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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.

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## I. Introduction

A poll of the analysts tasked with preparing the economic assessments of policies that improve air quality would likely 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 of the value of a statistical life (IEVSL). Numerous empirical studies, adopting various strategies, confirm the theoretical sign prediction.[2] However, in spite of the agreement across studies on the sign of the IEVSL, the empirical literature finds little consistency in its size.

As the IEVSL is often a central component in estimating the benefits of large-scale policy changes, 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

[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 [2003], Viscusi and Aldy [2003], Bowland and Beghin [2001]); 2) stated preference studies (see Hammitt and Graham [2000], Hammitt and Zhou [2000], Mitchell and Carson [1986]); 3) comparisons of VSL estimates at different points in time for a single country (see Hammitt, Liu, and Liu [2006], Costa and Kahn [2004]); 4) cross-country comparisons of VSL estimates (see Hammitt, Liu, and Liu [2006]).

approximating the future value of a statistical life (VSL) based on current VSL, the IEVSL, and projected future incomes. The U.S. Environmental Protection Agency Science Advisory Board (SAB) recently concluded that the empirical literature supports adjusting willingness-to-pay estimates to account for higher future income levels. The prospective report on the costs and benefits of the Clean Air Act Amendments for 1990 to 2010 conducted sensitivity analyses using three IEVSL estimates of 0.08, 0.4, and 1.0. 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.

Efforts to estimate the benefits of historical improvements in health and safety, as Murphy and Topel [2006] and Jena et al. [2008] have recently done for 1970 to 2000, offer a second application where the IEVSL plays an important role. 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 tradeoff resources for risk plays a key role in his conclusions. An extension to his work would 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 applying 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 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 benefit estimation.

Given the observed empirical inconsistencies and the policy implications of different values of the IEVSL, we might ask what insight on the IEVSL theory has to offer. 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 IV, 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 the next section 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 III we describe the results from our generalized model which yields some of the previous models as special cases.

## II. 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 the papers vary but each offers a key insight that motivates the structure of our analytical model discussed in section III.

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 (2.1).

$$u_D(m) = \alpha u_A(m) - \delta \qquad (2.1)$$

where $0 \le \alpha \le 1$ and $\delta \ge 0$.

Assuming *p* denotes the probability of death, expected utility is given by $V \equiv (1-p)u_A(m) + pu_D(m)$. Expressions (2.2) and (2.3) provide the implied VSL and IEVSL (denoted $\eta_{EH}$), respectively (with *m* treated as being synonymous with income).

$$\text{VSL} = \frac{(1-\alpha)u'_A(m) + \delta}{(1-p+p\alpha)u'_A(m)} \qquad (2.2)$$

$$n_{EH} = \frac{dVSL}{dm}\frac{m}{VSL} = \frac{(1-\alpha)}{(1-p+p\alpha)}\left(\frac{m}{VSL}\right) - m\frac{u''_A(m)}{u'_A(m)} \qquad (2.3)$$

where the subscript *EH* indentifies the Eeckhoudt and Hammitt measure. The second term in equation (2.3) is the coefficient of relative risk aversion (CRR) $\left(-m\frac{u''_A(m)}{u'_A(m)}\right)$.

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 that an approximation for the income elasticity of the VSL 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 VSL. A brief inspection of (2.3) 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 (2.3) 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 most estimates of the income elasticity for the VSL are significantly less that one (see Viscusi and Aldy [2003]) whereas estimates of the coefficient of relative risk aversion are approximately two (see Chetty [2006]).

Closer examination of Kaplow's model, which differs from that of Eeckhoudt and Hammitt along a few key dimensions, provides additional insight into this relationship. Kaplow allows an individual to reduce his risk of death, $p(x)$ with $p'(x) < 0$, through precautionary activities (expenditures), *x*. As in Eeckhoudt and Hammitt, individuals derive utility from a single source, in this case net consumption.[3] The simplest formulation of Kaplow's 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 (2.4).

$$V \equiv (1 - p(x))u_A(m - x) \qquad (2.4)$$

[3] 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.

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.[4] That is, the model assumes individuals derive no utility (or disutility) directly from engaging in pre-cautionary 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. The marginal utility of consumption is independent of $x$, and vice versa, in his formulation. 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 $\eta_K^c$:

$$\eta_K^c = \frac{dVSL}{dc}\frac{c}{VSL} = c\frac{u'_A}{u_A} - c\frac{u''_A}{u'_A} - c\frac{u'_A}{u_A}\frac{dx}{dc} \tag{2.5}$$

where the second term is the curvature of utility over net consumption, not over wealth or income as in (2.3). The term $\frac{dx}{dc}$ in (2.5) measures how (optimal) expenditures on pre-cautionary 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,

[4] The distinction 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.

$\eta_K^c$, 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 (2.6a) and (2.6b). The underlying model used to derive this measure is unchanged.[5]

$$\eta_K^m = \frac{dVSL}{dm}\frac{m}{VSL} = \frac{mu_A'}{u_A}\left(1-2\frac{dx}{dm}\right) - \frac{mu_A''}{u_A'}\left(1-\frac{dx}{dm}\right) \tag{2.6a}$$

$$= \frac{mu_A'}{u_A}\left(\frac{1-\dfrac{dx}{dc}}{1+\dfrac{dx}{dc}}\right) - \frac{mu_A''}{u_A'}\left(\frac{1}{1+\dfrac{dx}{dc}}\right) \tag{2.6b}$$

where expression (2.6b) results from substituting $\frac{dx}{dm} = \frac{dx/dc}{1+dx/dc}$ into (2.6a).

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 (2.5). Second, note that even when we assume $\frac{dx}{dc}, \frac{dx}{dm} \approx 0$ as argued by Kaplow ([2005], [2003]), a comparison of (2.5) and (2.6a) confirms that $\eta_K^c \neq \eta_K^m$.

[5] In fact, in a working paper version of his 2005 paper, Kaplow [2003] reports the measure given here as (2.6a).

Chetty's [2006] analysis, while not intended to consider the underlying determinants of the VSL, takes a significant step in this direction. 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.[6] 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). Connecting Chetty's insights to the earlier work by Eeckhoudt and Hammitt and Kaplow requires extending our characterization of the individual decision problem, as we do in the beginning of the next section.

Chetty and Szeidl [2007] add another component, the presence (or absence) of constraints on other behavioral adjustments to exogenous shocks, that 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 that 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. The basic questions we consider in the next section of the paper are how to treat: (1) behavioral

[6] Smith et. al. [2003] in an independent analysis use labor supply elasticity measures for specific preference functions to measure VSL.

adjustments in response to exogenous income shocks (section III.A.); and (2) other consumption components' responses that may well be costly to adjust (section III.B.).

## III. Model of Labor Supply, Mortality Risk, and Commitments

### *A. 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 labor supply respectively. We assume the risk of death, *p*, is a function of the time spent working so that $p = p(l)$ with $p'(l), p''(l) > 0$ .[7] Individuals gain utility from consumption and disutility from working so expected utility is given in (3.1).

$$V = (1 - p(l))u(c,l) = (1 - p(l))u(m + wl, l) \tag{3.1}$$

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 (3.2) and the expression for the VSL in (3.3).

$$-p'u(c_I*, l_I*) + (1 - p)[wu_c(c_I*, l_I*) + u_l(c_I*, l_I*)] = 0 \tag{3.2}$$

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).

$$VSL = \frac{w}{p'(l_I*)} = \frac{wu(c_I*, l_I*)}{(1 - p(l_I*))[wu_c(c_I*, l_I*) + u_l(c_I*, l_I*)]} \tag{3.3}$$

[7] 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.

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 (3.2). 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 (3.4) with $u' \equiv wu_c + u_l$

$$\eta_{I,l\ fixed} = \frac{mu_c}{u} - \frac{wmu_{cc}}{u'} - \frac{mu_{cl}}{u'} \qquad (3.4)$$

where the arguments of the preference function are suppressed. Expression (3.4) 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., $u_{cl}=0$ ).[8] Consider the channel through which this result occurs. 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 towards zero). The compensation required for

[8] 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*.

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) facilitate comparisons with the previous literature. Equation (3.5) defines the elasticity of utility to non-wage income and equation (3.6) the CRR (for *l* fixed at $l_I *$).[9]

$$\gamma_{I,l\ fixed} = \frac{mu_c}{u} \tag{3.5}$$

$$R_{I,l\ fixed} = -\frac{mu_{cc}}{u_c}. \tag{3.6}$$

Substitution using (3.5) and (3.6) allows us to rewrite (3.4) as follows:

$$\eta_{I,l\ fixed} = \gamma_{I,l\ fixed} + \frac{wu_c}{u'} R_{I,l\ fixed} - \frac{mu_{cl}}{u'} \tag{3.7}$$

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

[9] Note our definitions of $\gamma_{I,l\ fixed}$ and $R_{I,l\ fixed}$ are consistent with Kaplow [2003] in that these measures are defined with respect to expected utility, *V*. 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.

aversion.[10] 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 labor supply complicates the expression for the IEVSL as illustrated in equation (3.8).

$$\begin{aligned}\eta_{I,l\,\text{variable}} &= \frac{dVSL}{dm}\frac{m}{VSL} \\ &= \frac{mu_c}{u} - \frac{wmu_{cc}}{u'} - \frac{mu_{cl}}{u'} + m\frac{dl_I{}^*}{dm}\left[\frac{2u'}{u} - \frac{w^2u_{cc} + 2wu_{cl} + u_{ll}}{u'}\right]\end{aligned} \tag{3.8}$$

where

$$\frac{dl_I{}^*}{dm} = \frac{p'u_c - (1-p)(wu_{cc} + u_{cl})}{-p''u - \dfrac{2u(p')^2}{(1-p)} + (1-p)\left[w^2u_{cc} + 2wu_{cl} + u_{ll}\right]}. \tag{3.9}$$

Two important questions arise with respect to expression (3.8). 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,

[10] 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.

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 (3.10) and (3.11) respectively:

$$\eta_{I,l\ fixed} = \frac{mu_c}{u} - \frac{wmu_{cc}}{u'} \tag{3.10}$$

$$\eta_{I,l\ variable} = \frac{mu_c}{u} - \frac{wmu_{cc}}{u'} + m\frac{dl^*}{dm}\left[\frac{2u'}{u} - \frac{w^2u_{cc} + u_{ll}}{u'}\right] \tag{3.11}$$

The first two terms of (3.10) and (3.11) 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 (3.9) is negative by the second order condition. The bracketed term in (3.11) is positive. Thus, for this case the final term in (3.11) 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 ability 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 (3.8) 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

(3.6); the CRR must also account for the labor supply adjustment (Chetty [2006]). We obtain the following expression for the CRR with variable labor supply.[11]

$$R_{I,l\,\mathrm{variable}} = -\frac{mu_{cc}}{u_c} + m\frac{dl_I\,*}{dm}\left[\frac{p'}{(1-p)} - \frac{wu_{cc}+u_{cl}}{u_c}\right] \qquad (3.12)$$

Note that the first term in (3.12) 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, $R_{I,l\,\mathrm{variable}} < R_{I,l\;fixed}$.[12]

When we rewrite the expression for the IEVSL with variable labor supply ((3.8)) substituting for the CRR given in (3.12), the conditions under which the CRR serves as a lower bound for the IEVSL become even less transparent as illustrated in expression (3.13).

$$\eta_{I,l\,\mathrm{variable}} = \frac{mu_c}{u} + R_{I,l\,\mathrm{variable}}\frac{wu_c}{u'} - \frac{mu_{cl}}{u'} + \frac{dl_I\,*}{dm}\left[\frac{mu'}{u} + \frac{mu_l}{u} - \frac{m(wu_{cl}+u_{ll})}{u'}\right] \qquad (3.13)$$

Expression (3.13) 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 $\eta_{I,l\,\mathrm{variable}}$ as a function of $R_{I,l\;fixed}$ (the CRR with *l* fixed) as follows:

$$\eta_{I,l\,\mathrm{variable}} = \frac{mu_c}{u} + R_{I,l\;fixed}\frac{wu_c}{u'} - \frac{mu_{cl}}{u'} + \frac{dl_I\,*}{dm}\left[\frac{2mu'}{u} - \frac{m}{u}\left(w^2u_{cc} + 2wu_{cl} + u_{ll}\right)\right] \qquad (3.14)$$

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[11] 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).

[12] 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).

Now suppose $u_{cl} = 0$. Under independence, $\frac{dl_I *}{dm} < 0$ and the bracketed term in equation (3.14) 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, the 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.

*B. 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 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:

$$V = (1 - p(l))u(m + wl - z, z, l) \tag{3.15}$$

with the price of $z$ assumed to be unity. 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 with respect to exogenous income ($m$) while allowing both $l$ and $z$ to adjust as in equation (3.16).

$$\frac{dVSL}{dm} = \frac{wu_c}{(1-p)u'} - \frac{w^2uu_{cc}}{(1-p)(u')^2} - \frac{wuu_{cl}}{(1-p)(u')^2} + \frac{dl_{II}^*}{dm} \cdot A + \frac{dz_{II}^*}{dm} \cdot B \qquad (3.16)$$

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.[13] 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.

[13] See Chetty and Szeidl [2007] pp 845-846 for the derivation in a closely related model and further discussion.

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.

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 II 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.[14] 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.

## IV. 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).[15] 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 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

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

[15] 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.

attributes. In the second subsection, we explore the responsiveness of labor force participation to exogenous shocks in the presence and absence of consumption commitments.

A. *The effect of consumption commitments for risk preferences*

The measurement of risk aversion relies primarily on indirect methods. For example, Holt and Laury [2003] propose a paired lottery-choice experiment that provides estimates of risk aversion coefficients under various preference specifications. Alternatively, the auction literature has proposed structural models to estimate risk coefficients, for particular preference functions, using bidding data.[16] 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 method proposed by Barsky et al. [1997] is a notable exception. Their risk tolerance question is based 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 (the same dataset used in our analysis in the next section) 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.

We confirm similar results for the effects of commitments among the subset of HRS respondents who were asked the Barksky risk tolerance questions in 2000. That is, we find higher levels of risk aversion (based on the Barksy classification) among respondents in our sample with mortgage payments ($p$ = 0.109, $N$ = 1,375). Thus, we find additional support for the Chetty-Szeidl hypothesis that we expect to observe higher levels of risk aversion among those with commitments.

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

More recently the second author and Carol Mansfield (see Smith and Mansfield [2008]) 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 et al. risk classification questions. Following this question, respondents were informed, using a series of descriptive phrases, the risk classification implied by their answers. Respondents were asked to indicate whether they agreed with the assessment. If a respondent did not agree with the description of their attitudes, then he was given the opportunity to reclassify himself into another risk tolerance category. 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. Smith and Mansfield report a strong link between the CRR based on revised responses and the economic characteristics and behaviors of the respondents. 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. Two features of these findings are relevant for our 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.  Offering the opportunity to revise affects the ability of the model to uncover the effects of education.

B. *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 (2008) 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:

$$y_i = \alpha + x_i\beta + \gamma_0 z_i + \gamma_1 m_i + \gamma_2 z_i m_i + \varepsilon_i \qquad (4.1)$$

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 in 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 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.[17] 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 chronic and acute health conditions indicated limitations respectively.[18] 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

[17] 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?"

[18] 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].

without. Mean medical expenditures are more than $20,000 higher ($p$ = 0.00) among those with increased ADLs.[19]

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 household 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 significance 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

[19] All reported dollar figures are nominal.

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.

## V. 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 to their behaviors involving labor-leisure choices, financial and nonfinancial commitments, and health status. Recent theoretical advances by Chetty and Chetty and Szeidl have identified ways in which the models proposed by Eeckhoudt and Hammitt and 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 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 labor market behavior to health shocks and the influence of consumption commitments for this responsiveness.

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: $V = (1-p(x))u(c)$, $p' < 0$, 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: $V = (1-p(l))u(c,l)$, $p' > 0$, 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 | $R_{I,l\ variable} = \frac{-mu_{cc}}{u_c} - m\frac{dl^*}{dm}\left[\frac{wu_{cc}+u_{cl}}{u_c} - \frac{p'}{(1-p)}\right]$ | $\eta_{I,l\ variable} = \frac{mu_c}{u} + R\frac{wu_c}{u'} - \frac{mu_{cl}}{u'} - \frac{dl_I^*}{dm}\left[\frac{m(wu_{cl}+u_{ll})}{u'} - \frac{mu'}{u} - \frac{mu_l}{u}\right]$ | $\frac{dl_I^*}{dm} = \frac{p'u_c - (1-p)(wu_{cc}+u_{cl})}{-p''u - \frac{2u(p')^2}{(1-p)} + (1-p)\left[w^2u_{cc} + 2wu_{cl} + u_{ll}\right]}$ |
| Model II: $V = (1-p(l))u(c,z,l)$, $p' > 0$, 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 | $R_{II,l\ fixed,z\ variable} = \frac{-mu_{cc}}{u_c} - m\frac{d\hat{l}}{dm}\left[\frac{wu_{cc}+u_{cl}}{u_c} - \frac{p'}{(1-p)}\right]$ | $\eta_{II,l\ fixed,z\ variable} = \frac{mu_c}{u} + \bar{R}_z\frac{wu_c}{u'} - \frac{mu_{cl}}{u'} - \frac{d\hat{l}}{dm}\left[\frac{m(wu_{cl}+u_{ll})}{u'} - \frac{mu'}{u} - \frac{mu_l}{u}\right]$ | $\frac{dl_{II,z\ fixed}^*}{dm} = \frac{p'u_c - (1-p)(wu_{cc}+u_{cl})}{-p''u - \frac{2u(p')^2}{(1-p)} + (1-p)\left[w^2u_{cc} + 2wu_{cl} + u_{ll}\right]}$ |

| | | | |
|---|---|---|---|
| *l*, *z* variable | $R_{II,l\&z\,variable} = \frac{-mu_{cc}}{u_c}$ $-m\frac{d\hat{l}}{dm}\left[\frac{wu_{cc}+u_{cl}}{u_c}-\frac{p'}{(1-p)}\right]$ $-m\frac{d\hat{z}}{dm}\left(\frac{u_{cz}-u_{cc}}{u_c}\right)$ | $\eta_{II,l\&z\,variable} = \frac{mu_c}{u} + R_z\frac{wu_c}{u'} - \frac{mu_{cl}}{u'}$ $-\frac{d\hat{l}}{dm}\left[\frac{m(wu_{cl}+u_{ll})}{u'}-\frac{mu'}{u}-\frac{mu_l}{u}\right]$ $-\frac{d\hat{z}}{dm}\left[\frac{m(u_{lz}-u_{cl})}{u'}-\frac{u_z-u_c}{u}\right]$ | $\frac{d_{II}*}{dm} = \frac{(1-p)}{\lvert H\rvert}\left\{\begin{array}{l} p'u_c[u_{cc}+u_{zz}-2u_{cz}] \\ -(1-p)(wu_{cc}+u_{cl})(u_{zz}-u_{cz}) \\ -(1-p)(wu_{cz}+u_{zl})(u_{cc}-u_{cz}) \end{array}\right\}$ |

[a] Note that the table using *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.

Table 2: Smith Mansfield Results for Risk Aversion Index with KN Sample -2006[*]

| Independent Variables | Summary Statistics[a] | Imputed CRR with Revision | Imputed CRR without revision | Imputed CRR without revision and restricted sample |
|---|---|---|---|---|
| Own home (=1) | 0.70<br>(0.46) | 0.33<br>(1.75) | 0.37<br>(1.94) | 0.43<br>(2.07) |
| Female(=1) | 0.52<br>(0.50) | 0.53<br>(3.42) | 0.43<br>(2.78) | 0.56<br>(3.31) |
| Household income | 52,759<br>(41,160) | $-.51 \times 10^{-5}$<br>(-2.45) | $-.34 \times 10^{-5}$<br>(-1.61) | $-.45 \times 10^{-5}$<br>(-1.94) |
| Age | 48.1<br>(16.9) | 0.03<br>(6.18) | 0.03<br>(5.34) | 0.03<br>(6.29) |
| White(=1) | 0.74<br>(0.44) | 0.32<br>(1.52) | 0.61<br>(2.84) | 0.54<br>(2.30) |
| African American(=1) | 0.09<br>(0.30) | 0.32<br>(1.01) | 0.17<br>(0.53) | 0.32<br>(0.94) |
| Not high school grad (=1) | 0.13<br>(0.34) | 0.45<br>(1.91) | 0.12<br>(0.49) | 0.27<br>(1.06) |
| College grad(=1) | 0.17<br>(0.38) | -0.52<br>(-2.39) | -0.19<br>(-0.91) | -0.51<br>(-2.12) |
| Greater then college(=1) | 0.10<br>(0.30) | -0.95<br>(-3.43) | -0.38<br>(-1.35) | -0.95<br>(12.98) |
| Intercept | | 3.23<br>(10.22) | 3.98<br>(12.49) | 3.34<br>(9.54) |
| Sample size | 2,244 | 2,244 | 2,244 | 1858 |
| $R^2$ | | 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 [2008].

[a] 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.

Table 3. Summary statistics for primary sample—married HRS respondents who worked full time in 1998[a]

| 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 activities of daily living between 1998 and 2000, = 0 otherwise | 4.36 |
| Spouse ADL increase | = 1 if individual's spouse reported an increase in activities of daily living 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) |

[a] Sample size is 3920.

Table 4. Empirical results—Decision to exit full time labor force (in 2000) probit models[a,b]

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| | Male sample | Female sample | Male sample | Female sample |
| Spouse ADL increase | 0.067* (1.65) | -0.031 (-0.61) | 0.044 (1.10) | -0.039 (-0.78) |
| Mortgage commitment | -0.025 (-1.19) | -0.064** (-2.65) | -0.018 (-0.84) | -0.059** (-2.40) |
| Spouse ADL increase*mortgage commitment | -0.166** (-2.30) | 0.125 (1.04) | -0.159** (-2.12) | 0.122 (1.00) |
| Own ADL increase | | | 0.233** (4.43) | 0.262** (3.97) |
| Own ADL increase*mortgage commitment | | | -0.079 (-0.88) | -0.046 (-0.42) |
| Age2 | -0.135 (-1.30) | 0.140 (1.61) | -0.133 (-1.29) | 0.140 (1.59) |
| Age3 | -0.101 (-1.10) | 0.172** (2.19) | -0.102 (-1.12) | 0.173** (2.18) |
| Age4 | 0.125 (0.12) | 0.219** (2.78) | 0.013 (0.13) | 0.223** (2.81) |
| Age5 | 0.196* (1.79) | 0.421** (4.85) | 0.196* (1.80) | 0.431** (4.92) |
| Age 6 | 0.316** (2.61) | 0.548** (5.76) | 0.319** (2.65) | 0.549** (5.73) |
| Education | -0.0009 (-0.26) | -0.006 (-1.16) | -0.0006 (-0.19) | -0.005 (-1.03) |
| HH income (1998) | -0.003** (-1.98) | 0.001 (1.44) | -0.003** (-2.05) | 0.001 (1.48) |
| HH non-housing wealth (1998) | 0.0006** (2.18) | -0.00004 (-0.24) | 0.0006** (2.23) | -0.00003 (-0.23) |
| N | 2263 | 1655 | 2263 | 1655 |
| Pseudo R2 | 0.114 | 0.105 | 0.122 | 0.114 |

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

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 (3.9) yields

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

$\overline{K} = -p'' u - \frac{2u(p')^2}{(1-p)} + (1-p)[w^2 u_{cc} + 2wu_{cl} + u_{ll}] < 0$ 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 (3.6), it follows that

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

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