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Willingness to Pay for Improved Health: A Comparison of Stated and Revealed Preferences Models

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Abstract:
This paper discusses two approaches for valuing reduced asthma morbidity: revealed preference and stated preference. We study a population including 205 children ages 6-11 with clinically diagnosed asthma, for whom detailed health measures, utilization of health services, levels of antigens in the households and exposures to a wide rage of air pollutants were collected as part of a five-year epidemiological study. We administered two economic surveys to measure: 1) households' perceptions of risks to an asthmatic child; 2) averting and/or mitigating actions taken; and 3) households' stated willingness-to-pay for a reduction in their child's asthma morbidity.

Simply summing direct and indirect costs provides an incomplete measure of the value of health, as demonstrated by summary statistics from our surveys. The revealed preference approach uses a health production model in which the health outcome is a function of exposure to asthma triggers and mitigating and averting behavior. However, three key areas of this model are problematic in the context of health valuation: the separability of preference function and production function; existence of an interior solution to first order conditions; and the existence of a known health production. Descriptive statistics from our study demonstrate how household behavior violates of each of these assumptions; households have strong preferences over health inputs, hold subjective beliefs that vary widely from objective fact, select actions from a complex portfolio of market and non-market options in which choices may be exogenously constrained, and perceive an incomplete production function with substantial limits on achievable outcomes.

We developed a contingent valuation scenario to overcome these issues by minimizing systematic variation in preferences for characteristics related to the scenario rather than the reduction in asthma morbidity. Guided by extensive testing in focus groups, we selected a scenario based on a hypothetical asthma monitor that gives the wearer an indicator of current asthma status. This approach should provide a more inclusive and accurate valuation of health outcomes for children with asthma.

INTRODUCTION

The economic concept of value implies a trade-off. The monetary value of any item is defined in economics as the amount of money that a decision-maker – an individual, a household, or a firm, depending on the context – would be willing to exchange for the item. That monetary amount measures the worth of the item in monetary units in the sense that this monetary amount has the same impact on the decision maker's wellbeing (utility) as the item itself.[1] The challenge for economic measurement is to identify a trade-off through which value can be measured. There are two main types of approaches to this challenge: revealed preference and stated preference. Revealed preference approaches work by observing actual choices by decision-makers and inferring the trade-off underlying these choices. Depending upon the nature of the choice (whether it is a discrete, continuous, or mixed discrete/continuous choice), the choice behavior may reveal the trade-off either directly (a simple discrete choice) or indirectly (the cases involving continuous choices) by permitting the identification of an underlying set of preferences that motivate the observed choice behavior. In the latter case, the trade-off is inferred from the recovered preferences underlying the observed choice rather than directly from the observed choice itself. Stated preference approaches work by placing subjects in a survey or experimental setting and confronting them with choices that, directly or indirectly, indicate their preferences.

Valuation of non-market goods can critically inform public policy and is an important component of environmental regulatory analysis. One important area of environmental economic research is the non-market valuation of human morbidity related to pollution. In this context, the standard revealed preference approach assumes that health-related choice behavior reflects preferences for health outcomes that are generated by a perceived health "technology". This separation between preferences and production requires the researcher to differentiate between behavior that is an end in itself and behavior that is a means to an end. Consider, for example, assessing the value of good water quality at a beach from this perspective. In the case of amenity value, an individual's choice of which beach to visit (trading off cleaner but more distant beaches versus dirtier but closer beaches) bears directly on the trade-off of interest since going to a nice beach is presumably an end in itself. In the case of health outcomes, the precautions an individual chooses to take (spending money to purchase goggles, taking an antibiotic before going surfing, etc.) are means to an end – namely, good health – rather than ends in themselves from which the individual derives enjoyment. In the latter case, the valuation analyst has to disentangle the production component from the pure preference component that underlies the trade-off. We suggest that this complication may sometimes tilt the balance in favor of stated preference rather than revealed preference as the preferred valuation approach[2].

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[1] Generically, there are two ways to formulate the exchange: the maximum amount that the individual would be willing to pay (WTP) to obtain the item, if it is favorable, or to avoid it, if unfavorable; and the minimum amount of money that the individual would accept (WTA) to forego the item, if it is favorable, or to endure it, if unfavorable. The relationship between WTP and WTA is a separate issue that will not be pursued here. For simplicity, the discussion below focuses on the WTP measure of welfare.

[2] An important consideration in modeling health outcomes for children is the question of the identity of the decision maker. The decision maker is surely *not* the child but rather one or both of the parents; therefore, the framework is the household rather than individual decision making. Making the household the unit of analysis raises several important but difficult analytical issues that are addressed in other literature. In this paper we focus on the relationship between the health preference function and the health production function, and we make the simplifying

We examine the application of the revealed preference and stated preference approaches to the valuation of reduced asthma morbidity. Our economic study was done in collaboration with an epidemiological study that was the most detailed socio-demographic, indoor air quality and pollution monitoring data collection effort to date. Findings from multiple focus groups and two economic surveys suggest that the discrete nature of health investments and socio-cultural patterns of health care utilization make the revealed preference approach inadequate for the case of asthma. As an alternative we present a contingent valuation scenario and discuss the attribute of the scenario that are important to the context of children's health. .

This paper is organized as follows. First we describe the epidemiological study and economic surveys used to collect household level data. Second, we summarize the average household's expenditures related to asthma morbidity and discuss the conceptual limitations of using these costs as a measure of value. In the third section we present the standard household health production model. Conceptual limitations of the standard model are presented in the fourth section. Fifth, we present empirical evidence of these complexities and their implications for the household production model. Next we discuss how we used the findings from the first economic survey to create a contingent valuation scenario. Concluding remarks are included last.

1. Empirical Study

A. Study Setting

This project is a collaboration with an extensive epidemiological study of the effects of air pollution on asthmatic children, the Fresno Asthmatic Children's Environment Study, or FACES. The study is located in Fresno, California, which has highest rate of asthma hospitalizations in California at 28.8 per 10,000 (California Facts, 2003). Located in the Central Valley of California, Fresno County has a population of 815,734; the population has increased by 19.8% since 1990. Forty-four percent of the population is of Hispanic or Latin origin, followed by forty percent of white origin, eight percent Asian-American and five percent African-American. The Fresno population has lower median income, less education, poorer living conditions and a greater percent of residents below the poverty line than California overall. For example, median household income for 2001 was $34,725 as compared to $47,493 for California. The proportion of residents with a high school degree was 67.5% as compared to 76.8% for the state, and the proportion of residents below the poverty line was 22.9 % as compared to 14.2% (US Census data, 2000).

The FACES cohort included children with clinically diagnosed asthma residing in a section of Fresno County[3]. Children were 6-10 years of age at intake and were followed for approximately 4 years. The study population included children who had a physician's diagnosis of asthma and at least one of the following: 1) reported utilization of or a valid prescription for asthma medication in the previous 12 months; 2) symptoms consistent with asthma in the past 12 months; or 3) an emergent asthma visit or hospitalization in the past 12 months. These requirements minimized the chance of enrolling subjects whose asthma is quiescent (in

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assumption that household decisions regarding children's health reflect a unitary model of household preference and production.

[3] FACES has been recruiting households for the survey since 2000.

remission). Children who meet these criteria were eligible for participation regardless of asthma severity or level of control of symptoms. Children with major comorbidities that would confound the measurement of pulmonary function were excluded from the epidemiological study.

The FACES study screened 583 households, completed baseline interviews for 315 households, and retained 225 participating households. The major reasons households who inquired about the study were ineligible to participate included: other chronic disease; household lived in house for less than three months; child sleeps at home less than five nights/week; and family planned to move within two years (Tager et al, 2006).

Demographics and characteristics of the FACES cohort are in Table 1. The percentage of African-Americans enrolled in the FACES program (15.6%) is greater than the percentage of African-Americans in the Fresno population (5.3%), while Asian-Americans are underrepresented. This pattern is not surprising given the distribution of asthma morbidity by race/ethnicity. The median age of children in the FACES cohort is between seven and eight years. The majority of the children were covered by health insurance (96%). Almost 70% of households had at least one parent who was affected by asthma. One observable characteristic of the FACES cohort that differs significantly from the Fresno population is the lower frequency of smoking in the home.

Table 1: Comparison of FACES Cohort at Baseline and Economic Study Cohort

	FACES Cohort at Baseline (N=315)	**Economic Study Cohort**
Demographics of Participant	**Relative Frequency**	**Relative Frequency**
Race		
White	42	43
Hispanic	40	39
African American	16	14
Other/ Missing	2	4
Male	57	57
Demographics of Household		
Mother completed high school or more (N=311)	84.9	NA
Father completed high school or more (N=302)	82.1	NA
Own home (N=294)	56.5	NA
Income (N=304)		
less than 30,000	45.4	31.3
$31,000-50,000	25.0	27.5
$51,000 or more	29.6	41.2
Any smokers live in or regularly visit home	21.9	21.0

Participant's Health Status		
Prescribed oral steroids in last 12 months	37.5	NA
Ever hospitalized	22.5	NA
Positive skin test to at least one antigen (N=266)	61.0	NA
Prescribed at least one control inhaler	80.0	87
No asthma prescriptions**	3.2	14
Asthma severity*		
mild intermittent	28.2	27.8
mild persistent	47.6	54.9
moderate	21.3	15
severe	2.9	2.3
N	315	202

* Classification based on the Global Initiative for Asthma Symptom Severity Scale (GINA)
** FACES statistic reflects not *having* a prescription medication while only statistics reflects not *using* a medication in past 3 months.
FACES baseline statistics are from Tager et al, 2006.
NA- These questions were not included in the economic survey. In the future, we will be able to calculate them using FACES data.

B. Economic Surveys

Two economic surveys were conducted in the FACES cohort. The first survey was conducted by mail from February to August 2004. This survey included detailed questions on asthma related expenditures, asthma related symptoms and activity limitations, and health beliefs. A total of 202 households completed the first survey (representing 209 children with asthma), and 130 of these completed a contingent valuation survey between October 2005 and February 2006. Two surveys were conducted to explore the strengths and limitations of two approaches to valuing children's health: revealed preference (household health model) and stated preference (contingent valuation). In this paper we present descriptive statistics from the surveys to demonstrate the limitations of the revealed preference approach and to motivate our design for the contingent valuation scenario.

We wanted the household member who interacted with the child's healthcare provider and thus most familiar with the asthma to answer the survey: 95% responded that they are the caregiver responsible for taking children to medical appointments. The employment status of the respondent varied: 37% were employed full-time, 27% were employed part-time, 11% were not employed but were looking, and 24% were not employed outside the home and were not looking for employment.

The households that completed the economic surveys differed only slightly from the FACES baseline cohort (Table 1). Our sample had very similar distributions of gender, asthma severity and race of the child to the FACES cohort at baseline. Of the survey respondents, 79% reported that no one smokes in the home. These smoking rates are below those for the Fresno population, but are in line with those for the FACES cohort. The distribution of household income for participants that completed the economic survey was shifted up relative to the baseline cohort.

2. Costs Related to Asthma

Our study evaluated the direct costs that participating households incurred to manage asthma. These costs are often used as a proxy for the value of asthma morbidity. However, this section discusses some of the principal problems with this approach.

A. Health Expenditures

Direct expenditures on asthma were broken into four categories: fixed costs[4], household supplies, pharmaceuticals (prescription and over-the-counter) and alternative therapies. Variable costs are the sum of the last three categories.

Table 2: Asthma Related Expenditures[5]

	Median	Mean	Standard deviation	N
Fixed costs	240	357	716	202
Variable costs	110	139	114	199
Household supplies	49	81	86	202
Pharmaceuticals	37	53	61	202
Alternative therapies	0	4	22	199

Indirect costs related to asthma morbidity include employment impacts and time used for planned or unplanned medical visits (including in-clinic and emergency room). Of the 202 households, 43% reported that they usually needed to take time off from work to take their child to medical appointments, and the median time taken off from work for each medical appointment was 75 minutes (mean 83 minutes and standard deviation 37 minutes). Twenty- four percent of the families reported that they had gone to the emergency room for the child's asthma in the previous 12 months, requiring a median of 215 minutes per visit (mean 211 and standard deviation 128)[6].

B. Problems with Using Costs as a Measure of Value

There are two problems with using expenditures and indirect costs to measure the value of reducing asthma morbidity. First, there is an important difference between the concepts of cost and value, the latter being the concept of interest to economists. The second issue is the critical distinction between marginal and non-marginal value. We discuss each of these in this section.

[4] For fixed investments we distinguished: 1) purchased specifically to help asthma; 2) purchased prior to asthma diagnosis; and 3) never purchased.

[5] Fixed costs include service costs or purchases of: air filters, allergy mattress covers and/or pillow covers, humidifiers, dehumidifiers, air conditioners, HEPA vacuum cleaners, landscaping of yard, carpet removal, pest extermination, mold/mildew removal, removing pets, humidity gauge, nebulizers, peak flow meters, spacers for inhalers, replacement for window coverings, and fans. Household supplies include: replacement filters for air filters, filters for air conditioners, HEPA vacuum filters, heater filters, cleansers for mold and mildew, hypoallergenic or non-aromatic cleaners, allergen control sprays, and sprays for pest removal. Pharmaceutical costs include: prescription asthma or allergy medication, over the counter allergy or asthma medications, herbal remedies, and home remedies. Costs related to alternative therapies include visits to a: chiropractor, acupuncturist, doctor of osteopathy, homeopathic/herbalist, nutritionist, spiritual healer, or other alternative health care provider.

[6] Total time spent on medical visits and emergency room visits will be reported in future work.

Economists have been aware of the fundamental distinction between *what things cost* and *what they are worth* ever since Adam Smith posed the diamonds-water paradox (water is essential for life but inexpensive, while diamonds are entirely inessential but extremely expensive). Both may be important to know, but they are different things. What something costs is a question about *supply and demand*; what it is worth is a question about *preferences*. What something costs is *objective* and a matter of verifiable fact; what it is worth is *subjective* and a matter of preference and taste.

The divergence between costs and worth is particularly salient in the case of health where, in addition to indirect and direct costs, there are psychosocial (quality of life) impacts of morbidity. The impacts of asthma morbidity include changing family activities, interactions with peers and the burden of uncertainty surrounding the status of a child's asthma. For example, in focus groups parents frequently discussed difficulties in communicating their children's needs to school officials and to physical education teachers in particular. In our survey 21% (out of 170 responding) disagreed with the statement "My child's classroom teachers are helpful with my child's asthma needs" and 24% (out of 140) disagreed with the statement "The physical education teacher works with us to include my child." Other impacts were restrictions on normal childhood play: 38% of respondents (n=200) reported that they restricted the *amount of child's activity* more often specifically due to asthma; 46% (n=201) reported that they restricted the *amount of time outside* more often; 44% (n=201) reported that they restricted *where the child could play or visit* more often. A more dramatic, though less frequently reported change (11 households out of 199 reporting) was moving to a new home to avoid asthma triggers and to improve the child's asthma. The frequency of these impacts and extent to which they affect quality of life suggests that using expenditures to measure the value of reduced morbidity misses the complexities of how asthma affects household behavior.

Even for health inputs with associated direct costs, such as the quantity of healthcare visits (e.g., ER use, MD visits), the typical practice of using the total count of visits obscures important differences in the nature of the input. In the case of a chronic illness such as asthma it is important to distinguish between preventative care such as a planned doctor's visit, commonly used as a marker of appropriate asthma management, from emergency care such as an emergency room visit, hospitalization, and unplanned doctor's visit, used as indicators of failed asthma management. With appropriate preventative care, an asthmatic should expect to avoid emergency care, and thus ER visits, unplanned MD visits and hospitalizations should be rare events. In our sample only 24% reported an ER visit in the previous year. The majority of asthma management is in the domain of the household, and once a management plan is established only periodic, routine MD visits would be expected.

The second issue is the distinction between marginal and non-marginal, or *total* value, which also underlies the diamond-water paradox. *At the margin*, an additional kilo of water may have a lower value to people than an additional kilo of diamonds because water is abundant while diamonds are rare, but the *total* value of all water to mankind is likely to be greater than the total value of all diamonds: if we lost all access to water, people would surely judge this a greater harm than losing all access to diamonds. Similarly, Dupuit emphasized the distinction between marginal and *infra-marginal* value, for any consumer and any commodity, while the last unit of an item to be consumed would be just equal in value to its price (which is why it is the last unit

to be consumed), the previous units would be worth *more* than the price because of the phenomenon of diminishing marginal utility. For the infra-marginal units, the consumer would be willing to pay more than the price. Hence, the consumer receives a sort of "profit" or "surplus" on these units which he would lose if the item were not available at that price. This observation provides the foundation for Dupuit's concept of consumer surplus – the excess of what a consumer would be willing to pay for an item over and above what he actually does pay. If the consumer had valued all units of the item exactly at their price, his consumer surplus would be identically zero, but this does not generally happen. Dupuit's larger point was that value is measured by reference to the consumer's demand curve – by what we now call the Marshallian consumer's surplus.

In short, economic valuation is generically about what things are worth, not what they cost. While costs may provide some information about how households value health, costs alone are not an adequate measure. In the next section we present a standard household health production model and discuss some conceptual challenges in applying it to valuing children's health.

3. Revealed Preference Approach to Valuing Reduced Asthma Morbidity

At the core of the revealed preference approach to health valuation is Grossman's household health production model (1972), which Cropper extended to the case of health outcomes affected by pollution (1981). In this approach the household has choice over market goods, some of which affect health, and the household optimizes its utility function with respect to these goods given an exogenous level of pollution, market prices and a budget constraint. Using cross-section data on observed health behaviors, health outcomes and corresponding levels of pollution, the economist estimates the health production function. In the simplest case, ignoring preferences for pollution and health inputs, the willingness to pay is then the reduction in the expenditures required to achieve a level of health made possible by a reduction in pollution. In this section we review this approach in more detail.

A. Health Production Function

We begin with a standard model for household health and then proceed to show how it is a special case of the Lancaster-Maler utility model. The critical characteristic of the indirect utility function of the household health production model is that it has the same structure as the indirect utility function produced by the Lancaster-Maler utility model, and hence the implications of the Lancaster-Maler for welfare measurement are applicable to the case of the health model. We begin by developing the indirect utility function for the health model.

In the standard model, marketed commodities are divided into two groups, those which have some relation to health (z) – either in preventing ill health or in curing illness once it occurs – and those which have no relation to health (x). The corresponding price vectors are denoted p_x and p_z with individual elements denoted p_i and p_j, respectively. One could further subdivide the health related market consumption activities into those which promote good health and prevent illness (e.g., taking asthma control medication regularly), z_A, sometimes called averting behaviors, and those which reduce the adverse effects of falling ill (e.g., taking an asthma rescue medication), z_M, sometimes called mitigating behavior, so that $z = (z_A, z_M)$. Health status could be a scalar or vector of health states or outcomes but, for simplicity, we will treat H as a scalar

here.[7] Finally, q is some measure of environmental pollution that affects health. Thus, for the household there is a health production function given by:

$H = H(z, q)$

where

z is a vector composed of averting behaviors (z_a) and mitigating behaviors (z_m)

q is a measure of environmental pollution

There are several alternative formulations of the household's preferences, depending on what enters the household's utility function. Obviously, household health (H) and the consumption of non-health-related market commodities (x) enter the utility function. The question is whether any of the elements of z and/or q enter the utility function as well. The point is that, while z and q affect household utility *indirectly* through their influence on health/illness, H, they could also affect the household's utility directly if it cares about q or z for motives unconnected with their effect on H. The empirical evidence from our surveys suggests that both z and x are important elements of the household's utility. Thus we will use the most general case where all of the variables affect household utility directly, and the household maximizes utility subject to the health production function and a budget constraint (Y= income):

$Max_{x,z} \quad U = U(x, z, q, H)$

subject to $H = H(z, q)$ and $p_i x_i + p_j z_j = Y$

The result is a set of ordinary demand functions for all market goods, both non-health-related and health-related, $x_i = x_i(p_x, p_z, q, Y)$ and $z_j = z_j(p_x, p_z, q, Y)$, and a corresponding indirect utility function $v(p_x, p_z, q, y)$. Only prices of health-related and non-health-related goods and income appear as arguments in the demand functions.

If we compare the indirect utility function produced in the health model $v(p_x, p_z, q, y)$ to that in the generalized Lancaster-Maler utility model, $v(p,q,y)$, we can see that the former is a special case of the latter in which prices have been partitioned into non-health-related goods and health-related goods. The difference between the Lancaster-Maler model and the standard household health production model is simply that the household health production model makes the health production function explicit and implies that the production function can be estimated separately from the pure preferences represented by U(x,z,q,H).

B. Welfare Measurement with the Household Production Model

Recall that within the Lancaster-Maler framework, a consumer's utility depends not only on his consumption of market commodities, denoted by the vector x, but also on some other items, q; the utility function is thus u(x,q). While the consumer controls the level of x, subject to his budget constraint, q represents some things that affect the person's welfare but which he does not control. The Generalized Lancaster-Maler model provides both a theory of how q affects the consumer's choice of market commodities (x) and a framework for welfare evaluation of

[7] In this highly simplified version of a unitary model we are not bothering to distinguish between the health or illness of the different members of the household.

changes in q. The specific implication for purposes of valuing morbidity in children is that the Hicksian compensating and equivalent variation are expressed in terms of the indirect utility function. In the most general case, all elements (p',q',y') can change to a new level (p",q",y") and indirect utility can change from v(p',q',y') to v(p",q",y"). Then the compensating variation for this change is the quantity C such that

$$v(p'',q'',y''- C) = y(p',q',y'),$$

while the equivalent variation is the quantity E such that

$$v(p'',q'',y'') = v(p',q',y'+ E).$$

If the change is an improvement in the sense that u"> u', the quantity C measures the consumer's willingness to pay (WTP) for the securing the change, while E measures her willingness to accept to forego it, and vice-versa if the change entails a reduction in utility. We can use the concepts of compensating and equivalent variation as measures of the economic value of a change in environmental health risks for children.

Consider two important polar cases with regard to the impact of a change in environmental health risks: (A) the change in environmental health risks could simply and automatically trigger a reduction in the family's disposable income, but with no other concurrent effect, so that the change is from (p,q,y') to (p,q,y"); (B) the change in environmental health risks could simply trigger a change in q, with no other concurrent effect on p or y, so that the change is from (p,q',y) to (p,q",y). In the first case, the direct effect of the environmental change is that the household has less disposable income but everything else remains the same: the equivalent and compensating variations coincide. The only impact is a purely monetary loss and the economic value of this is the monetary loss itself: the impact is equivalent to a lump-sum reduction in income. In the second case, by contrast, the direct effect of the change is a loss of utility – wellbeing – for the household; C and E may differ[8], and they represent alternative ways of expressing this loss monetarily in terms of a loss of income that is equivalent in the magnitude of its impact on the household's wellbeing.

The practical implication of the distinction between (A) and (B) is that, in the first case, one can get along with information on the magnitude of the monetary loss without necessarily knowing anything about the structure of household preferences, u(x,q), while, in the second case, one cannot avoid the need to know about household preferences. In that case, the comparison between revealed- and stated-preference approaches to welfare measurement will hinge on the relative ease and reliability of the two approaches in providing an insight into the structure of household preferences. We argue below that characterizing household preferences is essential to defensible welfare measurement and present the limitations of using the household health production model, as typically applied, to measure welfare changes.

[8]See Willig (1975) and Hanemann (1989) for treatment of this issue.

4. Conceptual Limitations of the Household Production Model for Welfare Measurement

A. Health Cost Function

First we describe a common use of the health cost function to estimate the value of a change in health due to a change in pollution (see Dickie, 2003 and Clemmer et al., 1994 for reviews of empirical studies using this approach). For purposes of illustration, we assume that there are no changes in the price of any market goods (p_x, p_z) or income (Y), and environmental quality changes from q_0 to q_1. This scenario is equivalent to Case B described above. Here we describe the limitations to the standard approach to estimating a welfare measure in this case. Suppose the change is for the worse, so that $U_0 \equiv v(p_x, p_z, q_o, Y) \geq U_1 \equiv v(p_x, p_z, q_1, Y)$. In this case the equivalent variation measure (denoted E above) is the household's willingness to pay to *avoid* the change. The marginal WTP to avoid is given by:

$$\left.\frac{dE}{dq}\right|_{E=0} = \frac{v_q(p_x, p_z, q, Y)}{v_y(p_x, p_z, q, Y)}.$$

Moreover, by suitable manipulation of the first-order conditions for the solution to the household's maximization problem, one obtains

$$\frac{v_q(p_x, p_z, q, Y)}{v_y(p_x, p_z, q, Y)} = \frac{u_q(x, z, q, H)}{v_y(p_x, p_z, q, Y)} + c_q(p_z, q, H)$$

where

c_q is the derivative of health cost function w.r.t. q

Recall that we presented the most general utility specification in which environmental quality, q, entered directly into the household preference function. If instead we restricted environmental quality to entering the health production function only, in which case the preference function takes the form U(x,z,H), then the first term above would drop out. Then under this special case the expression becomes:

$$\frac{v_q(p_x, p_z, q, Y)}{v_y(p_x, p_z, q, Y)} = c_q(p_z, q, H)$$

This simplification gives rise to the following pragmatic approach to measuring the marginal value of pollution in a household production context: (1) Estimate the household health production function, H(z,q). (2) From the health production function, derive the corresponding health cost function, c(p_z, q, H). (3) Given the health cost function, calculate the marginal cost of pollution, $c_q(p_z, q, H)$, and assess the value of the given change in pollution, dq, as it relates to a health outcome is, the product

Value of health damage = $c_q(p_z, q, H)\, dq$.

An attractive feature of the expression above is that it only requires information derived from the health production function, avoiding the need for information about the household's utility function. However, there are two major flaws in this approach. First, as discussed in Section 2, valuations of welfare change should reflect the difference between the marginal and the infra-marginal unit. The expression above considers only the market-clearing price, not the Marshallian consumer surplus. Our second concern is the assumption that neither q nor z enters the utility function directly: The construction of the utility function as U(x,H), which omits both the health inputs and environmental quality, seems contrary to observations about household preferences[9], and in Section Five we present empirical evidence of three ways in which averting and mitigating behaviors are central to the concept of the preference function.

B. Production Function for Health

While the notion of a health production function is illustrative in the discussion of household choice, the extent to which it captures the complexity of trade-offs in the household is questionable. We have three conceptual concerns: deviation between objective and subjective attributes; the degree to which health is determined by individual choice; and the assumption that households can conceptualize a production function.

First, in the literature on revealed preference valuation of market commodities based on their attributes, researchers have often found that there is a divergence between the objective measures of attributes and people's perceptions of them. Whether people see a beach as clean, an automobile as safe or comfortable, or a computer as high-tech-looking, for example, is a matter of perception. How people see these attributes can be quite different from how an expert would assess them. A general finding is that people tend to overestimate small risks and underestimate high risks (Lichtenstein et al 1978; Morgan 1983). Consider the example of traffic safety.

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[9] The household production literature often makes reference to an approach to welfare measurement derived from work by Bockstael and McConnell (1983) based on the demand function for the z's or H. Bockstael and McConnell *do* permit q to enter the utility function directly, but not the z's. They show that that the Hicksian measure of WTP for a change in q can be measured exactly from information about the demand function for health, H, or the demand function for one or more of the z's that are inputs to the production of health. There are two qualifications that are critical to the application of their result to the health production context. The first qualification is that their result is about the area under the *compensated* demand function for H or for the z's, not the ordinary demand function. If there are income effects in the demand for H or for the z's, the two demand functions are different and it is not valid to use the area under the ordinary demand function as an approximation to the area under the compensated demand function. These areas involve a price change from the current "price" (marginal cost) of H to the cut-off price at which the demand for H would become zero, which is by no means a marginal change. Hanemann (1980) showed in an analogous situation that the difference in areas can be quite substantial. The second qualification is that preferences satisfy Maler's (1971, 1974) property of weak complementarity with respect to either H or the z's. In this context, weak complementarity implies, that, if a person is in poor health (H = 0), she is indifferent to a change in air quality (q). That seems unlikely to be true. Indeed, one can imagine circumstances under which, as long as the person is still alive, a worsening in air quality becomes more serious to her when she is ill (H = 0) than when she is healthy (H > 0). Furthermore, as pointed out by Johannsson (1997), weak complementarity implies that the health input is non-essential for survival. In the case of asthma and many other chronic obstructive pulmonary diseases], as an individual's health deteriorates, health inputs become increasingly essential for survival. For example, during an exacerbation, use of rescue medication is the only option for reversing airway constriction which otherwise could lead to death. Bockstael and McConnell were thinking of a household production function for recreation, not health, when they wrote their paper about weak complementarity and their analysis seems ill-suited to health applications.

Despite the fact that vehicle crashes are the most common cause of death to children aged 1-14 (CDC, 2000), and that use of a safety restraint is the most significant individual action to reduce this risk, the rate of use of safety restraints is estimated to be only 57% among youth age 5-11 (Winston and Durbin, 1999). People's choices are likely to be based on their own perception and understanding of the attributes ("It's only a short car ride. I'm a better than average driver."), not on those of the experts. Furthermore, safety experts have suggested that rather than communicating the objective measures of accident risk, an effective safety message must include elements of shock and surprise to trigger a response (Will, 2005). Even if a risk-reducing action is chosen, there can be a significant discrepancy between actual and perceived reduction. Continuing with the case of traffic safety, consider the following statistics from a study on parental participation in child seat installation. Inspections found that although 97% of participants believed they had correctly installed the safety equipment, only 14.5% had actually done the installation correctly (Eby and Kostyniuk, 1999). Therefore, researchers often find that to model choice behavior successfully, they need to elicit the decision makers' subjective perceptions of attributes involved in the choices. This perception can differ significantly from objective attributes and depend on how objective risk is communicated to the public. What matters is what the household – the parents – see as efficacious courses of action, not what the medical experts or the econometricians determine to be efficacious.

In summary, while households' decisions are based on *ex ante* expectations of the effectiveness of health producing actions, what the econometrician measures when fitting a health production function is the *ex post* outcome. If there were perfect knowledge or rational expectations, the *ex ante* expectation and the *ex post* outcome would coincide. To the extent that these conditions are not met, the *ex post* household production function estimated by the econometrician might be misleading as a guide to understanding household choice behavior. If this is so, it has the potential to bias not only the estimation of the production function but also the estimation of household preferences.

Second, the concept of a household production function implies that the household exercises a degree of control over its members' health that is exaggerated and unrealistic from at least two perspectives. First, postulating a household production function $H=H(z,q)$ implies that, for a given q, the household can in principle attain *any* desired level of health, H, providing it has sufficient financial resources to cover the cost of the required z's. If it is rich enough to purchase sufficient z's it can make itself as healthy as it wants, regardless of what might befall it in terms of q. From introspection, this notion is implausible. Second, the notion of an interior solution to the household's health production decision is unrealistic. It is conventionally assumed that, in the context of the household's production function, the z's are finely divisible, so that the household arrives at an exact, interior solution to its optimization decision. Households often face a limited and constrained set of options. These constraints may be imposed by the structure of the healthcare sector and the nature of averting and mitigating behaviors.

Third, the concept of a health production function assumes that households at the minimum conceive of a basic relationship between health inputs (behaviors) and health output (health status). The extensive public health literature on health literacy suggests that there are significant deficiencies in households' understanding of these relationships even for simple health conditions. Because asthma is both chronic and episodic, it is particularly difficult for

households to describe an exact causal relationship between behavior and asthma outcomes. A multitude of factors combine in complex ways to produce symptoms, and the natural evolution of asthma as a child grows changes how these relationships are manifested. While at a point in time a household may observe their asthma symptoms, these serve as very noisy signals of a true health state. Furthermore the production technology is not stable. This evidence suggests that modeling exercises that examine only the choice of inputs and outputs cannot distinguish between choices due to preferences versus imperfect information about a current underlying health production function and/or uncertainty about a future production function.

Thus, while the notion of the household's production of its own health certainly has some basis in reality, it can be pushed too far. People can look after their own health, but this does not mean that they can achieve *any* desired health outcome; therefore some levels of H are not attainable, regardless of the input of z's. The production function H(z,q) is likely to be bounded and it may have some flat segments. Similarly, people do not have an unlimited array of options and therefore they are more likely to be at corner solutions than interior solutions in their household production decisions. As Bartik (1988) has noted: "Defensive options often may be limited; for example, a household seeking to reduce the effects of toxic waste on its water supply might be able to defend itself only by a water filter, bottled water, or moving away."

If these doubts are justified, this can have important implications for health valuation. The usual first-order conditions do not hold and the simple approximations are apt to be unreliable. The household's marginal WTP for improved health might be considerably larger than the marginal cost, c_q, but it may have no viable option for further action. Also, in this case non-marginal valuation can become more complicated because of the need to specify a realistic, non-monotonically increasing health production function or a limited choice set with a few discrete alternatives.

These concerns lead to practical limitations of the revealed preference approach. In the next section we present empirical evidence of these limitations in the case of asthma and draw on the public health literature to suggest that they are relevant for a variety of health conditions. Furthermore we discuss how the data typically used to estimate revealed preference models can lead to misspecification because of unobserved heterogeneity.

5. Empirical Evidence of the Limitations of the Household Production Model

In the revealed preference approach to measuring the willingness to pay for pollution related morbidity, individuals must believe that there is a relationship between pollution and health and that they can take actions to reduce those risks. Previous reviews of such models have noted the data requirements and the difficulties of estimating the components of the health production model (Freeman, 2003). Here we address specific limitations related to the concept of health cost functions and production functions.

A. Health Cost Function

In Section 4.A, we suggest that simplifying the household model such that environmental quality, q, and health inputs, z, appear only in the health production function and not the utility function does not capture the complexities of household tradeoffs. Typical measures of

averting behavior in revealed preference studies of asthma include an encounter with a healthcare provider (either emergency room utilization or outpatient visit as in Rowe and Chestnut, 1986; Bresnahan, Dickie and Gerking, 1991) and reducing exposure to asthma triggers (typically measured as changing time spent outdoors as in Rowe and Chestnut, 1986; Bresnahan, Dickie and Gerking, 1997; Yen, Shaw and Eiswerth, 2004). In this section we discuss the evidence that these behaviors play important roles in the household preference function and that these preferences over health inputs are not unique to asthma. Next we present evidence that the set of averting behaviors as typically defined misses important changes in behaviors attributable to asthma.

1. Preferences over Health Inputs

The most commonly used health input in revealed preference studies is frequency of healthcare encounters, including emergency room visits, hospitalizations and doctor's visits. Two issues arise in relying on these inputs. First, the public health literature documents systematic differences in demand by race/ethnicity[10]. We would be less concerned if there were evidence suggesting that these differences in demand represented differences in preferences over health states, but in fact the literature suggests that they are driven by differences in preferences for health inputs. Racial and ethnic minorities report lower trust and satisfaction with the healthcare sector than their white counterparts (Cooper-Patrick, 1999; Shi et al 2003; Corbie-Smith et al 2002; Doescher et al 2000).[11] The experience with the healthcare sector influences preferences over health technologies as well. Studies of patient's choices for treatment for coronary artery disease (Whittle et al, 1997), renal disease (Ayanian, et al 1999), and colon cancer (Baldwin et al 2005), have demonstrated that non-whites select less invasive treatments than whites and the difference is greater than that explained by health system factors (nonprofit versus for-profit, teaching hospital, volume of colon cancer resection surgeries) and patient characteristics (age, severity of illness, social support, and neighborhood characteristics).

In the case of asthma, empirical studies on hospital care indicate that even when controlling for clinical factors and insurance, there are observed differences in the quantity and quality of health services for asthma received by non-whites (Brandt, 2007; Ash and Brandt 2006). In our sample, we found that minorities were more likely to be dissatisfied with the quantity of time spent at the

[10] Race/ethnic differences in consumption of health inputs have been documented in various health markets such as folic acid supplementation (Bentley et al 2006), influenza vaccination (Herbert 2005), complementary therapies (Keith et al 2005), and mammography following treatment for breast cancer (Keating et al 2006).

[11] Some of the dissatisfaction may be attributed to lack of "race concordance": empirical studies suggest that patients select physicians from their own race because of personal preferences and language (Saha et al, 2000, LaVeist and Nuru-Jeter 2002). Having a physician of the same race is associated with a more participatory style of decision making (Cooper-Patrick et al 1999 and LaVeist and Nuru-Jeter 2002), preventative care, and satisfaction with physician (Saha et al 1999). The limited availability of minority physicians makes race-concordance less common for minority patients (LaVeist and Nuru-Jeter 2002) and this imbalance in unlikely to change in the near future (Libby et al 1997). Race concordance (or lack thereof) not only affects the way in which decisions for health services are made, but also the level of positive health outcomes achieved (Carlson and Gabrel, 2001 and Ivanov and Flynn, 1999). Others have argued that because minorities participate more frequently in restrictive health plans, their bad experiences with insurers make them more likely to have bad feelings about the health care sector in general. Thus the observed differences do not result from inherent differences in risk beliefs or preferences but rather the structure of the insurance market. Hunt (2005) found that participation of minorities in restrictive health care plans does not explain differences in negative attitudes toward the health care system.

medical doctor's office than whites (51% versus 29%, p=0.01). Although minorities were more likely to have gone to the ER in the last two years (57% versus 47%), there was no statistically significant difference in dissatisfaction with time spent at the ER.

Our second objection to the use of health encounters as a measure of risk-reducing behavior is that it violates the assumption that the household is able to purchase any number of units of inputs if they are willing to pay the price. A repeated theme in focus groups was limited access to their child's MD during asthmatic episodes. In our survey, 11% of our sample (n=202) reported difficulties in making appointments with their medical doctor when needed (9% of whites and 14% of minorities), and 7% (n=202) reported that their medical doctor was not helpful when their child's asthma worsens.

Previous studies have aggregated all types of medical care into one count and used this count as a measure of demand, resulting in serious measurement error. An alternative measurement of health inputs would include behaviors those that occur on a regular basis such as medication use (such as used in Rowe and Chestnut, 1986). Central to asthma management for children with persistent asthma is the use of an inhaled steroid to control chronic inflammation. In order to decrease inflammation, control medications need to be taken consistently for 4-6 weeks, leading to a gap between taking the medication and experiencing the benefits. This control medication is supplemented with a "rescue" inhaler, a beta-agonist that relaxes the constriction of the smooth muscles surrounding the airways, in cases of acute exacerbation. In the revealed preference approach, medication usage would appear only in the production function and not in the preference function. However, this is contradicted by our findings on how families view medication.

Although the majority of the households (87%, n=195) reported that their children took medications to treat asthma, 30% of all households reported that they had concerns about those medications. Although not statistically significant (p=0.11), minorities were more likely to express concern over prescription medications than non-minorities (39% versus 26%). Minorities were slightly more likely to report that asthma medication either did not improve asthma symptoms or made them worse (20% versus 13%). A surprisingly common concern was that taking asthma medication as prescribed could lead a child to become addicted to or dependent on asthma medication (49% agree or strongly agree, n=187; 41% for non-minorities and 51% for minorities). Other households reported that they believed that having to take medications regularly was embarrassing to children (23% agree or strongly agree, n=189). The perceived ineffectiveness of medication could reflect 1) inappropriate prescription (ineffective due to technology failure), 2) non-adherence to prescription (ineffective due to implementation failure), or 3) difficulty in perceiving the benefit of a reduction in future risk (effective but not discernible technology).

In addition to these general concerns, households reported that their child experienced negative side effects from asthma medications. Table 3 reports the frequency of reported side-effects for specific drugs as well as the frequency with which households believe that children in general experience side-effects of those drugs. Note that 29% of households reported their child having side-effects from oral steroids, 27% from rescue medications (albuterol) and 16% from control medications (inhaled steroids). Three medications have marked differences in reported rates of

side-effects by race/ethnicity. Each of these medications is a standard treatment for asthma. Side-effects and negative attitudes towards taking medication are likely to substantially influence future use and should be incorporated into the preference function to adequately measure welfare changes.

A further issue with using medication as a measure of health inputs is the evidence that preferences over medications are correlated with race. For example, in a study of consumer-patient preferences, O'Conor and Blomquist (1997) find a statistically significant difference in willingness to pay for a safer drug. This finding makes sense in the context of a study by Hakes and Viscusi, who find a statistically significant divergence between actual and perceived risk between whites and non-whites. Hakes and Viscusi find that mortality risk perceptions of non-whites are less responsive to actual risks than for whites and that these differences are significant enough that pooling data on whites and non-whites is invalid for estimating risk perceptions.

One factor that could lead to differences in preferences and subjective risk assessments for medication use is previous side-effects to medications. In our sample, non-minorities were significantly more likely to report side-effects with over-the-counter allergy medications (89% versus 67% for minorities, p=0.007) and Tylenol (93% versus 78%, p=0.03). In the absence of a model of subjective risk perception, household models will be confounded by unobserved heterogeneity that is correlated with race.

Table 3: Frequency of Reported Side-Effects and Perceived Side-Effects

Medication	Personally experienced	Children in general
Oral steroids	29	37
Albuterol (rescue medication)	27	20
OTC allergy medications	18	13
OTC cold/flu medications	18	15
Inhaled steroids (control medication)	16	16
Antibiotics	16	9
OTC asthma medications	13	10
Intal	10	5
Tylenol	8	3
Vitamins	5	5

Medication is the largest category of direct costs for a typical asthmatic; however, the market prices of these medications do not reflect the perceived costs to households. Although our data lend only weak support for the hypothesis that there are race/ethnicity differences in risk perception, they do concur with the growing evidence of such differences in other health contexts. These concerns over medications affect how a household perceives their benefit, and omitting the disutility associated with the input distorts the model of household choice.

2. Difficulty of Measuring of Risk Reducing Behaviors

In addition to using medication to treat both components of asthma, chronic inflammation and acute bronchial constriction, standard asthma management guidelines include behavioral changes. Most of these behavioral changes are focused on reducing exposure to possible asthma triggers (Sadof, 2006). When taking behavioral changes into account, previous willingness-to-pay literature has focused primarily on changing the proportion of time spent outside on high smog days. In our sample, 92% of households report watching for smog alerts during the summer at least weekly, with 58% reporting that they check every day. On days when there is a smog alert, 78% report changing their activity. The most common change was keeping child indoors (reported 88% of the time).[12]

However, responding to smog alerts was only one of many adaptations reported by families. Table 4 lists the changes undertaken on a regular basis as well as large, one-time changes that were made to prevent asthma exacerbations.

Table 4: Non-Market Household Mitigating and Averting Behaviors

Routine Behaviors	**Frequency**	**N**
Dusting frequently	59%	200
Vacuuming frequently	59%	200
Mold removal	51%	197
Close windows	46%	199
Restrict amount of child's time outside	46%	201
Restrict where child can play	44%	201
Restrict amount of child's activity	38%	200
Limit where pet can spend time	31%	154
Restrict child's diet	15%	196
One-Time Changes		
Move household to avoid triggers	6%	199
Stop smoking	15%	189

In focus groups, parents reported that these averting behaviors required both substantial time investments and a level of persistence, which in itself was a burden on household relations. In fact, when asked what they do to prevent asthma exacerbations, they first reported these behavioral changes, not purchases nor medications. Although these behaviors do not have associated direct costs, they do have a sizable impact on households: 44% report that managing their child's asthma (including taking medications and trigger reduction) has been a burden to the family in the past two years. When asked about family goals, 84% report that it is "very important" to make asthma management easier and 64% report it is "very important" for the child to be able to manage asthma on his or her own. In general, these behaviors represent at least as great a cost to the household as traditional health care (doctor's visits and medications),

[12] Our sample appears to be more responsive to smog alerts than studies which include people without asthma. For example, Bresnahan et al 1997 found that 39% of households reported changing their leisure activity on high smog days with 40% reporting staying indoors .

but they have traditionally been neglected in valuation analyses because there is no obvious monetary price for them.

In addition to daily behavioral changes to reduce triggers, families with asthmatic children shift employment in order to care for the child. A typical indirect cost considered in the valuation literature is the opportunity cost associated with missing work to care for an ill child. In our sample more than one-half of the parents reported missing work in the last two years due to their child's asthma. However, missing work in response to a specific episode is only part of the actual impact asthma has on employment.[13] Households with asthmatic children may be forced out of the labor force in order to care for the child. In our sample, 18% of households reported changing their employment status due to the need to care for an asthmatic child. Most commonly the female caregiver elected to stop working outside the home, work part-time, or change work location, but changes forced by the employer were also reported.

Medical care and medication are only two types of averting/mitigating behaviors. Other household adaptations include changing employment to care for a child and daily activities to reduce asthma triggers. Standard surveys quantify the opportunity cost of lost employment by measuring the number of days missed due to asthma. This measure underestimates the true impact, because it neglects how households modify their employment status in response to their child's asthma symptoms. From a household perspective, the routine trigger reduction and monitoring of asthma symptoms are significant components of a portfolio of averting/risk reducing behaviors. These behaviors are typically omitted from economic studies because there are no markets for these routine behaviors. As a result, the market data that are used in estimating a cost function are incomplete.

B. Validity of a Production Function for Health

In Section 4.B we discussed conceptual limitations of the health production function. Here we discuss findings from the survey that suggest how these conceptual limitations apply to the case of valuing asthma morbidity.

1. Divergence Between Subjective and Objective Attributes

In this section we discuss two relevant ways in which subjective and objective assessments of asthma may differ. The first is the perception of a bounded production function, and the second is the discrepancy between *ex post* and *ex ante* evaluations of health investments.

A fundamental assumption of the household production model is that households perceive a health production function and make health choices accordingly. We examine how two simplifying assumptions fare in implementation. The first assumption is that health can be characterized as a well-defined scalar or vector H and that the definition of H is held in common across households. The second assumption is that households can achieve a level of health with the inputs determined by their corresponding first-order conditions.

[13] Of those who reported that they did not miss work, only 36% had not missed work because of their child did not have asthma symptoms. The other households were able to work even if their child had symptoms because they worked at home, the child was old enough to stay home alone, or another family member could care for the child.

Characterizing asthma is the subject of substantial epidemiological research because of the difficulty of capturing the natural variation in frequency and degree of symptoms. In our focus groups we asked households to describe what they consider "normal," "good" and "bad" asthma days. This process generated a set of impacts commonly used to describe asthma morbidity and included many impacts in addition to the standard asthma symptoms and measures of health care utilization. The category of impacts considered important to households included symptoms (wheezing or coughing, shortness of breath, black under eyes, increased mucous/phlegm or sputum, ribs showing, reduced ease of breathing), activity limitations (interrupted playtime, reduced ability to walk stairs, ride bike or jump rope, reduced ability to talk and sing) and social impacts (avoiding places with triggers, restricting time outdoors). Social impacts were used 79% of the time to describe asthma morbidity, activity limitations were used 96% of the time, and physical symptoms were used 98% of the time.

This finding is consistent with the literature that suggests that households tend to describe the severity of their medical condition in terms of activity limitations or impact on quality of life, whereas medical professional tend to categorize severity based on frequency of physical symptoms. For the purposes of estimating welfare effects of morbidity, it is the household perspective that matters and drives behavior. Furthermore these impacts affect households much more regularly than do the extreme events of emergency room visits or hospitalizations. Table 5: Asthma Related Morbidity, presents the percentage of households who report that their child experiences limited activity levels, a social impact or a physical symptom on each type of asthma day. What is striking about the statistics in Table 5 is that over one-half of the sample expects to have symptoms on a normal day and slightly less than one-half expect to have an activity limitation or social impact. Even on "good asthma days" a surprising proportion of the sample expects to have some type of activity limitation, social impact or physical symptom. 26% of the households who described their child's asthma as well to completely controlled would actually be classified as moderate to severe based on the frequency of their daytime symptoms during the winter 2003-2004. Underestimating asthma severity has been documented in other populations (Nguyen et al, 1996).

Table 5: Asthma Related Morbidity

	Relative Frequency of Experiencing		
	Limited activity level	**Social impact**	**Physical symptom**
Good day	13	29	28
Normal day	47	43	63
Bad day	93	73	97

Our interpretation of the data in Table 5 is that as people repeatedly experience symptoms, they adjust their expectation of a "normal" health state. In other words, their benchmark for normal or attainable respiratory health is shifted downward. This psychological adaptation to a lowered state of health is possible even in cases of significant changes (Groot, 2000). There is empirical evidence of adapting in several health contexts: transplants (Adang, 1997), heart conditions (Wu, 2000) and managing stressful events (Cassileth, 1984). In sum, the *level of health* becomes a less important driver of choice than *transitions between health states*.

These data suggest two modifications of the standard household health models. First, welfare estimates that are based on avoiding unplanned medical visits, emergency room visits or hospitalizations miss the larger, more routine impact of asthma morbidity on quality of life. The vector that describes health status should include quality of life impacts that are disease and age specific, should not be limited to physical symptoms, and should capture transitions between health states. Second, because the outcome of interest is a vector of related impacts, data analysis should utilize a multivariate approach with both symptoms and psycho-social outcomes.

A reasonable way to address this concern would be to create a comprehensive multivariate index for the impacts considered by households. In our survey we asked participants to rank the two impacts out of eleven that, if reduced, would most improve their quality of life. The five impacts most frequently ranked first were: reducing the physical pain/discomfort of asthma (ranked most important by 44% of the sample), reducing the number of missed school days (13%), reducing the frequency with which the child has to reduce his/her activities (9%), reducing the parent's worry about asthma (8%) and reducing the amount of time the family spends managing the asthma (7%). Creating such an index brings us to our second concern: the implicit assumption that a household can achieve its utility-maximizing health outcome by selecting the appropriate combination of health inputs. Empirical work avoids the obvious cases where this assumption is invalid (e.g., extreme conditions for which health technology is not available); however, we contend that this assumption is also not appropriate for a chronic, episodic condition such as asthma.

In addition to asking households to describe how asthma affects their daily quality of life, we asked if any of these impacts could not be changed (Table 6). Essentially, we were asking households if there were some aspects of living with asthma that were fixed. The results show that households believe that there are significant limits to how much the impact of asthma can be reduced. More than a third of our sample believed that impacts including parental worry, time spent managing asthma, time at the doctor's office, disruption of day-to-day activities, missing work, disruption of family plans, stress of asthma, and time at the ER could not be changed. The benefit of reduced asthma morbidity most frequently ranked most important was the reduction of pain and discomfort associated with asthma. In our sample 19% reported that the pain and discomfort of asthma *cannot* be changed. Of our sample, 29% believed that missing school and reducing limitations in child's activities could not be changed. The finding that a sizeable proportion of households perceive these impacts as fixed characteristics of asthma undermines the assumption that households select a level of health, and instead suggests that some portion of households consider their health status as fixed.

Table 6: Fixed Asthma Impacts

Impact	Relative Frequency*
parental worry about asthma	42
time spent on trigger reduction and medication	41
time at doctor's office	41
disruption of day-to-day activities	39
missing work to care for child's asthma	38
disruption of family plans	37
stress associated with asthma morbidity	36
time at ER	36
limitations on child's activity	29
missing school due to asthma	29
pain due to asthma	19

* Percentage of sample reporting outcome cannot be changed, even if asthma improves.

A second divergence may arise between *ex ante* and *ex post* assessments of health investments. Prior to making health-related expenditures, households do not necessarily have an accurate assessment of how helpful an input will be. To explore this, we asked households both the amount spent on fixed health inputs and their *ex post* evaluation of the effectiveness of each investment. Table 7 lists the households' assessments of purchases. Three patterns should be noted. First, although each of these investments is commonly recommended, none was unanimously regarded as helpful (44% to 98% reporting that the investment was helpful). Second, the investment that was most often reported to be helpful was a nebulizer, which provides relief during a current asthma exacerbation, followed by a spacer, which helps in delivery of medication; those investments that were less likely to be reported as helpful were those that reduce triggers, thus reducing the probability of an exacerbation in the future (e.g., air filters, removing pests, HEPA vacuums). Third, households perceived a value to the peak flow meter, which provides information useful in asthma management, but which in itself does not reduce triggers or alleviate symptoms. These patterns suggest that households' *ex ante* expectations and *ex post* outcomes do not coincide for all investments, and the timeframe for delivery of benefits may play an important role in the household's subjective assessment.

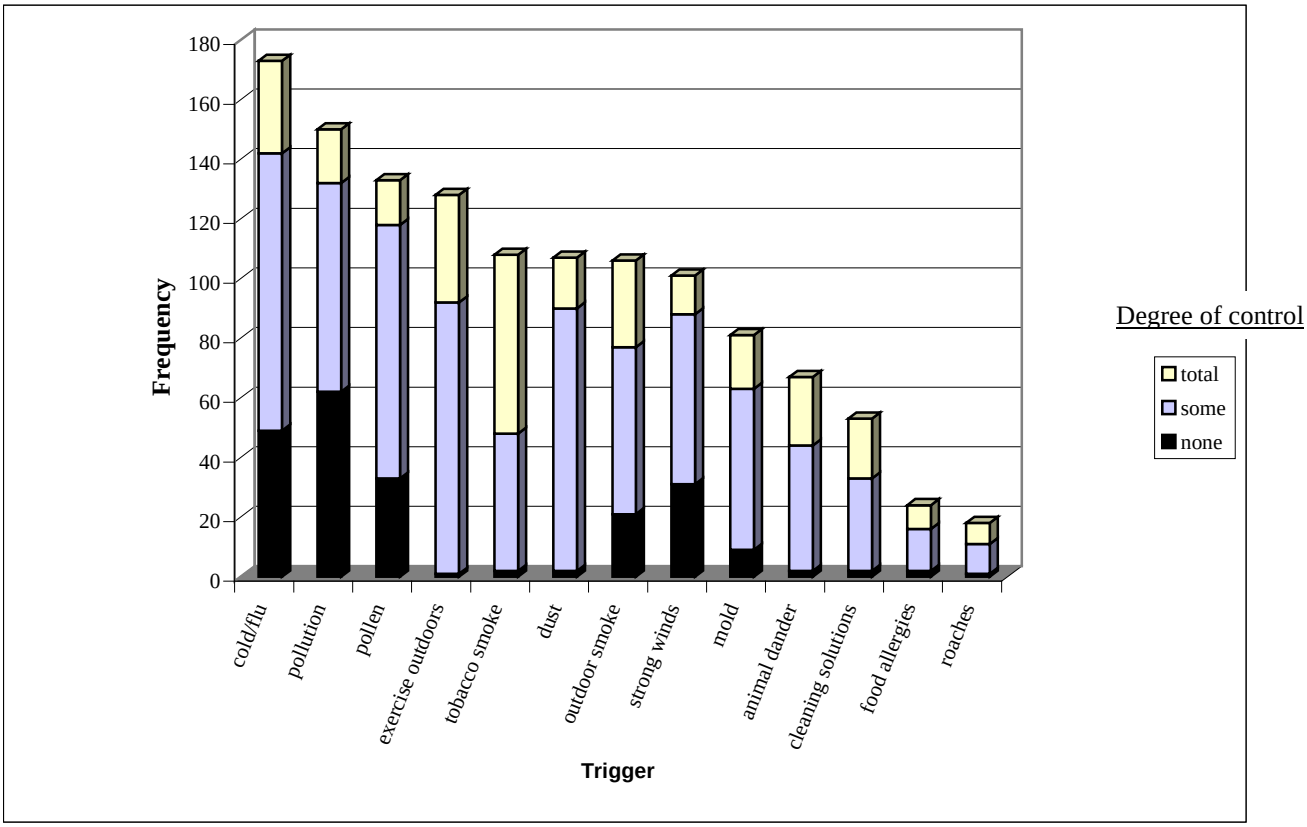
Table 7: Household Investments and Assessments

Investment	% purchased	% reported helpful	N
Air filter	30	69	200
Mattress cover	28	73	200
Pillow cover	27	82	201
Humidifier	31	74	202
HEPA vacuum	38	70	202
Removed carpet	25	78	201
Removed pests	25	44	202
Remove mold	39	72	201
Nebulizer	31	98	199
Peak flow meter	35	73	199
Spacer	54	93	200

2. Constrained Choice Sets

Reducing exposure to asthma triggers is an important part of asthma management and is often described as the most important behavioral change a household can take. In our sample, households were able to identify triggers for their child. The ten most commonly reported triggers for asthma exacerbation were: an existing cold/flu (86%), air pollution (74%), pollen (66%), exercising outdoors (63%), tobacco smoke (53%), dust (53%), outdoor smoke (52%), strong winds (50%), mold (40%), and animal dander (33%). Given the parents' perception of asthma triggers, the household health production model would then posit that households would make the relevant choices to reduce (avert) these risks; however, reducing exposure is not feasible for an important class of asthma triggers. The total height of the bars in Figure 1 shows the frequency with which households that a trigger affected to their child. The shadings indicate the degree to which households felt they had control over their child's exposure to that trigger. While households reported the ability to limit or reduce exposure to many of the commonly cited asthma triggers (exercising outdoors, tobacco smoke, dust, mold, animal dander, cleaning solutions, food allergies, and roaches), this was not uniformly the case. Of the top ten potential triggers, there were five triggers over which more than 20% of households reported that they had no control (pollution 41%, strong winds 31%, cold/flu 28%, pollen 25%, and outdoor smoke 20%).

Figure 1: Perception of Control over Asthma Triggers



These findings suggest that one of the cornerstones of asthma management, averting risk through reducing exposure to triggers, does not readily translate into a production function framework, because the ability to control these exposures is limited. The results of our survey corroborate our concern that there may be no interior solutions to the household's maximization problem as commonly formulated.

3. Household Conceptualization of Health Production Function

Empirical estimation of revealed preference models relies on the assumption that there is one well-defined production function in common across households. It would seem plausible that over time a household could observe health inputs and resulting outcomes and thus conceive a relationship between the two. Developing a notion of a production function by this trial and error process requires both a stable relationship and a tractable number of health inputs and outputs. Complicating the formation of a production function is that asthma has two major components, the inflammation of airways and spasms of the smooth muscle around the airways. Because asthma is a chronic condition with acute exacerbations, the severity with which an individual responds to a single trigger can vary depending on the degree of inflammation at the time of exposure. Although asthma is chronic, an individual can be asymptomatic for periods and then have acute symptoms when exposed to a set of triggers.

Our sample can be characterized as very familiar with asthma, as 43% of the households had at least one parent/guardian with asthma, and 73% of the children had asthma since before five years of age. We found that 59% of our sample characterized asthma as a condition that is always present, while 8% think of asthma as a condition that comes and goes and 33% think of asthma as an illness that occurs in conjunction with another illness (e.g. colds, flu, allergies) or time of year. The "no symptoms, no asthma" belief has been found to be prevalent in adult asthmatic populations and associated with failure to adhere to control medications (e.g., inhaled corticosteroids) and resulting asthma morbidity (Halm, 2006).

Despite familiarity with asthma and a general awareness that it is a chronic condition, a subset of households hold incorrect or outdated views on asthma. Of our sample, 16% (n=191) disagreed that asthma can be managed so that a child does not have symptoms; 13% (n=189) agreed with the statement that asthma episodes can cause problems but are not really harmful or dangerous; 58% (n=189) agreed with the statement that asthma episodes usually occur without warning; and 16% (n=202) report being uncertain about what to do when a child begins to have asthma symptoms. All of these responses indicate uncertainty regarding the production process for asthma status.

Within our sample, 17% of those prescribed a control medication were not taking the medication in the manner in which it is intended; of those prescribed a rescue medication, 43% were not taking the medication as intended. Minorities were less likely to take all medications correctly than whites (40% for minorities versus 57% for non-minorities). While the causes for non-compliance are complex and not well understood, it does suggest that using observed expenditures on medications may be confounded by factors other than preferences over health states.

One final issue that that arises when moving from the theoretical modeling of health decisions to their empirical application is the endogeneity between health inputs and health status. One source of endogeneity between the choice of health inputs (z) and asthma morbidity (H) arises from families "benchmarking" their concept of what is normal or attainable respiratory health. Even within the FACES population, we found that the concept of asthma control deviated from the standard medical concept of asthma control (normal or near normal respiratory function) as discussed previously.

As households that have children who routinely experience asthma morbidity come to expect these impacts as characteristic of a normal or "best possible" level of asthma control, their health investments will reflect this perceived limitation. This benchmarking could be thought of as creating categories of households with differing perceptions of the frontier for $H(z,q)$; the perceived frontier would be correlated with the unobservable characteristics that affect the baseline asthma severity.

In the case of household health, the typical instrumental variables approach to the problem of endogeneity is confounded by the complexity of fully specifying the production model. As shown by Griliches and Mairesse (1999), instrumental variables estimates of the production relationship will not produce valid estimates of the coefficients on the health inputs if there are omitted variables from the health production function that are correlated with the elements in the

vector of health inputs, z. As shown in the previous sections, households vary in their perceptions of the risks and benefits of health inputs, and unless a model can adequately capture the factors that determine this variation, instrumental variables will be an incomplete solution.

These empirical observations reinforce our concern that a production function for health may assume a relationship between health and choice that is artificially strict and complete. Given the limitations of applying the revealed preference approach in the context of a complex chronic condition such as asthma, we now discuss of the design of a stated preference study.

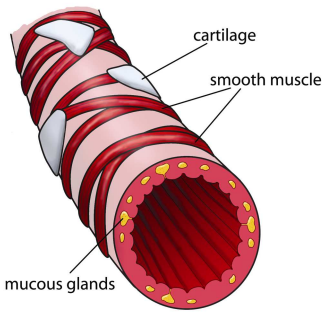
6. Stated Preference Approach

A major advantage of the stated preference approach over the revealed preference approach is that it allows the researcher to create a trade-off with which to confront survey respondents, making it possible to control the specification of the household production function. Instead of having to estimate an unknown production function, commingled with unknown household preferences, and complicated by the household's unknown subjective perceptions of what it can do to protect or improve its health, the researcher may be able to create his own specification of the trade-off, thereby limiting the unknowns to be estimated from the data to the respondent's preferences.

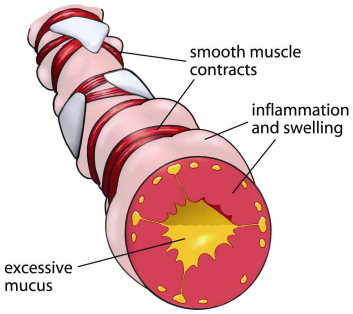
In our study, the second, in-person survey covered frequency of asthma symptoms corresponding to the updated Gina asthma severity classification (Luppi, 2004), severity of asthma symptoms, asthma triggers, asthma-specific health beliefs, rating and ranking of the impacts of asthma on quality of life, causes of household stress and a contingent valuation scenario. A total of 130 FACES households completed the second survey.

After the interviewer completed the health status questions, he presented the contingent valuation scenario. The participant was given a brochure that described a hypothetical asthma monitor that could be worn like a watch. The description of how the watch worked included diagrams of a normal airway and of an asthmatic airway with both constriction and inflammation.

Figure 2: Brochure Diagrams



Normal Airway



Asthmatic Airway

Asthma Monitor

The brochure explained that the watch monitors the level of oxygen in the child's blood and provided an indication when it varied. A green face on the watch indicated that oxygen was optimal whereas yellow indicated caution and red indicated an emergency. By monitoring the child's asthma, it was suggested, action could be taken to stop the asthma from progressing to the point that physical symptoms developed. The hypothetical monitor, the *BreatheRight* watch, was said to have been shown to cut the number of days with asthma symptoms by one-half. We used a one-and-a-half bounded dichotomous choice format to elicit bids for the hypothetical asthma product. Initial bids were based on the distribution of responses from a pilot of twenty-two non-FACES households in the Fresno area conducted in August of 2005[14]. Starting bids and subsequent bids were updated following Cooper, Hanemann and Signorello (2002).

We crafted the hypothetical scenario to have six characteristics based on the findings of the first survey (discussed in Section 5):

1. A scenario that reduced morbidity that did not rely on medication, and thus would not be confounded by preferences for medication.
2. A device that did not require behavioral changes to be effective, thereby reducing the issue of non-adherence.
3. A tool that reduced both the physical symptoms and the stress of monitoring the child's asthma, which addresses the larger issue of how asthma morbidity affects quality of life.
4. A device that helped families communicate quantitative information about their child's asthma, improving access to health care when needed.
5. An instrument that provided objective information on the child's health status and assisted families in assessing health risks and effectiveness of averting and mitigating behavior.

Results from the contingent valuation survey will be reported in future research (Brandt, 2007).

7. Conclusions

Valuation of non-market goods such as health outcomes is commonly done using revealed preference or stated preference approaches. The standard revealed preference approach assumes that health-related choices result from optimization of a preference function that includes health outcomes generated by a separable health production function. This produces an expression for willingness to pay that requires information derived from the health production function without information about the household's utility function. Implementing this model requires the researcher to differentiate between health inputs that enter in a production function but not a preference function. Households are then assumed to be able to select these inputs subject to a health production function and budget constraint.

These assumptions seem tenuous for a broad range of health conditions, including asthma. Our survey of households with children with asthma shows the limitations of the revealed preference model in capturing the trade-offs faced by households. Households have strong preferences over health inputs and are not uniformly free to choose their preferred quantity of inputs (independent

[14] Participants for the pilot were recruited through a newspaper ad in the local paper (*Fresno Bee*) and a recruitment table at the American Lung Association's annual walkathon in Fresno.

of price), and their primary risk reducing behaviors are daily behavioral modifications with no relevant market prices. Even households with substantial experience with asthma display a large degree of uncertainty over factors relating to asthma symptoms and perceive significant limitations to achievable health status. These empirical results call into question the assumptions on which the revealed preference approaches relies.

While the revealed preference approach is a helpful tool for thinking about household choices, its restrictive assumptions make it insufficient for valuing health improvements. In the contingent valuation approach to stated preference valuation, a researcher creates a trade-off with which to confront survey respondents, making it possible to control the specification of the household production function. We use the lessons from the first economic survey to construct a contingent valuation scenario that avoids the incorrect assumptions described above. By minimizing unobserved heterogeneity, this approach makes possible a more inclusive and accurate valuation of health outcomes.

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