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ABSTRACT

This paper empirically discriminates between alternative household decision-making models for estimating parents' willingness to pay for health risk reductions for their children as well as for themselves. Models are tested using data pertaining to heart disease from a stated preference survey involving 432 matched pairs of parents married to one another. Analysis is based on a collective model of parental resource allocation that incorporates household production of perceived health risks and allows for differences in preferences and risk perceptions between parents. Results are consistent with Pareto efficiency within the household, which implies that (1) for a given proportionate reduction in health risk, parents are willing to pay the same amount of money at the margin to protect themselves and the child; and (2) parents' choices about proportionate health risk reductions for their children are based on household valuations, rather than their own individual valuations. Results also suggest that the marginal willingness to pay of mothers and fathers for health risk protection is sensitive to a shift in intra-household decision-making power between parents.

Key Words: household decision-making; collective household model; non-cooperative household model; unitary household model; Pareto efficiency; environmental health risks to parents and children; willingness to pay; matched sample of mothers and fathers

JEL codes: D13, D61, I12, I38, J13, Q51

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[a] Department of Resource Economics and Environmental Sociology, University of Alberta, T6G 2H1, Edmonton, Alberta, Canada,
[b] Department of Economics, University of Central Florida, P.O. Box 1400, Orlando, FL 32816-1400, United States
[c] Department of Economics and Tilburg Sustainability Center, Tilburg University, P.O. Box 90153, 5000 LE Tilburg, the Netherlands
[d] Department of Economics, University of Verona, Vicolo Campofiore 2, 37129, Verona, Italy
[e] Institute for Environmental Decisions, Professorship of Environmental Policy and Economics, ETH Zurich, Universitatstrasse 22, 8092 Zurich, Switzerland

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1. Introduction

U.S. federal policy directs executive branch agencies to assign a high priority to reducing health and safety risks to children (Clinton 1997) and to use benefit-cost analysis in assessing the efficacy of major regulatory actions. For instance, special measures have been taken to protect children's health in establishing drinking water standards and for controlling air pollutants including particulates, nitrogen dioxide, sulfur dioxide, and mercury (U.S. Environmental Protection Agency 2013). Nonetheless, monetary benefits of improved children's health can be difficult to establish for two inter-related reasons. First, children are not autonomous economic agents (Harbaugh 1999; Dockins et al. 2002), so these estimates generally are constructed from the perspective of parents.[1] Second, the parental perspective does not define a unique approach to valuing reductions in risk to children's health. Instead, different models of household decision-making not only lead to potentially different estimates of parents' willingness to pay to reduce health risk to their children but also differ in their implications for how parents can be expected to respond to policy changes. Although Evans, Poulos, and Smith (2011) test features of alternative household decision-making frameworks that are relevant for valuing health risk reductions for children, these conceptual aspects have been given little prior attention in the literature.

This paper empirically discriminates between alternative household decision-making models for estimating parents' willingness to pay for health risk reductions for their children as well as for themselves. Three prominent models are considered: the unitary model, the collective model, and the non-cooperative model. The unitary model

[1] Parents' willingness to pay for reduced risks to their children's health can be included in monetary benefits to determine the socially optimal level of risk reduction if parents are safety-focused altruists (Jones-Lee 1991), but not if their altruism takes the form of benevolence (Bergstrom 2006).

(Becker 1993) treats the household as the decision-making unit. Household decisions are Pareto efficient and are unrelated to relative parental decision-making power. An implication of Pareto efficiency is that public policies to increase protection of children from health risks may to some extent be frustrated by the offsetting behavior of parents (Dickie and Gerking 2007). Although empirical evidence from non-valuation settings (e.g., Lundberg, Pollack, and Wales 1997; Duflo 2000) is largely against the unitary model, this model serves either implicitly or explicitly as the conceptual basis for virtually all existing estimates of parents' willingness to pay to reduce risks to children's health (Gerking and Dickie 2013).

The collective model (Blundell, Chiappori, and Meghir 2005) looks within the household to examine the interaction of two utility-maximizing parents with different preferences as they allocate resources between their own consumption and a household public good such as expenditures for a child. Household decisions are Pareto efficient and depend on relative decision-making power of each parent. Just as in the unitary model, Pareto efficiency raises the possibility that parents will engage in offsetting behavior in the face of policy changes aimed at increasing their children's protection from health risks. In the collective model, Pareto efficiency also implies that the household's marginal willingness to pay for a child's risk reduction may be determined from either parent's decisions.[2]

The non-cooperative approach (e.g., Browning, Chiappori and Lechene 2010) differs from the unitary and collective models in that household decisions are not Pareto efficient. Thus, this model raises the issue that parents may provide too little protection

[2] The relationship between individual and household willingness to pay for a public good has received considerable attention in environmental economics. For a recent treatment of this topic, see Ebert (2013).

for children relative to socially efficient amounts. Non-cooperative parents make choices about expenditures for the child individually, rather than collectively. The distribution of decision-making power between parents may or may not affect household marginal willingness to pay for reduced children's health risks.

Empirical estimates used to discriminate between the three models of household decision-making make use of data from a field study of heart disease collected in 2011 from a nationally representative (US) on-line panel maintained by Knowledge Networks, Inc. (now GfK) Heart disease is the leading cause of death in the United States and has been linked to exposure to environmental pollution such as airborne particulates (Brook et al. 2004). A unique feature of the data is that they include 432 matched pairs of mothers and fathers (i.e., 864 parents) with biological children aged 6-16 years that live together in the same household. The analysis uses stated preference methods to examine parents' intentions to purchase hypothetical goods that reduce their own and their children's risk of heart disease. The approach taken has the advantage that characteristics of these goods, such as price and the extent to which health risk is reduced, are experimentally controlled so that key parameters needed to test hypotheses of interest can be estimated consistently. Special attention is paid to minimizing the potential problem that respondents may misstate their true purchase intentions.

Empirical results support four main findings. First, the null hypothesis of Pareto efficiency in intra-household health resource allocations is not rejected. In the context of the present analysis, Pareto efficiency means that: (1) for a given proportionate reduction in heart disease risk, the household is willing to pay the same amount of money at the margin to protect the mother, father, and child and (2) parents' choices about proportionate health risk reductions for their children are based on household valuations, rather than their own individual valuations. This finding is interpreted as evidence against the non-cooperative model and contrasts with earlier results of Bateman and Munro (2009) and Lindhjem and Navrud (2009). On the other hand, Pareto efficiency is consistent with both the unitary and collective models.

Second, results show no statistically significant within-household differences between the marginal willingness to pay of mothers and fathers for an absolute (rather than proportionate) heart disease risk reduction for their child. This finding reflects more than Pareto efficiency as it also requires the mother and father in each household to perceive that their child faces the same initial level of heart disease risk. Estimates indicate that annual household marginal willingness to pay to reduce the child's risk by 1 chance in 100 of being diagnosed with heart disease by the age of 75 is $7.07 (s.e. = $2.12) for mothers and $3.79 (s.e. = $1.31) for fathers. The null hypothesis of equality between the mother's and father's marginal willingness to pay for a 1 chance in 100 risk reduction for the child is not rejected (*p-value* = 0.18). Nonetheless, parents' perceptions of risk to their child for a different disease may not be in close agreement. Thus, in general, even if Pareto efficiency prevails, spouses may give different values of marginal willingness to pay to reduce the child's health risk by a given absolute amount even though both parents respond on behalf of the household.

Third, a statistically significant within-household difference is found between mothers' and fathers' marginal willingness to pay to reduce their own heart disease risk by an absolute amount. The annual marginal willingness to pay of mothers to reduce their own risk of heart disease by 1 chance in 100 prior to the age of 75 is $6.02 (s.e. =

$1.83), whereas for fathers the corresponding estimate is $1.90 (s.e. = $0.93). The null hypothesis that marginal willingness to pay of mothers for a 1 chance in 100 reduction in heart disease risk equates to that for fathers is rejected at the 5% level of significance. Additionally, consistent with results of Hammitt and Haninger (2010) and Alberini and Scasny (2011), parents' marginal willingness to pay to reduce heart disease risk by 1 chance in 100 for their children is larger than their marginal willingness to pay to reduce this risk for themselves, although these differences are not different from zero at conventional levels of significance.

Fourth, evidence presented shows that a shift in intra-household decision-making power between parents significantly affects the marginal willingness to pay for an absolute reduction in health risk of any family member. Relative parental decision-making power is measured by relative earnings of the mother. This outcome is consistent with collective model, but not with the unitary model.

The paper is organized into four additional sections. Section 2 develops the theoretical model. Section 3 describes the data. Empirical estimates are presented in Section 4. Conclusions and implications for future research on valuing health risk reductions are drawn out in Section 5.

2. Theoretical Framework

This section adapts the collective model of household decision-making by a couple with children proposed by Blundell, Chiappori and Meghir (2005) to introduce household production of perceived health risk.[3] The household production feature is

[3] The Nash-bargaining models of household resource allocation contributed by Bolin, Jacobson and Lindgren (2001) and Strand (2005) also were considered as starting points for the analysis. Bolin, Jacobson and Lindgren's model, however, assumed that parents in a household had identical preferences and Strand's model did not include children.

added to support empirical analysis using data from the field study. This section also briefly contrasts implications from the collective model with those of the unitary and non-cooperative approaches to facilitate a more complete interpretation of the empirical analysis.

2.1 Model

The model envisions a household consisting of a mother (m), a father (f), and one child (k). Because the couple has one child, decisions about fertility or resource allocation among multiple children are not considered. Parents allocate household resources during one period and exhibit safety-focused altruism toward their child. The child has neither income nor bargaining power within the household. Unlike Blundell, Chiappori, and Meghir (2005), parents' labor supply is fixed in order to focus attention on intra-household allocation of health protection resources. Each parent faces a health risk and is concerned about a health risk facing the child. Parents treat reduced risk to the child as a public good within the household. They may purchase a market good to reduce health risks to themselves and to their child, so health risk is endogenous. Each parent's purchases of the risk reducing good are assumed to be observable.

Each parent's utility (U^i) is determined by

$$U^i = U^i(C^i, R^i, R^{ki}), \qquad i = m, f. \tag{1}$$

where C^i denotes her/his consumption of private goods, R^i denotes the mother's or father's perception of her/his own health risk, and R^{ki} denotes the mother's or father's perception of health risk to the child. Because the central questions in this paper deal with resource allocation to the child, neither parent is assumed to care about her/his spouse's health risk or consumption.[4] The parent's utility is strictly increasing and strongly concave in consumption and strictly decreasing and strongly concave both in own and child health risks.

Perceived risks are home-produced in an efficient and cost-minimizing way (Chiappori 1997) according to the production functions

$$\begin{aligned} R^i &= R^i(G^i, A_i), \\ R^{ki} &= R^{ki}(G^k, A_{ki}) \quad i = m, f. \end{aligned} \tag{2}$$

In these equations, G^i and G^k represent the parent's and the child's use of a market good (G) to reduce perceived health risk, and A_i and A_{ki} represent exogenous indices of parent *i*'s attitudes and information concerning her/his health risk and the child's health risk. Parents may differ in attitudes and information A_{ki} about the child's risk and may have different perception functions for the child's risk; thus R^{km} will equal R^{kf} only as a special case. Perceived risks are diminishing and convex in the risk-reducing good and use of G is not a direct source of utility.[5]

The household budget constraint is given by

$$y_m + y_f = Y = C^m + C^f + p(G^m + G^f + G^k), \tag{3}$$

[4] A model in which each parent cares about the utility of the other yields efficiency predictions that are consistent with those developed here. This outcome occurs because the efficiency conditions tested are derived from first-order conditions. As discussed by Bergstrom (2006), marginal conditions necessary for efficiency with benevolent preferences are the same as those without caring. The model with caring, however, does not as readily support the perspective of decentralized decision-making that is adopted below for consistency with the field study.

[5] The possibility that risk reducing goods directly affect parental utility is addressed in the econometric methods discussed later.

where pooled household income Y is the sum of parental incomes y_m and y_f. The price of the private consumption good is equal to unity and p denotes the common price of risk-reducing goods for each household member.

2.2 Decentralized Parental Decision-Making and Efficiency

Assume that parents maximize the weighted sum of their utilities given by

$$U = \mu U^m(C^m, R^m, R^{km}) + (1-\mu)U^f(C^f, R^f, R^{kf}) \tag{4}$$

subject to the budget constraint, the health risk production functions, and non-negativity restrictions on all purchased goods. The Pareto weight μ, interpreted as the relative decision-making power of the mother, is bounded by zero and one. It is a function of the price of risk-reducing goods, incomes of both parents, and a set of exogenous variables (z) referred to as distribution factors that can affect bargaining power in the household without affecting preferences or the budget constraint (Browning and Chiappori, 1998).[6] The function $\mu(p, y_m, y_f, z)$ is assumed to be continuously differentiable in its arguments and homogeneous of degree zero in prices and income (Browning, Chiappori, and Weiss in press).

A Pareto efficient allocation of resources involving public goods can be sustained by decentralized decision-making given a suitable distribution of household income and efficient settings of Lindahl prices (Cornes and Sandler 1996, Donni 2009). Implications of decentralized decision-making are emphasized here because in the field study, spouses made independent decisions about whether to purchase goods to reduce their own and their children's health risks.

[6] See Browning, Chiappori, and Lechene (2006), Chiappori and Ekeland (2006) for a general discussion on the key role played by distribution factors to identify the structure underlying the collective household model.

Decentralized decision-making can be thought of as a two-stage process. In the first stage, parents agree on a sharing rule governing the distribution of household income, and on Lindahl prices specifying each parent's contribution to intra-household public expenditures for the benefit of the child's health. The income share of parent i, s_i, constrains his/her expenditures according to the individual budget constraint $s_i = C^i + pG^i + t_i p\left(g^{km} + g^{kf}\right)$, where $s_m + s_f = Y$ and g^{ki} is the contribution that each parent makes to the good that reduces health risk for the child. Lindahl shares are $t_i = g^{ki} / G^k$, where $t_m + t_f = 1$. In the second stage, each parent chooses (C^i, G^i, g^{ki}) to maximize her/his own utility

$$U^i\left[C^i, R^i(G^i, A_i), R^{ki}(g^{km} + g^{kf}, A_{ki})\right], \tag{5}$$

subject to the individual's budget constraint and non-negativity restrictions on C^i, G^i, g^{ki}. To simplify discussion, assume an interior solution.

First order conditions for a household utility maximum require that for $i = m, f$

$$\begin{aligned} \frac{\partial U^i / \partial R^i}{\partial U^i / \partial C^i} &= \frac{p}{\partial R^i / \partial G^i} \\ \frac{\partial U^i / \partial R^{ki}}{\partial U^i / \partial C^i} &= \frac{t_i p}{\partial R^{ki} / \partial G^i}. \end{aligned} \tag{6}$$

As shown, each parent's marginal willingness to pay to reduce her/his own risk by one unit is equal to the marginal cost of doing so. If the production of risk reduction exhibits declining marginal productivity of G (see equation (2)), then the marginal willingness to pay for a one unit reduction in risk increases as risk declines. Likewise, each parent's marginal willingness to pay to reduce her/his child's risk by one unit equates to the marginal cost of doing so times the parent's Lindahl share. The product of the parent's

Lindahl share t_i and p represents the parent's individualized Lindahl price. Marginal willingness to pay for a one unit reduction in the child's risk also increases as risk declines. Outcomes in equation (6) do not depend on the relative decision power of the mother (μ).

Econometrically testing the null hypothesis of Pareto efficient resource allocation is simplified by examining behavior in the face of proportionate health risk reductions, rather than absolute health risk reductions. Thus, equation (6) is re-expressed as

$$\begin{aligned} W^i &= \frac{(\partial U^i / \partial R^i)R^i}{\partial U^i / \partial C^i}\Delta^i = p \\ W^{ki} &= \frac{(\partial U^i / \partial R^{ki})R^{ki}}{\partial U^i / \partial C^i}\Delta^{ki} = t_i p \end{aligned} \tag{7}$$

where $\Delta^i = (\partial R^i / \partial G^i) / R^i$ and $\Delta^{ki} = (\partial R^{ki} / \partial G^k) / R^{ki}$ denote proportionate health risk changes. Equation (7) demonstrates that a parent's marginal willingness to pay for risk-reducing goods (W^i and W^{ki}) equals the parent's marginal willingness to pay for proportionate risk reductions $((\partial U^i / \partial R^i)R^i \big/ (\partial U^i / \partial C^i)$ and $(\partial U^i / \partial R^{ki})R^{ki} \big/ (\partial U^i / \partial C^i))$ weighted by Δ^i and Δ^{ki}.

Equation (7) implies a version of the standard Lindahl-Samuelson efficiency condition for the public good G^k

$$W^k = \sum_i W^{ki} = \sum_i \frac{(\partial U^i / \partial R^{ki})R^{ki}}{\partial U^i / \partial C^i}\Delta^{ki} = p = \frac{(\partial U^j / \partial R^{kj})R^{kj}}{t_j(\partial U^j / \partial C^j)}\Delta^{kj}, \quad j = m, f. \tag{8}$$

Pareto efficiency implies that household marginal willingness to pay for the risk-reducing good for the child (W^k), computed as the sum of parents' individual marginal willingness to pay, equates to the price of the good. Furthermore, household marginal willingness-to-pay equals the ratio of either parent's individual marginal willingness-to-pay relative to her/his Lindahl share.

Collecting results in equations (7) and (8) and considering an equal proportionate reduction in all perceived risks $(\Delta = \Delta^m = \Delta^{km} = \Delta^f = \Delta^{kf})$ implies that the parents allocate resources so that the household is willing to pay an equal amount for an equal proportionate reduction in risk for any member. This outcome, shown in equation (9), provides the basis for the econometric tests for Pareto efficiency presented in Section 4.

$$\frac{(\partial U^m / \partial R^m)R^m}{\partial U^m / \partial C^m} = \frac{(\partial U^m / \partial R^{km})R^{km}}{t_m(\partial U^m / \partial C^m)} = \frac{(\partial U^f / \partial R^f)R^f}{\partial U^f / \partial C^f} = \frac{(\partial U^f / \partial R^{kf})R^{kf}}{t_f(\partial U^f / \partial C^f)} = \frac{p}{\Delta}. \tag{9}$$

As discussed in Section 4, the Lindahl shares (t_i) cannot be identified econometrically using data from the field study, so it is not possible to determine mother's and father's individual contribution to reducing health risk for their child. Nonetheless, the parents' joint contribution to reducing their child's health risk can be identified because $t_m + t_f = 1$. As shown in equation (10), given that equation (9) is satisfied, this joint contribution equates to each parent's individual marginal willingness to pay to reduce his/her own health risk.

$$\frac{(\partial U^m / \partial R^m)R^m}{\partial U^m / \partial C^m} = \frac{(\partial U^f / \partial R^f)R^f}{\partial U^f / \partial C^f} = \frac{(\partial U^m / \partial R^{km})R^{km}}{(\partial U^m / \partial C^m)} + \frac{(\partial U^f / \partial R^{kf})R^{kf}}{(\partial U^f / \partial C^f)} = \frac{p}{\Delta}. \tag{10}$$

2.3 Effects of Redistribution of Household Resources

As previously indicated, equation (9) does not depend on the mother's decision-making power (μ) in the household. The solution values for the choice variables $(C^{*i}, G^{*i}, g^{*ki})$ in the parents' utility maximization problem, however, do depend on μ because this parameter influences the share of resources allocated to each parent. These solution values are determined according to

$C^{*i}(p, y_m, y_f, \Delta_i, \Delta_{ki}, z), G^{*i}(p, y_m, y_f, \Delta_i, \Delta_{ki}, z), g^{*ki}(p, y_m, y_f, \Delta_i, \Delta_{ki}, z)$ where the proportionate health risk changes (Δ^i and Δ^{ki}), treated in the field study as experimentally assigned characteristics of the risk reducing goods, are included as arguments.

Inferences about how the distribution of household decision power affects children often rest on examination of effects of distribution factors (z) on a measure of children's health or on the demand for children's goods. Theoretical results derived by Blundell, Chiappori and Meghir (2005) imply that an increase in the mother's relative decision power arising from a change in z will boost household consumption of the risk reducing good for the child if the mother's individual marginal willingness to pay for this good is more sensitive to shifts in decision power than is the father's. Section 4 presents tests for whether changes in distribution factors affect marginal willingness to pay to reduce children's health risk.

2.4 Other Perspectives on Efficiency and Distribution

Unitary and non-cooperative models of household behavior provide alternatives to the collective perspective on efficiency and distribution within families. As previously indicated, the unitary model treats the household as the decision-making unit and interaction between parents is ignored. In this simplified situation, the model might envision a household consisting of one parent, the mother (m) and one child (k). If each person consumes the same risk-reducing good at the same unit price, Pareto efficiency occurs if the household's (i.e., the mother's) marginal willingness to pay for an X% reduction in health risk is the same as the household's marginal willingness to pay for an

X% reduction in the child's health risk. This outcome is shown in equation (11) using similar notation to that already established for the collective model.

$$\frac{(\partial U / \partial R^m) R^m}{(\partial U / \partial C^m)} = \frac{(\partial U / \partial R^k) R^k}{(\partial U / \partial C^m)} = \frac{p}{\Delta}. \tag{11}$$

Values of marginal willingness to pay for percentage risk reductions again are equated to p / Δ, but more restrictions must be satisfied to obtain Pareto efficiency in the collective model than in the unitary model (compare equations (9) and (11)). In the unitary model, the distribution of decision-making power between parents (μ) plays no role in the analysis.

The non-cooperative model of Browning, Chiappori and Lechene (2010), on the other hand, yields an alternative to the hypothesis of efficiency. In this model, a non-cooperative equilibrium occurs when each public good (except possibly one) is exclusively provided by one parent. If parent *i* is the sole provider of the risk-reducing good for the child, then

$$\begin{aligned} &\frac{(\partial U^i / \partial R^{ki}) R^{ki}}{(\partial U^i / \partial C^i)} \Delta^{ki} = p \\ &\frac{(\partial U^j / \partial R^{kj}) R^{kj}}{(\partial U^j / \partial C^j)} \Delta^{kj} < p, \quad j \neq i. \end{aligned} \tag{12}$$

In contrast to parents in an efficient household, non-cooperative parents make choices about the risk-reducing good for the child according to their individual valuations rather than household valuations. If the non-contributing parent *j* has a positive marginal valuation of child risk reductions, then with diminishing marginal rates of substitution the household's risk protection efforts for the child fall short of the Pareto efficient amount. The efficiency conditions given in equations (8) and (9) do not apply to the non-cooperative household, implying that the household's inefficient equilibrium can be distinguished from the Pareto-efficient solution.[7]

3. Field Study and Data

The field study examined decentralized choices of goods that would reduce heart disease risks for parents and children. The study also elicited parents' perceptions of their own and their children's risks of developing heart disease and collected other information. Data were obtained from Knowledge Networks, Inc.'s national online research panel.[8] The panel is representative of the U.S. population and prior research suggests that demands for health risk reductions estimated from samples drawn from the panel are not biased by selection (Yeager et al. 2011, Cameron and DeShazo 2010). Dickie and Gerking (2011) more fully document the field study and data. The survey instrument is available in Appendix C.

Panel members were eligible to participate in the study if they 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 coronary artery disease or experienced a heart attack. 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

[7] Efficient and inefficient outcomes are not as easily distinguished, however, if non-cooperative parents jointly contribute to one public good, and if that good happens to be health risk reduction for the child. In that case, both parents buy the risk-reducing good for the child until meeting the equilibrium condition $(\partial U^i / \partial R^{ki})R^{ki} \big/ (\partial U^i / \partial C^i)\Delta^{ki} = p$ for $i = m, f$. The sum of parents' marginal valuations of the child's risk reducing good would equate to twice the price and the household's risk protection efforts for the child exceed the Pareto efficient amount. Although the resulting allocation is inefficient, it cannot be distinguished from the efficiency restriction in equation (8) without identification of the Lindahl shares.

[8] Knowledge Networks recruits panel members by probability sampling from a sample frame that covers about 97% to 99% of U.S. households and includes cell-phone-only households, households with listed and unlisted telephone numbers, non-telephone households, and households with and without Internet access. Recruited households are provided with Internet access and hardware if necessary. Panel members typically are asked to complete one survey weekly. Members receive an e-mail invitation to participate in a survey and are provided with a link to the Internet address of the survey questionnaire.

more likely than younger children to earn income and make independent consumption decisions.[9] Children under age 6 years were excluded because in focus groups (see below) conducted prior to administering the survey parents expressed difficulty assessing and valuing heart disease risk for very young children. For the 74% of parents with two or more children living at home, one child was randomly selected and designated as the sample child. Roughly half (52%) of the sample children were male and the average age of sample children was 11 years.

A total of 2554 parents living with their spouses or partners completed the survey during January – March of 2011. Among these parents, 864 observations are utilized from matched pairs of spouses living together (i.e., 432 matched pairs).[10] A key element of the sample design was to maximize the number of paired spouses in the overall sample. The second parent in each matched pair received an email invitation to participate after the first parent had completed the survey. On average, the second parent in a pair completed the survey 29 days after the first parent.[11] Empirical analysis is based on the sample of matched parents because the focus of this paper is on resource allocation within two-parent households. Each parent in a matched pair is questioned about the same child, who was a biological child of both parents.

Table 1 presents a comparison of parents in the 432 matched pairs to demographic characteristics of married parents with spouse and own children present from the Current Population Survey (CPS). Matched parents in the sample resemble married parents in the

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[9] Dauphin et al. (2011) present evidence that teenagers 16 years of age and older are decision-makers in the household.
[10] 434 matched pairs of parents are available in the data. In two of these pairs, however, one member did not provide information about willingness to pay to reduce heart disease risk.
[11] The time gap between survey completion within pairs of parents had a minimum of 6, a median of 28, and a maximum of 50 days. The second parent completed the survey within 2 weeks of the first parent in 2.5% of cases and within 6 weeks in 90% of cases.

CPS in family size, age, employment status of husband, and earnings differences between spouses. Nonetheless, mothers in the matched pairs are slightly less likely than in the CPS to be employed (65% vs. 68%) and slightly more likely to contribute less than $5000 to family income (38% vs. 35%). Whites and the college educated are over-represented among the matched parents and median earnings of men and total family income are about $10,000 higher in the sample than in the CPS.

The final version of the survey reflected information obtained from 25 parents in two focus groups and over 400 parents in two pre-tests. The introductory part of the survey provided a brief description of coronary artery disease and explained that in the survey, the terms "heart disease" and "coronary artery disease" would be used synonymously. The main body of the survey was divided into three parts to elicit parents': (1) initial perceptions of the risk to themselves and to their children of being diagnosed with coronary artery disease before the age of 75 years, (2) revised perceptions of these risks, and (3) willingness to pay to reduce coronary artery disease risk to themselves and to their children. The median parent completed the survey in 27 minutes.

3.1 Initial Risk Perceptions

Parents estimated the risk of being diagnosed with coronary artery disease before age 75 years using an interactive scale similar to that used by Dickie and Gerking (2007). The scale depicted 100 numbered squares arranged in 10 rows and 10 columns. All 100 squares initially were colored blue. Parents re-colored squares from blue to red to represent risk levels (see Figure 1). For example, a parent could use a computer mouse to indicate a risk of 36 chances in 100 by selecting the square numbered 36 in the scale, causing all the squares from 1 to 36 to turn red. Beneath the scale, the level of risk was indicated by displaying the percentage of the 100 squares that were colored red. By selecting different squares, parents could make as many changes to the scale as desired before selecting the “Continue” button to record the final answer.

Parents practiced using the risk scale before estimating the risk of getting coronary artery disease. First, they were shown four examples of scales representing risk levels of 25%, 50%, 75% and 100% and were told the relationship between these percentages and “chances in 100.” Second, parents used the risk scales to represent the chances of experiencing an automobile accident for each of two hypothetical people, Mr. A, a relatively careless driver that had 33 chances in 100 of an accident and Ms. B, a relatively safe driver that had a 1% chance of an accident. Respondents then were asked which of these two people had the lesser chance of an accident. The 11% of parents that answered incorrectly were provided with additional review of the risk scales and then correctly identified the individual with lower risk.

After completing the risk tutorial, parents answered a few questions about familiarity with coronary artery disease. Most parents indicated that they were aware of this disease; 92% said that they had heard or read about it, 75% knew someone personally that had had it, 69% had thought about the possibility that they themselves might get it, and 32% had thought about the possibility that one of their children might get it. After answering these questions, parents used the risk scale to estimate chances of getting coronary artery disease before age 75, first for themselves and then for the sample child.

Parents’ initial assessments of heart disease risks are summarized in Table 2 for mothers, fathers and their children. Five features of these subjective risk perceptions are of interest. First, there is considerable variation in risk assessments, with standard deviations that are about 60% to 75% as large as corresponding means. Second, the average mother indicated that she had 35 chances in 100, and the average father indicated that he had 37 chances in 100, of getting coronary artery disease. The average mother appears to have overestimated her risk, whereas the average father's assessment is relatively close to epidemiological estimates of this risk. Average assessments of children's risks also closely match epidemiological estimates.[12] Third, mean risk assessments suggest that parents may recognize that risks are higher for men than for women. The null hypothesis that mean risk assessments are equal between mothers and fathers would be rejected at the 6% level in a matched samples test.

Fourth, parents believe that their own risk of heart disease exceeds the risk faced by their children. The null hypothesis that mean risk assessments are equal for mothers and their children is rejected at the 1% level in a matched samples test. Likewise the null hypothesis that mean risk assessments are equal for fathers and their children is rejected at 1% in a matched samples test. Finally, mothers and fathers broadly agree on the risks faced by their children. The null hypothesis that mothers and fathers make identical risk assessments for their children is not rejected in a matched samples t-test (*p-value* = 0.32).

3.2 Revised Risk Assessments

After making initial estimates of coronary artery disease risk, parents had the opportunity to revise their estimates after receiving information about the disease. In this section of the survey, parents were first told that the average person has about 27 chances in 100 of being diagnosed with coronary artery disease before age 75. This average risk was illustrated using a risk scale showing the 27% risk level next to the risk scales that

[12] Based on data from the Framingham Heart Study (Lloyd-Jones et al. 1999), the average U. S. person faces a 27% risk of diagnosis with coronary artery disease before age 75. For females, this risk is 19% and for males it is 35%.

parents had marked for themselves and their children, as shown in Figure 2. Parents then were told that they and their children would probably not have the same risk as the average person, because chances of getting heart disease depend on six risk factors that are different for everyone: gender, smoking, current health status, family history, exercise, and diet. The survey elicited information from parents about each of these risk factors while also providing information about how the factors influence risk. For example, parents' smoking status was assessed and respondents were advised that coronary artery disease risks are higher for the average smoker than for the average non-smoker. Risk levels for smokers and non-smokers were illustrated using risk scales.

After reviewing information on coronary artery disease risk factors, parents were given the opportunity to revise their initial risk estimates. Parents were shown their initial assessments as previously marked on the risk scales and were permitted to revise their assessments if desired. Revised risk assessments are shown in Table 2. Parents revised their own risk assessments about as frequently as they revised their assessments of their children's risk. About 40% of fathers and 45% of mothers made revisions. Downward revisions predominated, with parents on average reducing their own risk assessment by two to three percentage points and reducing their assessment for their children by about four percentage points. In separate matched samples tests, each of the hypotheses that (1) mean revised assessments are equal for mothers and their children and (2) mean revised assessments are equal for fathers and their children is rejected at the 1% level.

Similar to the outcome when considering initial risk assessments, the null hypothesis that mothers and fathers made identical revised assessments of their children's risk of heart disease is not rejected in a matched samples t-test (*p-value* = 0.17). These results indicate that the average pair of parents shares a common perception of the level of risk faced by their child. As Table 3 indicates, about 13% of mother/father pairs made identical revised risk perception estimates, about 27% of these pairs made revised risk perception estimates that differed by three percentage points or less, and about 57% of mother/father pairs made revised risk perception estimates that differed by nine percentage points or less.

3.3 Willingness to Pay

The final section of the survey elicited willingness to pay to reduce risk of coronary artery disease. Parents first were told that chest pain, shortness of breath, activity limits, and the need for more medical treatment and medication commonly followed a diagnosis of coronary artery disease. Then, to describe the timing of heart disease risks, the survey employed a graphical illustration of risk for all ages between the present and age 75. The illustration (see Figure 3) used a Gompertz hazard function to approximate the empirical (Kaplan-Meier) hazards estimated by Lloyd-Jones et al. (2006). Hazard functions showed the cumulative risk of contracting heart disease at any age from the present until age 75. These functions were constructed based on each parent's revised risk assessments, so that at age 75 the cumulative hazard shown on the graph was equal to the parent's revised risk estimate. When the respondent used the mouse to indicate a point on the hazard function above a given age, a text box appeared on the screen stating the risk of heart disease between the present and the selected age. Cumulative hazard graphs were displayed for the parent and then for the child.

To value reductions in heart disease risks, parents were told that they would be asked about their purchase intentions for each of two vaccines. One of the hypothetical vaccines reduced risk for the parent and the other reduced risk for the child. The two vaccines were presented one at a time in random order. Parents were told that the vaccines would slow the build-up of fatty deposits in the arteries, would be taken by injection annually, and would provide additional protection from coronary artery disease beyond the benefits that could be obtained from eating right and getting enough exercise. As the vaccines were described, their effectiveness was varied at random. Parents were assigned risk reductions of either 10% or 70% of their revised risk assessment, and children were assigned risk reductions of either 20% or 80%.[13] Each parent in a matched pair was assigned the same percentage risk reduction for the child, which always was larger than that assigned to either parent. Parents were told that risk reductions would be larger for children because the vaccination program produced greater benefits if it was initiated earlier in life. Each parent was asked to read the description of each vaccine and then was shown the previously marked risk scales for herself or for her child, which now indicated the risk reduction offered by the vaccine and the amount of risk remaining if the vaccine was purchased. Parents also were shown how the vaccine would shift the hazard function to reflect lower heart disease risks over time.

For the vaccine to reduce the child's risk, parents were asked, "Would you be willing to pay $p to put your child in the heart disease vaccination program for the first year?" The value of $p was randomly chosen from the five values $10, $20, $40, $80, $160. These values of p were selected on the basis of focus group input and pretest

[13] Percentage rather than absolute risk reductions were assigned to facilitate testing for Pareto efficiency in health resource allocation. See Section 2, equation (7) and accompanying discussion.

results so as to expect the field study to yield at least some positive intentions to purchase at each combination of price and risk change offered. Each parent in a matched pair was assigned the same price. Before asking for their purchase intentions, parents were: (1) told that they would have to pay this price with their own money, (2) reminded that putting the child in the vaccination program would mean that they would have less money to pay for other household members to participate as well as to buy other things, and (3) advised that the full prevention benefit of the vaccine would occur only if the child continued to participate in the program in future years. Parents that indicated that they were willing to pay $p were asked a follow-up question about the certainty of their intention to purchase: "You said that you would pay $p for your child to be in the heart disease prevention program for the first year. If the program was actually available, how certain are you that you would really do this?" Three answer options allowed respondents to indicate whether they were uncertain, or would probably or definitely pay. A parallel procedure was used to elicit purchase intentions for the vaccine to reduce the parent's risk. The prices of the vaccines presented to mothers and fathers for their own vaccine and for their child's vaccine were the same for each household: prices therefore varied only across households.

Parents' purchase intentions for vaccines to reduce heart disease risks are summarized in Table 4. A majority of parents declined to purchase vaccines. Among those that said they would purchase the vaccine, about 12 percent indicated on follow-up that they were uncertain about their purchase intentions. Blumenschein et al. (2008) and others (Blumenschein et al. 1998, 2001; Champ and Bishop 2001; Champ et al. 1997) have shown that hypothetical bias (misstatement of purchase intentions when actual payment is not made) can be reduced by treating those that indicate uncertainty about purchase intentions as non-purchasers. Thus, only parents that said that they were willing to pay for a vaccine and that said that they "probably" or "definitely" would pay for it are treated as stating positive purchase intentions.[14]

Table 5 presents the proportion of parents that "probably" or "definitely" would purchase a vaccine by price and by size of proportionate risk change. As shown, parents were more likely to say that they would purchase vaccines that offered larger risk reductions or that had lower prices. A positive fraction of respondents stated an intention to purchase both the parent and child vaccine at all combinations of risk change and price.

3.4 Other Variables: Distribution Factors

Distribution factors are measured in two ways: (1) the mother's relative contribution to total family earnings and (2) hypothetical unexpected changes in parents' income or expenses. Spouses' total incomes, relative incomes or relative wages have been posited as determinants of spousal decision-making power in prior empirical work (e.g., Cherchye, DeRock and Vermuelen 2012). In the present study, pre-tax earnings data were collected from each parent using 17 categories and then coded as category mid-points. The mother's relative earnings share was computed as the ratio of her earnings to total household earnings.[15] In this subsample, the mean of total earnings of the mother and the father is $94,728 and the mean relative earnings share of mothers is 0.31.

[14] Alternative treatments of parents' purchase intentions are examined in the empirical analysis of Section 4.

[15] Data on total household income also were collected from each parent in the field study however reports of this variable by the father and mother conflicted in 44% of cases. Because data on this variable were collected by asking respondents to tick a box denoting the correct income category, some discrepancies between the reports by mothers and fathers might be expected. Nonetheless, the sum of mother's and father's earnings exceeded the father's report of total household income in 44% of households and

Sensitivity of an expressed intention to purchase the vaccine to reduced relative contribution to the household budget was assessed by examining whether the parent would change this decision in the face of an unexpected personal expense (such as for a medical procedure or for money lost on an investment for which parent was personally responsible) coupled with an unexpected income increase for the spouse. The opposite scenario was used to assess sensitivity of the decision to decline the purchase of the vaccine: The parent was asked whether the decision would be reversed if she received an unexpected income increase and her spouse experienced an unexpected expense. In both cases, the magnitude of the unexpected expense was randomized to be either 2% or 10% of gross (pre-tax) household income from all sources and the unexpected income increase was randomized to be either half of the unexpected expense or 1.5 times the expected expense. Thus, each parent was presented with a change in both relative contribution to household income as well as a change in total household income.[16]

4. Econometric Methods and Results

exceeded the mother's report of total household income in 51% of households. In light of these issues, data on labor earnings were used exclusively in the analysis.

[16]For example, the changes in expenditure and income were described as follows to parents that initially expressed an intention to purchase the vaccine for the child. "Suppose that you personally had a new expense. For example, suppose that you felt obligated to give financial help to a relative on your side of the family, or that you had an expensive medical procedure, or that you lost money on an investment that you personally had made. Suppose that the total cost to you is $X per year, for the next year." The value of $X was randomly assigned as either 2% or 10% of gross family income. "At the same time, suppose that your (spouse/partner) unexpectedly received an additional $Y of income per year for the next year." The value of $Y was randomly assigned as either 50% smaller or 50% larger than $X. Parents then were asked, "If you had extra expense of $X per year and your spouse (partner) had extra income of $Y per year, for the next year, would you be willing to pay $p for your child to enroll in the prevention program for the first year?" A similar procedure was used for parents that initially declined the vaccine for the child, except that the spouse was assigned the increase in expense and the responding parent was assigned the increase in income.

This section uses the data described in Section 3 to test hypotheses developed in Section 2.[17] Subsection 4.1 describes results from a non-parametric test for Pareto efficiency in allocation of household health resources. Subsection 4.2 describes methods applied in a parametric test for Pareto efficiency, and subsection 4.3 describes the test outcome.

4.1 Non-Parametric Test for Pareto Efficiency

In the field study, a matched pair of parents that behaved efficiently would agree on whether to purchase the vaccine for the child because both parents received the same description of the vaccine (same percentage risk reduction and same price) and this decision is made based on household rather than individual valuations of risk reductions for the child (see equation (8)). In a non-cooperative household, however, parents make decisions based on individual rather than on household valuations of risk reductions for the child (see equation (12)), and one parent may be the sole provider of the child's vaccine.

These observations motivate the cross-tabulation shown in Table 6 of matched parents' stated purchase intentions for the vaccine that reduces heart disease risk for their child. In 74% of pairs, spouses state the same purchase intentions despite the mixture of yes/no responses reported in Table 5 at each combination of price and risk change.[18] Additionally, a McNemar test (see Agresti 2002) can be used to test the null hypothesis that, for a given pair of spouses, the probability that the mother will indicate an intention to purchase the vaccine equates to the probability that the father will indicate an intention

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[17] Bonke and Browning (2011) present survey evidence on household expenditures for goods for children but do not estimate willingness to pay or test for Pareto efficiency.

[18] The extent of expected or intended agreement may be higher than actual agreement reflected in Table 6. After stating their purchase intentions for the child's vaccine, parents were asked whether they thought that their spouse would agree with their decision. About 95% of parents expected their spouses to agree.

to buy it. The McNemar test statistic, which can be computed using information shown in Table 6, is a chi-square with one degree of freedom under the null hypothesis and takes a value of 0.143 (*p-value* = 0.71). Thus, the null hypothesis is not rejected at conventional significance levels, an outcome that is consistent with efficiency in the collective model, but not with the inefficient outcome of the non-cooperative model.

4.2 Parametric Tests for Pareto efficiency: Econometric Procedures

Parametric tests for Pareto efficiency apply the model developed in Section 2 to econometrically estimate determinants of parents' stated intentions (i.e., their solution values) to purchase the hypothetical vaccine for themselves and for their children. To derive the equations to be estimated, the first order conditions in equation (7), which are expressed in terms of proportionate risk reductions, are rewritten in more compact notation as:

$$\begin{aligned} W^{i} - p &= \gamma^{i}\Delta^{i} - p \\ W^{ki} - t_i p &= \gamma^{ki}\Delta^{ki} - t_i p, \qquad i = m, f. \end{aligned} \tag{13}$$

Equation (13) applies to the *i*th parent in the *h*th household, but the household observation index (*h*) is suppressed to economize on notation. The variables p, Δ^{i}, and Δ^{ki} respectively represent the vaccine price and the percentage-point risk reductions that were randomly assigned to the parent and to the child in the field study. Price is measured in dollars per year and the risk change variables were coded 10 and 70 for the parent (Δ^{i}) and 20 and 80 for the child (Δ^{ki}) and then mean-centered. The parameters γ^{i} and γ^{ki} are interpreted as the annual marginal willingness to pay of parent *i* for one percentage-point reductions in heart disease risk for the parent (γ^{i}) and for the child (γ^{ki}

). W^i and W^{ki} denote the true (unobserved) annual willingness to pay of parent *i* (*i* = *m*, *f*) for vaccines to reduce heart disease risk, and t_i represents the *i*th parent's Lindahl share of child vaccine expenditures. Equation (13) allows for differences in marginal willingness to pay by parents in the same household and ensures that marginal willingness to pay for vaccines is proportional to marginal willingness to pay for risk reductions as in equation (7) (see also Hammitt and Graham 1999).

Estimates of γ^i and γ^{ki} are based on stated willingness to pay for vaccines $(\tilde{W}^i$ and $\tilde{W}^{ki})$ rather than on the true values of willingness to pay (W^i and W^{ki}). Stated willingness to pay is latent: Parents only were asked whether they would be willing to pay a randomly assigned price. To account for these features, the discrepancy between true willingness to pay and stated willingness to pay is modeled as a sum of parent-specific effects as shown in equation (14)

$$\begin{aligned} \tilde{W}^i - p &= \gamma^i \Delta^i - p + \omega_i \\ \tilde{W}^{ki} - t_i p &= \gamma^{ki} \Delta^{ki} - t_i p + \omega_{ki}, \qquad i = m, f. \end{aligned} \tag{14}$$

where the random disturbances $\omega_i = \eta_i + \upsilon_i$ and $\omega_{ki} = \eta_{ki} + \upsilon_{ki}$ capture effects of household characteristics and unobserved heterogeneity (η_i, η_{ki}) on willingness to pay for vaccines as well as differences between stated and true willingness to pay for vaccines ($\upsilon_i = \tilde{W}^i - W^i, \upsilon_{ki} = \tilde{W}^{ki} - W^{ki}$).

The disturbances ω_i, ω_{ki} are distributed independently of Δ^i, Δ^{ki}, and p, because the risk reductions and vaccine prices are randomly assigned experimental treatments. Thus, $E\left(\omega^i \mid \Delta^i, \Delta^{ki}, p\right) = \alpha^i$ and $E\left(\omega^{ki} \mid \Delta^i, \Delta^{ki}, p\right) = \alpha^{ki}$. The constants α^i and α^{ki} may not equal zero in part because of nonzero mean differences between stated and actual willingness to pay for the vaccines. Therefore, let $\sigma_i \varepsilon_i = \omega_i - \alpha^i$ and $\sigma_{ki} \varepsilon_{ki} = \omega_{ki} - \alpha^{ki}$ and re-express equation (14) as

$$\begin{aligned} \tilde{W}^i - p &= \alpha^i + \gamma^i \Delta^i - p + \sigma_i \varepsilon_i \\ \tilde{W}^{ki} - t_i p &= \alpha^{ki} + \gamma^{ki} \Delta^{ki} - t_i p + \sigma_{ki} \varepsilon_{ki}, \qquad i = m, f, \end{aligned} \tag{15}$$

where ε_i and ε_{ki} are assumed to be jointly normally distributed with zero means, unit variances, and correlation coefficient ρ_ε, and where σ_i^2 and σ_{ki}^2 represent the variance of stated willingness to pay for the vaccine for the parent and the child, respectively.

A parent is assumed to state an intention to purchase a vaccine for herself/himself if $\tilde{W}^i \geq p$ and for the child if $\tilde{W}^{ki} \geq t_i p$. Thus, in the case where the parent indicates a willingness to purchase a vaccine,

$$\begin{aligned} \varepsilon_i &\leq (\alpha^i / \sigma_i) + (\gamma^i / \sigma_i) \Delta^i - (1/\sigma_i) p \\ \varepsilon_{ki} &\leq (\alpha^{ki} / \sigma_{ki}) + (\gamma^{ki} / \sigma_{ki}) \Delta^{ki} - (t_i / \sigma_{ki}) p. \end{aligned} \tag{16}$$

To estimate the two equations in (16), data are structured as a panel of 432 households with two observations on each equation, one for the mother and one for the father. Coefficient estimates are obtained using bivariate probit with random effects (see Greene 2012, pp. 738-746). This approach is consistent with previous assumptions about ε_i and ε_{ki} (jointly normally distributed with a possible non-zero correlation) and allows for inclusion of a random "household effect" in each equation (u and u_k). In addition to a constant term, each equation includes covariates for the percentage risk reduction offered (Δ^i and Δ^{ki}) and the annual cost of the vaccine (p). Differences in estimated coefficients between spouses are allowed by including interactions of risk change and price variables with indicators of whether the mother or father made the intended purchase decision. Other covariates such as measures of distribution factors, are initially excluded from equations estimated but are brought into the analysis later.

The econometric design has six important features. First, it links members of the same household together and takes advantage of the fact that both parents in a given household provided responses on behalf of the same child. Second, the coefficient of vaccine price in the parent equation (see equation (16)) equals $-1/\sigma_i$. This value can be used to recover the parent's marginal willingness to pay to reduce her/his risk (γ^i) from the normalized coefficient γ^i/σ_i (see Cameron and James 1987).[19]

Third, in the equation for the child, the parents' Lindahl shares (t_i) cannot be identified. This means that the individualized contributions of mothers and fathers to (the public good) risk reduction for the child cannot be estimated. Nonetheless, the coefficient of price equals $-t_i/\sigma_{ki}$ which can be used to recover an estimate of household marginal willingness to pay for a one percentage point risk reduction for the child (γ^{ki}/t_i) from each parent. The conceptual model in Section 2 predicts that $(\gamma^{km}/t_m) = (\gamma^{kf}/t_f)$ (see equation (9), so the inability to identify (t_i) poses no difficulties for testing the hypothesis of Pareto efficiency.

Fourth, methods applied facilitate testing the validity of equation (9) regarding efficiency in household allocations of health resources. Appropriate econometric tests can be devised simply by testing coefficient equality constraints within and between the

[19] If the risk reducing goods are direct sources of utility, a possibility suggested earlier, the correct cost value to use in equation (15) would be the randomly assigned cost variable presented to respondents net of monetized utility/disutility $(p^* = p + \delta)$. The term $-(1/\sigma)\delta$ that would be added to equation (16) can be treated as an additional component of the error already present in this equation. This term will affect the estimate of the constant term if it has a non-zero mean, but will not affect the point estimates of the coefficients of price and parent/child risk reduction because these variables were randomly assigned.

two equations.[20] Also, to test the validity of equation (9), it is unnecessary to include covariates in these equations to account for other factors that may influence the purchase decision (e.g., parent characteristics and distribution factors) because risk changes and vaccine prices are randomly assigned.[21]

Fifth, the potential for errors in inferences arising from parental misstatement of purchase intentions is minimized in three ways. (1) As discussed previously, parents expressing an intention to purchase are treated as purchasers only if they also indicated that they would definitely or probably make this decision if the vaccine was actually available. (2) Inferences focus on marginal willingness to pay for heart disease risk reductions. Prior research indicates that stated and revealed preference methods yield similar estimates of marginal (as opposed to total) willingness to pay particularly for private goods (e.g. Lusk and Schroeder 2004; Taylor et al. 2010). (3) The econometric treatment of the possible discrepancy between stated and true marginal willingness to pay implies that any systematic tendency for respondents to misstate willingness to pay is confined to the constant terms which play no role in estimation of marginal willingness to pay for reduced risk or in tests for Pareto efficiency.[22] In light of these features and randomization of prices and risk changes, the parameters γ^i and γ^{ki} / t_i can be consistently estimated from equation (15) provided that the functional form is correct.

[20] Bergstrom et al. (1988) present an alternative approach for using stated preference data to test efficiency of local (as opposed to intra-household) public goods provision.

[21] Neither is it necessary to include variables for the child risk changes in the parent equation or the parent risk change in the child equation.

[22] Thus, in the specification applied (see equation (15)), the experimentally assigned risk changes and prices are assumed to be unrelated to the difference between true and stated willingness to pay. Another perspective on this specification is that it formalizes the Carson and Groves (2007) theoretical result and empirical findings in Taylor, Morrison and Boyle (2010) and Lusk and Schroeder (2004) that for private goods, the difference between true and stated responses, or actual and hypothetical responses, is captured in the intercept of the willingness to pay model and that marginal willingness to pay estimates are accurate (see Carson and Groves 2011). See also Vossler et al (2012) for a discussion of this issue and conditions under which it appears to hold for public goods.

Sixth, effects of a shift in household decision power between mothers and fathers can be analyzed by including measures of distribution factors in equation (15). Econometric issues involved in this aspect of the analysis are discussed in subsection 4.4.

4.3 Parametric Tests for Pareto Efficiency

Columns 2 and 3 of Table 7 present estimates of normalized coefficients (e.g., γ^i / σ_i) in the intended purchase equations for parent and child vaccines.[23] Brief descriptions of covariates in each equation are listed in column 1. For instance, the first covariate in the child equation refers to the percentage risk reduction offered by the child's hypothetical vaccine interacted with a dummy variable indicating that the responding parent was the mother. In the parent equation, this covariate refers to the percentage risk reduction offered by the parent's vaccine interacted with the dummy variable for the mother. Other covariates listed in column 1 are interpreted similarly.

Estimates were obtained by bivariate probit with random effects. Binomial probit estimates and bivariate probit estimates without random effects also were obtained for the two equations shown.[24] Binomial probit imposes the restriction of zero correlation between the disturbance terms (ε_i and ε_{ki}) in the equations (i.e., $\rho_\varepsilon = 0$), whereas bivariate probit without random effects allows this error correlation to differ from zero. Based on estimates using each of these two methods, the null hypothesis $H_o : \rho_\varepsilon = 0$ is

[23] Preliminary estimates of the Table 7 equations also controlled for the randomized order of presentation of vaccines (child first or parent first), but no significant effects of order were found. Using a likelihood ratio test to compare equations estimated in the columns (2) and (3) of Table 7 to those that controlled for order, the null hypothesis that constant terms do not shift with order for either the mother or the father is not rejected based on the Chi-square statistic of 6.84 with four degrees of freedom. The hypothesis that no parameters differ by order is not rejected based on the Chi-square statistic of 12.74 with 16 degrees of freedom.

[24] Binomial probit estimates and bivariate probit estimates without random effects are not presented here in order to economize on space but are available from the authors on request.

rejected at significance levels less than 1% under a likelihood ratio test.[25] As shown, the estimate of ρ_ε based on bivariate probit with random effects is 0.78.

Bivariate probit with random effects allows not only for non-zero correlation between ε_i and ε_{ki}, but also introduces an error component into each equation (u and u_k) to account for unobserved heterogeneity between households. A test of the null hypothesis that unobserved household effects are unimportant can be obtained from bivariate probit estimates with and without random effects. This hypothesis is rejected at significance levels less than 1% under a likelihood ratio test.[26] The estimated correlation between the random household components, denoted as ρ_u, is 0.9998.

Columns 2 and 3 of Table 7 show that at the 1% level of significance, parents were more likely to purchase a vaccine for themselves and for their child when it produced a larger risk reduction or was offered at a lower price. In the child equation, the identity of the respondent parent (mother or father) was not a significant determinant of the purchase decision but in the parent equation, fathers stated an intention to purchase the vaccine more often than mothers at the 1% level.

Coefficient estimates of the proportionate risk reduction variables are more easily interpreted by obtaining estimates of un-normalized coefficients (γ^i and γ^{ki} / t_i). Point estimates of these coefficients are computed by multiplying the normalized coefficients by estimates of σ_i for parents and σ_{ki} for children. This calculation suggests that mothers and fathers are willing to make annual payments of \$2.27 and \$1.06, respectively, to

[25] The resulting Chi-Square statistic, with one degree of freedom, is 463.19.

[26] Bivariate probit with random effects estimates allow the family effects to be correlated across equations and to have different variances. Thus, the resulting test statistic of 100.53 is Chi-Square with three degrees of freedom.

reduce their own heart disease risk by one percentage point.[27] Parents' estimates of household annual marginal willingness to pay to reduce their child's risk by one percentage point by age 75 are $2.15 for mothers and $1.43 for fathers.

The un-normalized estimates can also be used to test the null hypothesis of Pareto efficiency in the collective model. The null hypothesis, which can be stated as $H_o: \gamma^{km}/t_m - \gamma^m = 0,\ \ \gamma^{km}/t_f - \gamma^f = 0, \gamma^{km}/t_m - \gamma^{kf}/t_f = 0$ (see equation (9)), imposes more restrictions than would be (or could be) imposed in a corresponding test of Pareto efficiency based on the unitary model with one observation per household. A Wald test of H_o can be carried out by constructing a quadratic form involving a vector of the three estimated differences and their covariance matrix. The resulting test results in a chi-square statistic of 3.25 with three degrees of freedom. The null hypothesis of Pareto efficiency is therefore not rejected at conventional significance levels (*p-value* = 0.36). This outcome is consistent with the view that mothers and fathers: (1) are willing to pay the same amount of money at the margin for a given percentage point reduction in heart disease risk for themselves and for their children and (2) in contrast to prior results (Bateman and Munro 2009; Lindhjem and Navrud 2009), provide their household's marginal willingness to pay to reduce risk to their child.

4.4 Estimates of Marginal Willingness to Pay to Reduce Risk by 1 Chance in 100

Columns 4 and 5 of Table 7 present bivariate probit with random effects estimates of marginal willingness to pay for heart disease risk reduction by 1 chance in 100.

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[27] All marginal willingness to pay estimates are significantly different from zero at 1% based on standard errors estimated by the delta method.

Estimates are computed with the restriction that $\rho_u = 1.0$.[28] Whereas the estimates of marginal willingness to pay for proportionate risk reductions are useful in testing for Pareto efficiency, estimates of marginal willingness to pay for 1 chance in 100 risk reductions facilitate between group (e.g., parents vs. children) comparisons because the amount of risk reduction is held constant.

Equations estimated are specified similarly to those presented in columns 2 and 3, except that: (1) randomly assigned proportionate risk change variables are interacted with revised perception of heart disease risk (see Section 3) and (2) linear terms measuring revised estimates of heart disease risk are included as covariates. Interactions between percentage risk reduction and revised risk perception measure the number of chances in 100 by which the vaccine would reduce heart disease risk for each parent and child. Coefficients of these covariates are interpreted as estimates of household marginal willingness to pay to reduce heart disease risk by 1 chance in 100, normalized by σ_i in the case of parents and σ_{ki} in the case of children. These coefficients are consistently estimated given that the randomly assigned percentage reductions in heart disease risk are exogenous (see Appendices A and B). Results indicate that: (1) coefficients of absolute risk reduction are positive and differ significantly from zero at the 5% level or less, (2) coefficients of price are negative and differ significantly from zero at less than 1% and (3) coefficients of the linear terms in perceived risk do not differ from zero at conventional levels, indicating that vaccine purchases are insensitive to changes in the level of heart disease risk perceptions. Perceived risk, however, is endogenously

[28] Recall that the estimate of the correlation in the regressions in columns 2 and 3 of Table 7 is 0.9998.

determined in the Section 2 model; thus coefficients of the linear terms in perceived risk may not be consistently estimated.

Un-normalized values of household marginal willingness to pay for 1 in 100 risk reductions can be obtained by multiplying coefficients of the absolute risk reduction variables by estimates of σ_i or σ_{ki} as appropriate. These calculations imply that annual values of marginal willingness to pay of mothers and fathers to reduce heart disease risk by 1 chance in 100 by age 75 for their children are \$7.07 (s.e. = \$2.12) and \$3.79 (s.e. = \$1.31), respectively.[29] This outcome illustrates that a mother and father in a Pareto efficient household may provide different marginal willingness to pay values to reduce a health risk to their child by a given absolute amount. This possible difference may emerge because a mother and father hold different perceptions of risk faced by their child and, as indicated in Section 2, the marginal cost of reducing perceived risk by one unit increases as this risk declines. In the case of heart disease, however, a Wald test does not reject the null hypothesis that the marginal willingness to pay of mothers equates to the corresponding value for fathers (*p-value* = 0.18). This outcome might be anticipated because, as indicated in Section 3.2, the average pair of parents shares a common perception of risk faced by their child.

The annual marginal willingness to pay values of mothers and fathers to reduce their own heart disease risk by 1 chance in 100 by age 75 are \$6.02 (s.e. = \$1.83) and \$1.90 (s.e. = \$0.93), respectively. This outcome illustrates that parents in a Pareto efficient household may have different marginal willingness to pay values for reducing a health risk by a given absolute amount if they hold different perceptions of illness risk.

[29] Standard errors are computed using the delta method.

The null hypothesis that mothers and fathers are willing to pay equal amounts for a 1 chance in 100 reduction heart disease risk is rejected at 5% using a Wald test, but not rejected at 1% (*p-value* = 0.04). Additionally, mothers and fathers are willing to pay more at the margin to reduce their child's risk by 1 chance in 100 than to reduce their own risk by 1 chance in 100. These results are broadly consistent with recent findings by Hammitt and Haninger (2010) and Alberini and Scasny (2011), however null hypotheses that the marginal willingness to pay of mothers and fathers to reduce their own heart disease risk by 1 chance in 100 equates to their marginal willingness to pay to reduce heart disease risk to their child by 1 chance in 100 are not rejected at conventional significance levels.

The regressions in Table 8 investigate whether parents' marginal willingness to pay to reduce heart disease risk by 1 chance in 100 are sensitive to the mother's relative share of total household earnings (defined as the sum of the mother's and father's earnings).[30] As previously indicated, the collective model allows for the possibility that household choices are altered in the face of changes in sources of income, whereas in the unitary model household choices are independent of income sources. Bivariate probit with random effects estimates are obtained by expanding the specification used in columns 4 and 5 of Table 7 to include interactions between variables measuring 1 chance in 100 risk reductions and the mother's relative share of total household earnings. Interactions between the absolute risk reduction variables and total household earnings as well as linear terms measuring total household earnings and the mother's relative share also are included as controls. Estimates presented were obtained with the restriction that

[30] The mother's wage relative to the father's wage might be a better variable as it would remove the influence of hours of work. The field study, however, did not collect information on wages or on hours of work.

$\rho_u = 1.0$. Total earnings and the mother's relative share of total earnings are mean centered and expressed in standard deviation units.

In Table 8, estimates of the coefficients of the absolute risk change and price variables are little changed from their counterparts in columns 4 and 5 of Table 7. Estimates of the child equation show that with total household earnings held constant the father's, but not the mother's, marginal willingness to pay for a 1 chance in 100 risk reduction increases significantly (at 5%) with increases in the mother's relative earnings. Estimates of the parent equation also show that after controlling for total household earnings, the father's marginal willingness to pay for his own risk reduction significantly (at 10%) increases with increases in the mother's relative share of earnings. These estimates indicate that a one standard deviation increase in mother's relative earnings increases annual willingness to pay of fathers by: (1) $2.10 to reduce the child's heart disease risk by 1 chance in 100 by age 75 and by (2) $1.80 to reduce his own risk of heart disease by 1 chance in 100 by age 75. These estimates suggest that parents' marginal willingness to pay to reduce heart disease risk to themselves and to their children is affected by the relative contributions of mothers and fathers to total household earnings, a finding consistent with the collective model but not the unitary model.[31]

Estimates presented in Table 8 also show that changes in total household earnings have no effect on marginal willingness to pay to reduce risk either for the child or for the

[31] As a counterpoint to this result, random effects bivariate probit equations specified similarly to those in column 2 of Table 7 were estimated to determine whether the hypothetical redistribution of expenses/income described in subsection 3.4 affected the intended vaccine purchase decisions for the child. Estimates suggest that a change in the mother's income or expense leaves marginal willingness to pay to protect the child from heart disease risk unaltered both for mothers and fathers. This result, while consistent with the collective model, reflects a central feature of the unitary model that changes in sources of household income have no effect on parents' marginal willingness to pay to reduce risk for the child.

parents. The coefficients of the linear terms in total household earnings and mother's relative earnings are positive and differ from zero at conventional significance levels. Although these coefficients may not be consistently estimated, they suggest that respondents more frequently express intentions to purchase the vaccines when mother's relative earnings and total household earnings are higher.

5. Conclusions

This paper finds evidence in favor of estimating values of health risk reductions to parents and their children by using the collective model of household decision-making, rather than by using the unitary or non-cooperative models. Based on an analysis of stated preference values for a vaccine to reduce the risk of heart disease, the null hypothesis of Pareto efficiency in intra-household health resource allocations is not rejected. Additionally, parents' marginal willingness to pay for health risk reductions for their child are found to depend on the relative share of household earnings accounted for by the mother. Results presented in the paper have two implications for interpreting prior health valuation studies as well as for conducting future studies. First, parents respond on behalf of the household when providing values of marginal willingness to pay for reductions in health risk for their children, however the values provided by a mother and a father may differ unless their perceptions of risk faced by the child are congruent. Second, two parents in a Pareto efficient household may hold different values of marginal willingness to pay for illness risk reductions if they each believe that they face different initial levels of risk. These nuances are not taken into account in prior health valuation studies based on the unitary model with one observation per household.

Further research might make use of the estimation framework developed in this paper to investigate: (1) the role of both parent and child age in determining a parent's marginal willingness to pay to reduce health risk, (2) whether marginal willingness to pay to reduce health risk for sons and daughters differs by parent gender and marital status, and (3) the extent to which values of household marginal willingness to pay based on the collective model differ from their counterparts obtained using the approach taken in prior studies based on the unitary model together with one observation per household. More generally, additional research would be warranted to improve conceptual and empirical understanding of efficiency of parent's decisions about health of family members and effects of relative decision power of parents on these decisions, in particular when a different health risk is examined. For instance, additional research might extend the analysis to account for corner solutions in collective models with nonparticipation (Donni 2003) and relax the assumption that children cannot influence the household decision-making process (Dauphin et al. 2011).

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Figure 1.

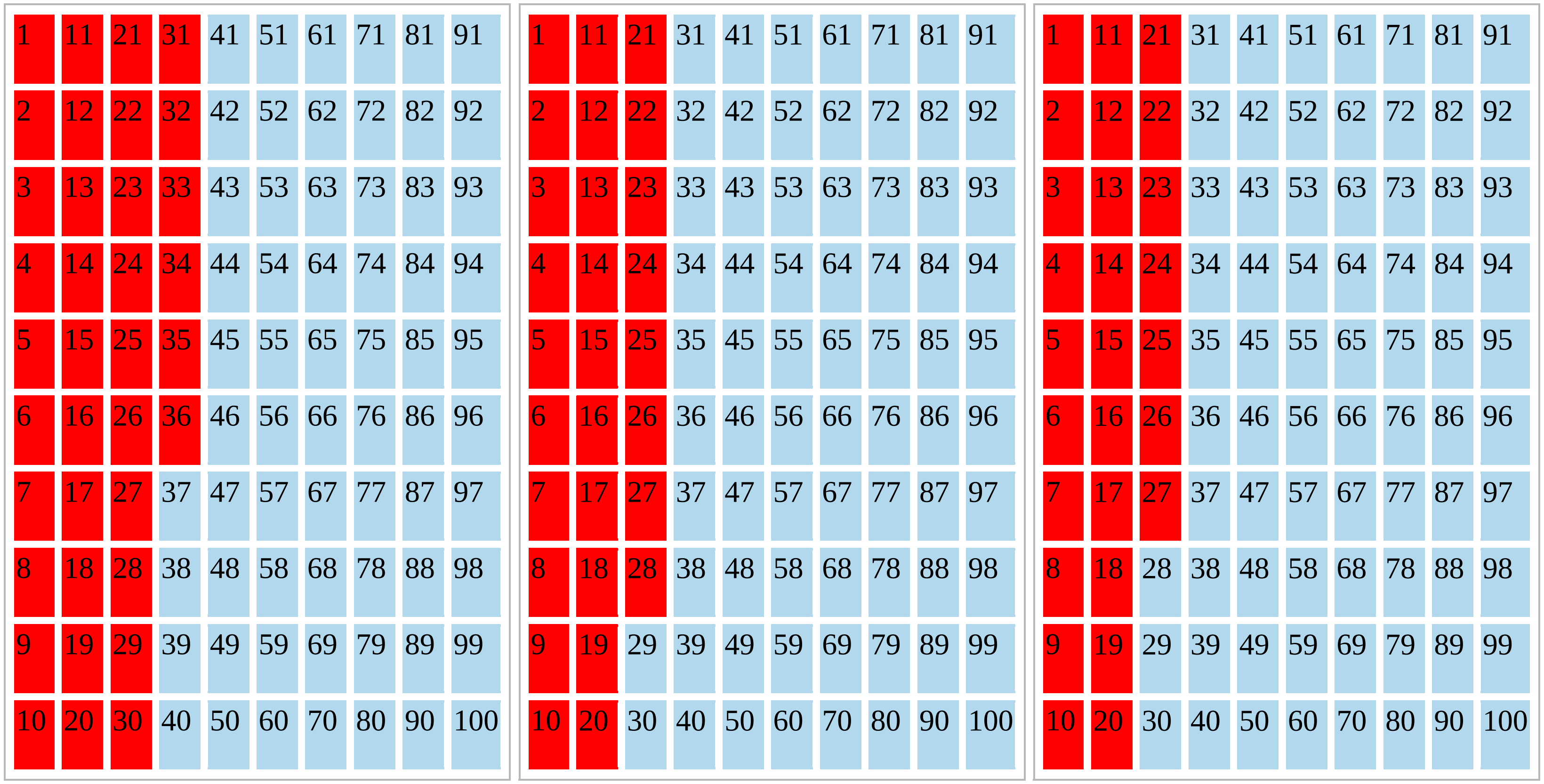
How many chances in 100 do you think you have of getting coronary artery disease before you reach age 75? Please mark the scale to show your answer.

1	11	21	31	41	51	61	71	81	91
2	12	22	32	42	52	62	72	82	92
3	13	23	33	43	53	63	73	83	93
4	14	24	34	44	54	64	74	84	94
5	15	25	35	45	55	65	75	85	95
6	16	26	36	46	56	66	76	86	96
7	17	27	37	47	57	67	77	87	97
8	18	28	38	48	58	68	78	88	98
9	19	29	39	49	59	69	79	89	99
10	20	30	40	50	60	70	80	90	100

Risk level 36% chance of heart disease.

Figure 2. Display of Perceived and Average Risks.

Your chances | Your child's chances | An average person's chances



Risk level 36%. | Risk level 28%. | Risk level 27%.

Figure 3. Display of Hazard Function for 42 Year-Old Parent's Revised Risk Assessment of 34%, Showing Cumulative Risk of 12% by Age 60.

Note: The figure shows the display as it would appear to a respondent using the cursor to determine the cumulative risk at age 60 years.

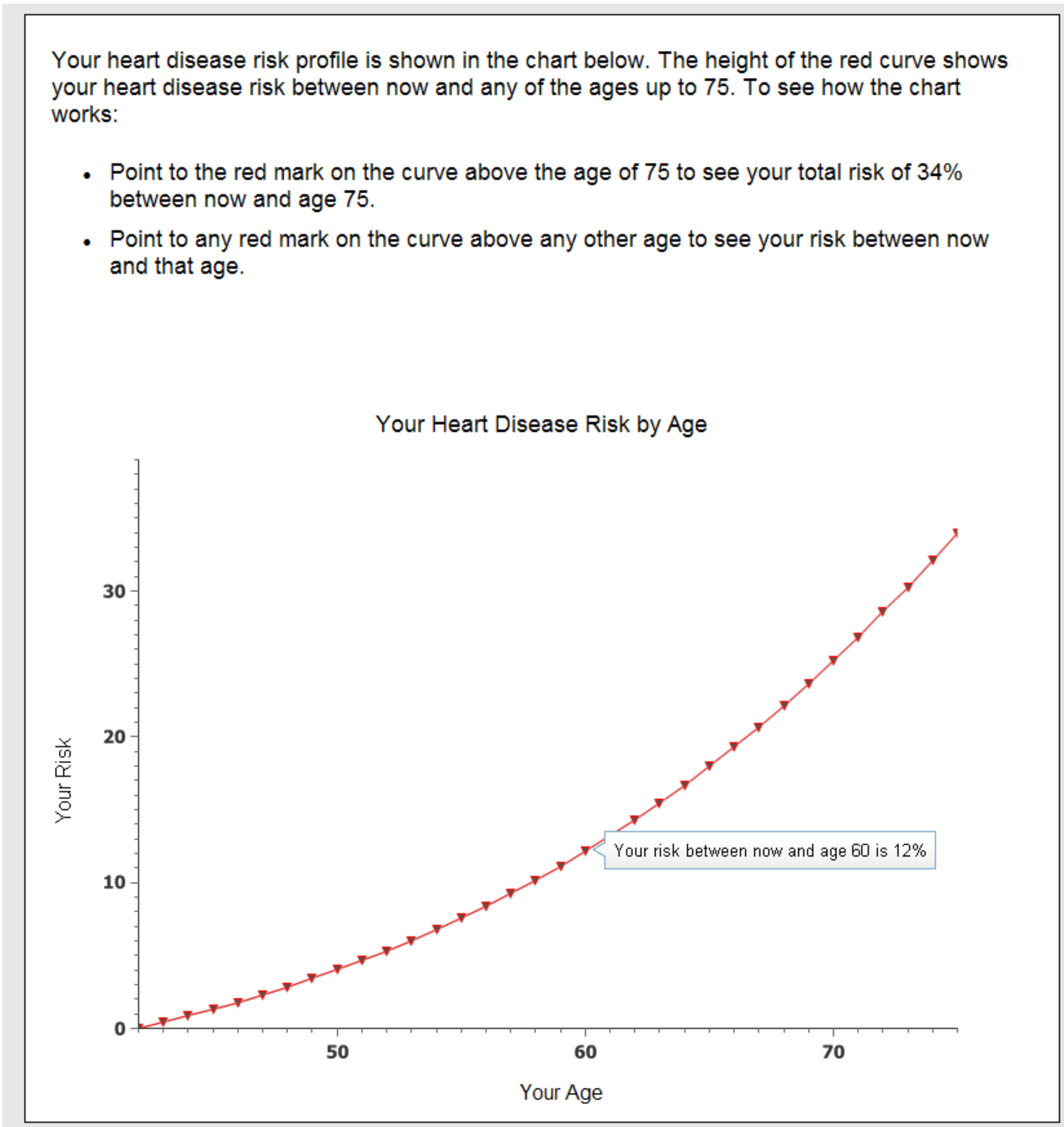


Table 1. Comparison of Parents in Survey Sample to Parents in Current Population Survey.

	Matched Parents Sample		March 2010 CPS[a]	
A. Data on Individual Parents				
	Husband	Wife	Husband	Wife
Employed (%)	89.6	64.5	88.8	67.8
Median Earnings ($1000)	50 to < 60	10 to <20	40 to < 50	15 to < 20
Earn < $5000 (%)	10.8	38.0	8.8	35.3
Median age (yrs)	43	41	40 to 44	35 to 39
Bachelor's degree or more (%)	51.8	55.5	35.8	38.3
White, not Hispanic (%)	81.6	83.6	66.6	67.2
Black, not Hispanic (%)	3.5	2.1	7.7	7.0
Hispanic (%)	7.6	5.5	17.5	17.3

B. Data on Family Household	Matched Parents Sample	March 2010 CPS[a]
Both spouses employed (%)	57.4	58.2
Earnings difference ($1000)	Husband earns 20 to 30 more than wife	Husband earns 10 to < 30 more than wife
Age difference	Husband is 1 to 2 years older than wife	Husband is 2 to 3 years older than wife
Median Income ($1000)	80 to < 90	75 to < 100[b]
Family size (number of persons)	4.4	4.3
Number of own children under age 18	2.2	1.9

[a]Estimates for US population of married couple family households, spouse present, with own children under age 18 years. Tables AVG3, FG2 and FG3 available at http://www.census.gov/population/www/socdemo/hh-fam/cps2010.html.
[b]48[th] percentile is $50,000 to $75,000.

Table 2. Relative Frequency Distribution of Matched Pairs of Parents' Assessments of Risk of Coronary Artery Disease Diagnosis before Age 75 (N=432).

		Mothers' Risk Estimates for				Fathers' Risk Estimates for			
Chances in 100		Self		Child		Self		Child	
From	Through	Initial	Revised	Initial	Revised	Initial	Revised	Initial	Revised
0	10	0.171	0.104	0.263	0.196	0.148	0.092	0.254	0.201
11	20	0.166	0.207	0.189	0.297	0.118	0.138	0.224	0.353
21	30	0.171	0.281	0.180	0.283	0.214	0.286	0.224	0.283
31	40	0.127	0.138	0.118	0.111	0.120	0.182	0.069	0.060
41	50	0.205	0.157	0.171	0.085	0.191	0.136	0.159	0.069
51	60	0.053	0.030	0.028	0.014	0.065	0.058	0.021	0.014
61	70	0.039	0.037	0.021	0.002	0.046	0.042	0.018	0.009
71	80	0.058	0.042	0.025	0.007	0.081	0.053	0.023	0.007
81	90	0.012	0.005	0.005	0.002	0.014	0.009	0.009	0.005
91	100	0.000	0.000	0.002	0.002	0.005	0.005	0.000	0.000
	Mean	35	32	28	24	37	35	27	23
Standard Deviation		21	18	20	14	22	19	19	14

Table 3. Relative Frequency Distribution for Absolute Value of Difference between Mother's and Father's Revised Risk Estimate for the Child

Absolute Value of Difference in Risk Estimates	Frequency	Cumulative Frequency	Cumulative Percentage
0	58	58	0.134
1	18	76	0.176
2	18	94	0.218
3	21	115	0.266
4	39	154	0.357
5	36	190	0.440
6	9	199	0.461
7	14	213	0.493
8	9	222	0.514
9	25	247	0.572
10-19	82	329	0.762
20-29	67	396	0.917
30 or more	36	432	1.000

Table 4. Proportion of Matched Parent pairs that said that they would purchase vaccines to reduce risks of coronary artery disease.

-	Mother Decision for:		Father Decision for:	
	Self	Child	Self	Child
Would not buy vaccine	0.57	0.50	0.49	0.50
Would buy vaccine	0.43	0.50	0.51	0.50
Certainty of decision among those that would buy:				
Uncertain	0.14	0.14	0.08	0.13
Probably	0.51	0.52	0.55	0.52
Definitely	0.35	0.34	0.37	0.35
Number of Observations	432		432	

Table 5. Overall proportion of parents that would buy vaccine by price and risk change (N = 432).

		Proportion that would "probably" or "definitely" buy vaccine					
	Risk Reduction (%)	$10	$20	$40	$80	$160	All
Parent	10	0.413	0.385	0.317	0.267	0.183	0.315
	70	0.585	0.488	0.508	0.552	0.304	0.490
	All	0.453	0.410	0.367	0.328	0.211	0.356
Child	20	0.414	0.337	0.322	0.242	0.183	0.299
	80	0.531	0.524	0.416	0.457	0.315	0.453
	All	0.477	0.422	0.371	0.341	0.245	0.374

Table 6. Matched Parents' Purchase Intentions for the Child's Vaccine (Number of Observations).

Would parent "probably" or "definitely" buy vaccine for child?				
		Mother		
		No	Yes	Total
Father	No	188	54	242
	Yes	58	132	190
	Total	246	186	432

Table 7. Heart Disease Vaccine Purchase Intentions: Percentage vs. Absolute Risk Changes. 432 Matched Pairs of Parents. Bivariate Probit with Random Effects Estimates, Normalized Coefficients.

(1) Covariate[a]	(2) Child Equation[b]	(3) Parent Equation[b]	(4) Child Equation[c]	(5) Parent Equation[c]
Percentage Risk Change if Mother was Respondent; = 0 otherwise	0.0131*** (0.0024)	0.0158*** (0.0028)	---[d]	---[d]
Vaccine Price if Mother was Respondent; = 0 otherwise	-0.0061*** (0.0015)	-0.0069*** (0.0015)	-0.0061*** (0.0015)	-0.0064*** (0.0015)
Percentage Risk Change if Father was Respondent; = 0 otherwise	0.0102*** (0.0023)	0.0084*** (0.0026)	---[d]	---[d]
Vaccine Price if Father was Respondent; = 0 otherwise	-0.0071*** (0.0016)	-0.0079*** (0.0015)	--0.0076*** (0.0016)	-0.0079*** (0.0015)
Father was Respondent = 1; = 0 otherwise	0.0476 (0.1096)	0.3767*** (0.1053)	0.0766 (0.1105)	0.3401*** (0.1093)
Absolute Risk Change if Mother was Respondent; = 0 otherwise	---[d]	---[d]	0.0432*** (0.0086)	0.0384*** (0.0081)
Absolute Risk Change if Father was Respondent); = 0 otherwise	---[d]	---[d]	0.0287*** (0.0079)	0.0150** (0.0069)
Risk Perceived by Mother if Mother was Respondent; = 0 otherwise	---[d]	---[d]	-0.0102 (0.0070)	-0.0001 (0.0047)
Risk perceived by Father if Father was Respondent; = 0 otherwise	---[d]	---[d]	0.0028 (0.0057)	0.0024 (0.0032)
Intercept	-0.3315*** (0.789)	-0.5247*** (0.0780)	-0.3433*** (0.0795)	-0.5001*** (0.0797)
Standard Deviation $(\varepsilon_{ki}, \varepsilon_i)$	1.0000	1.0000	1.0000	1.0000
Standard Deviation (u_k, u)	1.3586*** (0.0854)	1.1670*** (0.0760)	1.3657*** (0.0855)	1.1673*** (0.0797)
ρ_ε	0.7833*** (0.0365)		0.7870*** (0.0364)	
ρ_u	0.9998		1.000	
Log-Likelihood	-838.6957		-836.0061	

[a] Percentage risk change and price are mean-centered, risk and risk change are measured in number of squares on the risk scale
[b] Estimates obtained in 41 iterations
[c] Estimates obtained in 39 iterations.
[d] Denotes omitted variable
*** Denotes significantly different from zero at 1%. ** Denotes significantly different from zero at 5%. * Denotes significantly different from zero at 10%.

Table 8. Effect of Mothers' Relative Earnings on Marginal Willingness to Pay for 1 Chance in 100 Risk Reductions. 432 Matched Pairs of Parents. Bivariate Probit with Random Effects Estimates, Normalized Coefficients.

(1) Covariate[a]	(2) Child Equation[c]	(3) Parent Equation[c]
Absolute Risk Change if Mother was Respondent; = 0 otherwise	0.0446*** (0.0090)	0.0381*** (0.0091)
Vaccine Price if Mother was Respondent; = 0 otherwise	-0.0062*** (0.0016)	-0.0065*** (0.0016)
Absolute Risk Change if Father was Respondent; = 0 otherwise	0.0278*** (0.0085)	0.0141*** (0.0079)
Vaccine Price if Father was Respondent; = 0 otherwise	-0.0078*** (0.0017)	-0.0080*** (0.0015)
Father was Respondent = 1; = 0 otherwise	0.0774 (0.1148)	0.3399*** (0.1160)
(Relative Earnings of Mother) * (Absolute Risk Change if Mother was Respondent); = 0 otherwise	-0.0028 (0.0080)	0.0131 (0.0090)
(Relative Earnings of Mother) * (Absolute Risk Change if Father was Respondent); = 0 otherwise	0.0165** (0.0082)	0.0143* (0.0074)
(Total Household Earnings) * (Absolute Risk Change if Mother was Respondent); = 0 otherwise	0.0062 (0.0105)	-0.0119 (0.0131)
(Total Household Earnings) * (Absolute Risk Change if Father was Respondent); = 0 otherwise	-0.0136 (0.0104)	0.0001 (0.0035)
Mother's Relative Earnings if Mother was Respondent; = 0 otherwise	0.2801*** (0.0811)	0.1915** (0.0816)
Mother's Relative Earnings if Father was Respondent; = 0 otherwise	0.1938** (0.0873)	0.1263* (0.0763)
Total Household Earnings if Mother was Respondent; = 0 otherwise	0.3151*** (0.0935)	0.2679*** (0.0945)
Total Household Earnings if Father was Respondent; = 0 otherwise	0.2077** (0.0843)	0.1369* (0.0764)
Absolute Risk Level if Mother was Respondent; = 0 otherwise	-0.0096 (0.0074)	0.0006 (0.0048)
Absolute Risk Level if Father was Respondent; = 0 otherwise	0.0026 (0.0060)	0.0023 (0.0034)
Intercept	-0.3547*** (0.0827)	-0.5045*** (0.0835)
Standard Deviation $(\varepsilon_{ki}, \varepsilon_i)$	1.0000	1.0000
Standard Deviation (u_k, u)	1.3334*** (0.0855)	1.1404*** (0.0763)
ρ_ε	0.7990*** (0.0362)	
Log-Likelihood	-817.8229	
Number of Iterations	59	

[a] Relative earnings and total earnings are mean-centered and expressed in standard deviation units

*** Denotes significantly different from zero at 1%. ** Denotes significantly different from zero at 5%. * Denotes significantly different from zero at 10%.

Appendix A. Consistent Estimation of Effects of Individual Characteristics on Marginal Willingness to pay for Heart Disease Risk Reduction.

Effects of individual or household characteristics such as revised perception of risk or a distribution factor on marginal willingness to pay for reduced risk can be estimated by interacting the characteristic, denoted z below, with percentage risk reductions as shown in equation (A1).

$$\begin{aligned} \tilde{W}^{i} - p &= \left(\alpha^{i} + \alpha^{iz} z\right) + \left(\gamma^{i} + \gamma^{iz} z\right)\Delta^{i} - p + \sigma_{i}\varepsilon_{i} \\ \tilde{W}^{ki} - t_{i} p &= \left(\alpha^{ki} + \alpha^{kiz} z\right) + \left(\gamma^{ki} + \gamma^{kiz} z\right)\Delta^{ki} - t_{i} p + \sigma_{ki}\varepsilon_{ki}, \qquad i = m, f. \end{aligned} \tag{A1}$$

This specification allows the individual characteristic to shift the constant terms as well as marginal willingness to pay for risk reduction.

Now suppose that an unobserved determinant of a parent's marginal willingness to pay for a vaccine, such as an attitude toward health risk, is correlated with the individual characteristic. For example, attitude toward health risk may be correlated with perception of risk. Then the individual characteristic is correlated with the disturbances ε_i and ε_{ki} in equation (A1) and the estimator of the main effect of z on vaccine purchase intentions is not consistent. Nonetheless, the interaction coefficient measuring effect of z on marginal willingness to pay to reduce risk (γ^{iz}) is estimated consistently.

To see this, let D denote the vector of experimental variables (percentage risk change and price), and let $f_x(x)$ and $f_{xy}(x, y)$ respectively denote marginal and joint probability density or distribution functions for random variables X and Y. By definition, the conditional distribution $f(\varepsilon_i \mid D_i, z_i) = f(\varepsilon_i, D_i, z_i) / f_{Dz}(D_i, z_i)$. By random assignment, D_i is statistically independent of ε_i and of z_i so that

$f(\varepsilon_i, D_i, z_i) = f_{\varepsilon z}(\varepsilon_i, z_i) f_D(D_i)$ and $f_{Dz}(D_i, z_i) = f_D(D_i) f_z(z_i)$. Therefore, $f(\varepsilon_i \mid D_i, z_i) = f(\varepsilon_i \mid z_i)$. In other words, conditional on z, ε_i is distributed independently of experimental variables. Consequently $E(\varepsilon_i \mid D_i, z_i) = E(\varepsilon_i \mid z_i)$ and the estimator of γ^{iz} is consistent because ε_i is mean-independent of D_i conditional on any individual or household characteristic. Interestingly, the weaker assumption that D is mean-independent of ε_i and of z is not sufficient to establish that ε_i is mean-independent of D conditional on z.

Similar reasoning applies to the vaccine purchase equation for the child. Coefficients of interaction variables between an individual or household characteristic and randomly assigned percentage risk reductions are estimated consistently for both the parent and the child in equation (A1).

When the individual characteristic is the revised perception of risk, the equations estimated in Table 8 are based on equation (A2).

$$\tilde{W}^i - p = \left(\alpha^i + \alpha^{iR} R^i\right) + \gamma^{iR}\left(R^i \Delta^i\right) - p + \sigma_i \varepsilon_i$$

$$\tilde{W}^{ki} - t_i p = \left(\alpha^{ki} + \alpha^{kiR} R^{ki}\right) + \gamma^{kiR}\left(R^{ki} \Delta^{ki}\right) - t_i p + \sigma_{ki} \varepsilon_{ki}, \qquad i = m, f.$$

(A2)

Coefficients of the interaction variables $R^i \Delta^i$ and $R^{ki} \Delta^{ki}$ measuring absolute risk changes are estimated consistently.

Appendix B. Empirical Assessment of Exogeneity of Experimental Treatments

Table B-1 presents three ordinary least squares regressions examining the (linear) relationship between experimental design variables on the one hand and mother's relative earnings or total family earnings on the other. The dependent variables in these equations (mother's relative earnings and total earnings of mother and father) are regressed on the experimental design point variables (percentage risk changes for child and parent and price of vaccine). The original data are used, rather than mean-centered values of independent variables and standardized values of dependent variables, so a constant term is included. Results are consistent with the presumption that random assignment has resulted in no relationship between design variables and mother's relative earnings or total earnings.

Table B-1. Regression of Distribution Factors and Family Earnings
On Experimental Design Point Variables: Coefficients (Standard Errors).

	Dependent Variable			
Design Variable	Mother's Relative Earnings	Total Earnings of Mother and Father	Revised Perception of Risk for Child	Revised Perception of Risk for Parent
Percentage Risk Change, Child	-0.0157	0.0738	0.0010	---[a]
	(0.0594)	(0.1168)	(0.0162)	
Percentage Risk Change, Parent	0.0140	0.0244	---[a]	-0.0088
	(0.0698)	(0.1372)		(0.0251)
Price	-0.0089	0.0195	0.0025	-0.0123
	(0.0284)	(0.0559)	(0.0094)	(0.0123)
Constant	31.6938	89.3981	23.2905	34.4476
	(3.3356)	(6.5571)	(1.1032)	(1.1266)
F(3,428)	0.05	0.3	---[b]	---[b]
F(2,861)	---[c]	---[c]	0.04	0.55
R-squared	0.0004	0.002	0.00008	0.001

---[a]Denotes excluded variable.
---[b]Mother's relative earnings and total earnings are measured by couple, for 432 observations.
---[c]Revised perceptions of risk are measured by individual parent, for 864 observations.