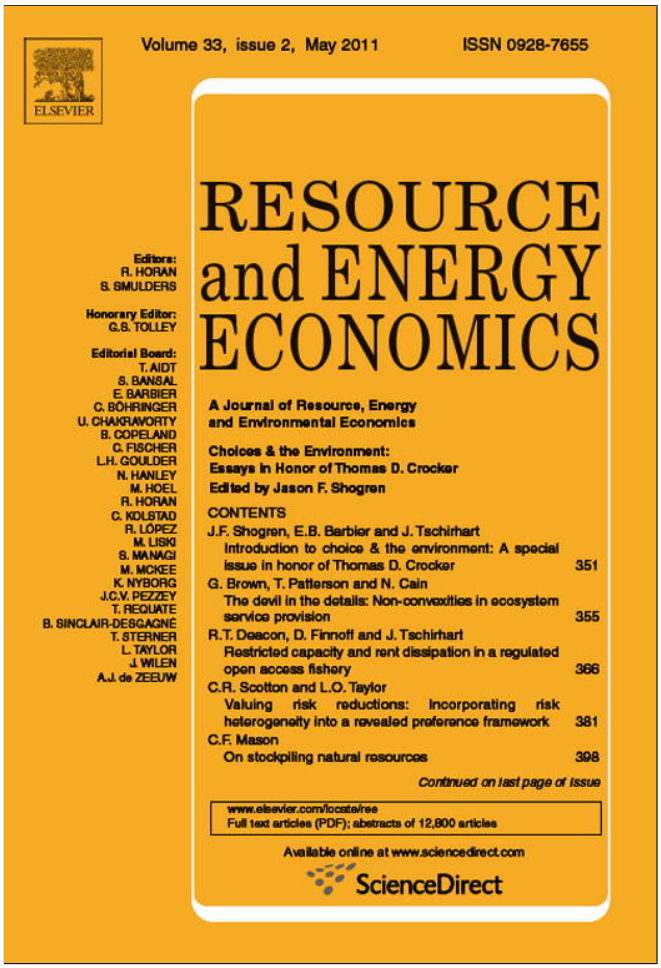

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Willingness to pay for improving fatality risks and asthma symptoms: Values for children and adults of all ages☆

Glenn C. Blomquist [a,*], Mark Dickie [b,1], Richard M. O'Conor [c]

[a] Department of Economics, Martin School of Public Policy and Administration, Gatton College of Business & Economics 335, University of Kentucky, Lexington, KY 40506-0034, United States
[b] Department of Economics, University of Central Florida, P.O. Box 161400, Orlando, FL 32816-1400, United States
[c] Independent Consultant, Cincinnati, OH, United States

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ABSTRACT

We examine effects of age on valuation of mortality and morbidity risks using a two-stage contingent valuation survey and a sample including parents of children aged 4–17 years and adults aged 18–92. The survey used a hypothetical improved asthma therapy to elicit (1) tradeoffs between asthma control and fatality risk, (2) willingness to pay (WTP) for reduced fatality risk, and (3) WTP for asthma control. The mean value of statistical life (VSL) at average age is $3.8M, but age affects VSL and nonlinearly. Estimated VSL is highest at age four ($14.1M), falls until age 30 ($3.7M), rises until age 66 ($6.7M), and then falls to $1.5M by age 92. Results from the wide age range considered may partly reconcile apparently conflicting results from previous studies focused on narrower age

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* Corresponding author. Tel.: +1 859 257 3924; fax: +1 859 323 1920.
E-mail addresses: gcblom@uky.edu (G.C. Blomquist), mdickie@bus.ucf.edu (M. Dickie), roconor40@gmail.com (R.M. O'Conor).
[1] Tel.: +1 407 823 4730; fax: +1 407 823 3269.

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ranges. The value of asthma control is not as strongly related to age as VSL and ranges from $1700 to $4000 annually.

1. Introduction

Valuing health is vital for efficient environmental, health, and safety policy. Tolley et al. (1994), Johannesson (1996), and Freeman (2003, Chapter 10) provide ample evidence that much is known about valuing health and preference-based measures of values of changes in health. Much is known about valuing fatality risks, also, especially for individuals who are of an age of workers in the labor market. Mrozek and Taylor (2002), Viscusi and Aldy (2003), and Blomquist (2004) review and synthesize results from nearly 30 years of research and dozens of studies that estimate values of statistical life implicit in labor markets, implicit in averting behavior in consumption, and explicit in stated preferences in contingent markets.

Despite the advances, however, significant gaps remain in knowledge about the value of reductions in mortality and morbidity risks. For example, the U.S. Environmental Protection Agency assessed the research needed to improve policy analysis and concluded that information on the value of reduced mortality and morbidity were the greatest short-term and long-term research needs, respectively (US EPA, 2005). In the case of mortality, a key unresolved issue concerns how the value of statistical life (VSL) varies with age (Aldy and Viscusi, 2007; Krupnick, 2007). Although children and senior adults may be more vulnerable and more likely to benefit from improvements in air quality, there are few estimates of the VSL for children and adults over the age of 65. In the case of morbidity, there are relatively few estimates of willingness to pay (WTP) to avoid specific non-fatal health effects, especially for effects experienced by children and for chronic diseases (US EPA, 2005). For example, asthma is one of the most common chronic illnesses in the U.S. and is exacerbated by exposure to air pollution, yet relatively little is known about the value of improved asthma control for adults, and even less is known for children (Brandt et al., 2008).

Previous research provides mixed results on the relationship between the VSL and age. In theory, WTP for reduced mortality risk at any age depends on the discounted expected utility of future consumption and thus may increase or decrease with age as consumption, or the utility of derived from consumption, varies over the life cycle (Alberini et al., 2004). In their review of estimates from the labor market, Aldy and Viscusi (2007) conclude that the VSL rises with age, peaks in mid-life, and then falls. In contrast, Krupnick's (2007) review of stated preference studies offers little basis for concluding that a senior discount, i.e., lower value for older adults, is a robust finding. For example, Alberini et al. (2004) find only a weak effect of age on VSL, and then only for individuals older than 70 years. Aldy and Viscusi's review does not offer evidence for adults older than 65 years and neither their review nor Krupnick's considers children. As Robinson (2007, p. 291) notes, the U.S. EPA and other agencies tend to use the same VSL for children and adults because of little relevant research on children. Some researchers report a higher VSL for children than for adults (e.g., Bateman et al., 2009; Blomquist et al., 1996; Hammitt and Haninger, 2010), while others have not found a higher mortality valuation for children (Alberini et al., 2009; Jenkins et al., 2001).

In previous research on the value of reduced morbidity, several studies report WTP values that are 1.5–2.6 times larger for children than for adults (e.g., Agee and Crocker, 2007; Aziz et al., 2008; Dickie and Gerking, 2003; Liu et al., 2000). Agee and Crocker (2008) and Dickie and Messman (2004) report a ratio of child to adult WTP for reduced morbidity that is about two, on average, but is larger for younger children and falls toward unity as children approach adulthood. Brandt et al. (2008) estimate mean WTP for reductions in children's asthma morbidity of $678–$778 annually. Other asthma valuation studies typically focus on adults. For example, Rowe and Chestnut (1986) report an

estimated WTP to avoid one "bad asthma day" for adults between $16 and $76 ($2007), depending on severity. O'Conor and Blomquist (1997) gave asthmatics a hypothetical choice between two medicines that differed in safety (risk of fatal reaction) and efficacy (degree of asthma control). Based on respondents' safety-efficacy tradeoffs and an assumed $6 million VSL, they estimate that effective control of asthma is worth about $2000 annually ($2007).[2]

This paper addresses research gaps in the valuation of reduced mortality and morbidity by providing estimates of: (1) the VSL for children, (2) the VSL for older/senior adults, and (3) the value of asthma control for both children and adults.[3] Estimated values for children are derived from parental WTP. Estimates are based on a simple model that provides a consistent treatment of morbidity and mortality risks and a unique survey sample that reflects an age range of four to 92 years. The survey used a hybrid contingent valuation method to elicit preferences for the safety and efficacy of hypothetical asthma medications. We find statistically significant effects of safety, efficacy and cost on choices of asthma medications. The mean VSL implied by WTP for fatality risk reduction is $3.8M for age 35, the average age in our sample. We find a significant non-linear effect of age on the value of reduced mortality, with VSL declining from a high of $14.1M at age four to a local minimum of $3.7M at age 30, then rising to an estimated $6.7M at age 66, and again declining for the oldest adults with an estimated VSL at age 92 of $1.5M. The high but declining VSL for children and the persistence of high VSL well into senior years is consistent with stated preference studies of these age groups. The increase in VSL from young adulthood through prime earning years and eventual decline in retirement is likewise consistent with various labor market studies but the decline begins later. We did not find a significant direct effect of age on the value of asthma control, although parents as a group were willing to pay more to relieve their children's asthma than were adults to relieve their own asthma. The estimated mean value of asthma control ranges from about $1700 to $4000 annually. The next section presents the model used to guide empirical work, while Section 3 discusses survey methods and data. Empirical results are presented in Section 4, and conclusions follow in Section 5.

2. Risk–risk and risk-dollar tradeoffs for asthma

Assume that the decision-maker's expected utility depends on consumption of a composite good and on the outcome of asthma treatment. Consumption is the residual obtained by deducting costs of asthma treatment (C) from income (I). Possible outcomes of asthma treatment include death from an adverse reaction to medication, occurring with probability q. If death does not occur, treatment may control asthma effectively with probability p or may be ineffective with probability $1-p$. Expected utility is given by

$$EU = (1-q)[pU_e(I-C) + (1-p)U_n(I-C)] + qU_d(I), \tag{1}$$

where U_e, U_n and U_d, respectively, denote state-dependent utility functions when asthma treatment is effective, not effective, or results in death.

This simple model supports estimation of two types of measures of preferences concerning outcomes of asthma treatment: risk–risk and risk-dollar tradeoffs. Viscusi et al. (1991) introduced the idea of a risk–risk tradeoff, giving the offsetting changes in two risks that hold expected utility constant. O'Conor and Blomquist (1997) applied this idea to estimate a safety-efficacy tradeoff, reflecting the willingness of adult asthmatics to exchange risk of fatal reaction for probability of effective treatment. Holding expected utility constant, the safety-efficacy tradeoff is given by:

$$\frac{\partial q}{\partial p} = \frac{(1-q)(U_e - U_n)}{pU_e + (1-p)U_n - U_d}. \tag{2}$$

[2] Estimated efficacy-dollar tradeoffs (from the hypothetical purchase of a more effective but more expensive drug) were not statistically significant in the small sample, but implied an annual value of asthma control of about $2100.

[3] Tom Crocker's contributions to environmental economics were acknowledged when he was named a 2008 AERE Fellow, see http://www.aere.org/meetings/tomcrocker.php. His pioneering work on children's health and the environment has inspired and influenced research in this area including our own.

The safety-efficacy tradeoff equals the increase in expected utility from a higher probability of effective treatment relative to the reduction in expected utility from an increase in the risk of fatal reaction.

An alternative measure of preferences is a risk-dollar tradeoff, giving the offsetting changes in income and risk that hold expected utility constant. Risk-dollar tradeoffs may be defined in terms of the option price, the *ex ante*, state-independent change in income that holds expected utility constant when risk changes. The efficacy-dollar tradeoff is defined as the marginal impact of efficacy on the option price for efficacy, OP_p:

$$\frac{\partial(OP_p)}{\partial p} = \frac{(1-q)(U_e - U_n)}{E\lambda}, \tag{3}$$

where $E\lambda = (1-q)[p(\partial U_e/\partial I) + (1-p)(\partial U_n/\partial I)] + q(\partial U_d/\partial I)$ denotes the expected marginal utility of income. Similarly, the fatality risk-dollar tradeoff is defined as the marginal impact of risk on the option price for fatality risk, OP_q:

$$-\frac{\partial(OP_q)}{\partial q} = \frac{pU_e + (1-p)U_n - U_d}{E\lambda}. \tag{4}$$

The efficacy-dollar and risk-dollar tradeoffs equal the change in expected utility from a change in the relevant probability, weighted by the expected marginal utility of income.

Empirical analysis presented in Section 4 applies this simple model to two types of decision-making contexts: (1) an adult evaluating her own asthma treatment and (2) an adult parent evaluating her child's asthma treatment. Tests for the validity of applying the same model to both decision contexts also are reported in Section 4.

3. Survey methods and data

Data analyzed in this paper come from two surveys, one designed to elicit parents' values of controlling their children's asthma and the other to elicit adults' values of controlling their own asthma. Each survey employs a two-step procedure previously used to estimate the value of an improvement in health status among chronic asthmatics by O'Conor and Blomquist (1997). In the first step of this hybrid contingent valuation technique, respondents are offered a choice between alternative bronchodilator medications, Drugs A and B, which are described in terms of their probabilities of safety and efficacy. By design, the choice of drug implies a tradeoff between these two dimensions. For instance, Drug A might be safer than Drug B, but it is also less effective. The hypothetical choice between these two drugs reveals information concerning respondents' willingness to trade off increased mortality risk for an expected reduction in asthma symptoms. This technique resembles a standard gamble in that the drug choice requires respondents to trade off an improvement in asthma status against the probability of a fatal adverse reaction.

The second step consists of a standard contingent valuation (CV) question concerning WTP for an improvement along a single risk dimension, either safety or efficacy. All respondents are asked whether they are willing to pay a given dollar amount per month for Drug C, instead of the drug previously chosen (A or B). Thus, respondents who previously chose the safer but less effective drug are offered the chance to purchase additional efficacy, while respondents who previously chose the more effective but riskier drug are offered the chance to purchase additional safety. Because the contingent valuation of Drug C involves a dollar-risk tradeoff, responses may not be influenced directly by the preceding risk–risk question.

Both choices in the two-stage procedure are presented in closed-ended format. The closed-ended binary (dichotomous) choice elicitation format is a standard approach in contingent valuation (see NOAA, 1993). Some concern exists that a dichotomous choice may be too constrained for situations in which respondents may wish to express the strength of their preferences or feel some uncertainty with regard to either the nature of the good or even their own preferences. We include a "neither" option when eliciting the drug choice during the first stage. People who choose neither drug are then prompted to voice their concerns in a follow-up question. These respondents are then presented a

description of a more severe asthma condition and asked if they would choose one of the medications given the presence of this more severe illness. In the second stage, willingness to pay is elicited using a closed-ended polychotomous choice format consisting of four possible responses: Definitely Yes, Probably Yes, Probably No, and Definitely No. In this manner, respondents who are somewhat ambivalent can reveal the degree of intensity of their preferences. This response format also allows better control for potential hypothetical bias. Blumenschein et al. (2001) examined actual and hypothetical decisions to purchase an asthma management plan in a small sample of asthma patients in Kentucky. Their results suggest that the discrepancy between actual and hypothetical choices is eliminated if only those subjects who indicate that they "definitely" (as opposed to "probably") would purchase the hypothetical management plan are counted as buyers. Similar results have been obtained for other goods (Blumenschein et al., 1998, 2008).

Although the two surveys employ parallel methods of valuation, there are some differences in survey design and sample recruitment. Features that are unique to each survey are described below.

3.1. The parent survey

An individual was eligible to complete the parent survey if he or she were an adult and the parent or legal guardian of a child between the ages of four and 17 years old who had physician-diagnosed asthma. The lower age limit was imposed because standard asthma therapy differs for younger children (US DHHS, 1997). Recruiting a random sample of parents of asthmatic children would be quite costly because only 30 percent of households include children and only five percent of children have asthma (US CDC, 2001). Consequently, a convenience sample of 192 parents was recruited in two ways in 2001.

First, brochures describing the study were distributed at schools in the Hattiesburg, Mississippi metropolitan area and through chapters of the American Lung Association in nine states, including Mississippi. Parents who wished to complete the survey would return a postage-paid address form attached to the brochure. A cover letter and survey then would be mailed to these parents. Reminder postcards were sent to all respondents ten days after the survey was mailed, and a second cover letter with a replacement survey was mailed to those who had not responded within three weeks of the initial mailing. Overall, 142 (77.6 percent) of surveys mailed were returned.

Second, 50 respondents were recruited through in-person contacts. The largest group of these (27) was respondents to an in-person survey about skin cancer risks conducted in Hattiesburg. After finishing the skin cancer survey, about 300 respondents were asked whether they had any children with asthma, and if so, if they would complete the asthma survey. Another 16 respondents were recruited from parents of pediatric asthma patients at a Hattiesburg clinic, while seven were recruited at an "asthma walk" in Orlando, Florida.

The survey began with questions to assess severity of the child's asthma and the effectiveness of asthma treatment, such as frequency of symptoms, and continued to assess medications taken and their cost. The survey then provided information about standard asthma therapy, continued with the hybrid CV technique to assess preferences for asthma treatment, and concluded with standard demographic and socioeconomic questions.

In the first stage of the hybrid CV technique, respondents were told that Drug A effectively controlled asthma symptoms in 80 percent of patients, but caused fatal reactions in 4 of 100,000 patients each year. Efficacy and risk of Drug B, the more effective but riskier drug, were varied in design. Efficacy varied over the levels 90, 95 and 99 percent, while annual risk varied over 5, 8 and 12 deaths from fatal reactions per 100,000 patients. Respondents also were told that using either drug would be safer than riding in a car, with an annual fatality risk of 20 in 100,000. In the second stage, incremental, out-of-pocket costs for Drug C varied over nine levels from $5 to $90 per month.

3.2. The survey of the general population

In "A Survey About Budget, Environmental, and Health Choices" respondents were given the opportunity to make choices concerning the allocation of "extra" state resources to various governmental program areas and, more relevant for the purpose of this paper, were given the opportunity to make choices about asthma drugs with different characteristics.

The University of Kentucky Survey Research Center used a random digit dialing procedure to call and ask about willingness to participate in a mail survey. The random digit dialling procedure gives each Kentucky household with a phone an equal probability of being contacted. During November 1995 the Survey Research Center contacted 807 Kentucky households. Calls were made during both morning and evening hours. Socioeconomic information was collected for each household, and each phone respondent was invited to participate in the mail survey. Of the 807 contacts, 692 (86%) agreed to participate in a mail survey and provided their names and addresses. In the original mailing in November 1995, each survey instrument was mailed with a cover letter, a stamped and labeled return envelope, and a one-dollar bill as appreciation for anticipated participation. One month later cards were sent to each of the mail survey participants thanking them for their participation and asking them to contact us if they needed another copy of the survey instrument. After another month, a follow-up mailing was sent to each mail survey participant who had not returned a survey. Of the 692 surveys mailed 415 (60%) were returned. Cases with missing data were deleted so that 317 (46% of 692) observations remain for multivariate analysis.

There are indications that the characteristics of the people who responded with usable surveys are comparable to the characteristics of the typical person in the Kentucky population. We got approximately equal response from men and women. Compared to the Kentucky adult averages from the U.S. Census our respondents are only approximately 0.5 years older and have only 0.8 years more of schooling. Our respondents do have approximately $15,000 more of annual household income. This difference is costly to avoid for a survey which is based on an initial phone survey and which requires a concerted effort to read and respond.

Because this sample is drawn from a general population, as a prelude the survey provides information about asthma and asks respondents to imagine that they suffer from chronic moderate asthma. To assist them in this process, the survey begins with a series of descriptions and questions designed to familiarize them with asthma symptoms and their effects upon everyday life. Asthma triggers such as cold air, cigarette smoke, infections, allergic reactions and air pollution are identified. Chronic moderate asthma symptoms such as night-time mild attacks 2–3 times per week, cough and low-grade wheezing often present between attacks, mild attacks occurring several times per week, and urgent care treatment required up to 3 times per year are described. After this familiarization and warming-up process, respondents are presented with the two-stage hybrid CV technique.

Steps were taken to avoid potential embedding problems and compliance behavior in responses to hypothetical valuation questions. The survey does not focus on asthma alone. A companion purpose of the survey was to elicit values individuals place on environmental programs. The instrument first asks respondents to allocate funds among several general, then environmental, budget categories. All of the budget questions precede the asthma questions. The inclusion of the questions about environmental values and asthma medication on the same survey instrument can help alleviate embedding and compliance problems.

Variable definitions and summary statistics for the samples (combining data from both surveys) with age and control variables for respondents are given in Table 1. Our samples have at least 11 percent younger than 10 and at least 8 percent older than 69 years with ages that range from 4 to 92 for all but the WTP for efficacy in controlling asthma for which 81 is the oldest respondent. Fig. 1 shows the age distribution for those whose health is considered for the sample involving the choice of Drug A or Drug B when only the scope variables, fatality risk and efficacy are included.

4. Results

4.1. Risk–risk choice: Drug A or Drug B

Logistic regression results for the choice between Drug A and Drug B are shown in Table 2. The tradeoff is between risk of fatal adverse reaction and risk of the drug not controlling asthma. The dependent variable equals one if the more effective, riskier drug is chosen and zero if the safer, less effective drug is chosen. The specification with only the two scope variables is shown in the leftmost column of results. Drug choice depends on the drug characteristics, as expected. The greater the increase in fatality risk, the less likely the more effective drug is chosen. The greater the increase in

Table 1
Variable definitions and summary statistics.

Variable	Units	Mean (standard deviation)		
		Drug A or B sample	WTP for Safety sample	WTP for efficacy sample
Chose riskier drug	Riskier more effective drug=1	0.420 (0.494)	All	None
WTP response for drug C	Definitely yes=4 Probably yes=3 Probably no=2 Definitely no=1	–	2.590 (1.038)	2.437 (0.959)
Dollar bid	2007 dollars per month	–	51.56 (31.15)	52.85 (30.94)
Change in fatality risk	Annual deaths/100,000	6.360 (4.880)	5.606 (4.663)	–
Efficacy improvement	% chance of effective control	11.47 (4.53)	–	10.80 (4.52)
Age	Years	35.67 (22.62)	35.56 (23.75)	37.43 (21.35)
Age (min. and max.)	Years	4, 92	4, 92	4, 81
Age Under 10, over 69	Years	13.0%, 9.6%	11.2%, 11.2%	11.4%, 8.7%
Household Income	2007 dollars, thousands	52.31 (35.31)	55.10 (36.94)	51.54 (34.42)
Schooling	Years completed	13.97 (2.27)	13.99 (2.36)	13.94 (2.23)
Female	Female=1	0.437 (0.497)	0.426 (0.496)	0.437 (0.497)
Reluctant chooser	Chose after asthma severity hypothetically increased=1	0.186 (0.390)	0.133 (0.340)	0.224 (0.418)
Riskier first	Riskier, more effective drug presented first=1	0.345 (0.476)	–	–
Familiar	Asthmatic or has friend or relative with asthma=1	0.699 (0.456)	0.676 (0.469)	0.692 (0.463)
Observations	Number	478	188	263

For Drug A or B familiar: $n=334$ with age range (4, 92) with 18.6% (62) under 10 and 6.3% (21) over 69.

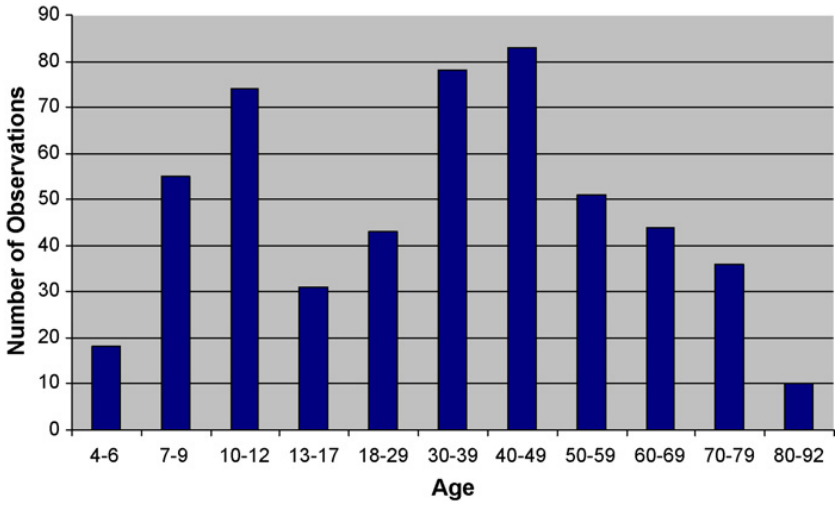

Fig. 1. Distribution of age by categories for Drug A or Drug B choice sample, $n=526$.

efficacy, the more likely the more effective drug is chosen. Estimated scope coefficients increase in absolute value and remain statistically significant in the other two specifications with control variables as well.

The middle column of results includes the two scope variables, age in cubic form, and several control variables. An age cubic was used to allow for nonlinear effects of age and drug choice with greater flexibility than a quadratic specification. Reluctant choosers, who would not make a choice between the two drugs until endowed with more severe asthma, are less likely to choose the riskier drug. There are indications at the ten percent level of significance that adults who are presented the riskier drug first chose the riskier drug and respondents who were familiar with asthma were less likely to choose the riskier drug. In this sample, which includes respondents who do not have asthma

Table 2
Logistic regressions of drug choice responses, Drug A or Drug B (chose riskier drug=1 if respondent chose more effective but riskier drug, and 0 if respondent chose safer but less effective drug).

Independent variables	Scope only	Age effects and controls	Familiar with asthma[a]
Increase in fatality risk	−0.0749** (−3.80)[b]	−0.0994** (−4.09)	−0.1091** (−3.40)
Efficacy improvement	0.0663** (3.28)	0.1031** (3.99)	0.1148** (3.55)
Age		0.0071[c] (0.13)	0.0786[d] (1.05)
Age squared		−0.0007 (−0.46)	−0.0032 (−1.50)
Age cubed		0.835×10^{-6} (0.76)	0.32×10^{-4}* (1.88)
Household income		0.0036 (1.22)	0.0026 (0.74)
Schooling		0.0215 (0.46)	0.0635 (1.04)
Female		−0.0501 (−0.25)	−0.0340 (−0.14)
Reluctant chooser		−1.0308** (−3.66)	−1.5178** (−4.46)
Riskier first		0.4255* (1.75)	0.1878 (0.55)
Familiar with asthma		−0.4382 (−1.80)*	–
Constant	−0.6800** (−2.49)	−0.9583 (−1.03)	−2.4245** (−2.13)
Log likelihood	−342.69	−299.25	−197.70
Pseudo R^2	0.0358	0.0800	0.1283
χ^2	25.44	52.02	58.20
% correct	64.07	67.78	70.96
N	526	478	334

[a] Familiar subsample consists of people who have asthma or have a friend or relative who has asthma; adults unfamiliar with asthma are excluded. The range for age is [4, 92] with 18.6% under 10 and 6.3% over 69. The null hypothesis that the differences between all the pairs of coefficients of the regressions for the familiar sample (n=334) and for the unfamiliar sample (n=144) are zero is rejected at the 5% level, $\chi^2(11)=21.07$ (p=0.03).
[b] Ratio of coefficient to standard error in parentheses.
[c] The null hypotheses that coefficients of all three age variables equal zero cannot be rejected, $\chi^2(3)=4.29$ (p=0.23).
[d] The null hypotheses that coefficients of all three age variables equal zero is rejected at the 5% level, $\chi^2(3)=9.94$ (p=0.02).
* Statistical significance at the 10% levels.
** Statistical significance at the 5% levels.

and do not have a friend or family member with asthma, the age variables do not have a statistically significant effect in that the null hypothesis that all three equal zero cannot be rejected, $\chi^2(3)=4.29$ and $p=0.23$. A test of the null hypothesis that the derivative of the dependent variable with respect to age equals zero was done for various ages. The hypothesis could not be rejected for most ages, but it was rejected at the ten percent level or better for approximately ages 60–75.

Results for only those familiar with asthma are shown in the rightmost column. Predictive performance improves in this subsample, as indicated by the percentage correct predictions ($70.96 > 67.78 > 64.07$). For those familiar with asthma the survey format order variable, *Riskier First*, is no longer statistically significant at any usual level. The estimates of the coefficients for the scope variables are similar to those in the middle column; higher fatality risk reduces the probability of choosing the riskier drug and greater efficacy increases the probability or choosing the riskier drug. For those familiar with asthma, the marginal effect (evaluated at the means) of increasing the annual fatality risk by 1 death per 100,000 is to reduce the probability of choosing the riskier drug by 0.027. The marginal effect for an increase in effective control by 1 percentage point, say 11–12, is to increase the probability of choosing the riskier drug by 0.029. For those familiar with asthma, age matters. The null hypothesis that the coefficients of all three age variables is zero is rejected, $\chi^2(3)=9.94$ and $p=0.02$. A test of the null hypothesis that the derivative of the dependent variable with respect to age equals zero is rejected at the five percent level or better for all ages greater than 57.[4] Based on the estimated effect of age in cubic form, we find that the probability of choosing the riskier, more effective drug is nonlinear. The probability rises through age 17, falls to a minimum at age 50, and rises again with age. After age 70 the probability of choosing the riskier drug rises sharply and is much higher than at younger ages.

[4] In the drug choice equation and in willingness to pay equations discussed below, standard errors of derivatives with respect to age are computed by treating age as a known constant.

The familiar subsample ($n=334$) yields more reliable results than the larger combined sample in that the overall performance of the regression is better and the format order does not matter, as should be the case. We do find, as expected, that the larger is the increase in fatality risk to get greater efficacy, the less likely the riskier drug will be chosen. Also, as expected, the larger is the increase in efficacy, the more likely the riskier drug will be chosen. We find that age affects the drug choice in a nonlinear way with older adults more likely to choose the riskier drug. Household income, schooling, and gender have no statistically significant effect, but respondents who would not choose a drug until endowed with a more severe case of asthma were less likely to choose the riskier drug.[5]

An advantage of the hybrid CV used in this study is that it focuses respondents' attention on asthma and introduces tradeoffs. Age influences the risk–risk drug choice. If age is also a determinant of the willingness to pay for a superior drug that is both safer and more effective, an implication is that willingness to pay for reductions in fatality risk and the value of asthma control can depend upon age.

4.2. Willingness to pay for reduced fatality risk and VSL by age

Ordered logit regression results for willingness to pay for reductions in fatality risks associated with treatment for asthma are shown in Table 3. Respondents indicated their choice and how certain they were that they would actually purchase the safer drug by responding Definitely Yes, Probably Yes, Probably No, or Definitely No. Column 2 shows the most basic specification with only price and fatality risk reduction. As expected, the coefficient of the price variable (*Dollar Bid*) is negative and the coefficient of the scope variable (*Fatality Risk Reduction*) is positive; both are statistically significant. Column 3 shows results for age in cubic form and control variables added. The results for the price and scope variables hold with the absolute size of the coefficients increasing. Household income and schooling both tend to increase the probability of being willing to pay for the safer drug.

The age cubic reveals that willingness to pay decreases with age for children, rises during middle adult years, and finally decreases at advanced adult ages. The effects of age are statistically significant at the 10 percent level, $\chi^2(3)=6.52$ and $p=0.09$. The tests of the derivatives of the willingness to pay response with respect to age evaluated at various ages reveal that the null hypothesis that the age effects are zero can be rejected at the 5 percent level or better for ages up to 20 and at the 10 percent level up to age 23, for ages 45–55 and again around age 85.

Familiar with Asthma does not seem to matter for willingness to pay for reductions in fatality risk. The coefficient on the familiarity variable is not significant at any usual level. Based on seemingly unrelated estimation for respondents familiar with asthma ($n=127$) and those unfamiliar ($n=61$), we could not reject the hypothesis of no differences between coefficients, $\chi^2(9)=6.88$ and $p=0.65$. Similarly neither *Female* nor *Reluctant Chooser* has a statistically significant effect on willingness to pay for safety. Column 4 reports results for a specification without these three variables and shows little change in the coefficients of the remaining variables. In fact, a seemingly unrelated estimated test for differences in the common coefficients in columns 3 and 4 indicates no statistically significant changes, $\chi^2(7)=2.21$ and $p=0.95$.

Our hybrid CV prepares respondents for the hypothetical purchase decision by preceding the risk-dollar choice with a choice between two drugs that involves a tradeoff between risk of fatal adverse reaction and risk of not controlling asthma. Only respondents who choose the more effective, riskier drug are offered the opportunity to buy a safer drug. Only respondents who choose the safer, less effective drug are offered the opportunity to buy a more effective drug. Because of this nonrandom

[5] We have tested for sensitivity of the drug choice results to pooling the data using a set of interaction variables of the children. Results for the specification with age effects and control variables for the respondents who are familiar with asthma indicate they can be pooled, $\chi^2(7)=11.10$ and $p=0.13$. In addition, the age cubic effect is still present with the specification with child interactions and the null that all three age variables have coefficients equal to zero can rejected at the 5% level, $\chi^2(3)=8.58$ and $p=0.04$. For the scope only specification we reject the null that all the interaction coefficients are zero, $\chi^2(3)=9.67$ and $p=0.02$. (Interactions terms are for age squared and age cubed are not included because we are not testing that there is a nonlinear effect of age for children and a nonlinear effect of age for adults and that they are the same.) For the specification with age effects and control variables for the sample that combines respondents who familiar with asthma and respondents who are not again we reject, $\chi^2(7)=15.18$ and $p=0.03$. For the risk-risk drug choice the specifications with interactions are not shown in order to focus on the preferred specification for the familiar sample.

Table 3
Ordered logit regressions of willingness to pay for reduced fatality risk (dependent variable is WTP response for Drug C: definitely no, probably no, probably yes, or definitely yes).

Independent variables (1)	Bid and scope only (2)	All controls (3)	Significant controls (4)	With selection[a] (5)
Dollar bid	−0.0157** (−3.61)[b]	−0.0194** (−4.06)	−0.0191** (−4.04)	−0.0108** (−4.13)
Fatality risk reduction	0.0669** (2.37)	0.1158** (3.41)	0.1214** (3.65)	0.0778** (3.77)
Age		−0.1784**,[c] (2.52)	−0.1991**,[d] (−2.88)	−0.1109**,[e] (−2.78)
Age squared		0.0044** (2.42)	0.0047** (2.67)	0.0027** (2.64)
Age cubed		-0.304×10^{-4}** (−2.32)	-0.325×10^{-4}** (−2.50)	-0.191×10^{-4}** (−2.54)
Household income		0.0084** (2.08)	0.0078* (1.95)	0.0036 (1.49)
Schooling		0.1215* (1.87)	0.1291** (2.01)	0.0798** (2.16)
Female		0.2007 (0.72)		
Reluctant chooser		0.3205 (0.83)		
Familiar with asthma		0.3183 (0.96)		
Constant 1	−2.0197 (−6.23)	−1.3411 (−1.12)	−1.8534 (−1.65)	−1.3665** (−1.95)
Constant 2	−0.5748 (−2.00)	0.2496 (0.21)	−0.2808 (−0.24)	−0.4148 (−0.62)
Constant 3	0.8418 (2.86)	1.7936 (1.50)	1.2725 (1.11)	0.4548 (0.66)
Log likelihood	−265.16	−236.18	−239.08	−520.93
Pseudo R^2	0.0317	0.0816	0.0798	
χ^2	17.34	41.97	41.46	78.62
% correct (2 categories)	63.50	64.36	62.63	
(4 categories)	36.50	36.70	41.05	
Rho				−0.4380[f]
N	200	188	190	478/190

[a] The selection equation for choice of Drug A or Drug B includes *Fatality Risk Reduction*, *Efficacy Improvement*, the age cubic, *Household Income*, *Schooling*, *Female*, *Reluctant Chooser*, *Riskier First*, and *Familiar with Asthma*.
[b] Ratio of coefficient to standard error in parentheses.
[c] The null hypotheses that coefficients for all age variables equal zero is rejected at the 10% level, $\chi^2(3)=6.52$ ($p=0.09$).
[d] The null hypotheses that coefficients for all age variables equal zero is rejected at the 5% level, $\chi^2(3)=9.35$ ($p=0.03$).
[e] The null hypotheses that coefficients for all age variables equal zero is rejected at the 5% level, $\chi^2(3)=9.01$ ($p=0.03$).
[f] Rho has $\chi^2(1)=1.66$, $p=0.20$ and is not significant at usual levels.
* Statistical significance at the 10% levels.
** Statistical significance at the 5% levels.

division of the sample at the first stage, estimated willingness to pay at the second stage may be affected. We use a generalized linear latent and mixed model (GLLAMM) with the ssm command in Stata to estimate a sample selection model that accounts for the drug choice at the first stage (Miranda and Rabe-Hesketh, 2006). The selection equation for choice of Drug A or Drug B is a probit and the WTP equation is an ordered logit.

We estimate the selection model for two pairs of equations: (1) bid and scope only selection in the leftmost column of Table 2 along with the bid and scope WTP for fatality risk reduction in column 2 of Table 3, and (2) age effects and controls in the middle column of Table 2 along with age effects and statistically significant controls in column 4 of Table 3. For the most basic specification with only bid and scope variables $\rho=-0.64$ and the null hypothesis that the errors between the equations are uncorrelated is rejected at the $p=0.00$ level with $\chi^2(1)=364.05$. The negative point estimate of the correlation between the disturbances in the drug choice and WTP equations is consistent with the intuition that unmeasured factors which increase the probability of choosing the riskier drug in the initial stage also decrease the WTP for safety in the second stage. However, for the model with age effects and significant controls, the selection effect is weaker and not statistically significant; $\rho=-0.44$, $\chi^2(1)=1.66$ with $p=0.20$. Hence, we will use the specification without selection reported in column 4 of Table 3 to estimate values of reductions in fatality risks.

Willingness to pay for fatality risk reductions, expressed as VSL, can be estimated from the equation evaluated at the sample means and the constant (cut) for *Definitely Yes* in order to calibrate for

Table 4
Willingness to pay for risk reductions – values of statistical life (2007 dollars, millions).[a]

Age	VSL
Children 4	14.08 (7.29, 20.88)[c]
5	12.84 (6.95, 18.73)
8	9.82 (5.96, 13.68)
11	7.68 (4.97, 10.39)
15	5.81 (3.77, 7.85)
17	5.18 (3.29, 7.08)
Adults 23	4.08 (2.38, 5.77)
30[b]	3.69 (2.11, 5.27)
35	3.78 (2.24, 5.32)
45	4.58 (2.95, 6.22)
55	5.83 (3.68, 7.98)
65	6.66 (3.99, 9.34)
66[b]	6.68 (3.98, 9.38)
75	5.96 (3.23, 8.69)
85	3.46 (0.61, 6.31)
92	1.57 (−0.75, 3.89)

[a] All estimates are based on "definitely yes" responses as the only "yes" responses for the specification reported in column 4 of Table 3. Equations are evaluated at the means for all respondents for *Fatality Risk Reduction*, *Household Income*, and *Schooling*.
[b] The two inflection points are at ages 30 and at 66.
[c] 90% confidence intervals are shown in parentheses.

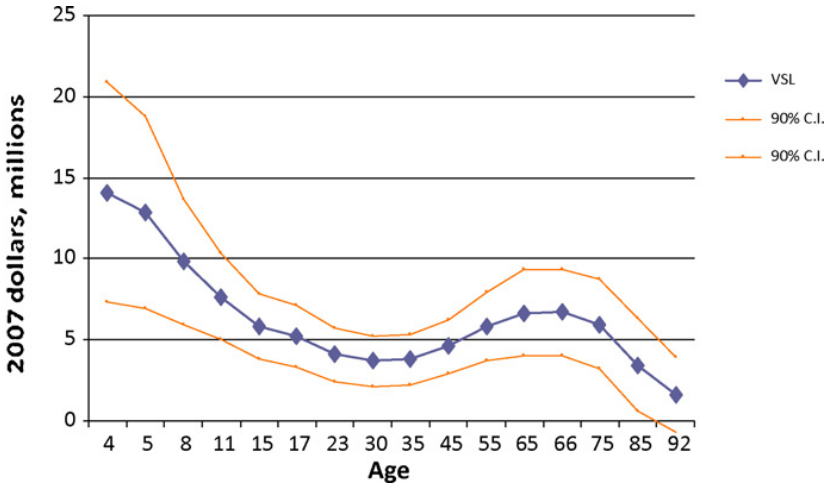

Fig. 2. Value of statistical life by age, millions of 2007 dollars, $N=188$. The two inflection points are at ages 30 and 66.

hypothetical bias.[6] Point estimates for VSLs are shown for ages 4–92 in Table 4. VSL is highest at $14.1 million for children age 4, falls to $3.7 million for young adults age 30, rises to $6.7 million for adults age 66, and falls to $1.5 million for senior adults age 92. Fig. 2 illustrates that the relationship between VSL and age is a horizontal S pattern (rotated counterclockwise). VSL for a child age 4 is greater than

[6] Mean WTP is estimated by: $-(1/b_D)\ln(1+e^z)$ where b_D is the estimated coefficient on *Dollar Bid* and z represents the effect of all of the other covariates evaluated at their means including only one constant, the constant for *Definitely Yes*. This is appropriate when individual WTP is non-negative (Johansson, 1995). Results from column 4 in Table 3 are evaluated and do not include *Female*, *Reluctant Chooser*, and *Familiar with Asthma*. VSL is estimated by dividing mean WTP by the mean of *Fatality Risk Reduction* for the subsample. Standard errors are computed treating values of explanatory variables as known constants. See Blumenschein et al. (1998, 2001, 2008) on calibration to avoiding differences between hypothetical and real values.

Table 5
Ordered logit regressions of willingness to pay for efficacy in asthma control (Dep. Var. is WTP Response for Drug C: definitely no, probably no, probably yes, or definitely yes).

Independent variables	Bid and scope	Age effects and controls	With selection[a]
Dollar bid	−0.0228** (−5.90)[b]	−0.0305** (−5.83)	−0.0174** (−5.74)
Efficacy increase	0.0610** (2.52)	0.1080** (3.14)	0.0668** (3.31)
Age		−0.0771[c] (−1.52)	−0.0469[d] (−1.60)
Age squared		0.0006 (1.28)	0.0004 (1.40)
Household income		0.0116** (2.60)	0.0069** (2.59)
Schooling		−0.0502 (−0.82)	−0.0269 (−0.76)
Female		−0.0366 (−0.13)	−0.0364 (−0.22)
Reluctant chooser		0.8925** (2.15)	0.4786* (1.93)
Familiar with asthma		−0.2837 (−1.03)	−0.2035 (−1.23)
Child × dollar bid		0.0110 (1.28)	0.0064 (1.31)
Child × efficacy increase		−0.0339 (−0.48)	−0.0180 (−0.45)
Child × household income		0.0055 (0.70)	0.0033 (0.74)
Child × schooling		0.3925* (1.94)	0.2264** (2.02)
Child × female		−0.9362 (−1.66)	−0.5435* (−1.68)
Child × reluctant chooser		−1.4014** (−2.36)	−0.9732** (−2.60)
Child		−6.8914** (−2.25)	−3.9350** (−2.32)
Constant 1	−2.2709 (−6.54)	−4.6433 (−2.99)	−2.8605** (−3.13)
Constant 2	−0.3236 (−1.02)	−2.4608 (−1.60)	−1.6077* (−1.77)
Constant 3	1.3089 (3.94)	−0.7716 (−0.50)	−0.6455 (−0.71)
Log likelihood	−369.16	−310.47	−586.88
Pseudo R^2	0.0506	0.1074	
χ^2	39.34	74.68	117.89
% correct (2 categories)	67.8	65.8	
(4 categories)	40.7	40.3	
Rho			0.3235[e]
N	295	263	478/263

[a] The selection equation for choice of Drug A or Drug B includes *Fatality Risk Reduction*, *Efficacy Improvement*, the age cubic, *Household Income*, *Schooling*, *Female*, *Reluctant Chooser*, *Riskier First*, *Familiar with Asthma*, *Child*, and the *Child* interaction variables.
[b] Ratio of coefficient to standard error in parentheses.
[c] The null hypothesis that *Age*, *Age Squared*, and *Child* (for under 18) all have coefficients equal to zero is rejected at the 10% level, $\chi^2(3)=6.88$, $p=0.08$.
[d] The null hypothesis that *Age*, *Age Squared*, and *Child* (for under 18) all have coefficients equal to zero is rejected at the 10% level, $\chi^2(3)=6.72$, $p=0.08$.
[e] Rho has $\chi^2(1)=1.12$, $p=0.29$ and is not significant at usual levels.
* Statistical significance at the 10% level.
** Statistical significance at the 5% level.

VSL for a child age 17, $t=2.07$, $p=0.02$, and VSL for a senior adult age 92, $t=2.86$, $p=0.00$. We find VSL declines for older persons, but the peak for adults is at age 66 and the VSL of $3.5 million for age 85 is not significantly different from the VSL of $3.7 million for age 30, $t=0.22$, $p=0.83$. VSL for age 66 is greater than VSL for age 92, $t=2.35$, $p=0.01$. VSL for a child of age 11, our sample average for children, is greater than the VSL for an adult of age 45, our sample average for adults, $t=1.60$, $p=0.06$.[7] The ratio of the VSLs for ages 11 and 45 is 1.7. The ratio of VSLs for a child age 4 and a senior adult age 92 is 9.0.[8]

[7] The average child is about 10.5 years old and the average adult is 48.
[8] We are interested in the effect of age over a wide range of ages (4–92) and have pooled the data from the parent and general population surveys. Let *Child* be a variable that equals one for age <18 and zero otherwise. We tested for pooling for the specification of the willingness to pay for safety logit with all controls, column 3 in Table 3. The test using a specification with *Child* and *child* interactions indicates no significant difference, $\chi^2(7)=10.31$ and $p=0.17$. For the more parsimonious specification shown in column 4, there is some indication against pooling in that the test for the coefficients on all Child and child interaction variables equal zero can be rejected at the 10 percent level, $\chi^2(5)=9.55$ and $p=0.09$. Given our strong interest in considering the entire range of ages in as straightforward manner as possible, we focus on the pooled results in Tables 3 and 4. VSL estimates from a specification with *Child* and *child* interactions and age quadratic (since the child variables allow the first part of the age profile to differ) are generally similar to VSL values reported in Table 4. The VSL in millions for age 5 is $11.9 instead of $12.8, for age 45 it is $3.9 instead of $4.6, and for age 85 it is $3.1 instead of $3.5. The pattern differs in that VSL does not fall with age for children and the peak value for adults is at about age 55 instead of 66.

4.3. Willingness to pay for asthma control for children and adults

Ordered logit results for willingness to pay for more effective control of asthma are reported in Table 5. The leftmost column of results is for the most basic specification with only bid price and increase in efficacy. The middle column adds age, control variables, and child interactions along with a dummy for child. As with the risk–risk choice and WTP for reduction in fatality risk, we tested for pooling the child and adult samples. Unlike the WTP for fatality risk reduction, we use the child interaction and dummy variables because the null hypothesis that all the child variables are zero is rejected at the 5 percent level, $\chi^2(7)=16.81$ and $p=0.02$. Like the WTP for fatality risk reduction, we do not present a separate equation for respondents familiar with asthma. In Table 5 *Familiarity with Asthma* is not significant at any usual level, a result that was somewhat unexpected. Consistent with this result is that based on seemingly unrelated estimation for all respondents to WTP for efficacy ($n=263$) and those familiar with asthma ($n=182$) we could not reject the hypothesis of no differences between coefficients, $\chi^2(14)=11.87$ and $p=0.62$.[9] Unlike the WTP for safety, we do not report results that account for selection. Because respondent choice of Drug A or Drug B may influence willingness to pay for controlling asthma we estimate a selection model using the specification shown in the rightmost column of Table 5. We find $\rho=0.34$ and the null hypothesis that the errors between the equations are uncorrelated cannot be rejected at any usual level, $\chi^2(1)=1.12$, $p=0.29$.[10] The positive point estimate of the correlation between the disturbances in the drug choice and WTP equations is consistent with the intuition that unmeasured factors which increase the probability of choosing the riskier and more effective drug in the initial stage also increase the WTP for efficacy in the second stage.

In all three specifications, as expected, the coefficient of the price variable (*Dollar Bid*) is negative and the coefficient of the scope variable for increase in efficacy is positive; both are statistically significant. Household income increases the probability of being willing to pay for the more effective drug and is statistically significant at 5 percent level. More schooling for the parent tends to increase WTP for controlling the child's asthma. Adults who were reluctant to choose either Drug A or Drug B were willing to pay more, but the opposite effect occurs for parents' WTP for their children. This effect is reinforced by the negative and statistically significant coefficient for *Child*. Parents apparently want to control their children's asthma, but they do not want to do so with a new medication. No other coefficients are statistically significant at the usual levels including coefficients of the age variables. Because Child and the child interaction variables are used and they will account for any effect at young ages, an age quadratic is used to allow for nonlinearity for adults. For the specification with controls and without selection, the null hypothesis that *Age*, *Age Squared*, and *Child* (for under 18) all have coefficients equal to zero is rejected at the 10% level, $\chi^2(3)=6.88$, $p=0.08$.

Willingness to pay for efficacy in the form of an annual value of asthma control (VAC) can be estimated based on the results for middle column of results in Table 5. Similar to estimation of VSL, the estimated equation for VAC is evaluated at the sample means and for the constant for Definitely Yes.[11] Point estimates for VACs are shown in Table 6 for ages 4–81, the youngest and oldest ages in the subsample. The annual value of asthma control is highest for parent of a child age 4, $4055. The point estimates of mean VAC fall from young children to teenagers, jump to $3908 for young adults age 18, decline until age 60 for adults for whom VAC is $1744, and then rise to $2159 for senior adults age 81. At the 10 percent level of significance, VAC for age 4 is greater than VAC for age 60, $t=1.29$, $p=0.09$, and

[9] We cannot test between familiar and unfamiliar with child interactions and dummy because all the children have asthma.

[10] We have a three-equation system (A–B, C–B, and C–A) where one of the three disturbance correlations has to be zero. It is C–A with C–B because no individual observation is in both of these equations. A priori, one would expect both of the other two correlations to be non-zero (C–B with A–B and C–A with A–B) causing selectivity bias and inconsistency in both the C–B and the C–A equations. We have avoided inconsistency by estimating two selection models, one for C–A and one for C–B, where the selection equation is A–B in each case. It is true that one would expect an efficiency gain to estimating all three equations jointly, rather than two separate two-equation models, assuming both disturbance correlations are substantially different from zero. But, it turns out that both ρ values cannot be distinguished from zero. We found a similar result estimating a Kimhi (1999) endogenous switching model too. In short, the idea that the three equations are part of one system is inconsistent with the data.

[11] Estimation of VSL is described in footnote 5. For VAC the equation is evaluated at zero for *Female*, *Reluctant Chooser*, and *Familiar with Asthma*. Mean VAC equals the mean of WTP divided by the mean of *Efficiency Increase*.

Table 6
Willingness to pay for efficacy – annual values of asthma control (2007 dollars).

Age	VAC[a]
Children 4	4055 (1201, 6910)[c]
5	3852 (1186, 6518)
8	3304 (1064, 5544)
11	2842 (859, 4825)
15	2340 (535, 4145)
17	2130 (376, 3884)
Adults 18	3908 (1818, 5997)
23	3324 (1821, 4830)
35	2382 (1485, 3279)
45	1960 (1163, 2757)
55	1768 (1021, 2516)
60[b]	1744 (1010, 2478)
65	1764 (1013, 2515)
75	1945 (933, 2958)
81	2159 (746, 3572)

[a] All estimates are based on "definitely yes" responses as the only "yes" responses. Equations are evaluated at the means of *Efficacy Increase*, *Household Income*, and *Schooling* for males with moderate asthma. The WTP equations upon which these estimates are based include interaction terms for children.
[b] The inflection point is at age 60.
[c] 90% confidence intervals are shown in parentheses.

VAC for age 18 is greater than VAC for age 60, $t = 1.60$, $p = 0.06$. The pattern hints that values are higher for children and young adults. The ratio of the VAC for an 11-year old to the VAC for a 45-year old, the average ages of the children and adults in our sample, is about 1.5. The VACs are not estimated precisely enough to make more definitive statements about differences between age groups.

5. Conclusions and discussion

The survey population in this study is unique with respect to the breadth of the age range of the sample. The effect of age on VSL is significant but non-linear as shown in Fig. 2. Parents of very young children express the largest WTP for reductions in fatality risk, with VSL declining as the child's age increases, from \$14.1M at age 4 to \$5.2M at age 17. VSL continues to decrease, but at a slower rate, through young adulthood, reaching as low as \$3.7M at age 30. It then rises steadily through remaining working years until reaching \$6.7M at age 66. Estimated VSL falls as age increases beyond 66 years, but does not drop off sharply until after age 75. Because of the wide age range of our sample, support is found for the variety of age related patterns seen in previous studies. For the segment of the sample of working age, the pattern in Fig. 2 is consistent with labor market studies showing VSL increasing with age from a local minimum in early adulthood, steadily increasing through retirement age. However, our data also exhibit the slower and later drop off after retirement age consistent with the stated preference studies as well as the higher VSL for young children found in several studies. The ratio of child VSL to adult VSL of about 1.7, near the sample mean ages of children and adults, lies within the range of previous studies that find a higher VSL for children. The result that, for any given adult age, the ratio declines with age of child mirrors findings in previous research on the valuation of reduced morbidity. The wide age range of the current study and its consistency with seemingly conflicting results from studies looking at narrower age bands imply that age is indeed an important determinant of VSL but that its effect depends on stage of life. Earlier studies may appear to offer conflicting results because of their more narrow focus on different life stages.

Willingness to pay for asthma control was not related to age in the same way as VSL. Instead of a horizontal S pattern over the life cycle, VAC tends to be highest for young children and young adults, at

about $4000 annually, and lowest for adults in their fifties and sixties, at around $1700 annually. The ratio of child VAC to adult VAC of about 1.5, near the sample mean ages of children and adults, is somewhat more modest than the ratio of two often reported at the means in earlier research.

Baker et al. (2008) provide a framework and insightful discussion for thinking about valuing health and risks equally for all individuals in benefit-cost analysis. They suggest that while a persuasive case can be made for values independent of income, a persuasive case can be for values that vary by age. Our results support the importance of considering the influence of age when evaluating the efficiency of health and environmental policies which may have differing age-dependent effects on various sub-populations.

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