Review of Revealed Preferences Studies on Children's Environmental Health

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Paper prepared for the OECD Project on the "Valuation of Environment-Related Health Impacts, with a Particular Focus on Children" (VERHI).

Valuation of Environment-Related Health Impacts with a Particular Focus on Children

Background

The lack of empirical surveys and associated lack of data in this area is a barrier to the provision of sound policy advice. Indeed, existing values used for monetisation of environment-related health impacts focus on adult populations and use scenarios that often do not match well with environmental scenarios. As such, there is concern that the continued use of existing estimates from unrelated contexts that do not take these factors into account may result in a misguided benefit-cost analyses, and in a possible misallocation of resources, especially when environmental policies with significant implications for children are under consideration.

In this context, the OECD Environment Directorate implemented in 2006 a project on the valuation of environmental health impacts, with a particular focus on children: the VERHI Project.

Objectives

This three-year project (2006-2008) funded by the European Commission under the 6th Framework Programme of Research (contract number SSPE-CT-2005-006529) seeks to improve the incorporation of environment-related health impacts in policy-making. An original survey instrument will be applied in three OECD countries (United Kingdom, Italy and the Czech Republic) that have disparities in terms of important factors, such as social insurance systems, health care systems, social concern about the environment, etc.

This survey will be developed so as to obtain methodologically comparable values for adults and children for similar risks, and will also seek to cast light on the context of the risk reduction, and on latency issues. Finally, the project will explore the potential for benefits transfer across countries with different socioeconomic characteristics.

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For more information on the VERHI Project and to download documents, visit the website: http://www.oecd.org/env/social/envhealth/verhi

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1. Introduction

The purpose of this paper is to inform the decision by the VERHI consortium as to whether and how to structure the research on valuing children's health to include a complementary exercise to the planned stated preference study, valuing mortality and/or morbidity risks using revealed preference data. In order to achieve this purpose, we review the empirical studies that have attached a value to mortality and morbidity risks reductions in children by observing parents' or societal behaviours. These studies primarily use the avertive/defensive behaviour or health production function methods to derive these values and are based solely on adoption of the parental perspective.

The structure of the paper is as follows. First, we outline the theoretical basis, and resulting models, that typically underpin the empirical estimates of morbidity and mortality values for children, derived using revealed preference techniques. In the subsequent analysis of individual studies this description of the basic models provides a reference against which the studies can be evaluated. The review of the empirical studies therefore draws out key elements to consider in the decision as to whether and how to conduct a revealed preference study within VERHI. These key elements include: the conceptual model and its justification; the resulting data requirements, and; the study results and their evaluation. We categorise the studies in a summary table and summarise our recommendations.

1.1 Theoretical basis

In valuing a given health end-point it is customary in the first instance to construct a model that reflects the a priori expectations of the researcher relating to the nature and interaction of the determinants of the willingness to pay (WTP) for (avoiding) that end-point. In this section we outline the two main types of models that are used in the context of valuation of children's health. The two model types are: (a) consumer market models that essentially plot the additional expenditures incurred to avoid risks of illness, injury or death, and; (b) health production functions in which consumers' demand for a health input reveals the value they place on the health output (Henkel, 2003). In principle, both types of models can be used to value morbidity and mortality end-points. However, in our examples below we outline a consumer market

[1] Information given in this report reflects the author's views only. The Community is not liable for any use that may be made of the information contained therein.

model in the context of mortality risk valuation and a health production function in the context of morbidity end-point valuation.

1.1.1 Consumer market model

The conventional consumer market model used to describe the valuation of mortality risks in adult population is the general life-cycle consumption model developed by Shepard and Zeckhauser (1982) which explicitly includes mortality-risk mitigating goods or services among the consumption possibilities of individuals over an uncertain lifetime. In this model the consumer devotes her resources either to purchase reductions in her probability of death or general consuming, constrained by income. By doing this Shepard and Zeckhauser focused on the way some age-related attributes (mainly income and consumption) could be introduced into a utility function for life and allowed analysis of how individual willingness to pay for a mortality risk reduction relates with individuals' age and income. Whilst the model suggests, and some empirical studies support, (*e.g.* Jones-Lee *et al*., 1985), that the Value of Statistical Life (VSL) will adopt an inverted U-shape in relation to age, the steady climb to a peak at around the age of 40 has generally been demonstrated to start at age 20. Thus, the model was not developed to include children – excluded, presumably, on the basis that children have neither the maturity nor the financial resources to clearly define their willingness-to-pay.

The only model that we are aware of that extends the scope of the life-cycle consumption model to include children is that developed by Chestnut and Schulze (1998) and is therefore briefly described below, using their notation. This model is adopted in an empirical revealed preference study reported later in this paper (Mount et. al. 2000).

Chestnut and Schulze extended lifecycle-consumption model

This model is developed in the context of automobile safety but can be straightforwardly generalised to any avertive or defensive behaviour context. The starting point for the model is the situation where there is a single individual with no family who may or may not survive for a single period. The individual maximises expected utility defined in the term:

$$[(\Pi - r).m].U(c,a,m)$$

Subject to the budget constraint:

$$[(\Pi - r).m].(w-c) - P(r,a).m - G.F(r,a).m = 0$$

Where:

Π = prob. of survival without (automobile) fatality risk

(Π-r) = prob. of survival with (automobile) fatality risk

m = total miles driven;

c = consumption;

w = wage income

a = level of some other positive automobile attribute;

P(r,a) = automobile (annualised) price per mile/kilometre driven;

G = price of fuel;

F(r,a) = fuel consumption per mile;

U(c,a,m) = strictly concave utility function. Subscripts denote derivatives.

The optimal choice for (r), risk of a fatal automobile accident per mile, is determined by[2]

$$VSL = -(\mathrm{P_r} + G.F_r{}^{*})$$

Where

$$VSL = \left(\frac{U}{U_c}\right) + w - c$$

i.e. the marginal increase in cost for purchasing and operating a safer car per mile is set equal to the VSL, where the VSL is equal to the monetised value of utility (U/Uc) which would be lost in death, plus the excess of wages over consumption.

Chestnut and Schulze (1998) extend the model to include children within a family by adopting a Nash parental cooperative bargaining solution for a single car family. The optimisation problem for the family is how to allocate to each family member the variables: consumption, the risk level of the vehicle, other vehicle attribute (a) and the number of miles/kilometres driven in total and for each person. Each child's utility is assumed to depend on own consumption, the car attribute and the miles they travel in the vehicle. Investment in the safety of their children is a public good to the parents, which is the subject of negotiation, as is the consumption of each. As the Nash model implies, the family unit is not taken as a given in this case; each parent has a "threat point", E^i, (where i is an individual), defined as the maximum utility they each could obtain outside the marriage, and likely to be a function of divorce laws etc. The model solution in this case therefore maximises the multiplication of the increase in the expected utility of the outcome over the threat point of expected utility in separation for the mother and father. Therefore,

$$[(\Pi_m - r).U^m(c_m,...,(\Pi_k - r).U^k(c_k),...) - E^m].[(\Pi_f - r).U^f(c_f,...,(\Pi_k - r).U^k(c_k),...) - E^f]$$

is maximised with respect to c_i, r, a, m, and m_i, subject to the budget constraint

$$\sum_{i=1}^{n}(\Pi_i - r).(w_i - c_i) - P(nr) - F(nr) - H(\Pi_1,...,\Pi_n) = 0$$

Where

i = 1, 2,..n denotes individual family members

i = f =1 = the father

i = m = 2 = the mother

i = k = 3,..n = children

H = family health expenditures

Consequently, given reasonable conditions relating to the level of vehicle risk and miles driven, the individual VSLs of family members all take the form:

$$VSL = \left(\frac{U^i}{U^i{}_c}\right) + w_i - c_i$$

which is identical to that for the single individual. Note that (U^i/U^i_c) depends simply on c_i in the single period model and on the lifetime consumption in the full inter-temporal version of the model. The VSL is therefore determined in part by $w_i - c_i$ so that given $w_i - c_i < 0$ for children and parent without income, the bread-winner's VSL will be highest. Furthermore, since the child's consumption will be a function of the

[2] Note that first order derivatives throughout this report are indicated by subscripts.

parent's (or parents') income and wealth, her consumption will be maintained at a high level leading to a high VSL. At the same time, the utility derived (by the child and consequently the parents) from a given level of consumption may be high or low suggesting that the VSL of children is an empirical question determined by their own life cycle wealth, the income and wealth of their parents and the beliefs of their parents regarding their children's utility. In this case, the optimal choice for r, risk per mile, is determined by

$$\sum_{i=1}^{n} k_i.VSL_i = -(\mathrm{P_r} + G.F_r^{\ *})$$

Where usage rates of the vehicle for each family member are: $k_i = m_i/m$. VSL estimates can then be calculated by obtaining predicted values for the marginal cost of reduced risk per kilometre and the share of vehicle use for each family member by age group for different households this equation can be used to derive estimates of VSL_i.

1.1.2 Health Production Function model

As with mortality, the utility function can be either unitary or pluralistic. These functions are then sometimes combined with a health production function model to derive WTP estimates[3]. We therefore outline this model here. Morbidity[4], or sickness, is influenced by behaviour and is "produced" according to a health production function which has the following generic form (after Dickie, (2003) and Harrington and Portney, (1987)):

$$S = S(E, G, Z)$$

Where

S = sick time

E = exposure to environmental risk

G = mitigating activity (*e.g.* preventative medicine)

Z = exogenous factors that affect the length of illness (*e.g.* age)

E is also influenced by behaviour since E = E(A, α) where

A = avertive behaviour (*e.g.* changing activities or buying goods to reduce exposure) and;

α = the existing level of risk

Thus, G and A are simply different ways of reducing illness for a given environmental health risk level.

The budget constraint is given by:

$$I + w.T_w = C + p_g.G + p_a.A + M(S)$$

Where

I = non-labour income

w = wage rate

[3] The alternative to use of a health production function is a consumer-market approach of the type outlined above for mortality.

[4] Clearly, the health production function approach can be used to value changes in mortality risk as well as morbidity.

T_w = work time

p_g = unit price of G

p_a = unit price of A, so that $p_g.G + p_a.A$ are the individual's defensive expenditures.

M(S) = remedial medical expenses, dependent on S

If the health production function is substituted into the utility function and budget constraint and then differentiated by changes in defensive expenditures the marginal rate of technical substitution between defensive behaviour and environmental risk is derived. The expenditure on the defensive expenditure therefore gives the WTP for the risk change.

$$WTP = -p_g.\left(\frac{\partial S}{\partial E}.\frac{\partial E}{\partial \alpha}.\frac{\partial S}{\partial G}\right) = -p_a.\left(\frac{\partial E}{\partial \alpha}.\frac{\partial E}{\partial A}\right)$$

WTP is therefore driven by the opportunities available for the parent to substitute defensive behaviour for reduced environmental risk. Equivalently, of course, the health of an individual – in this context that of a child – is determined by the positive investments (health inputs *e.g.* pre- or post-natal care) made either prior to or after birth. In this case the WTP for improved health is estimated by measuring these investment expenditures against the subsequent (positive) health outcome.

These models, and variants of these models, provide the conceptual basis of a number of the empirical studies reported below and so are not described again in their reporting, but simply cross-referenced. One reason for highlighting these models is that they determine the range and type of data required to undertake a revealed preference study in this valuation context.

1.1.3 Unitary and Pluralistic models

Note that in the consumer market model the use of the Nash cooperative bargaining solution implies that individual (adult) preferences are specified in individual (pluralistic) utility functions, rather than a common (unitary) household utility function. Typical pluralistic utility functions for the mother and father respectively are:

$$Um\ (c_m, c_k, H_m, H_k) \text{ and } U_f\,(c_f, c_k, H_f, H_k)$$

where H = health and m, f, and k denote mother, father and children, respectively. Generalising from the specific case for mortality risk to include morbidity in an overall health attribute, such a unitary function would have the form:

$$F(c, Hm, Hf, Hk).$$

The distinction between unitary and pluralistic models is thought to be a potentially important one in determining the willingness to pay for children's health given the belief that intra-household resource allocation is often more complex than the unitary models allow. However, the practicalities of distinguishing alternative intra-household utility functions using revealed preference techniques generally results in unitary functions being adopted. The issue is discussed further in the discussion of the empirical studies, below.

1.2 Empirical studies

This paper is written in the context of determining the approach the VERHI researchers should take in valuing children's health. By way of summarising the range of existing evidence we provide a table, (Table 1 below), that lists the principal empirical studies that have – to our knowledge – been undertaken in the valuation of children's health, using revealed preference techniques. For information, the second part of the table lists studies using stated preference techniques.

Table 1. Children's Health Valuation: Revealed and Stated Preference studies

Study Reference	Country of study	Nature of the risk	Component of the monetary trade-off	Study method	Unitary or Pluralistic Utility function
Revealed Preference Studies					
Joyce *et al* (1989)	US	Air pollution health risks	Pre- and neonatal care	Health Production Function	U
Carlin and Sandy (1991)	US	Fatality risks with use of children's car seats	Purchase prices of car seats plus time to buckle children	Consumer-market	U
Blomquist *et al* (1996)	US	Vehicle safety restraints	Purchase prices of seat-belts	Consumer-market	U
Agee and Crocker 1996	US	Development problems: lead poisoning	Purchase of chelation therapy	Consumer-market	U
Jenkins *et al.* (2001)	US	Bicycle helmets & fatal head injury risks	Purchase prices of bicycle helmets	Consumer-market	U
Mount *et al* 2001	US	Death from automobile accidents	Automobile purchases	Consumer-market	P
Agee and Crocker 2001	US	Illness associated with tobacco smoke	Reduction in domestic ETS	Health Production Function	U
Maguire *et al* 2002	US	Illness from pesticide exposure	Purchases of organic babyfood	Consumer-market	U
Nastis and Crocker 2003	US	Neo-natal health (birthweight)	Pre- and neo-natal care	Health Production Function	U
Stated Preference Studies[5]					
Viscusi *et al* 1987	US	Insecticide and domestic hygiene-related	N/A	CV	U
Tolley and Fabian 1999	US		N/A	CV	
Liu *et al* (2000)	Taiwan	A cold	N/A	CV	U
Dickie and Ulery 2002	US	Air pollution-related acute illness	N/A	CV	U
Dickie and Gerking 2001	US	Skin cancer	N/A	CV	U
Dickie and Brent 2002	US	Air pollution-related acute illness	N/A	CV	U
Dockins *et al*	US	Review of 3 studies:	N/A		

[5] Details on the scenario design applied in the stated preferences studies are provided in Table 3 (see Annex).

(2002) (review of 3 studies)		various			
Dickie and Gerking 2003	US	Skin cancer	N/A	CV	U
Maguire *et al* (2004)	US	Pesticide-related cancer	N/A	CV	U
Dickie and Hubbell (2004)	US	Asthma	N/A	CV	U
Dickie and Gerking 2005	US	Skin cancer	N/A	CV	U

Table 1 serves to emphasise a number of issues in this area of valuation. First, there are a limited number of studies in this area and all but the study by Liu *et al*. (2000) have been undertaken in the US. Second, whilst the revealed preference studies mostly estimate accident-related health values, the stated preference studies generally address environmental risk values. This split may reflect the policy question to be addressed but, in all likelihood, also reflects the data constraints faced by those wishing to undertake revealed preference studies. Third, whilst the revealed preference studies all adopt unitary utility functions in their model, there is some exploration of pluralistic functions in the stated preference studies, reflecting the difficulty, mentioned above, of distinguishing differing utility functions between household members on the basis of revealed preference data.

2. Review of studies that have observed parents' and societal behaviours

In this section we provide an overview of the individual studies undertaken to date that use revealed preference techniques to value children's health end-points. This overview is designed to allow us to address the following questions: Do existing studies produce robust estimates, and is it possible to produce improved results using a) better data; b) better method in the EU? In order to try to answer these questions, for each study we describe the overall study purpose, including the specific end-point and the sub-population addressed *e.g.* by age-group. We indicate the type of underlying model and specific features of that model and the data sources used, as well as the main WTP results.

2.1 Studies using Consumer market models

Carlin and Sandy (1991)

Carlin and Sandy (1991) calculate the implicit value of a young child's life (age 1 – 5) to his, or her, mother as revealed by her decisions about child car safety seat usage.

A two-period life-cycle model of the type developed by Chestnut and Schulze (1998), and outlined above, was used. An additional variable for child life-saving activity, S, was included in the utility function to allow for effects apart from life-saving properties.

Data used was 1985 data from Indiana, USA, where decisions of mothers to purchase and properly use car seats were effectively unconstrained by law (state law rarely enforced) but constrained by time and income. Survey data of car seat usage was gathered at ten sites in the State, where all cars passing the sites were stopped. The data was gathered on the basis of a quick visual examination of car seat usage and a one page mail-in questionnaire given to each driver asking for data on their socio-economic characteristics. A sample-size of 190 was reached, of which 131 had car seats. (The possibility of selection bias was recognised as it was thought that those who returned their questionnaire were more likely to favour car seat usage).

The data was used to estimate a maximum likelihood probit estimate of the probability of a mother purchasing and properly using a car seat before calculating the average value to the mother of a child's life V.

$$V = \frac{K}{P_S} = \frac{[\theta . w_e + d - (\frac{U_S}{\lambda})]}{P_S}$$

Where:

K = marginal cost of child car safety activity in terms of time (e), money (d) and the monetised value of the net utility component of the child life-saving activity.

θ = adjustment to nominal wage rate, w, on the basis that the opportunity cost of time spent harnessing children into car seats may be less than nominal wage rate.

P_s = change in the probability of the child's survival due to the car safety activity

Thus the VSL equals the cost of the car safety activity divided by the change in the probability of the child's survival due to the car safety activity. A resulting VSL estimate of €950,000 (2005 prices) was derived which – the authors suggest – is lower than many estimates of own VSL. The VSL is found to be most dependent on the assumptions relating to the number of trips with small children per week, the effectiveness of car seats, time spent in harnessing children, and the probability of survival.

The validity of the VSL estimate depends on validity of assumptions are mothers well-informed about the effectiveness of car seats in saving lives, and do they make conscious, logically consistent decisions based on that information? It is also not known whether differences between individuals reflect differing degrees of resistance from child, risk neutrality, or a different size of risk change.

The authors initially assume that there is no role for the child car-seat in non-fatal injury prevention. However, to account for this possibility, they subsequently suggest a 20% adjustment downwards to account for this. The relevance of this adjustment depends on the availability use information to the purchaser. For example, it is not clear how much information is provided about safety standards relating to both life-saving and injury reduction characteristics. Carlin and Sandy assume that the mother/driver makes decisions about car seat usage independent of this information so that the problem of aggregating across two utility functions is avoided.

Blomquist et al. (1996)

Blomquist *et al*. (1996) examine the use of safety-belts, child restraint systems and motorcycles to derive VSLs and value of injury-reducing activity for adults and children. They adopt the same model individual life-saving activity used in Blomquist (1979) to show how the value of life saving is implied by observable behaviour, and estimated a value of a statistical life based on the premium individuals pay in the seatbelt use in order to reduce their risk of death. The value of a statistical life is demonstrated to correspond to the value of a unit change in the probability of survival and equal to the monetary worth to the individual of his or her future utility of consumption – as in the Chestnut and Schulze model above. The first order condition of the budget constraint allows estimates of injury values and VSLs to be made.

$$(P'_F . V_F + P'_{NF} . V_{NF}) - (q + \frac{U_S}{z}) = 0$$

Where

P'_F and P'_{NF} are the increases in annual probabilities (P) of survival (F) and avoiding non-fatal injuries (NF) due to an intrinsic increase in protection

V_F and V_{NF} are the values of decreases in fatal and non-fatal risks.

q = time cost incurred

Us = the marginal disutility associated with the activity

z = the marginal utility of income

Empirically, the value of a statistical life is therefore considered as money costs plus disutility costs less morbidity benefits, all divided by the change in the probability of survival. Seatbelt-use money costs include time costs, such as installation of seatbelts and buckling, and disutility costs consist of the discomfort of using belts, distastefulness of buckling and unbuckling, and resistance to use due to habit.

Data used included US Department of Transportation's 1985 Nationwide Personal Transportation Study supplemented by various other departmental data sources. Approximately 7,900 households were included. Monetary disutility estimates are taken from external estimates, including *e.g.* the marginal rate of substitution between vehicle weight and fastening time.

The sample for child safety-seat use – and for all child safety equipment – only includes parents with children under the age of five. The authors' favoured estimate of the child's VSL is a value of €5.2million – €9.3million whilst the value for a non-fatal injury is €220,000. These values compare with equivalent values for adults from seat-belt analysis of €3.5million (VSL) and €100,000, (non-fatal injury) and €2.4million (VSL) and €76,000 (non-fatal injury) for the motorcycle helmet analysis.

The study was possible because seatbelt usage at that time was voluntary: only 23% of US drivers used seatbelts at the beginning of the seventies, which enabled the use of probit analysis to estimate the value of life for the typical driver who did not use seatbelts. Such study would presumably not be possible nowadays, since the use of seatbelts is mandatory in most countries.

Agee and Crocker (1996)

Agee and Crocker (1996) used parents' decisions to treat their children's body burdens of lead (in order to avoid long term cognitive and adaptve behaviour deficits) to infer WTP for reduced burdens. A joint parental utility function was assumed, based on cooperative equilibrium. Expenditure on chelation therapy medical treatment, after lead screening was used to derive the WTP estimates. This has the advantage – as with the Carlin and Sandy study reported above – of avoiding the complexity introduced by the existence of joint products: chelation therapy has no alternative benefit to an individual apart from reducing risk of lead poisoning.

$$WTP = \left(\frac{P_m}{\lambda}\right) \cdot \left(\frac{\partial v.M}{\partial l}\right)$$

Where:

P_m = probability, following screening, of parents obtaining chelation therapy for their child.

vM = parents' maximum expected utility if chelation is chosen

λ = marginal utility of income

l = lead level in child

The sample was made up of 256 children aged 3-6 in Boston, Massachusetts, derived from 1978 and 1985 health care surveys in the city, and supplementary data on wage levels and treatment results was utilised. The mean parental WTP for a 1% reduction in the lead burden of their child was estimated to be €29.

The authors note that the probit estimator can be highly sensitive to the assumed form of the underlying distribution, thereby skewing the WTP estimates. In addition, there is an issue as to whether chelation therapy is essential if parents can reduce exposure by correcting hazard sources, variable A in the utility function. Since exposure reduction is a complement to chelation therapy then positive parental benefits associated with a reduction in l exist even when chelation therapy is not purchased. The WTP estimate obtained will then under-estimate the true WTP.

Jenkins et al. (2001)

Jenkins *et al.,* (2001) studied the market for bicycle safety helmets in order to estimate the value of a statistical life for different age groups, including children. By using the same methodology and data to estimate values for both children and adults the authors provided a set of values for reduced mortality risks that are directly comparable across child and adult age categories. As with the other studies, above, bicycle helmets do not generate any positive effect other than safety improvement.

The assumption underlying the valuation exercise is that consumers (cyclists) purchase a helmet if their value for the reduced risk of head injury (whether resulting in death or not) is greater than the cost of the helmet, including the purchase, time and disutility costs. This means that the value of a statistical life is greater than the annualised cost of a helmet divided by the change in the probability of death due to the purchase and use of the helmet. In other words, this study generated lower bound estimates of the value of a statistical life for helmet purchasers and, by implication, an upper bound estimate of the value of a statistical life for cyclists who do not purchase helmets. The underlying model therefore conforms to the Chestnut and Schulze model outlined above.

The annualised cost of a bicycle safety helmet was estimated using average market prices, a replacement period of four years, and zero value for time (fastening/unfastening) and disutility (discomfort) costs for children and adults, given the difficulty of obtaining such data. The reduction in the probability of head-injury death was estimated as follows: an estimate was made of the number of bicycle trips by age group using results of a national survey; the number of deaths due to head injury from bicycle accidents, (data from the US Centers for Disease Control and Prevention); and the effectiveness of bicycle helmets at reducing mortality risk.

The estimated value of a statistical life VSL for helmet users varied between €1.6million and €3.4million (5 to 9 years); €1.4million and €3.3million (10 to 14) years; and €2.5million and €6.5million (20 to 59 years), according to different assumptions on the length of time using helmets and equal concern between death and injury (assumptions of 0% and 50% of cost attributed to non-fatal injury). The results suggest a non-linear relationship with age, starting high, then falling in teen years before rising towards middle-age.

Mount et al. (2001)

Mount *et al* (2001) examine family automobile purchases to show how parents may value risks to their children's lives and health and so to determine how much money to invest in the health and safety of their children. Automobile safety is a family public good and the marginal cost of purchasing and operating a safer automobile is set equal to the usage-weighted sum of the values of statistical life of family members.

The authors use data on automobile purchases to estimate how many families with children spend on automobile safety and how many families with retired members and no children spend on safety, compared to families without children or retired members.

The model used is Chestnut and Schulze (1998) adopting a Nash parental cooperative bargaining solution the family unit is not taken as a given in this case; each parent has a "threat point", E^i, (where i is an individual), defined as the maximum utility they each could obtain outside the marriage. The individual VSLs of family members all take the form:

$$VSL = \left(\frac{U^i}{U^i{}_c} \right) + w_i - c_i$$

the optimal choice for r, risk per mile, is determined by

$$\sum_{i=1}^{n} k_i . VSL_i = -(\mathrm{P_r} + G.F_r{}^*)$$

Thus, the average VSL is obtained by inserting into hedonic equations the various costs associated with owning and using automobiles against their safety, including driver characteristics and socio-economic variables. Data on household's choice of automobile was taken from the 1995 National Personal Transportation Survey: a data sub-set of 4036 one-car households owning a 1990-1995 vehicle. The number of fatalities per model-year and driver characteristics was derived from the U.S. Department of Transportation' Fatality Analysis Reporting System for 1995-1997. Injury rates were calculated from insurance data kept by the Highway Loss Data Institute.

The "raw" VSL estimates were subsequently adjusted for income and driver perceptions about their driving ability and safety (roughly 80% of drivers think that their driving skill is above average). Multi-car households were not accounted for, thereby limiting the analysis. In addition, the seating position of family members – and therefore their risk was not accounted for because of lack of data. VSL estimates differ primarily according to: income elasticity assumed and the extent of the adjustment for risk perception. However, central estimates derived suggested that children (of average age of 8) have VSL of €11.7million, whilst adults have a VSL of €11.4 and retired people have revealed VSL of €8.3.

Maguire et al. (2002)

This study estimates the price premium associated with organic baby food by applying a hedonic model to price and characteristic data for baby food products in two US cities. The consumption of organic food is interpreted as a way of avoiding ingestion of pesticides; thus, the premium on jarred organic baby foods can be interpreted by as the WTP to avoid pesticide residues. The hedonic price function is expressed as

$$Pi = h(Si, Fi, Oi)$$

Where

P_i = price of the ith jar of baby food

S_i = shop/store characteristics

F_i = characteristics associated with the ith jar of baby food other than organic

O_i = the organic component/characteristic of the baby food

The data was collected from a random selection of 83 shops in Raleigh, North Carolina and San Jose, California in 2001. There were a resulting total of 1,697 usable observations. Using a linear estimation model, the premiums are found to be approximately 14 Eurocent per jar. It was impossible to separate out the relative importance of other preferences associated with organic food products such as those for environmentally friendly farming practices or to avoid worker exposure to pesticides.

For our current purposes the salient points to note at this stage are:

- The 2:1 ratio between transport safety-based and environmental risk valuations, likely to be reflecting the relative policy interest in these two areas, but also the availability of data that differentiates child risks and measures from those applied to adults.
- The attention given to the avoidance of joint products.
- The general failure to be able to systematically distinguish between fatal and non-fatal health end-points in the WTP estimates.
- The requirement for large data sets to be used in order to generate sufficient sample sizes for particular sub-sets.
- The problems of treatment of variables, especially the disutility of applying safety measures, where there is no observed data.

2.2 Studies using Health Production Function approach

Joyce et al. (1989)

The Joyce *et al* (1989) study estimates race-specific WTP for the pre-natal and neo-natal benefits of a ten percent reduction in sulphur dioxide levels in the US. These estimates are made with the use of a health production function. A unitary utility function for the household is assumed to depend on parents' consumption, the number of births and the survival probability of each offspring. Maximisation of the utility function subject to production and resource constraints generates a demand function for survival in which the survival probability is related to input prices, efficiency, income, environmental quality and tastes. The interaction between the survival demand and the production function determines demand functions for medical care and other endogenous inputs. The neonatal mortality rate production function is given by:

$$1-\pi = f(n,m,a,c,q,s,x,e)$$

Where

π = survival probability

n = neonatal care inputs

m = medical inputs

a = use of abortion services

c = use of contraceptive services

q = environmental quality

s = maternal cigarette smoking

x = exogenous risk variable

e = infant's biological endowment

From this, the direct and indirect effects on neonatal mortality of the basic health inputs and environmental quality can be estimated. The fact that e is not an observed variable means that a two-stage least squares procedure is required to estimate the production function. The marginal WTP is then obtained directly from the production function and is equal to the marginal product of environmental quality in the production function multiplied by the ratio of a health input (*e.g.* prenatal medical care use) to the marginal product of that input:

$$WTP = \pi_q.(\frac{p}{\pi_m}).dq$$

Where

π_q = increase in survival probability caused by a small improvement in environmental quality, and

π_m = the marginal product of prenatal care

The neonatal mortality rate production functions are estimated with a data set for the years 1976-78 constructed for the 677 most populated counties in the US in 1970. Air pollution data was taken from the Environmental Protection Agency's Storage and Retrieval of Aerometric Data (SAROAD). The regressions find that when a range of five pollutants are employed as explanatory variables, sulphur dioxide is the only significant predictor of neonatal mortality. The WTP for a 10 percent reduction in sulphur dioxide is then estimated using the equation above.

The marginal WTP for prenatal care for a white person is €2 whilst it is €7 for a black person. The marginal WTP for neonatal care is higher for both white families (€29) and black families (€200). Dickie and Nestor (1998) subsequently divide by the appropriate mortality risk to derive VSL estimates for white births of between €78,000 and €1.35million, and between €107,000 and €2.6million for black births. The robustness of the estimates are strengthened by the fact that since expectant mothers are less likely to move during their pregnancies they are therefore less likely to have been exposed to pollutants at other locations.

The authors' place more emphasis on the methodological developments incorporated in this study than the robustness of their results. Indeed, no explanation is offered for the striking difference between the results for black and white families.

Agee and Crocker (2001)

Agee and Crocker (2001) estimate smoking parents substitution rates between their own consumption and own health, between own consumption and their children's home exposure to environmental tobacco smoke, (ETS), and between their own health and own children's health. The main motivation for the study is to explore whether restrictions on smoking in public places have increased smoking in the home by way of compensation, and whether the attendant health effects are considered. It is also thought that smokers have different health risk-wealth trade-off preferences from non-smokers.

The authors adopt a standard household health production function, as outlined above. The parents' marginal valuation of an exogenous improvement in their child's health is defined as the trade-off between family income and the marginal improvement.

$$\frac{\partial Y_t}{\partial H_t} + 1 = \frac{-p.h}{\frac{\partial H_{t+1}}{\partial h_{t+1}}}$$

Where:

Y = household income

H = Household health

h = child-specific health-related product

and

$$\frac{\frac{\partial Y_t}{\partial H_t}}{\frac{\partial Y_t}{\partial h_t}} = \sigma$$

Where σ is the marginal rate of substitution between own health and children's health.

Observed data on adult expenditures on health, smoking behaviours and child and adult ETS exposure response relationships enable assessment of parental valuations of own health and child health and health enhancing reductions in home ETS exposures. The key data is taken from the National Maternal and Infant Health Survey, 1991. The sample size taken from this data set is 5,631 (mostly women), of which 1,533 are smokers. All children incorporated in the sample are three years old.

The smoking sample values a ten percent improvement in their children's health roughly twice that of the same improvement in their own health. Statistically significant negative association between sample parents' assessed health of their child and that child's daily exposure to ETS. Estimated annual parental WTP for a one percent reduction in their child's daily ETS exposure ranges from €15.6 to €20.7. The value of the study may be enhanced were the preferences of a parallel analysis of non-smokers undertaken, thereby allowing us to identify how preferences vary between such groups and inform applications of restrictions on public smoking.

Nastis and Crocker (2003)

The Nastis and Crocker (2003) study uses a pregnant woman's own consumption in its various commodity-specific forms to estimate the value she attaches to own-health relative to the health of the fetus she carries. A mother's weight gain during her pregnancy has a strong positive influence on her child's birth-weight. Given that birth-weight drives post-natal child health, it is plausible that an adults' relative valuation of own to post-natal child health reflects the in utero investment the pregnant mother makes. If so, an estimate of the own/fetus health valuation will be predictive of the evolution of her own/child health valuation.

Estimation of the birth-weight production function is made using a 2-period model: before and including birth and accounts for probabilities of live birth, or not. The specified production accounts for endogeneity of mother's health on child's health and could be – but is not here - extended to post-natal care. Given a live birth, a mother's marginal valuation of an exogenous improvement in health infrastructure is her monetised marginal rate of substitution between income on the one hand and health inputs to her and her child's health on the other. Cooperative equilibrium exists such that household preferences can be described by a single preference function.

Data is taken from the National Maternal and Infant Health Survey, 1988, a data set specifically designed to acquire information on pregnancy outcomes for US women. A sample size of 12,876 mother/child observations results. Other key data gathered includes medical visit costs and socio-economic characteristics.

The results of the study suggest that pregnant mothers value child health six times more than their own health; that mother's health and child's health are complements, and; the indirect effect of maternal behaviour increases the estimated contribution mother's health makes to child health. Furthermore, women who do not have children already value their child's health relative to their own more than twice as much as do other women who already have children.

Summary comments that relate specifically to the studies estimating health production function include:

- Health production functions are applicable to a range of factors determining children's health – as reflected in the contrasting subjects of the three studies considered here. However, these studies also indicate that derivation of specific end-points is more demanding; all three studies derive WTP to reduce environmental or other hazards, rather than the range of individual end-points associated with these hazards.
- The data requirement implied in constructing health production functions is high, reflecting the large numbers of variables often specified in the models.
- The econometric demand of estimating health production functions is also high, reflecting, in part, the need to account for dependent variable endogeneity by using two-stage least squares regression analysis.
- The problems implied by joint production are only avoided by careful model specification and its empirical implementation.

3. Conclusions and Discussion

The results of the studies reviewed are presented in Table 2. Table 2 shows:

- Parents are more willing to pay to reduce their children's health risks than their own. The estimated marginal rate of substitution (MRS) is generally greater than one, and is, on average close to 2 (though Jenkins *et al*. is an exception).
- In absolute terms, the VSL estimates are comparable with those for those found for adults in other studies (though the ranges suggest a similarly high degree of uncertainty associated with them).
- Values for younger children are generally found to be higher than for older children.
- Values for the reduction of children's mortality risk are greater than the values for the reduction of morbidity risk.
- On the basis of this limited evidence it is impossible to discern systematic differences in the values between consumer market and health production function methods. (Though it is worth noting that Blomquist (2003) identifies higher valuations for health production function models when studies of adult health valuation are also considered).

Table 2: Valuation of child health end-points

Study Reference	Study method	Health end-point	Unit value (child)	Ratio of child-parent unit values
Carlin and Sandy (1991)	Consumer-market	Accident-based Mortality risk	VSL €0.95m	<1:1
Blomquist *et al* (1996)	Consumer-market	Accident-based Mortality risk Severe injury	VSL €5.2m – €9.3m €0.22m	2:1 2:1
Agee and Crocker 1996	Consumer-market	1% reduction in lead burden	€29	-
Jenkins *et al.* (2001)	Consumer-market	Accident-based Mortality risk	VSL €1.6m - €3.4m (5 - 9); €1.4 - €3.3m (10-14)	0.6:1
Mount *et al* 2001	Consumer-market	Accident-based Mortality risk	€11.7m	1.1:1

Maguire *et al* 2002	Consumer-market	Cancer	-	-
Joyce *et al* (1989)	Health Production Function	Air pollution health risks	VSL €0.078m - €1.35m (white) €0.1m - €2.6m (black)	-
Agee and Crocker 2001	Health Production Function	ETS health risks	-	2:1
Nastis and Crocker 2003	Health Production Function	Post-natal health	-	6:1

Our review of the studies has indicated to us that whilst there has been a growing need for policy relevant values for children's health end-points, revealed preference (and indeed stated preference) studies have primarily been preoccupied by the development of methodological approaches that can adequately address the difficulties inherent in deriving robust values. In particular, the need for complex modelling of (intra-) household preferences presents major data demands.

Perhaps the area of greatest weakness in this regard is the recognition of the potential relevance of pluralistic utility functions in determining WTP contrasting with the inability of datasets to allow intra-household utility functions to be separated. Thus, whilst the studies by Agee and Crocker (2001) and Mount *et al*. (2001) distinguish themselves through their incorporation of parental bargaining model, it is not clear how the co-operative solutions assumed differentiate the estimation procedures in practice since separate WTPs are not estimated for different family members. That having been said, it is difficult to envisage any empirical context where the data would be sufficiently disaggregated to allow this differentiation. The issue of quality-quantity trade-off with respect to the number of children is similarly challenging to explore with revealed preference data alone.

Other areas of concern can be noted. First, as with all revealed preference studies there is the potential for joint production hindering recovery of preferences from observed behaviour relating to health choices. Similarly, whilst this problem can be avoided with careful selection of the valuation context, (see *e.g.* Agee and Crocker, 1996), the problem of identification of other avertive or productive behaviour that might impact on the utility function remains.

A further issue is that of risk perception being at odds with objective, or expert, risk estimation. The discrepancy between subjective and objective risks is, of course, a potentially distortionary influence on WTP for adult health risks as well but is perhaps exacerbated in the children's health context where parents mistakenly transfer their knowledge of adult risk to their child's context.

Finally, by their nature revealed preference studies do not allow information on the motivation of parent(s) to be extracted. This weakness is important in the context of children's health valuation because there is a significant literature (*e.g.* Harbaugh, (1999)), that shows that it is important to know whether, and of what form, altruism determines WTP.

4. Conclusions

Based on this review and the companion paper that reviews the epidemiological evidence relating to children's health end-points the following conclusions may be drawn:

1. There are methodological limitations of, and high data demands implied by, the use of revealed preference studies in the present context that argue against undertaking a study of this sort

complementary to the planned stated preference study in VERHI.

2. The epidemiological literature review suggests that the health end-points of most importance are air pollution induced mortality and respiratory symptoms, and cancers associated *e.g.* with pesticide use. It is difficult to think of examples of action taken through market transactions with the intention of avoiding these end-points, though the housing market and organic food market are potential possibilities. In both these cases, however, the challenge of identifying the WTP for the air pollution and cancer end-points alone is likely to be significant.

3. On the basis of points 1) and 2) we recommend the VERHI team not to proceed with a revealed preference study without additional resources.

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Table 3: Annex

Study Ref	Location	Health end-point valued	Size of Risk change(s)	Timing of risk change(s)	Payment vehicle	Format of WTP question	Test for altruism	Sample size & Survey popn. (+ children)
Viscusi et al 1987	Greensboro, N.C., US Shopping mall & hardware store	Insecticide and toilet bowl cleaner	+1; -5;-10;-15 per 10,000	Immediate	Private good	OE	Asked whether thought other h'holds affected	Insecticide: 672 with no C <5; 113 with C<5 Toilet Cleaner: 551 with no C <5; 183 with C<5 Adult over 21
Liu et al (2000)	4 regions in Taiwan	A cold	Prevention of mother and child's cold events	Immediate	Private good (preventative medicine)	Triple bounded binary choice (same starting bid for mother and child)	Not mentioned	598 mothers randomly selected through schools Face-to-face
Dickie and Gerking 2001	Hattiesburg, US	Skin cancer (melanoma & non-melanoma)	Max protection from both; Limited protection from both; Combination of max and limited protection	Immediate (use of 1-period model - latency effects included)	Private good (sunscreen product)	Double bounded DC	Parent & one child. Told not to consider other members of family	160 parents with C 3-12 recruited with RDD. $30 incentive Face-to-face
Dickie and Brent 2002; Dickie and Ulery 2002; Dickie & Hubbell (2004)	Hattiesburg, US	4 Air pollution-related acute illness	Max relief of symptoms from 4 illnesses.	Immediate	Private good (medicine on 1st day of illness)	Double bounded DC	Parent & one child. Told not to consider other members of family	284 parents with C 3-17 recruited with RDD. Asthmatic children over-sampled $20 incentive Face-to-face
Dickie and Gerking 2003	Hattiesburg, US	Skin cancer Morbidity & mortality	2 degrees of risk reduction of skin cancer (10%, 50%) (own, child);	Immediate (use of 1-period model -	Private good (sunscreen product with	Double bounded DC	Parent & one child. Told not to consider other members of	610 parents with C 3-12 recruited with RDD. $25 incentive

Comments on the reviewed survey instrument scenarios

- The majority of studies have been undertaken by Mark Dickie and colleagues, valuing skin cancer or acute air pollution risks, and using samples in Hattiesburg, Mississippi, USA. In these valuations the parent – child trade-offs are made with one (randomly selected) child from the family and a parent who is knowledgeable about family health and health costs. (On the same basis, mothers only are surveyed in Liu *et al.* (2000)).

- In all studies apart from Dickie and Gerking (2005), a one-period model is used that abstracts from the question of latency and discounting.

- All studies use a unitary model that abstracts from differences in intra-family resource allocations. This appears to have been assumed partly to enable the survey to most effectively isolate the trade-offs between parent and child, and partly to keep the length of interview reasonable.

- The Dickie *et al.* studies use the grid squares tool – as also used by Alberini and Krupnick - to express risk changes

- All studies include at least some degree of familiarisation with the good – either their own experience or others that they know;

- All dichotomous choice questions randomise the starting values over the survey population.

- There is little testing for the degree of certainty that respondents have in their WTP answers. Viscusi *et al.* (1987) test for a certainty premium when the outcome of a trade-off is certain.