Mean	Median
Family history of heart disease?								
No	32	25	29	25	24	20	24	20
Yes	42	40	40	40	32	30	29	25
Exercise								
At least as much as recommended	33	25	29	25	28	25	25	23
Less than recommended	42	45	40	40	35	33	34	30
Fruit & vegetable consumption								
At least as much as recommended	33	25	31	25	28	25	24	20
Less than recommended	41	40	39	35	32	30	31	25
Diet?								
Healthy	32	30	29	30	24	25	24	23
Unhealthy	42	50	40	50	32	35	29	33
Subjective Health								
Excellent	23	20	22	20	26	24	22	20
Very Good	34	30	32	27	32	30	31	25
Good	44	50	41	40	39	40	39	43
Fair or Poor	53	50	55	50	49	40	63	70

Table 4. Parents' Updates of Prior Risk Assessments.

A. Means of Initial Risk Assessment and Revision by Direction of Revision

	Parents			Children		
	Direction of Revision:			Direction of Revision:		
	Down	None	Up	Down	None	Up
Initial risk	51.03	35.71	18.66	43.56	25.38	11.35
Revision	-18.48	0	11.06	-19.31	0	9.86

B. Relative Frequencies of Direction of Revision by Initial Risk Assessment Relative to Objective Risk

	Parents				Children			
	Direction of Revision:				Direction of Revision:			
Initial risk:	Down	None	Up	Total	Down	None	Up	Total
< Objective by gender	0.013	0.171	0.147	0.330	0.049	0.286	0.156	0.491
= Objective by gender	0.002	0.005	0.001	0.008	0.007	0.007	0.001	0.015
> Objective by gender	0.241	0.353	0.068	0.662	0.260	0.215	0.018	0.494
Total	0.257	0.528	0.215	1	0.317	0.508	0.176	1
Chi-square(4)	464.48				582.02			

Table 5. Parents' Updates of Prior Risk Assessments: Ordered Probit Estimates

	Parents' Perception of Risk to:					
	Self			Child		
	100 x Effect on Probability that Revision is:			100 x Effect on Probability that Revision is:		
Information gap for:	Downward	Zero	Upward	Downward	Zero	Upward
Females	-0.024	0.004	0.020	-0.591***	0.262***	0.329***
	(0.096)	(0.015)	(0.080)	(0.085)	(0.044)	(0.050)
Males	-0.019	0.003	0.016	-0.572***	0.253***	0.318***
	(0.119)	(0.019)	(0.100)	(0.085)	(0.044)	(0.051)
Nonsmokers	0.731***	-0.118**	-0.612***	---[a]	---[a]	---[a]
	(0.189)	(0.052)	(0.161)			
Smokers	1.176***	-0.190**	-0.986***	---[a]	---[a]	---[a]
	(0.225)	(0.077)	(0.193)			
Do not have diabetes	-0.480***	0.078**	0.402***	---[a]	---[a]	---[a]
	(0.105)	(0.033)	(0.090)			
Have diabetes	-0.332***	0.054*	0.278***	---[a]	---[a]	---[a]
	(0.124)	(0.028)	(0.105)			
BMI < 25	-1.194***	0.193***	1.001***	-0.143	0.063	0.079
	(0.175)	(0.074)	(0.152)	(0.114)	(0.051)	(0.063)
25 <= BMI < 30	-0.972***	0.157**	0.815***	-0.348	0.154	0.194
	(0.170)	(0.062)	(0.147)	(0.227)	(0.101)	(0.128)
30 <= BMI	-0.830***	0.134**	0.695***	0.052	-0.023	-0.029
	(0.189)	(0.056)	(0.162)	(0.347)	(0.153)	(0.193)
Not told to lower blood pressure	-0.149**	0.024*	0.124**	---[a]	---[a]	---[a]
	(0.072)	(0.014)	(0.060)			
Told to lower blood pressure	-0.063	0.010	0.053	---[a]	---[a]	---[a]
	(0.103)	(0.017)	(0.087)			
Not told to lower cholesterol	0.024	-0.004	-0.020	---[a]	---[a]	---[a]
	(0.089)	(0.015)	(0.074)			
Told to lower cholesterol	0.036	-0.006	-0.030	---[a]	---[a]	---[a]
	(0.129)	(0.021)	(0.107)			
At least as much exercise as recommended	0.062	-0.010	-0.052	-0.419***	0.186***	0.233***
	(0.076)	(0.013)	(0.063)	(0.117)	(0.055)	(0.066)
Less than recommended exercise	-0.383**	0.062*	0.321**	-0.647***	0.287***	0.360***
	(0.156)	(0.033)	(0.132)	(0.214)	(0.098)	(0.120)
At least as much fruit/veg as recommended	-0.125	0.020	0.105	-0.022	0.010	0.012
	(0.076)	(0.014)	(0.064)	(0.129)	(0.057)	(0.071)
Less fruit/veg than recommended	-0.392**	0.063*	0.329**	-0.743***	0.330***	0.414***
	(0.163)	(0.034)	(0.138)	(0.157)	(0.076)	(0.091)
Healthy diet	-0.114	0.018	0.095	-0.149	0.066	0.083
	(0.073)	(0.013)	(0.061)	(0.122)	(0.055)	(0.068)

Unhealthy diet	0.135	-0.022	-0.113	-0.116	0.051	0.065
	(0.300)	(0.050)	0.251	(0.247)	(0.109)	(0.138)
No family history	-0.138*	0.022	0.115*	-0.039	0.017	0.022
	(0.075)	(0.014)	0.062	(0.134)	(0.059)	(0.076)
Family history	-0.334**	0.054*	0.280**	-1.152***	0.511***	0.641***
	(0.154)	(0.031)	0.130	(0.137)	(0.075)	(0.084)
Parent knows someone with heart disease	1.785	-0.234	-1.551	3.417	-1.397*	-2.020
	(1.821)	(0.209)	1.633	(2.122)	(0.803)	(1.338)
Parent has thought might get heart disease	-4.439**	0.927*	3.513***	4.203**	-1.743**	-2.461**
	(1.797)	(0.512)	1.351	(1.919)	(0.758)	(1.189)
Parent has thought child might get heart disease	---[a]	---[a]	---[a]	-2.247	0.970	1.277
				(1.904)	(0.808)	(1.110)
College graduate	4.701***	-0.686**	-4.015***	5.039***	-2.183***	-2.857***
	(1.516)	(0.340)	(1.329)	(1.774)	(0.780)	(1.031)
$60,000<= Household income <= $100,000	4.757**	-0.978**	-3.779***	4.214**	-1.963*	-2.252**
	(1.851)	(0.526)	(1.405)	(2.118)	(1.044)	(1.093)
$100,000<Household income	0.311	-0.051	-0.260	3.087	-1.418	-1.669
	(1.829)	(0.319)	(1.529)	(2.237)	(1.074)	(1.184)
Ethnicity black	-7.014***	-0.487	7.501**	-4.578	1.679*	2.899
	(2.461)	(1.015)	(3.364)	(3.342)	(0.959)	(2.396)
Ethnicity Hispanic	-2.343	0.232	2.111	-2.986	1.186	1.800
	(2.603)	(0.166)	(2.513)	(3.078)	(1.078)	(2.022)
Ethnicity other	2.395	-0.521	-1.874	2.084	-0.983	-1.101
	(2.886)	(0.789)	(2.106)	(3.361)	(1.666)	(1.668)
Parent age > 43 years	-1.568	0.245	1.323	-0.365	0.161	0.203
	(1.465)	(0.238)	(1.236)	(1.825)	(0.805)	(1.015)
Child age > 11 years	---[a]	---[a]	---[a]	-1.074	0.475	0.599
				(1.820)	(0.805)	(1.015)
Log-likelihood	-1809.786			-1749.582		
McFadden pseudo R^2	0.192			0.217		

[a] Denotes excluded variable.

***, **, * denote significance at the 1%, 5% and 10% level, respectively. Standard errors are presented in parenthesis.

Table 6. Parents' Updates of Prior Risk Assessments: Estimates of Equation (2)

	Parents		Children	
Information Gap for:	All	Nonzero revision	All	Nonzero revision
Females	-0.010	-0.003	0.151***	0.302***
	(0.029)	(0.044)	(0.030)	(0.029)
Males	-0.016	0.018	0.095***	0.277***
	(0.030)	(0.049)	(0.022)	(0.032)
Nonsmokers	-0.288***	-0.564***	---[a]	---[a]
	(0.055)	(0.102)		
Smokers	-0.475***	-0.861***	---[a]	---[a]
	(0.066)	(0.130)		
Do not have diabetes	0.180***	0.344***	---[a]	---[a]
	(0.043)	(0.092)		
Have diabetes	0.224***	0.336***	---[a]	---[a]
	(0.055)	(0.076)		
BMI < 25	0.399***	0.603***	0.206***	0.270***
	(0.054)	(0.077)	(0.051)	(0.046)
25 <= BMI < 30	0.309***	0.548***	0.072	0.174**
	(0.048)	(0.078)	(0.053)	(0.077)
30 <= BMI	0.252***	0.527***	-0.069	-0.006
	(0.050)	(0.085)	(0.062)	(0.111)
Not told to lower blood pressure	0.081***	0.158***	---[a]	---[a]
	(0.024)	(0.037)		
Told to lower blood pressure	0.053*	0.141***	---[a]	---[a]
	(0.031)	(0.046)		
Not told to lower cholesterol	-0.017	0.031	---[a]	---[a]
	(0.027)	(0.041)		
Told to lower cholesterol	0.005	0.012	---[a]	---[a]
	(0.037)	(0.056)		
At least as much exercise as recommended	0.019	0.106**	0.225***	0.244***
	(0.036)	(0.042)	(0.054)	(0.047)
Less than recommended exercise	0.073*	0.135**	0.080*	0.085
	(0.042)	(0.060)	(0.044)	(0.068)
At least as much fruit/veg as recommended	0.073**	0.100**	0.031	0.019
	(0.035)	(0.042)	(0.061)	(0.052)
Less fruit/veg than recommended	0.077*	0.068	0.080***	0.131***
	(0.042)	(0.054)	(0.030)	(0.045)
Healthy diet	0.091***	0.103**	0.180***	0.256**
	(0.032)	(0.047)	(0.055)	(0.049)
Unhealthy diet	0.205	0.441***	0.134**	0.153*
	(0.136)	(0.159)	(0.063)	(0.091)
No family history	0.086**	0.137***	0.075	0.212***

	(0.034)	(0.040)	(0.067)	(0.049)
Family history	0.0004	0.043	0.068***	0.104***
	(0.037)	(0.045)	(0.023)	(0.036)
r^2	0.365	0.694	0.470	0.745
N	2204	1040	2204	1085

[a] Denotes excluded variable.

[b] Squared correlation between fitted and observed dependent variable. There is no constant term in the model.

***, **, * denote significance at the 1%, 5% and 10% level, respectively. Heteroscedasticity-consistent standard errors are presented in parenthesis.

Table 7. Parents' MWTP for Reductions in Heart Disease Risk. Bivariate Probit Estimates.

	Relationship of MWTP for 1/100 risk reduction to posterior risk:			
	Constant		Piecewise linear	
Covariate	Parents	Children	Parents	Children
Risk reduction	.01993***	.02205***	.02801*	.04484***
	(.00228)	(.00259)	(.01584)	(.01653)
Vaccine price	-.00413***	-.00375***	-.00328**	-.00460***
	(.00054)	(.00053)	(.00156)	(.00170)
Posterior risk	.00432***	.00178		
	(.00131)	(.00195)		
Constant	-.4209***	-.3714***	-.5516***	-.4578***
	(.02824)	(.02780)	(.11979)	(.15514)
Risk reduction × Posterior risk (lowest tercile)			-.00204	-.00106
			(.00140)	(.00172)
Risk reduction × Posterior risk (middle tercile)			-.00199***	-.00359***
			(.00061)	(.00140)
Risk reduction × Posterior risk (highest tercile)			-.00024*	-.00036***
			(.00014)	(.00013)
Vaccine price × Posterior risk (lowest tercile)			.00003	-.00015
			(.00009)	(.00013)
Vaccine price × Posterior risk (middle tercile)			-.00011	-.00014
			(.00010)	(.00019)
Vaccine price × Posterior risk (highest tercile)			.00003	.00002
			(.00004)	(.00005)
Posterior risk (lowest tercile)			-.01299	-.02327
			(.01007)	(.01745)
Posterior risk (middle tercile)			.00879	-.01341
			(.00562)	(.01141)
Posterior risk (highest tercile)			.00216	.00686**
			(.00249)	(.00297)
Disturbance correlation	.8818***		.8935***	
	.1247		.1189	
Log-likelihood	-2224.7015		-2192.7693	

***, **, * denote significance at the 1%, 5% and 10% level, respectively.
Standard errors are presented in parenthesis.

Table 8. Parents' Annual MWTP for 1 chance in 100 Reductions in Risk of Future Heart Disease.

	MWTP evaluated at:		
		Mean of Subjective Risk	
Reduction in risk faced by:	Objective Risk	Posterior	Prior
Parents	\$12.65**	\$8.69**	\$7.25**
	(6.13)	(4.20)	(3.58)
Fathers	7.84**	7.60**	6.37**
	(3.83)	(3.73)	(3.24)
Mothers	17.54**	9.25**	7.70**
	(8.63)	(4.46)	(3.77)
Children	5.57**	6.29***	5.45**
	(2.22)	(2.46)	(2.16)
Sons	4.96**	5.70**	5.35**
	(1.96)	(2.27)	(2.27)
Daughters	10.27**	7.29***	5.56**
	(4.11)	(2.81)	(2.21)

***, ** denote significance at the 1% and 5% level, respectively.
Standard errors were computed by the delta method and are presented in parenthesis.

Table 9. Distribution of Individual Parents' Annual MWTP for Absolute (1 chance in 100) Reductions in Heart Disease Risk.

Percentile of Distribution of MWTP	MWTP to Reduce Risk by 1 Chance in 100 for:	
	Parent	Child
5	3.34	3.80
25	5.44	5.35
50	10.88	9.64
75	17.04	11.90
95	25.15	14.21
Mean	12.03	8.53
Standard Deviation	6.90	3.73

Table 10. Parents' Annual MWTP for 1 chance in 100 Reductions in their own Risk of Future Heart Disease.

	Point estimate (standard error) of MWTP evaluated at:		Mean (standard deviation) of MWTP evaluated at
Risk factor:	Objective Risk	Mean Posterior Risk	Individual Posterior Risk
Nonsmoker	16.41^{**}	9.32^{**}	12.33
	(7.98)	(4.49)	(6.88)
Smoker	12.10^{**}	5.69^{**}	9.36
	(5.85)	(2.91)	(6.50)
Not have diabetes	15.17^{**}	9.20^{**}	12.26
	(7.33)	(4.44)	(6.88)
Have diabetes	4.28^{**}	5.09^{**}	7.21
	(2.15)	(2.56)	(5.35)
Not told to lower BP	18.29^{**}	10.43^{**}	13.00
	(9.10)	(5.02)	(6.90)
Told to lower BP	5.66^{**}	5.68^{**}	8.97
	(2.89)	(2.90)	(5.94)
Not told to lower cholesterol	18.29^{**}	10.21^{**}	12.92
	(9.10)	(4.92)	(6.95)
Told to lower cholesterol	6.63^{**}	5.82^{*}	9.47
	(3.34)	(2.99)	(6.06)
BMI < 25	16.41^{**}	14.16^{**}	15.52
	(7.98)	(6.88)	(6.75)
25 <= BMI < 30	14.54^{**}	10.02^{**}	12.57
	(7.04)	(4.82)	(6.62)
30 <= BMI	9.67^{**}	5.80^{**}	9.43
	(4.66)	(2.98)	(6.16)

**, * denote significance at the 5% and 10% level, respectively.
Standard errors in columns 2 and 3 were computed by the delta method.