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# Measuring How Risk Tradeoffs Adjust with Income

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# Measuring how risk tradeoffs adjust with income

**Mary F. Evans · V. Kerry Smith**

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**Abstract** Efforts to reconcile inconsistencies between theory and estimates of the income elasticity of the value of a statistical life (IEVSL) overlook important restrictions implied by a more complete description of the individual choice problem. We develop a more general model of the IEVSL that reconciles some of the observed discrepancies. Our framework describes how exogenous income shocks, such as unexpected medical expenditures, may affect labor supply decisions which in turn influence both the coefficient of relative risk aversion and the IEVSL. The presence of a consumption commitment, such as a home mortgage, also alters this labor supply adjustment. We use data from the Health and Retirement Study to explore the responsiveness of labor force exit decisions to spousal health shocks and the role of a home mortgage as a constraint on this response.

**Keywords** Value of a statistical life · Risk aversion · Consumption commitment · Labor supply

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A poll of the analysts tasked with preparing the economic assessments of policies that improve environmental quality would undoubtedly identify the estimates of the value of a statistical life (VSL) as the single most influential economic parameter in their evaluations. Adapting estimates of the VSL to account for differences between the labor market context on which they are based and the policy context where they are applied has been an important and controversial area of research.[1] Economic theory identifies several factors that we expect to influence an individual's marginal willingness to pay for a mortality risk reduction. With regards to variation in income, theory predicts a positive income elasticity for the value of a statistical life (IEVSL). Numerous empirical studies, adopting various strategies, confirm the theoretical sign prediction. However, in spite of the agreement across studies on the sign of the IEVSL, the empirical literature finds little consistency in its size. Meta-analyses of existing VSL studies report estimates that range from 0.4 to over 2.0 while Costa and Kahn's (2004) time series assessment for the U.S. suggests an IEVSL between 1.5 and 1.7.[2]

As the IEVSL is often a central component in estimating the benefits of large-scale policy changes over long periods of time in which income growth is expected, its magnitude is of considerable importance. Several examples illustrate why. First, major changes in existing rules or proposals for new regulations require estimating the benefits of the proposed changes over time (due to Executive Order 12866). Environmental regulations in particular often yield reductions in mortality risks today and into the future and these risk reductions are a major component of the associated benefits. With insufficient information to estimate the marginal willingness to pay for risk reductions for the time period of interest, an alternative indirect method of obtaining benefit estimates involves approximating the future value of a statistical life based on current VSL, the IEVSL, and projected future incomes. The U.S. Environmental Protection Agency (EPA) recommends this process and notes that adjusting willingness-to-pay estimates to account for higher future income levels is consistent with the empirical literature (see http://yosemite.

[1] For example, see Lisa Heinzerling's indictment of all of benefit cost analysis based on her dissatisfaction with the important role VSL estimates play for policy (Ackerman and Heizerling 2004). Heinzerling is the current Associate Administrator of EPA's Office of Policy, Economics and Innovation.

[2] We are aware of four methodologies used to estimate the IEVSL: 1) meta-analyses of hedonic wage studies (see Mrozek and Taylor 2002; Viscusi and Aldy 2003; Bowland and Beghin 2001); 2) stated preference studies (see Hammitt and Graham 1999; Hammitt and Zhou 2000; Mitchell and Carson 1986); 3) comparisons of VSL estimates at different points in time for a single country (see Hammitt et al. 2003; Costa and Kahn 2004); 4) cross-country comparisons of VSL estimates (see Hammitt et al. 2003).

epa.gov/ee/epa/eed.nsf/webpages/MortalityRiskValuation.html, accessed 10/12/2009).[3]

The EPA's first prospective report on the costs and benefits of the Clean Air Act Amendments for 1990–2010 conducted sensitivity analyses using three IEVSL estimates of 0.08, 0.4, and 1.0 (U.S. EPA 1999). The potential policy implications of different values are striking; the difference between the estimated 2010 VSL based on the upper and lower IEVSL estimates is more than $1 million dollars. The $1 million difference in the VSL estimates translates into a $1 million difference in estimated benefits for *each* avoided fatality. With mortality risk reductions serving as the lion's share of benefits, this type of variation in estimates for future VSL measures is a major influence on projected future aggregate benefits.

The income elasticity of the VSL has also had an important effect in simulation studies. For example, when considering the benefits of historical improvements in health, Murphy and Topel (2006) assume an income elasticity of 1.57 (see also the more recent study by Jena et al. 2008).[4] Weitzman (2009) recently used VSL estimates as a gauge in calibrating the importance of a disastrously low level of consumption for his assessments of how to deal with climate uncertainty. Once again this measure of a people's willingness to trade off resources for risk plays a key role in his conclusions. An extension to his work might explore the dependence of this linkage on income. The IEVSL would be an important component of such an analysis.

A final context in which the IEVSL has important policy implications is in benefit transfer. Methods for transferring measures of the marginal willingness to pay for risk reductions from one context to another are often the only available basis on which to estimate the benefits of some policies. A common application of benefit transfer involves using VSL estimates based on revealed or stated choices of individuals in developed countries for policies intended to reduce premature mortality in developing countries. An assessment of the benefits of policies that reduce mortality risks for populations in developing countries would ideally use VSL estimates derived from choices, revealed or stated, of residents of these countries. Of course, obtaining these estimates is costly and therefore they are often unavailable for many countries and applications. In these cases, benefit transfer, which relies on the IEVSL and the associated income differences across countries, provides an option for developing the benefit estimates for short term policy assessments of projects that affect mortality rates in developing countries.

[3] In contrast, with respect to contemporaneous differences in income and wealth, EPA's Science Advisory Board (U.S. EPA 2007) notes that "…the SAB Panel recognizes our current empirical abilities may not permit these adjustments. One is to adjust for differences in real income and wealth between study populations. Since the value of reducing mortality risk increases with income and wealth, differences in these factors are expected to yield differences in estimated valuation. However, the appropriate magnitude of adjustment is not clear, because of uncertainty about the value(s) of the income elasticity and very little empirical evidence concerning the relationship between wealth and mortality valuation" (p. D7-8). For additional discussion of considerations in using VSL for benefit analyses of rules see U.S. EPA (2000).

[4] Murphy and Topel do not report their implied income elasticity. We computed the implied IEVSL based on their assumptions about the preference specification and model parameters. They assume an elasticity of intertemporal substitution equal to 0.8 and a consumer surplus per unit of the composite of consumption and leisure at age 50 equal to about 2.11. These assumptions imply an income elasticity for the VSL of 1.57. See pp. 882–886 of Murphy and Topel (2006).

Given the observed empirical inconsistencies and the policy implications of different values of the IEVSL, we might ask what insight theory offers on the magnitude and properties of the IEVSL. Theory has provided some guidance on factors that influence the IEVSL and, in doing so, on its expected magnitude. For example, Eeckhoudt and Hammitt (2001) and Kaplow (2005) highlight the relationship between the IEVSL and the coefficient of relative risk aversion (CRR). Both models suggest the IEVSL should be at least as large as the CRR, a theoretical prediction that is not supported by a comparison of empirical estimates of the IEVSL and the CRR. Thus, in addition to the conflicting IEVSL estimates among empirical studies, there is little consistency between theoretical predictions and empirical evidence on the IEVSL.

We propose a more general theoretical model that helps to reconcile some of the observed inconsistencies related to the IEVSL. Our model of the labor supply decision demonstrates how relaxing key simplifying assumptions results in an alternative explanation for the bounds of the IEVSL. While relaxing these assumptions complicates the relationship between the IEVSL and the CRR, doing so allows us to isolate other factors that influence the IEVSL. Our analysis identifies behavioral (e.g., labor supply) adjustments to an exogenous income shock, for example unanticipated medical expenditures, as a key component of the IEVSL.

A final innovation of our theoretical model involves considering the role of constraints to these behavioral adjustments, in the form of consumption commitments. Home mortgages, automobile purchases, and the acquisition of other consumer durables often involve fixed payment schedules that consumers find costly to adjust. As a result, short run adjustments to exogenous shocks will differ from responses when the consumption commitments can be modified. Our model confirms that the presence of consumption commitments affects risk preferences (Chetty and Szeidl 2007) and the responsiveness of labor supply to income changes. Both effects have implications for the IEVSL.

While full estimates of a structural model are beyond the scope of this paper, it is nonetheless important to consider whether features of our theoretical model are empirically relevant. To address this question we consider, in Section 3, the empirical relevance of two key features of our theoretical model, the responsiveness of labor supply decisions to spousal health shocks and the role of a home mortgage as a constraint on this response. Data from the Health and Retirement Study (HRS) permits an empirical investigation of these issues. Our results suggest that the presence of consumption commitments alters individuals' abilities to respond to shocks, especially for the male workers in our HRS sample.

We begin in Section 1 by describing how the recent work of Eeckhoudt and Hammitt (2001), Kaplow (2005), Chetty (2006), and Chetty and Szeidl (2007) relate to the structure of our conceptual model. In Section 2 we describe the results from our generalized model which yields some of the previous models as special cases.

## 1 Background

Several studies contain descriptions of how we should expect VSL estimates to vary with individual circumstances. We focus our attention on four such papers (Eeckhoudt and Hammitt (2001), Kaplow (2005), Chetty (2006), and Chetty and

Szeidl (2007)). The primary objectives of these papers vary but each offers a key insight that motivates the structure of our analytical model discussed in Section 2.

Eeckhoudt and Hammitt (2001) propose a state dependent expected utility specification to explore how different types of background risk influence the properties of VSL estimates. They assume a simple preference specification where utility derives from wealth ($m$), $u_j = u_j(m)$, where $j$=$A$, $D$ denote the two possible states, alive and dead, respectively. Utility in the dead state, associated with bequest motives, is assumed to be a linear function of utility in the living state as in equation (1.1).

$$u_D(m) = \alpha u_A(m) - \delta \tag{1.1}$$

where $0 \leq \alpha \leq 1$ and $\delta \geq 0$.

Assuming $p$ denotes the probability of death, expected utility is given by $V \equiv (1-p)u_A(m) + pu_D(m)$. Expressions (1.2) and (1.3) provide the implied VSL and IEVSL (denoted $\eta_{EH}$), respectively (with $m$ treated as being synonymous with income).

$$VSL = \frac{(1-\alpha)u'_A(m) + \delta}{(1-p+p\alpha)u'_A(m)} \tag{1.2}$$

$$n_{EH} = \frac{dVSL}{dm}\frac{m}{VSL} = \frac{(1-\alpha)}{(1-p+p\alpha)}\left(\frac{m}{VSL}\right) - m\frac{u''_A(m)}{u'_A(m)} \tag{1.3}$$

The subscript $EH$ indentifies the Eeckhoudt and Hammitt measure. The second term in equation (1.3), $-m\frac{u''_A(m)}{u'_A(m)}$, is the coefficient of relative risk aversion (CRR).

Expressed in these terms, the Eeckhoudt and Hammitt analysis is consistent with the model Kaplow (2005) develops in his paper a few years later. By assuming a utility function that exhibits constant relative risk aversion, Kaplow shows, and we review in formal terms below, that an approximation for the IEVSL is expected to be slightly greater than the CRR. While in practice the difference may be small, his result has been interpreted as implying the CRR provides a lower bound for the income elasticity of the VSL. A brief inspection of (1.3) confirms why we might expect the difference to be small. Suppose $m$ is small relative to the VSL, which we might expect. In this case, the first term of expression (1.3) is small (but positive) and the income elasticity of the VSL, $\eta_{EH}$ , just exceeds the CRR. As noted by Kaplow, this result creates a puzzle since many estimates of the IEVSL are significantly less than one (see Viscusi and Aldy 2003) whereas estimates of the coefficient of relative risk aversion are approximately two (see Chetty 2006).

To appreciate how Kaplow develops his result requires a closer examination of his model, which differs from that of Eeckhoudt and Hammitt along a few key dimensions. While the specification of preferences is similar in the two models, Kaplow allows an individual to reduce his risk of death, $p(x)$ with $p'(x)<0$, through precautionary activities (expenditures), $x$. The simplest formulation of his model, which we review here, ignores bequest motives (thus we drop the $D$ subscript for notational simplicity). Modifying notation for consistency with Eeckhoudt and Hammitt, expected utility in Kaplow's model is given in equation (1.4).

$$V \equiv (1 - p(x))u_A(m - x) \tag{1.4}$$

Utility depends only on net consumption ($c$) with $c = m - x$ where $m$ now represents exogenous income rather than wealth as in Eeckhoudt and Hammitt.[5] That is, the model assumes individuals derive no utility (or disutility) directly from engaging in precautionary activities. While this formulation has been applied in some settings, such as sunscreen (see for example Dickie and Gerking 2007), it is also plausible to assume individuals derive utility or disutility from the activities measured by $x$ (e.g., physical exercise). The most important implication of this assumption for our discussion is that it removes the possibility of considering complementarity or substitution relationships between $c$ and $x$. Indeed, Kaplow's model has the feature that $x$ simply absorbs resources that could go to consumption. We return to this point later in our discussion.

Kaplow derives the following expression for the consumption elasticity of the VSL implied by his model, denoted $\eta_K^c$:

$$\eta_K^c = \frac{dVSL}{dc}\frac{c}{VSL} = c\frac{u'_A}{u_A} - c\frac{u''_A}{u'_A} - c\frac{u'_A}{u_A}\frac{dx}{dc} \tag{1.5}$$

where the second term is the curvature of utility over net consumption, not over wealth or income as in (1.3). The term $\frac{dx}{dc}$ in (1.5) measures how (optimal) expenditures on precautionary activities vary as consumption changes.

In general, the consumption elasticity of the VSL does not equal the income elasticity of the VSL. The income elasticity of the VSL indicates the responsiveness of the VSL to changes in an exogenous factor ($m$). On the other hand, the consumption elasticity of the VSL, $\eta_K^c$, measures the responsiveness of the VSL to changes in an endogenous variable ($c$). Of course, the VSL responds to changes in $m$ through changes in consumption. However, this adjustment occurs via two channels, one direct and one indirect. The income elasticity of the VSL separates these two channels. Additionally, in contrast to $\eta_K^c$, the formation of and intuition associated with the IEVSL parallel those for income elasticity measures found in other contexts.

The IEVSL (i.e., the responsiveness of the VSL to changes in $m$) for Kaplow's model, denoted $\eta_K^m$, is given in equations (1.6a) and (1.6b). The underlying model used to derive this measure is unchanged.[6]

$$\eta_K^m = \frac{dVSL}{dm}\frac{m}{VSL} = \frac{mu'_A}{u_A}\left(1 - 2\frac{dx}{dm}\right) - \frac{mu''_A}{u'_A}\left(1 - \frac{dx}{dm}\right) \tag{1.6a}$$

$$= \frac{mu'_A}{u_A}\left(\frac{1 - \frac{dx}{dc}}{1 + \frac{dx}{dc}}\right) - \frac{mu''_A}{u'_A}\left(\frac{1}{1 + \frac{dx}{dc}}\right) \tag{1.6b}$$

where expression (1.6b) results from substituting $\frac{dx}{dm} = \frac{dx/dc}{1+dx/dc}$ into (1.6a).

[5] Since prices are normalized to unity and $x$ is a perfect substitute for $c$, the Kaplow formulation is equivalent to assuming an indirect utility function in describing preferences. The distinction between wealth and income for static models is largely one of terminology. The models we discuss do not have an inter-temporal dimension so there is no saving and asset accumulation.

[6] In fact, in a working paper version of his 2005 paper, Kaplow (2003) reports the measure given here as (1.6a).

Two observations are important to highlight. First, $-m\frac{u''_A}{u'_A}$ measures the curvature of the utility function over exogenous income, rather than over net consumption as in (1.5). Second, note that even when we assume $\frac{dx}{dc}, \frac{dx}{dm} \approx 0$ as argued by Kaplow (2005, 2003), a comparison of (1.5) and (1.6a) confirms that $\eta_K^c \neq \eta_K^m$.

Chetty's (2006) analysis did not consider the underlying determinants of the VSL. Rather, his framework was directed at reconciling estimates of the CRR implied by choices in financial markets with estimates implied by the elasticity of labor supply.[7] His partial explanation for divergences in these estimates identifies the failure of past models to account for consumption-labor supply complementarities—"…increased consumption makes work less painful" (p. 1821). The connection between Chetty's insights and the earlier work by Eeckhoudt and Hammitt and Kaplow lies in a more complete specification of the other arguments in the preference function. We return to these issues at the outset of the next section.

Chetty and Szeidl (2007) add another component to the framework, the presence (or absence) of constraints on other behavioral adjustments to exogenous shocks, which may cause additional differences in the relationship between the coefficient of relative risk aversion and the income elasticity of the VSL. Chetty and Szeidl (2007) conclude that:

> "…the wealth elasticity of labor supply is larger in magnitude when households have commitments. Insofar as commitments are retained when households face small or temporary wealth fluctuations but are adjusted in the long run, this result implies that the wealth (unearned income) elasticity of the labor supply is larger in the short run than the long run" (p. 862).

To explain the intuition for this result, they note that if a primary earner is temporarily unemployed, then there are incentives for the spouse to enter the labor force to help pay the mortgage and other household commitments, which are effectively fixed in the short run. Thus, these two papers provide the motivation for the questions we consider in the next section of the paper, namely how to treat the following: (1) behavioral adjustments in response to exogenous income shocks (Section 2.1); and (2) other consumption components' responses that may well be costly to adjust (Section 2.2).

## 2 Model of labor supply, mortality risk, and commitments

### 2.1 Implications of behavioral adjustments for risk preferences and the IEVSL

In this subsection, we develop a model (denoted Model I) of labor supply that combines the consumption-labor supply complementarities Chetty highlights with a feature of Kaplow's model which recognizes behavioral influences on survival probabilities. We ignore the bequest motive and re-define $c$ as the sum of non-wage, exogenous income ($m$) and wage income ($wl$) where $w$ and $l$ denote the wage and

[7] In an independent analysis, Smith et al. (2003) use labor supply elasticity measures for specific preference functions to measure VSL.

labor supply respectively. We assume the risk of death, $p$, is a function of the time spent working so that $p=p(l)$ with $p'(l)$, $p''(l)>0$.[8] Individuals gain utility from consumption and disutility from working so expected utility is given in (2.1).

$$V \equiv (1-p(l))u(c,l) = (1-p(l))u(m+wl,l) \tag{2.1}$$

We assume $u_c(c,l)>0, u_l(c,l)<0$ and $u_{cc}(c,l), u_{ll}(c,l)<0$ where subscripts are used to denote partial effects. The first order condition for an interior solution in selecting $l$ is then given in (2.2) and the expression for the VSL in (2.3).

$$-p'u(c_I{}^*, l_I{}^*) + (1-p)[wu_c(c_I{}^*, l_I{}^*) + u_l(c_I{}^*, l_I{}^*)] = 0 \tag{2.2}$$

where $l_I$* and $c_I{}^* = m + wl_I{}^*$denote optimal labor supplied and consumption in Model I respectively (the subscript $I$ identifies the Model I results).

$$VSL_I = \frac{w}{p'(l_I{}^*)} = \frac{wu(c_I{}^*, l_I{}^*)}{(1-p(l_I{}^*))[wu_c(c_I{}^*, l_I{}^*) + u_l(c_I{}^*, l_I{}^*)]} \tag{2.3}$$

As the IEVSL measures the responsiveness of the VSL, which is a function of the optimal labor supply, to changes in $m$, constructing an expression for the IEVSL requires an assumption regarding the ability of labor supply to adjust to income shocks. For now, assume $l$ is fixed at the optimal level implied by (2.2). That is, (optimal) labor supply cannot adjust to changes in $m$ (i.e., $\frac{dl_I{}^*}{dm} = 0$). This assumption is comparable to Kaplow's assumption that expenditures on risk reducing goods will not respond to changes in consumption. In both cases, the behavioral response to an exogenous shock is assumed to be negligible.

For $l$ fixed at $l_I$*, the income elasticity of the VSL is given by equation (2.4) with $u' \equiv wu_c + u_l$

$$\eta_{I,l\,fixed} = \frac{mu_c}{u} - \frac{wmu_{cc}}{u'} - \frac{mu_{cl}}{u'} \tag{2.4}$$

where the arguments of the preference function are suppressed. Expression (2.4) implies that even when we assume no behavioral adjustments to exogenous income shocks, complementarity between consumption and labor supplied ($u_{cl}>0$) *reduces* the income elasticity of the VSL relative to the value that would obtain under independence (i.e., $u_{cl}=0$).[9]

Consider the mechanism that leads to this result. With fixed labor supply, an increase in $m$ results in a one-for-one increase in consumption (i.e., $dc_I{}^*=dm$); consumption entirely absorbs the effect of the income shock. When consumption and labor supply are complements consumption makes work less painful and the increased consumption decreases the marginal disutility of labor (i.e., $u_l$ moves

[8] Our assumption of $p'(l)>0$ implies that an individual faces a relatively lower probability of death in non-work related activities so that substituting an hour of leisure with an hour of work increases the risk of death. Ruhm (2000) suggests that mortality rates are pro-cyclical. Specifically, he finds that an increase in a state's unemployment rate is associated with a decrease in that state's mortality rate. While this result is based on aggregate data and therefore is not specific to a particular working environment, the direction of the estimated effect is consistent with our assumption.

[9] A comparable result holds in Kaplow's model if we allow $x$ to affect utility and the marginal utility of consumption ($c$) to vary with $x$.

towards zero). The compensation required for accepting the increase in risk associated with working an additional hour (VSL) is lower as a result.

An examination of the relationship between the IEVSL and the coefficient of relative risk aversion (CRR) facilitates comparisons with the previous literature. Equation (2.5) defines the elasticity of utility to non-wage income and equation (2.6) the CRR (for $l$ fixed at $l_I$*).[10]

$$\gamma_{I,l\,fixed} = \frac{mu_c}{u} \tag{2.5}$$

$$R_{I,l\,fixed} = -\frac{mu_{cc}}{u_c} \tag{2.6}$$

Substitution using (2.5) and (2.6) allows us to rewrite (2.4) as follows:

$$\eta_{I,l\,fixed} = \gamma_{I,l\,fixed} + \frac{wu_c}{u'} R_{I,l\,fixed} - \frac{mu_{cl}}{u'} \tag{2.7}$$

Since $u_l < 0$, $\frac{wu_c}{u'} > 1$. Therefore, assuming independence between $c$ and $l$ (i.e., $u_{cl}=0$), $R_{I,l\ fixed}$ bounds $\eta_{I,l\ fixed}$ from below as in Eeckhoudt and Hammitt, and Kaplow. However, we find that sufficient complementarity alters the role of the CRR as a lower bound for the income elasticity of the VSL. Thus, when we expand the description of consumption to individual earnings and non-wage income, the model suggests that even when labor supply is held fixed, risk preferences alone (as measured by the coefficient of relative risk aversion) do not provide a lower bound for the income elasticity for the VSL; with sufficient labor-consumption complementarity, the income elasticity is less than the coefficient of relative risk aversion.[11] This result stands in contrast with the conclusions drawn from both Eeckhoudt and Hammitt (2001) and Kaplow (2005) whose preference specifications do not allow for the consumption/labor supply link.

Now consider how the ability to adjust labor supply in response to an exogenous change in non-wage income affects the link between the income elasticity of the VSL and the CRR. Intuitively, when $l$ can adjust to income shocks, a change in $m$ affects the VSL through two channels. First, the change in $m$ affects $c$ directly, as in the case with fixed $l$. Second, the change in $m$ affects the optimal choice of $l$, which influences both the level of consumption (through changes in wage income) as well as the marginal utility of consumption when $u_{cl}>0$. As a result, allowing for variable

[10] Note our definitions of $\gamma_{I,l\ fixed}$ and $R_{I,l\ fixed}$ are constructed to be consistent with Kaplow (2003) in that these measures are defined with respect to expected utility, $V$. Conventional practice would define $R$ in terms of the curvature properties of the utility function. With no labor supply adjustment, comparable measures defined with respect to utility, $u$, are identical. Thus, the distinction is irrelevant for Model I with $l$ fixed.

[11] One potential explanation for this complementarity could be health related. Indeed, following research by Hall and Jones (2007), we recently argued (Evans and Smith 2008) that improved health increases complementarity between consumption and leisure (implying substitution between consumption and labor). Thus, for a given degree of risk aversion, those individuals in good health are likely to have higher income elasticities for their risk tradeoffs then those in poor health.

labor supply complicates the expression for the IEVSL as illustrated in equation (2.8).

$$\eta_{I,l\,variable} = \frac{mu_c}{u} - \frac{wmu_{cc}}{u'} - \frac{mu_{cl}}{u'} + m\frac{dl_I{}^*}{dm}\left[\frac{2u'}{u} - \frac{w^2u_{cc} + 2wu_{cl} + u_{ll}}{u'}\right] \tag{2.8}$$

where

$$\frac{dl_I{}^*}{dm} = \frac{p'u_c - (1-p)(wu_{cc} + u_{cl})}{-p''u - \frac{2u(p')^2}{(1-p)} + (1-p)[w^2u_{cc} + 2wu_{cl} + u_{ll}]} \tag{2.9}$$

Two important questions arise with respect to expression (2.8). First, how does allowing for variable labor supply affect the magnitude of the IEVSL? Second, how does variable labor supply affect the relationship between the IEVSL and the CRR? To address the first question, consider the case of independence between consumption and labor supply. With $u_{cl}$=0, the expressions for the income elasticity of the VSL with fixed and variable labor supply can be written as in (2.10) and (2.11) respectively:

$$\eta_{I,l\,fixed} = \frac{mu_c}{u} - \frac{wmu_{cc}}{u'} \tag{2.10}$$

$$\eta_{I,l\,variable} = \frac{mu_c}{u} - \frac{wmu_{cc}}{u'} + m\frac{dl^*}{dm}\left[\frac{2u'}{u} - \frac{w^2u_{cc} + u_{ll}}{u'}\right] \tag{2.11}$$

The first two terms of (2.10) and (2.11) are identical when they are evaluated at the same level of labor supply (and therefore consumption). With $u_{cl}$=0, $\frac{dl_I{}^*}{dm} < 0$ since the denominator of (2.9) is negative by the second order condition. The bracketed term in (2.11) is positive. Thus, for this case the final term in (2.11) is negative and $\eta_{I,l\,variable} < \eta_{I,l\,fixed}$.

Variable labor supply provides the individual with an additional margin along which he can adjust to income shocks. This opportunity to adjust dilutes the effect of an income shock on the marginal willingness to pay for a risk reduction. Note also that the larger is the reduction in labor supply in response to an increase in $m$, the larger is the deviation between $\eta_{I,l\,variable}$ and $\eta_{I,l\,fixed}$. While our discussion here focuses on independence between consumption and labor supply, the result also holds with sufficiently modest levels of complementarity.

To explore the second question posed above, we rearrange expression (2.8) to express $\eta_{I,l\,variable}$ as a function of the elasticity of utility to consumption and the CRR. However, with labor supply adjusting to changes in exogenous income, the CRR is no longer expressed as in (2.6); the CRR must also account for the labor supply adjustment (Chetty 2006). We obtain the following expression for the CRR with variable labor supply.[12]

$$R_{I,l\,variable} = -\frac{mu_{cc}}{u_c} + m\frac{dl_I{}^*}{dm}\left[\frac{p'}{(1-p)} - \frac{wu_{cc} + u_{cl}}{u_c}\right] \tag{2.12}$$

[12] Our derivation of the CRR with variable labor supply parallels a related measure developed by Chetty (2006). However, our expression for the CRR is different from Chetty's because his model does not consider risk as a function of labor supply. Thus in his model, the CRR defined in terms of utility is identical to the measure we define with respect to expected utility (as in Kaplow).

Note that the first term in (2.12) is the coefficient of relative risk aversion with $l$ fixed at $l_I$* (which we denoted $R_{I,l\,fixed}$ above). As in Chetty (2006), with $l$ variable, the agent has increased flexibility to adjust to exogenous income shocks and thus is less risk averse when adjustment is possible. Therefore, $R_{I,l\,variable} < R_{I,l\,fixed}$.[13]

When we rewrite the expression for the IEVSL with variable labor supply (2.8) substituting for the CRR given in (2.12), the conditions under which the CRR serves as a lower bound for the IEVSL become even less transparent as illustrated in expression (2.13).

$$\eta_{I,l\,variable} = \frac{mu_c}{u} + R_{I,l\,variable}\frac{wu_c}{u'} - \frac{mu_{cl}}{u'} + \frac{dl_I{}^*}{dm} \times \left[\frac{mu'}{u} + \frac{mu_l}{u} - \frac{m(wu_{cl}+u_{ll})}{u'}\right] \tag{2.13}$$

Expression (2.13) confirms that the degree of complementarity between $c$ and $l$ again plays a key role in determining the relationship between the CRR and the IEVSL. To highlight the potential role of complementarity, rewrite $\eta_{I,l\ variable}$ as a function of $R_{I,l\ fixed}$ (the CRR with $l$ fixed) as follows:

$$\eta_{I,l\,variable} = \frac{mu_c}{u} + R_{I,l\,fixed}\frac{wu_c}{u'} - \frac{mu_{cl}}{u'} + \frac{dl_I{}^*}{dm} \times \left[\frac{2mu'}{u} - \frac{m}{u}\left(w^2u_{cc} + 2wu_{cl} + u_{ll}\right)\right] \tag{2.14}$$

Now suppose $u_{cl}$=0. Under independence, $\frac{dl_I{}^*}{dm} < 0$ and the bracketed term in equation (2.14) is positive so that the final term, their product, is negative. Thus, even with $u_{cl}$=0, $R_{I,l\,fixed}$ need not provide a lower bound for the IEVSL when we allow for labor market adjustments to income shocks ($\eta_{I,l\,variable}$). What about $R_{I,l\,variable}$? Since $R_{I,l\,variable} < R_{I,l\,fixed}$, under certain conditions (i.e., $u_{ll}$ sufficiently close to zero or $u_l$ sufficiently negative) $R_{I,l\,variable}$ provides a lower bound for $\eta_{I,l\,variable}$ when $u_{cl}$=0. However, this result does not hold generally even under independence. Not surprisingly, the presence of consumption-labor supply complementarity ($u_{cl}$>0) further confounds the relationship between $R_{I,l\,variable}$ and $\eta_{I,l\,variable}$. Although the relationship between the income elasticity of the VSL and the coefficient of relative risk aversion is less transparent with variable labor supply, our analytical derivations again suggest key roles for both the behavioral responses to exogenous income shocks as well as consumption-labor supply complementarities.

## 2.2 Implications of consumption commitments for risk preferences and the IEVSL

The final model extension we explore (reported as Model II) involves considering the possibility that the presence of other constraints, such as those related to

[13] See the Appendix for a proof of this result. It is important to recognize that this conclusion depends on defining the CRR in terms of expected utility as Kaplow has proposed. Arrow's (1971) overview of the theory underlying the definition of the coefficient of risk aversion describes it as a feature of the utility function *not* the expected utility function. We have adopted the Kaplow convention in order to facilitate direct comparisons between our results and those of Kaplow and others. Chetty and Szeidl (2007) also define a CRR in terms of expected utility (p. 844).

consumption, may limit the ability of some individuals to adjust their labor supply in response to income shocks. Our objective is to examine how the presence of consumption commitments impacts the IEVSL. To do so, we add a third argument, denoted $z$, to the utility function specified above. That is, we assume expected utility is given by:

$$V = (1 - p(l))u(m + wl - z, z, l) \tag{2.15}$$

with the price of $z$ assumed to be unity. We assume $u_z > 0$ and $u_{zz} < 0$. With this specification, we can use assumptions about whether $z$ can adjust to exogenous income shocks to further explore the relationship between the IEVSL and the CRR in the presence (or absence) of additional behavioral constraints. It is straightforward to see the parallel structure of the problem by differentiating the relevant expression for the VSL, denoted $\mathrm{VSL}_{\mathrm{II}}$, with respect to exogenous income ($m$) while allowing both $l$ and $z$ to adjust as in equation (2.16).

$$\frac{dVSL_{II}}{dm} = \frac{wu_c}{(1-p)u'} - \frac{w^2uu_{cc}}{(1-p)(u')^2} - \frac{wuu_{cl}}{(1-p)(u')^2} + \frac{dl_{II}^*}{dm} \cdot A + \frac{dz_{II}^*}{dm} \cdot B \tag{2.16}$$

where

$$A \equiv \frac{-w^3uu_{cc} - 2w^2uu_{cl} - wuu_{ll} + w(u')^2}{(1-p)(u')^2}$$

and

$$B \equiv \frac{w^2uu_{cc} - w^2uu_{cz} + wuu_{lc} - wuu_{lz} - wu'(u_c - u_z)}{(1-p)(u')^2}$$

$l_{II}^*$ and $z_{II}^*$ denote the optimal choices of labor supply and consumption of $z$ for Model II respectively.

An argument similar to what we developed for Model I above would yield a generalization to the CRR and the implication that restrictions on adjustments to $z$ lead to measures for the CRR that imply magnified risk aversion with commitments. When $z$ is fixed (i.e., the individual faces a consumption commitment), adjustment is precluded on this margin and with complementarities the effect of this constraint can be magnified.[14] What is important for our situation is the fact that this added restriction further compromises seemingly clear-cut judgments about the relationship between the IEVSL and measures of risk aversion.

The basic logic of our model implies that we should be able to detect the effects of these commitments by considering other margins of adjustment. For example if $z$ corresponds to a commitment to a home and associated mortgage payments, then a shock to household income should be reflected in hours worked or the labor force participation decisions of household members. We should expect to observe different behavioral responses among individuals in households with significant mortgage or other commitments relative to those in households with smaller or no pronounced commitments.

[14] See Chetty and Szeidl (2007) pp. 845–846 for the derivation in a closely related model and further discussion.

Table 1 combines the results from all the cases we have considered for Models I and II, with fixed and variable labor supply as well as accounting for the role of prior consumption commitments. Specifically, the table reports the implied coefficient of relative risk aversion (CRR), the income elasticity of the VSL (IEVSL), and labor supply responses to exogenous income shocks for each model specification. The first row of the table includes the three measures of interest derived from Kaplow's model for comparison.

Consistent estimates of the VSL that capture the effects of differences in exogenous non-wage income or in other factors influencing individuals' labor supply and consumption decisions must be based on a structural model. Fortunately this does not mean we must have a comprehensive dataset that would support estimation of a fully structural model of labor supply and commodity choices under uncertainty. Policy can be based on consistently calibrated models. Indeed, none of the four studies that we discuss in Section 1 report new estimates of structural models based on the arguments these authors develop. Instead, they present numerical exercises based on calibrated models. However, there is an important distinction between these numerical exercises and most extrapolations currently used in benefit transfers for environmental policy. These numerical analyses maintain a consistent framework to describe how optimal choices respond to exogenous shocks in the presence of constraints. This type of analysis imposes the structural linkages derived from utility-theoretic models of decision making.[15] The same would be possible for the case of adjustments to VSL for income differences or other factors important to a consistent economic model for risk tradeoffs. Of course, imposing this structure is warranted when the estimates of the necessary model parameters are available and when there is empirical support for the importance of the role of commitments and labor supply adjustments. The next section presents some empirical evidence that begins to make a case for the relevance of such a structural framework.

## 3 Empirical relevance of consumption commitments

This section reports the results of a simple exercise that explores the empirical relevance of labor supply responses to shocks and the role of consumption commitments as a constraint on these responses. Recall our conceptual analysis suggested that measures of both risk preferences and labor supply responses would be influenced by the ability to adjust commitments in response to exogenous shocks. Our empirical analysis uses data from the Health and Retirement Study (HRS).[16] Because of the demographic group represented in these data, the sample has some special features, such as detailed information on health conditions, which work to our advantage. In addition, income constraints may also be more pronounced among these respondents. We divide our empirical findings into two parts. The first

[15] This is the point of arguments for using preference calibration in other types of benefits transfer.

[16] The HRS is a national panel study intended to be representative of individuals who fell in the age cohort of 51 to 61 years old in 1992 (wave 1) and their spouses. The HRS (Health and Retirement Study) is sponsored by the National Institute of Aging (grant number NIA U01AG09740) and conducted by the University of Michigan. We rely on the RAND Corporation's cleaned version of the HRS.

**Table 1** Theoretical findings[a]

| | Coefficient of relative risk aversion (CRR) | Income elasticity of the VSL (IEVSL) | Labor supply response to exogenous income shock |
|---|---|---|---|
| Kaplow model: $V \equiv (1-p(x))u(c),\ p'<0$, choice variable is $x$ | | | |
| $x$ fixed at initial optimum | $R_K = \frac{-mu_{cc}}{u_c}$ | $\eta_K = \frac{mu_c}{u} - \frac{mu_{cc}}{u_c}$ | 0 |
| Model I: $V \equiv (1-p(l))u(c,l),\ p'>0$, choice variable is $l$ | | | |
| $l$ fixed at initial optimum | $R_{I,l\ fixed} = \frac{-mu_{cc}}{u_c}$ | $\eta_{I,l\ fixed} = \frac{mu_c}{u} - \frac{wmu_{cc}}{u'} - \frac{mu_{cl}}{u'}$ | 0 |
| $l$ variable | $R_{I,l\ variable} = \frac{-mu_{cc}}{u_c}$ $-m\frac{dl_I{}^*}{dm}\left[\frac{wu_{cc}+u_{cl}}{u_c} - \frac{p'}{(1-p)}\right]$ | $\eta_{I,l\ variable} = \frac{mu_c}{u} + R_{I,l\ variable}\frac{wu_c}{u'} - \frac{mu_{cl}}{u'}$ $-\frac{dl_I{}^*}{dm}\left[\frac{m(wu_{cl}+u_{ll})}{u'} - \frac{mu'}{u} - \frac{mu_l}{u}\right]$ | $\frac{dl_I{}^*}{dm} = \frac{p'u_c - (1-p)(wu_{cc}+u_{cl})}{-p''u - \frac{2u(p')^2}{(1-p)} + (1-p)\left[w^2u_{cc} + 2wu_{cl} + u_{ll}\right]}$ |
| Model II: $V \equiv (1-p(l))u(c,z,l),\ p'>0$, choice variables are $l$ and $z$ | | | |
| $l$, $z$ fixed at initial optima | $R_{II,l\&z\ fixed} = \frac{-mu_{cc}}{u_c}$ | $\eta_{II,l\&z\ fixed} = \frac{mu_c}{u} - \frac{wmu_{cc}}{u'}$ $-\frac{mu_{cl}}{u'}$ | 0 |
| $l$ variable, $z$ fixed at initial optimum | $R_{II,z\ fixed} = \frac{-mu_{cc}}{u_c}$ $-m\frac{dl_{II,z\ fixed}{}^*}{dm}\left[\frac{wu_{cc}+u_{cl}}{u_c}\right.$ $\left.-\frac{p'}{(1-p)}\right]$ | $\eta_{II,z\ fixed} = \frac{mu_c}{u} + R_{II,z\ fixed}\frac{wu_c}{u'} - \frac{mu_{cl}}{u'}$ $-\frac{dl_{II,z\ fixed}{}^*}{dm}\left[\frac{m(wu_{cl}+u_{ll})}{u'} - \frac{mu'}{u} - \frac{mu_l}{u}\right]$ | $\frac{dl_{II,z\ fixed}{}^*}{dm} = \frac{p'u_c - (1-p)(wu_{cc}+u_{cl})}{-p'u - \frac{2u(p')^2}{(1-p)} + (1-p)\left[w^2u_{cc} + 2wu_{cl} + u_{ll}\right]}$ |
| $l$, $z$ variable | $R_{II,l\&z\ variable} = \frac{-mu_{cc}}{u_c}$ $-m\frac{dl_{II}{}^*}{dm}\left[\frac{wu_{cc}+u_{cl}}{u_c} - \frac{p'}{(1-p)}\right]$ $-m\frac{dz_{II}{}^*}{dm}\left(\frac{u_{cz}-u_{cc}}{u_c}\right)$ | $\eta_{II,l\&z\ variable} = \frac{mu_c}{u} + R_{II,l\&z\ variable}\frac{wu_c}{u'} - \frac{mu_{cl}}{u'}$ $-\frac{dl_{II}{}^*}{dm}\left[\frac{m(wu_{cl}+u_{ll})}{u'} - \frac{mu'}{u} - \frac{mu_l}{u}\right]$ $-\frac{dz_{II}{}^*}{dm}\left[\frac{m(u_{lz}-u_{cl})}{u'} - \frac{u_z-u_c}{u}\right]$ | $\frac{dl_{II}{}^*}{dm} = \frac{(1-p)}{\lvert H\rvert}\left\{\begin{array}{l} p'u_c\left[u_{cc}+u_{zz}-2u_{cz}\right] \\ -(1-p)(wu_{cc}+u_{cl})(u_{zz}-u_{cz}) \\ -(1-p)(wu_{cz}+u_{zl})(u_{cc}-u_{cz}) \end{array}\right\}$ where $H$ is the Hessian matrix of second order derivatives. |

[a] Note that the table uses $u$ to denote the three utility functions presented in the Kaplow model and in Models I and II. However, these utility functions are not equivalent. Thus the arguments of the marginal utility terms (and second derivative terms), which are suppressed in the table, differ across the three models. Therefore the values of these terms differ across models so that, for example, $u_{cc}$ for Model I is not equal to $u_{cc}$ for Model II

where $u' = wu_c + u_l$

subsection reports some simple cross tabulations investigating the link between estimates of the extent of risk aversion based on stated choices and a set of economic and demographic attributes. In the second subsection, we explore the responsiveness of labor force participation to exogenous shocks in the presence and absence of consumption commitments.

### 3.1 The effect of consumption commitments for risk preferences

The measurement of risk aversion relies primarily on indirect methods. In an experimental setting, Holt and Laury (2002) use a paired lottery-choice experiment to estimate risk aversion coefficients. Alternatively, the auction literature has proposed structural models to estimate risk coefficients, for particular preference functions, using bidding data.[17] Many of these indirect methods involve inferring risk preferences from models of decision making in various settings but as a result rely on the maintained assumptions of these models. The survey method proposed by Barsky et al. (1997) is more closely aligned with a job choice context. Their risk tolerance measure is based on responses to questions about choices between a secure job for life and another job with a 50-50 chance of two different income levels. With locally constant relative risk aversion the answers classify respondents into one of four risk tolerance categories from least risk averse to most averse. Barsky et al.'s analysis of wave one (1992) of the HRS found higher levels of risk aversion among women (relative to men) and among homeowners (relative to renters). The latter finding is consistent with the results of Chetty and Szeidl.

Some of the findings reported by Holt and Laury suggest differences in risk aversion measures for the real versus hypothetical treatments of their paired lottery choice experiments. These results might raise concerns with using Barsky's hypothetical questions as an approach to recover risk attitudes. More specifically, Holt and Laury find little responsiveness in measures of risk aversion based on their stated choices among lotteries to increases in the size of payoffs among participants in the hypothetical treatment. This finding contrasts with the changes in the actual choices among the same lotteries with increases in payoffs for the participants in the real treatments. These differences lead the authors to conjecture that participants making a hypothetical decision may have difficulty imagining how they would actually behave when faced with high incentive conditions. Fortunately, other evidence suggests that the risk aversion measures derived with the Barsky questions provide a reliable basis for classifying individuals into broad categories of risk preferences. For example, in earlier analyses using the HRS to evaluate labor market choices and risk tradeoffs (see Smith et al. 2004) and to explore how changes in health conditions influence these tradeoffs (see Evans and Smith 2008), we found that the implied risk classification was informative in describing how the heterogeneity in risk attitudes influenced these individuals' labor market choices.

Recently, Anderson and Mellor (2009) use a within-subject experimental design to explore consistency between the risk aversion measures (i.e., CRR) from the Holt and Laury lottery choice mechanism and from versions of the hypothetical survey

[17] See Chetty (2006) for citations of additional studies that use indirect methods to estimate risk coefficients.

questions used in several ongoing panel surveys (i.e., the Panel Study on Income Dynamics and the HRS).[18] For their full sample, they find weak evidence of consistency between the two measures. However, when they restrict their sample to subjects whose responses to the hypothetical survey questions were internally consistent, they find a higher degree of consistency between the two measures. While not highlighted in their analysis, Anderson and Mellor's results provide some evidence of similarities between responses to hypothetical and real risk preference elicitation methods among subjects who understand the choices they face.

Our previous analyses benefited from the broad classification of risk attitudes afforded by the Barsky questions. As we explore related empirical questions here, we continue to use the index of risk aversion derived from the Barsky questions. In this context, we confirm the Chetty–Szeidl results for the effects of commitments among the subset of HRS respondents who were asked the Barsky risk tolerance questions in 2000. That is, we find higher levels of risk aversion (based on the Barsky classification) among respondents in our sample with mortgage payments ($p$=0.109, $N$=1,375).

More recently the second author and Carol Mansfield (see Smith and Mansfield 2009) consider a representative sample of adults 18 years or older from Knowledge Networks Internet panel in 2006. The survey asked a series of questions to investigate risk preferences. Respondents were first asked the Barsky risk classification questions. Following these questions, respondents were informed, using a series of descriptive phrases, of the risk classification implied by their answers. Respondents were then asked to indicate whether they agreed with the assessment. If a respondent did not agree with the description of his attitudes, then he was given the opportunity to reclassify himself into another risk tolerance category using brief descriptive phrases about the willingness to take financial risks. About one third of respondents expressed disagreement with the Barsky classification of their risk preferences and chose a revised classification that differed from the Barsky measure. Table 2 reproduces their results from three models as well as summary statistics for the sample. The third column reports regression results using the full sample where the dependent variable is either the implied CRR (for respondents who agreed with the original assessment) or the revised CRR (for those who disagreed and chose an alternative category). The fourth column reports the same model using the original responses and the last restricts the sample to those individuals who agreed with the original assignment. A comparison of the model results across all samples and measures used for the dependent variable (i.e., implied CRR or revised CRR) reveals a similar pattern. Using the revised CRR measures

[18] Subjects faced two sequences of hypothetical survey questions, beginning with the Barsky et. al. (1997) job choice questions. After answering the Barsky sequence, subjects faced a second set of hypothetical gamble questions, identical to the Barsky sequence except for the context. The second set of questions related to tradeoffs involving a hypothetical inheritance, rather than a job. The authors changed the format of the original Barsky questions by asking multiple variations to the same respondent. They varied the odds of the job and inheritance outcomes and asked each version of the question to each respondent. In addition, since subjects were students they were told to use the income of their parents in evaluating the job prospects. Both of these changes are important departures from the format used in asking these questions of HRS respondents as well as from the format used in the Smith and Mansfield (2009) work. See Anderson and Mellor (2009) for a more detailed discussion of the results with respect to the inheritance questions.

**Table 2** Smith Mansfield results for risk aversion index with KN sample—2006

| Independent variables | Sample means | Imputed CRR with revision | Imputed CRR without revision | Imputed CRR without revision and restricted sample |
|---|---|---|---|---|
| Own home (=1) | 0.70 | 0.33 | 0.37 | 0.43 |
| | (0.46) | (1.75) | (1.94) | (2.07) |
| Female(=1) | 0.52 | 0.53 | 0.43 | 0.56 |
| | (0.50) | (3.42) | (2.78) | (3.31) |
| Household income | 52,759 | $-.51\times10^{-5}$ | $-.34\times10^{-5}$ | $-.45\times10^{-5}$ |
| | (41,160) | (−2.45) | (−1.61) | (−1.94) |
| Age | 48.1 | 0.03 | 0.03 | 0.03 |
| | (16.9) | (6.18) | (5.34) | (6.29) |
| White(=1) | 0.74 | 0.32 | 0.61 | 0.54 |
| | (0.44) | (1.52) | (2.84) | (2.30) |
| African American(=1) | 0.09 | 0.32 | 0.17 | 0.32 |
| | (0.30) | (1.01) | (0.53) | (0.94) |
| Not high school grad (=1) | 0.13 | 0.45 | 0.12 | 0.27 |
| | (0.34) | (1.91) | (0.49) | (1.06) |
| College grad(=1) | 0.17 | −0.52 | −0.19 | −0.51 |
| | (0.38) | (−2.39) | (−0.91) | (−2.12) |
| Greater then college(=1) | 0.10 | −0.95 | −0.38 | −0.95 |
| | (0.30) | (−3.43) | (−1.35) | (12.98) |
| Intercept | | 3.23 | 3.98 | 3.34 |
| | | (10.22) | (12.49) | (9.54) |
| Sample size | 2,244 | 2,244 | 2,244 | 1,858 |
| $R^2$ | | 0.05 | 0.04 | 0.06 |

CRR designates the inverse of the risk tolerance measure derived using the mean values Barsky et al. assign to responses to their stated choice questions. See Smith and Mansfield (2009).

The numbers in parentheses for the first column are standard errors. In the remaining columns they are t-ratios for the null hypothesis of no association.

* denotes significance at the 10% level and ** denotes significance at the 5% level.

increases the precision of coefficient estimates but does not change the sign of any of the variables. Thus, these results provide additional support for the Barsky measure as an indicator of risk aversion. They are also consistent with the Anderson and Mellor findings in that the fit of the relationship between measures of the CRR and economic variables improves when the sample focuses on respondents who appear to understand the questions as they are intended. The primary reason for summarizing them here is that they are also relevant for our conceptual arguments. Commitments in the form of home ownership increase measured risk aversion as Chetty and Szeidl's analysis suggests. Income level appears to reduce risk aversion as theory would suggest and age increases measured risk aversion. Finally, offering respondents the opportunity to revise did affect the ability of the model to uncover the effects of education.

### 3.2 The effect of consumption commitments for labor market responses to shocks

Our second empirical exercise involves exploring the relevance of consumption commitments as constraints to individual labor market responses to exogenous shocks. Coile (2004) proposes a model to examine the impact of own and spouse health shocks on labor market behavior. We adapt her specification to consider how older individuals' decisions to exit the labor force in response to a change in the health status of a spouse vary with the presence of consumption commitments. We focus on the decision of HRS respondents to exit the full-time labor force between 1998 (wave 4) and 2000 (wave 5). We estimate the following model:

$$y_i = \alpha + x_i\beta + \gamma_0 z_i + \gamma_1 m_i + \gamma_2 z_i m_i + \varepsilon_i \tag{3.1}$$

where $y_i$=1 if respondent $i$ exited from full-time work between 1998 and 2000. That is, $y_i$=1 if $i$ worked full time in 1998 but worked part-time, was fully or partly retired, unemployed, disabled, or not in the labor force in 2000. $y_i$=0 if respondent $i$ continued to work full-time in 2000. $x_i$ denotes a vector of individual characteristics. $m_i$ indicates the presence of an exogenous (negative) income shock. $z_i$ is a binary variable which takes a value of one if the individual faces a consumption commitment.

We indicate the presence of a consumption commitment if the value of all mortgages on the respondent's first home exceeds \$50,000. A reported increase in (own) functional limitations by the respondent's spouse between 1998 and 2000 serves as a proxy for an exogenous shock that may influence the labor market behavior of the respondent. During each interview wave, survey participants (target respondents and their spouses) indicate whether or not they experience difficulty with various activities of daily living (ADLs) including bathing, dressing, eating, getting in and out of bed, and walking across a room. Using summary measures available in the RAND version of the HRS data, we construct a binary variable that equals one if the number of ADLs with which the respondent's spouse reported having some difficulty increased between waves 4 and 5.

We focus on increased difficulties with activities of daily living rather than other changes in health such as a new diagnosis of a serious health condition for two reasons. First, as noted by Coile, indicators of specific health conditions may mask important heterogeneity. That is, the severity of and therefore the behavioral response to a spousal health shock are likely to vary across individuals and across diagnoses. For example, a respondent whose spouse suffers a stroke that results in significantly reduced capacity may face increased care-giving responsibilities relative to one whose spouse also suffers a stroke but whose capacities are not severely diminished as a result. A binary variable indicating the occurrence of the stroke would treat these two scenarios identically. Second, relative to spouses in our sample with new health diagnoses between 1998 and 2000, spouses who had an increase in ADLs are more likely to report limitations in the type or amount of paid work in which they engage in 2000.[19] Of those spouses in our sample with an increase in ADLs, 74% reported work limitations while only 26% and 47% of spouses with new diagnoses of

[19] The text of the survey question is: "Now I want to ask how your health affects paid work activities. Do you have any impairment or health problem that limits the kind or amount of paid work you can do?"

chronic and acute health conditions indicated limitations respectively.[20] To explore the suitability of our measure of increased ADL difficulties as a proxy for an income shock, we examine the mean difference in average medical expenditures in 2000 among spouses with increased difficulties and those without. Mean medical expenditures are more than $20,000 higher ($p$=0.00) among those with increased ADLs.[21]

Table 3 reports summary statistics for our primary sample, which is restricted to 3,920 married respondents who reported working full time, at least 35 hours per week for at least 36 weeks, in wave 4 (1998). About 25% of respondents exited the full time labor force between 1998 and 2000. The average respondent in our sample is about 59 years old with 13 years of education. About 58% of individuals in our sample are male. Almost a third of respondents live in households with mortgages that exceed $50,000. Mean household income and non-housing assets in 1998 were both approximately $90,000.

Table 4 contains the results of our full time labor market exit probit models. The table reports marginal effects and $z$ statistics. Following Coile, we estimate separate models for male and female respondents in our sample. The final two columns of the table add additional controls for own ADL shock and own ADL shock interacted with the mortgage commitment variable. The results suggest that the labor exit decisions of women in our sample are not significantly affected by spousal ADL shocks independent of the presence of a mortgage commitment. Specifications (1) and (3) indicate significant differences in the impact of a spousal ADL shock on the labor exit decision for those men in our sample who have mortgage commitments relative to those who do not. Specification (1) suggests that for men without significant mortgage commitments, an increase in spousal ADLs increases the probability of exiting the full time labor force by about 7%. For men in our sample with mortgage commitments, a spousal ADL shock decreases the exit probability by about 10% ($p$-value=0.06). Once we control for own ADL shocks (specification 3), we continue to find differences in the responsiveness of the labor exit outcome to spousal ADL shocks between men in our sample with commitments and those without. The results with respect to the other controls are generally consistent with expectations.

To summarize our empirical analysis, we find clear evidence consistent with the notion that significant consumption commitments alter individuals' abilities to respond to exogenous income shocks. The constraints to behavioral adjustments implied by these commitments are more pronounced among men in our sample. Among women in our sample, the decision to exit the full time labor force in response to increased spousal functional limitations is insensitive to the presence of commitments. While our empirical model focuses on the extensive margin of adjustment, these findings are nonetheless broadly consistent with our analytical model which suggests that the presence of consumption commitments can alter labor market responses (at the intensive margin) to exogenous income effects.

[20] Chronic health conditions include diabetes or high blood sugar, lung disease such as chronic bronchitis or emphysema, arthritis or rheumatism, and high blood pressure or hypertension. We define an acute health condition as a stroke or transient ischemic attack, cancer or a malignant tumor of any kind except skin cancer, heart attack, coronary heart disease, angina, congestive heart failure, or other heart problem. These definitions are broadly consistent with Coile (2004).

[21] All reported dollar figures are nominal.

**Table 3** Summary statistics for primary sample—married HRS respondents who worked full time in 1998 (Sample size is 3,920)

| Variable name | Variable description | Sample mean (standard deviation) or sample percentage |
|---|---|---|
| Exit | =1 if individual reported a labor force status other than full time in 2000, =0 if individual reported continuing to work full time in 2000 | 24.16 |
| Own ADL increase | =1 if individual reported an increase in ADL difficulties between 1998 and 2000, =0 otherwise | 4.36 |
| Spouse ADL increase | =1 if individual's spouse reported an increase in ADL difficulties between 1998 and 2000, =0 otherwise | 6.30 |
| Mortgage commitment | =1 if individual belongs to household with mortgage exceeding $50,000, =0 otherwise | 31.76 |
| Age | Individual's age in 2000 | 58.51 |
| | | (6.62) |
| Male | =1 for male, =0 for female | 57.73 |
| Education | Years of education | 13.05 |
| | | (2.94) |
| HH income | Total household income reported in 1998 (in $10,000) | 8.72 |
| | | (17.11) |
| HH non-housing wealth | Net value of non-housing household financial wealth reported in 1998 (in $10,000) | 9.20 |
| | | (54.97) |

Sample size is 3,920

## 4 Conclusion

Our analysis was motivated by the policy importance of how estimates of the marginal willingness to pay for risk reductions are adapted to fit the conditions required by the policies they help to evaluate. Most of the available estimates of these tradeoffs are derived from reduced form models that consider the marginal changes in compensation different individuals are willing to accept for different working conditions. These working conditions include variations in serious risks of injury or death on the job. Using these reduced form estimates outside the domain of the conditions underlying the measurement of the tradeoffs requires an understanding of how people adapt to a wide range of influences on their behaviors involving labor-leisure choices, financial and nonfinancial commitments, and health status. Recent theoretical advances by Chetty and by Chetty and Szeidl have identified ways in which the models proposed by Eeckhoudt and Hammitt and by Kaplow require revision in order to accommodate the multiple margins available to people to adjust to shocks. We have demonstrated that integrating these diverse conceptual treatments of individual behavior and risk preferences leads to substantial changes in the widely accepted conclusions of Eeckhoudt and Hammitt and of Kaplow on how we should think about the role of exogenous income changes as influences to risk tradeoffs. Moreover our preliminary empirical findings support the empirical relevance of two key components of our theoretical analysis, the responsiveness of

**Table 4** Empirical results—Decision to exit full time labor force (in 2000) probit models

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| | Male sample | Female sample | Male sample | Female sample |
| Spouse ADL increase | 0.067* | −0.031 | 0.044 | −0.039 |
| | (1.65) | (−0.61) | (1.10) | (−0.78) |
| Mortgage commitment | −0.025 | −0.064** | −0.018 | −0.059** |
| | (−1.19) | (−2.65) | (−0.84) | (−2.40) |
| Spouse ADL increase*mortgage commitment | −0.166** | 0.125 | −0.159** | 0.122 |
| | (−2.30) | (1.04) | (−2.12) | (1.00) |
| Own ADL increase | | | 0.233** | 0.262** |
| | | | (4.43) | (3.97) |
| Own ADL increase*mortgage commitment | | | −0.079 | −0.046 |
| | | | (−0.88) | (−0.42) |
| Age2 | −0.135 | 0.140 | −0.133 | 0.140 |
| | (−1.30) | (1.61) | (−1.29) | (1.59) |
| Age3 | −0.101 | 0.172** | −0.102 | 0.173** |
| | (−1.10) | (2.19) | (−1.12) | (2.18) |
| Age4 | 0.125 | 0.219** | 0.013 | 0.223** |
| | (0.12) | (2.78) | (0.13) | (2.81) |
| Age5 | 0.196* | 0.421** | 0.196* | 0.431** |
| | (1.79) | (4.85) | (1.80) | (4.92) |
| Age6 | 0.316** | 0.548** | 0.319** | 0.549** |
| | (2.61) | (5.76) | (2.65) | (5.73) |
| Education | −0.0009 | −0.006 | −0.0006 | -0.005 |
| | (−0.26) | (−1.16) | (−0.19) | (−1.03) |
| HH income (1998) | −0.003** | 0.001 | −0.003** | 0.001 |
| | (−1.98) | (1.44) | (−2.05) | (1.48) |
| HH non-housing wealth (1998) | 0.0006** | −0.00004 | 0.0006** | 0.00003 |
| | (2.18) | (−0.24) | (2.23) | (−0.23) |
| N | 2263 | 1655 | 2263 | 1655 |
| Pseudo R2 | 0.114 | 0.105 | 0.122 | 0.114 |

Table reports marginal effects and z statistics. All models include a set of dummy variables indicating occupation and industry in 1998

* denotes significance at the 10% level and ** denotes significance at the 5% level.

labor market behavior to health shocks and the influence of consumption commitments for this responsiveness.

## 5 Appendix

To show $R_{I,l\ variable}<R_{I,l\ fixed}$, define $R_{I,l\ variable}$ generally as $R_{I,l\,variable} = -\frac{mv_{mm}}{v_m}$ where

$$v = v(m) = (1 - p(l(m)))u(m + wl(m), l(m)) \tag{A.1}$$

denotes indirect (expected) utility over income and $l(m)=l_I$*. By the envelope condition,

$$v_m = (1 - p(l(m)))u_c(m + wl(m), l(m)) \tag{A.2}$$

Therefore,

$$v_{mm} = (1 - p(l))u_{cc} + \frac{\partial l}{\partial m}[(1 - p(l))(wu_{cc} + u_{cl}) - p'u_c] \tag{A.3}$$

Substituting for $\frac{\partial l_I{}^*}{\partial m}$ using (2.9) yields

$$v_{mm} = (1 - p(l))u_{cc} - \frac{1}{\overline{K}}[(1 - p(l))(wu_{cc} + u_{cl}) - p'u_c]^2 \tag{A.4}$$

$\overline{K} \equiv -p''u - \frac{2u(p')^2}{(1-p)} + (1-p)[w^2u_{cc} + 2wu_{cl} + u_{ll}] < 0$ by the second order condition so the second term in (A.4) is positive and $v_{mm} > (1 - p(l))u_{cc}$. Combining this result with (2.6), it follows that

$$R_{I,l\,variable} = -\frac{mv_{mm}}{v_m} < -\frac{(1 - p(l))mu_{cc}}{v_m} = -\frac{(1 - p(l))mu_{cc}}{(1 - p(l))u_c} = R_{I,l\,fixed}.$$

## References


Ackerman, F., & Heinzerling, L. (2004). *Priceless: On knowing the price of everything and the value of nothing*. New York: New Press.

Anderson, L. R., & Mellor, J. M. (2009). Are risk preferences stable? Comparing an experimental measure with a validated survey-based measure. *Journal of Risk and Uncertainty, 39*, 137–160.

Arrow, K. J. (1971). *Essays in the theory of risk bearing*. Chicago: Markham.

Barsky, R. B., Juster, F. T., Kimball, M. S., & Shapiro, M. D. (1997). Preference and behavioral heterogeneity: an experimental approach in the Health and Retirement Study. *Quarterly Journal of Economics, 112*, 537–580.

Bowland, B. J., & Beghin, J. C. (2001). Robust estimates of value of a statistical life for developing economies. *Journal of Policy Modeling, 23*, 385–396.

Chetty, R. (2006). A new method of estimating risk aversion. *American Economic Review, 96*, 1821–1834.

Chetty, R., & Szeidl, A. (2007). Consumption commitments and risk preferences. *Quarterly Journal of Economics, 122*, 831–877.

Coile, C. C. (2004). "Health shocks and couples' labor supply decisions," NBER Working Paper Number 10810.

Costa, D. L., & Kahn, M. E. (2004). Changes in the value of life, 1940–1980. *Journal of Risk and Uncertainty, 29*(2), 159–180.
Dickie, M., & Gerking, S. (2007). Altruism and environmental risks to health of parents and their children. *Journal of Environmental Economics and Management, 53*, 323–341.
Eeckhoudt, L. R., & Hammitt, J. K. (2001). Background risk and the value of a statistical life. *Journal of Risk and Uncertainty, 23*(3), 261–279.
Evans, M. F., & Smith, V. K. (2008). Complementarity and the measurement of individual risk tradeoffs: accounting for quantity and quality of life effects. *Environmental and Resource Economics, 41*, 381–400.
Hall, R. E., & Jones, C. J. (2007). The value of life and the risk in health spending. *Quarterly Journal of Economics, 122*, 39–72.
Hammitt, J. K., & Graham, J. D. (1999). Willingness to pay for health protection: inadequate sensitivity to probability? *Journal of Risk and Uncertainty, 18*, 33–62.
Hammitt, J. K., & Zhou, Y. (2000). *Economic value of reducing health risks by improving air quality in China. Sino-US Research Workshop on Economy, Energy, and Environment*. Beijing: Tsinghua University.
Hammitt, J. K., Liu, J.-T., & Liu, J.-L. (2003). Is survival a luxury good? The increasing value of a statistical life. Working paper originally prepared for the 2000 NBER Summer Institute Workshop on Public Policy.
Holt, C. A., & Laury, S. K. (2002). Risk aversion and incentive effects. *American Economic Review, 92* (5), 1644–1655.
Jena, A., Mulligan, C., Philipson, T. J., & Sun, E. (2008). The value of life in general equilibrium. NBER Working Paper Number 14157.
Kaplow, L. (2003). The value of a statistical life and the coefficient of relative risk aversion. NBER Working Paper No. 9852.
Kaplow, L. (2005). The value of a statistical life and the coefficient of relative risk aversion. *Journal of Risk and Uncertainty, 31*, 23–34.
Mitchell, R. C., & Carson, R. T. (1986). *Valuing drinking water risk reductions using the contingent valuation method: A methodological study of risks from THM and Giardia*. Washington, D. C.: Resources for the Future.
Mrozek, J. R., & Taylor, L. O. (2002). What determines the value of life? A meta-analysis. *Journal of Policy Analysis and Management, 21*, 253–270.
Murphy, K. M., & Topel, R. H. (2006). The value of life and longevity. *Journal of Political Economy, 114*, 811–904.
Ruhm, C. J. (2000). Are recessions good for your health? *Quarterly Journal of Economics, 115*(2), 617–650.
Smith, V. K., & Mansfield, C. (2009). Puzzles with measures of risk aversion: do people agree with our measures? Unpublished paper.
Smith, V. K., Pattanayak, S., & Van Houtven, G. (2003). VSL reconsidered: what do labor supply estimates reveal about risk preferences? *Economics Letters, 80*(1), 147–153.
Smith, V. K., Evans, M. F., Kim, H., & Taylor, Jr., D. H. (2004). Do the near-elderly value mortality risks differently? *The Review of Economics and Statistics, 86*(1), 423–429.
U.S. Environmental Protection Agency. (1999). *The benefits and costs of the Clean Air Act: 1990–2010*. Prepared for Congress by Office of Air and Radiation and Office of Policy, EPA 410-R-99-001, November.
U.S. Environmental Protection Agency. (2000). *Guidelines for preparing economic analyses,* Office of the Administrator. EPA-240-R-00-003, December.
U.S. Environmental Protection Agency Science Advisory Board. (2007). *SAB advisory on EPA's issues in valuing mortality risk reduction*, October 12.
Viscusi, W. K., & Aldy, J. E. (2003). The value of a statistical life: a critical review of market estimates throughout the world. *Journal of Risk and Uncertainty, 28*(1), 5–76.
Weitzman, M. L. (2009). On modeling and interpreting the economics of catastrophic climate change. *Review of Economics and Statistics, 91*, 1–19.