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Valuing pain using the subjective well-being method

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ABSTRACT

Chronic pain clearly lowers utility, but valuing the reduction in utility is empirically challenging. Here, we use improvements over prior applications of the subjective well-being method to estimate the implied trade-off between pain and income using four waves of the Health and Retirement Study (2008-2014), a nationally representative survey on individuals age 50 and older. We model income with a flexible functional form, allowing the trade-off between pain and income to vary across income groups. We control for individual fixed effects in the life-satisfaction equations and instrument for income in some models. We find values for avoiding pain ranging between 56–145 USD per day. These results are lower than previously reported and suggest that the higher previous estimates may be heavily affected by the highest income level and confounded by endogeneity in the income variable. As expected, we find that the value of pain relief increases with pain severity.

1. Introduction

Chronic pain clearly lowers utility, but quantifying exactly how much people are willing to trade-off pain and income is challenging. To avoid the problems of market-based valuation, stated-preference methods, and hedonic wage regressions, we use the subjective well-being method to estimate the monetary value of pain relief among individuals age 50 and older. State of the art econometric methods are applied with a piecewise-linear model introduced as a model of particular interest, while comparing the statistical relationship between subjective well-being and health to that of subjective well-being and income. Our model specifications are an improvement over prior applications of the method and could be applied to other longitudinal survey data on subjective well-being, income, and health.

Because chronic pain is associated with psychological distress, functional impairment, and disability (Hardt et al., 2008; Nahin, 2015), pain-relief treatment increases well-being. In addition to other benefits, such as productivity gains (Kapteyn et al., 2008), the direct effect of pain relief on quality-of-life is likely to be extensive. Monetizing this well-being improvement is thus needed when choosing treatments by their net benefit, or even when choosing between a pain treatment and other well-being-increasing policies.

Developments in subjective well-being research have led to a consensus on the importance of three methodological attributes; i.e. to control for unobserved heterogeneity, to account for decreasing marginal utility of income, and to instrument for income (Becchetti and Pelloni, 2013; Clark et al., 2008; Di Tella and MacCulloch, 2006; Frey et al., 2010; Frey and Stutzer, 2002). However, previous studies on valuing pain relief have failed to include all of these attributes (Graham et al., 2011; McNamee and Mendolia, 2014). Moreover, given the few applications of the subjective well-being method to health, validating results using different data sets and exploring the sensitivity of results to different model specifications is important before settling on the most consistent estimate.

Apart from addressing these two issues, we have four specific econometric contributions to the literature. First, we study detailed, longitudinal individual-level data on a sample for which pain is prevalent and we can control for individual heterogeneity. Second, we explore the methodology of the subjective well-being method from a new perspective — using models that are more flexible by allowing a piecewise-linear relationship in the income variable. Third, we address endogeneity in income with instrumental variables, because theory and previous research suggests that simple models have a downward-biased coefficient on the

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income variable. Fourth, we test the sensitivity of results to the level of pain severity. Thus, this is the first paper to estimate willingness to pay for pain relief that allows for heterogeneous effects across income levels and instruments for income.

We find that the value of pain relief increases with income and with pain severity. Our estimates of the value of pain relief are lower than previous research using data from Australia and Latin-America suggest. Our exploration shows the value of pain to be sensitive to the functional form of income.

2. Background

Because health care is generally highly subsidized through insurance, it is challenging to infer the value of medical treatment simply by observing the behaviors of buyers and sellers in the market. To overcome the lack of revealed preferences, we use an income-compensated monetary measure; the compensating variation (CV) (Hicks, 1939). CV is the amount of money received by an individual that leaves him at his original level of well-being following a health change. CVs are calculated under the assumption that the indifference curve represents the constant-utility trade-off between income (consumption) and the non-market good (pain), where survey responses to a subjective well-being question are taken as a proxy for utility.

There are relatively few applications of the subjective well-being method to health. Research using cross-sectional data include severe headache and migraine (Groot and van den Brink, 2004), cancer, thyroid disease, arthritis and infectious disease (Rojas, 2009), cardiovascular disease (Groot and van den Brink, 2006,2007; Groot et al., 2004; Rojas, 2009), EQ5D conditions, extreme pain and anxiety (Graham et al., 2011). Applications that use longitudinal data with fixed-effects (FE) models include chronic diseases (Ferrer-i-Carbonell and van Praag, 2002), 13 health conditions (Powdthavee and van den Berg, 2011), chronic pain (McNamee and Mendolia, 2014) cardiovascular disease (Latif, 2012) and general health status (Brown, 2015). Asgeirsdottir et al. (2017) and Howley (2017) use longitudinal data to value dozens of health conditions, but are not able to control for individual heterogeneity.

We compare our results to the only previous research on chronic pain evaluation that uses longitudinal data (McNamee and Mendolia, 2014). They estimate FE-models, as we do, using log of equivalised household income. However, their covariates are not identical to ours, they do not instrument for income, and their sample is younger, with an average age of 45 compared to 68 in our sample.

With the subjective well-being method, people are not aware that their responses will be used to derive their preferences for health and thus strategic responses are highly unlikely and they do not have to express choices in imaginary situations. Other methods that have been used for non-market valuations of the WTP are mainly either contingent valuation, the most widely used of stated preference methods, or the hedonic wage method, a revealed preference approach. The contingent-valuation method remains controversial (Carson et al., 2001) e.g. since it is more likely to capture attitudes rather than preferences whereof attitudes are more sensitive to situations, the focusing illusion and to the scale-of-reference bias (Kahneman and Sugden, 2005). Comparison of the hedonic method to the subjective well-being method has revealed that price differentials obtained from the hedonic method may only partly represent the value being estimated (van Praag and Baarsma, 2005). For example, if the physical or emotional transaction costs of changing jobs are high, then the hedonic value of health would not be reflected in wage differentials. Furthermore, those who take on risky jobs are likely to evaluate their health lower than others.

Results can differ considerably between methods, underscoring the importance of between-methods comparisons. In addition to the three aforementioned methods discussed that estimate the WTP, other methods estimate an index measure — quality-adjusted life years (QALY) — of the value of health outcomes. An example of methods-comparison is that Dolan and Metcalfe (2012) found that being confined to bed is worse than having extreme anxiety when using time-trade-off method (TTO); a QALY-method, but subjective well-being estimates showed the opposite.

The subjective well-being method is not without limitations (Becchetti and Pelloni, 2013; Clark et al., 2008; Luechinger, 2009) since biases in the coefficients of interest, income and pain, can arise because of a possible violation of the zero-conditional-mean assumption; $E(\varepsilon|x) = 0$, where ε is an error term in a regression model and the regressor(s), x, thus are correlated with the error term because of a) simultaneous determination of the dependent variable and regressors (or reverse causality), b) omitted variables and c) measurement error in the regressors. We address these potential biases in the following ways: First, individual FE models are used where applicable to control for unobserved time-invariant characteristics. Second, by using last year's reported income to address the possibility of life satisfaction affecting income levels. Third, by analyzing a subsample of people aged 65 years and older, we exploit that income is plausibly exogenous in retirement as a function of past values of the variables in the model. Since past values of income are likely correlated with individual characteristics and preferences, results from FE models are preferred for this age group. Finally, we report results from models where income is instrumented with mother's education, further addressing both the endogeneity of income and possible measurement error.

Researchers have experimented with various instrumental variables (IVs) for income in the subjective well-being literature. Examples include father's and spouse's years of education (Knight et al., 2009), industry and occupation (Luttmer, 2005), exogenous over-time variation in the proportion of household members with payslip information (Powdthavee, 2010), as well as substituting household income with lottery winnings and other irregular sources of income (Ambrey and Fleming, 2014). Those resulted in up to four times larger income coefficients than obtained in baseline happiness estimations. Howley (2017), being the first study to use IV estimates in a health application of the subjective well-being method while comparing CVs of 15 health conditions with cross-sectional data, used parental education to instrument for income and found the income coefficient to more than triple in size between OLS and two-stage least squares (2SLS) models.

To summarize, we estimated CVs in a way that controls for unobserved individual heterogeneity, allows for a flexible specification of income, and controls for potential endogeneity of income.

3. Methodology

Define indirect utility (V) as a function of income (y), health (h), and a set of demographics and personal characteristics (x):

$$V(y, h, x) \tag{1}$$

Consider a reduction in health from h^1 to h^0, without changes to y or x. A resulting change in utility is then defined as follows:

$$\Delta V = V\left(y, h^0|x\right) - V\left(y, h^1|x\right) \tag{2}$$

The compensating variation (CV) is then the amount of money that equalizes the individual's utility before and after the change in health so that:

$$V\left(y + CV|h^0, x\right) = V\left(y|h^1, x\right) \tag{3}$$

The empirical well-being equation is as follows:

$$V_{it} = \beta_o + \beta_1 y_{it} + \beta_2 h_{it} + \sum_{k=1}^{K} \alpha_k X_{k,it} + \varepsilon_{it} \tag{4}$$

where V_{it} in our case is reported life satisfaction of individual i at time t, and h is pain. The alphas and betas are coefficients and the K variables $X_{k,it}$ are demographics and personal characteristics. ε_{it} is a composite error term for individual time-invariant characteristics and time-varying characteristics for individual i at time t. We then use Eq. (4) and solve for CV in (3), which results in the negative ratio of the coefficients for pain and income:

$$CV = -\frac{\beta_2}{\beta_1} \tag{5}$$

Estimation of the parameters in Eq. (4) and the corresponding CV in Eq. (5) involves several econometric issues. First, the correct functional form of the covariate income is not necessarily linear, as is assumed in Eq. (4). We thus let the continuous variable income enter Eq. (4) in three different ways: linear, log-transformed and piecewise linear (PWL). Previous studies using the subjective well-being method use either linear income or more commonly its logarithmic transformation. The latter to model diminishing marginal utility of income (Layard et al., 2008) but also to reduce effects of influential observations. We thus highlight the empirical and theoretical reasons for our choice of functional form for income, although we also report linear income results for reason of comparability between studies and to compare results using different model specifications.

In models with the log transformation of income, the coefficient ratio compares marginal changes in pain to marginal percent changes in income. Thus calculating CV calls for reverting the proportion of coefficients for pain and income from the logarithmic scale by using the exponential function. Thus, replacing income with ln(income) in (4) and solving for CV in (3) yields:

$$CV = \bar{y}\left(exp\left(\frac{-\beta_2}{\beta_1}\right) - 1\right) \tag{6}$$

where $\bar{y}$ is average income in the sample. We report CVs as daily monetary amount and since the income variable is in 10,000 USD,

$$CV\ pr.\ day\ in\ USD = \ (CV*10,000)/365 \tag{7}$$

This amount is in between WTP and willingness to accept (WTA) but for simplicity we refer to it hereafter as WTP. The CV is thus interpreted as the additional equivalised household income per day that the individual is willing to forgo to be relieved from pain (WTP). Although ln(income) generally provides a better fit than using linear income, another option that allows for a more flexible trade-off between income and pain across income levels is to use a piecewise linear functional form for income. CVs from PWL models are calculated the same way as in the case of linear income for each income spline (see Eq. (5)).

The second econometric issue is that we have repeated observations for each person, which allows the use of FE models in addition to OLS and PWL-models. Previous research suggests that fixed effects play an important role in well-being equations (Ferrer-i-Carbonell and Frijters, 2004; McNamee and Mendolia, 2014). Furthermore, Powdthavee's (2010) review of the literature suggests that extroverts do better in the labor market and are happier. The same characteristics could also be associated with being healthy or even how pain is experienced.

Third, because the data are collected from a complex, multistage probability survey, subjects are sampled with unequal weights. Models with and without weights yielded quite similar results, relieving our concerns of not being able to include sampling weights in FE-models. For ease of comparison between models, we thus report unweighted results but provide results from weighted regressions in an Appendix. Fourth, we attempt to separate the life-satisfaction effects of pain from the underlying health conditions that might cause pain with carefully selected health controls. Fifth, although we attempt to control for all possible confounders, including person-level fixed effects, there is still the possibility that either income or pain (or both) are correlated with unmeasured factors that also affect happiness. An example of such a variable is unmeasured health status. Therefore, we provide results from 2SLS models with mother's education as an instrument for income as a way to control for endogeneity. Sixth, we test whether the results are sensitive to inclusion of additional covariates by comparing unadjusted models, which include only pain and income on the right hand side of Eq. (1) and adjusted models that include all independent variables as feasible for each model estimator. Seventh, we test for heterogeneous treatment effects by age and gender. We report results from analyses of a subsample of people age 65 and above because it is more plausible to think of income as an exogenous variable in a model with this age group. Previous research has reported gender differences in CVs (Groot and van den Brink, 2006; McNamee and Mendolia, 2014) and we provide results by gender for completeness. Further, estimates with pain severity instead of the pain dummy are included since the CVs are likely to be sensitive to whether pain is mild, moderate or severe.

The PWL specifications consistently showed a better fit to the data than the transformation of income to logarithm scale, using goodness-of-fit test statistics; the Akaike information criterion (AIC) and the Bayesian information Criterion (BIC). The breakpoints at 30,000 and 50,000 USD (annual income) were chosen by comparing different specifications using AIC and BIC and correspond to the 51 st and 72nd percentiles of the income distribution. Life satisfaction increases with income, and it increases at a slower rate as income rises, as shown using a non-parametric smoother and a fitted PWL function of income with the chosen knots marked by the horizontal lines (Fig. 1). We include only income below 300,000 USD in Fig. 1 for better visibility of the difference in the slope of the function at income levels where the marginal utility of income (non-adjusted) is proportionally large over the income distribution. Therefore, the observed declining marginal utility of income suggests also trying a model specification that takes the natural logarithm of income.

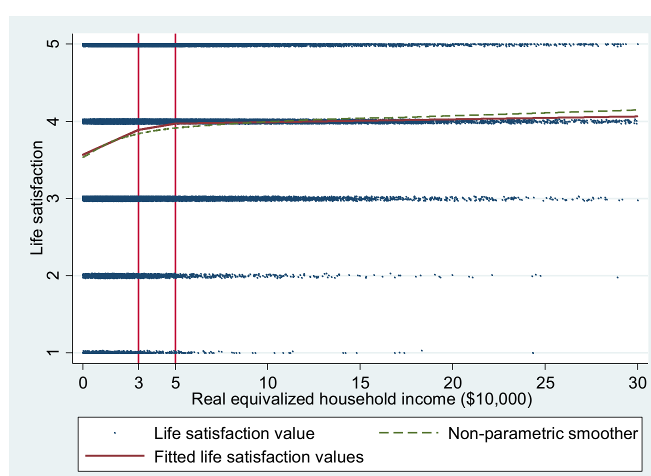

Fig. 1. Scatterplot of life satisfaction by income, plotted with lowess (non-parametric smoother) and fitted life-satisfaction values from a PWL-OLS regression of three splines on life satisfaction, with knots at 30,000 and 50,000 USD (annual income). Equivalised household income values are at the 2015 price level in 10,000 USD. Income is restricted to levels below 300,000 USD (99th percentile).

Table 1
Origin of final sample size.

Reasons for sample restriction	Obs	Obs dropped	Individuals	ID dropped
Original sample of 4 waves	78,553		24,967	
Drop if age< 50 or living in a nursing home		6,435		1,886
	72,118		23,081	
Drop if life satisfaction is missing		3,853		829
	68,265		22,252	
Drop if missing right-hand side variables		2,064		481
	66,201		21,771	
Drop if income is zero		1,981		663
	64,220		21,108	
Drop if influential outlier		15		4
Final sample used in analyses	64,205		21,104	
Total		14,348		3,863

4. Data

For our study, we need person-level data with measures of life satisfaction, income, pain, controls for health status and suitable instruments for income. In addition, we want a population for whom pain is prevalent and income is plausibly exogenous. Furthermore, we need longitudinal data to control for unobserved time-invariant characteristics. The Health and Retirement Study (HRS), a biannual nationally-representative panel of adults over 50 in the United States, has all of these features. We use data from the four waves of the HRS that include a question on life satisfaction; 2008, 2010, 2012 and 2014 (Ólafsdóttir et al., 2017).

The original sample consisted of 78,553 observations on 24,967 individuals. Of those, we excluded individuals under 50 years and those living in a nursing home. We also dropped observations that had missing values on the dependent and independent variables. Because of concerns about misreporting income and wanting to focus on the middle of the income distribution, we dropped observations with reported income equal to zero (n = 1,981) or above 3,940,000 USD (n = 15). The final sample consists of 64,205 observations on 21,104 individuals (see Table 1) and did not differ significantly from the original data in terms of observable characteristics (results available on request). We use sample weights to account for the differential selection probabilities (Ofstedal et al., 2011) in models that allow for time-varying sample weights.

The dependent variable is a subjective measure of life satisfaction from the question:

> "Please think about your life as a whole. How satisfied are you with it?"

We code the answers on a scale from 5 ("completely satisfied") to 1 ("not at all satisfied") (Fig. 2). The independent variables of interest are real household equivalised income (reported in wave t for wave t–1) and a pain indicator from the question:

> "Are you often troubled with pain?"

For those who answered yes, the survey also includes a question on the severity of pain with three answer options: Mild, moderate, or severe. We use this variable to test whether the estimated CVs are sensitive to degree of pain severity.

The question on pain does not explicitly distinguish between acute pain and chronic pain. However, following Banks et al. (2009), we assume that responses to the HRS pain question reflect pain that is recurrent and not completely relieved by treatment. They let 2000 respondents, 25 and older from the Dutch CentERpanel survey answer the HRS pain question and another question on whether they had experienced any pain in the last 30 days. 59 % of the sample reported having "any pain in the last 30

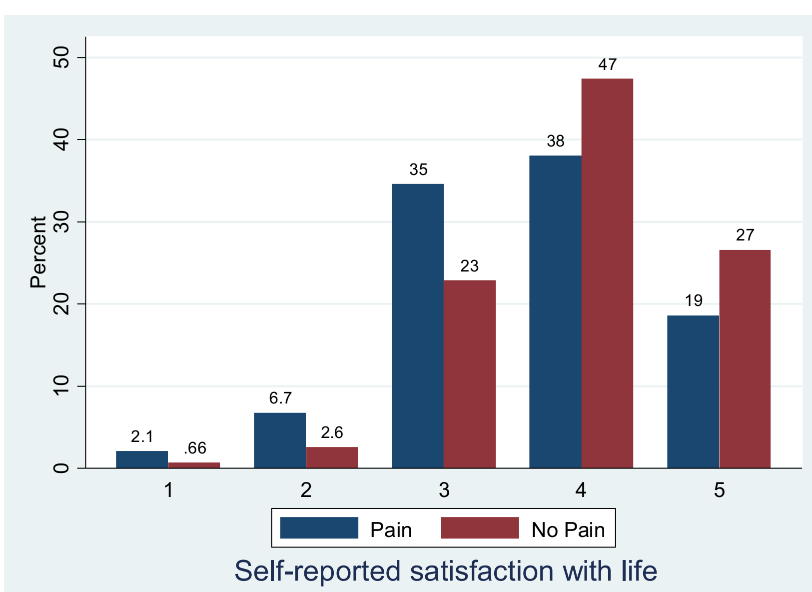

Fig. 2. Self-reported satisfaction with life by pain status. 1=Not at all satisfied and 5=Completely satisfied. Figures above bars are percentages.

Table 2
Descriptive statistics by pain status (weighted).

Variable	All	No pain	Pain
Yearly household income (equivalized)			
mean	5.69	6.30	4.58***
(SD)	(8.74)	(9.22)	(7.67)
Pain%	35.40		
Mild			29.63
Moderate			54.60
Severe			15.78
Age			
mean	66.27	66.23	66.33
(SD)	(9.97)	(10.02)	(9.86)
Gender%			
Men	45.02	47.57	40.36***
Women	54.98	52.43	59.64***
Education %			
Less than high school (base)	13.01	11.14	16.42***
GED and high school graduate	32.73	30.85	36.17***
Some college	25.94	25.43	26.86***
College and above	28.32	32.58	20.54***
Marital status %			
Married or partnered (base)	65.38	67.22	62.04***
Divorced or separated	14.34	13.26	16.31***
Widowed	14.27	13.60	15.48***
Single	6.02	5.93	6.17
Race %			
White/caucasian (base)	84.61	85.24	83.46***
Black/African American	9.68	9.43	10.14***
Other	5.71	5.33	6.40***
Indicator for Hispanic %	7.40	6.77	8.54***
Labor force status %			
Employed (base)	36.66	41.43	27.94***
Unemployed	2.62	2.70	2.47
Partly retired	8.53	9.32	7.09***
Retired	46.33	42.00	54.22***
Out of the labor force	5.86	4.54	8.28***
Health conditions %			
Cancer	14.28	13.20	16.26***
Lung disease	9.46	6.32	15.19***
Heart problems	22.39	18.58	29.33***
Stroke	6.98	5.65	9.41***
Psychiatric problems	18.36	12.13	29.72***
Arthritis	56.21	44.05	78.41***
High blood pressure	55.67	51.32	63.59***
Smoker	13.94	12.34	16.87***
Number of children in household	0.36	0.36	0.34
Health insurance %	80.56	79.61	82.29***
N	64,205	40,967	23,238

Note: Out of the labor force refers to disability or if none of the other options applied at the time of the survey. Census division (10 dummies) is left out of the table due to space limitations. *** is for difference in means (%) by pain status at the 1 % significance level. Yearly total equivalized household income is in 10,000 USD (2015 price level).

days" but only 27 % of the same respondents reported being "often troubled by pain". This suggests that those who reported being often troubled by pain are referring to recurrent pain, not short-term or acute pain that may be fully alleviated with treatment.

The most common clinical definition of pain was introduced by the International Association for the Study of Pain in 1979 (IASP Subcommittee on Taxonomy, 1979) as "an unpleasant sensory and emotional experience associated with actual or potential tissue damage, or described in terms of such damage". The definition appreciates the multidimensional nature of pain and takes into account both physiological processes and the subjectivity of pain experience. Therefore, it is important to control for individual heterogeneity that affects the subjective experience of both life satisfaction and pain.

We use household income, in accordance with the economics literature (Brown, 2015; Ferrer-i-Carbonell and van Praag, 2002; Groot and van den Brink, 2004; Howley, 2017; Latif, 2012; Luechinger, 2009; McNamee and Mendolia, 2014; Powdthavee and van den Berg, 2011; Rojas, 2009; van Praag and Baarsma, 2005) to reflect the individual's consumption possibilities. Household income is the sum of the previous year's wage and salary income, bonuses, business income, asset income, pensions, benefits, compensations, and inheritance for respondent and spouse. To adjust for number of people in the household we calculated equivalised household income at the 2015 price level using the modified OECD scale.

We control for age in 5-year brackets because life satisfaction varies by age-groups (Blanchflower and Oswald, 2008; Cheng et al., 2017; Easterlin, 2006; Frijters and Beatton, 2012; Sutin et al., 2013; Wunder et al., 2013). The age variables control for deterioration in health capital (Grossman, 1972) not captured by the health controls. We control for health insurance status because health insurance is welfare-increasing from mid-life (Pelgrin and St-Amour, 2016). Marital status partly controls for relational goods, including companionship and emotional support (Becchetti and Pelloni, 2013).

Other covariates are likely correlated with chronic pain and income (Table 2). These include indicators for health conditions that could be the cause of the reported pain status that where asked about in the following manner: "Has a doctor ever told you that you have a ....?" querying about cancer, lung disease, heart disease, stroke, psychological condition, arthritis and high blood pressure. While those controls are important, we note that one of them, psychological condition, could be theoretically and empirically problematic. The relationship between psychological conditions and pain is complex, because they can contribute to pain directly or indirectly. To allow for this composition effect (Angrist and Pischke, 2009), we ran the estimations both with and without psychological conditions. Other time-varying covariates included are: Labor-force status, wave dummy, smoking dummy, nine census geographic divisions, and number of children. Time-invariant covariates include gender, race, and education.

5. Results

Our main results show that the estimated CV for pain is positive, increasing in income, modest in magnitude for most people, and sensitive to the exact econometric specification (see Table 3). Under the restrictive assumption of constant CV across all income levels, the estimated CV is 910 USD per day (see column one, Table 3). In contrast, results in column 2 (panel A) allow the CV to differ across three different income ranges. That result shows that the CV is by far largest for those with income above $50,000. Furthermore, comparing panel A and B in column one, the calculated CV with ln(income) is 2.6 times larger than when income enters the model in linear form. The value of pain differs by income levels, ranging from 95 to 1,720 USD per day. Those results suggest that the estimated CVs in columns one of Tables 3–5, are likely to be heavily affected by the trade-off between income and pain at the highest income levels.

In FE models, the coefficients decrease in absolute value as expected (Table 3). However, the CV estimate is only statistically significant in the FE model in the case of linear income (panel A) because the standard errors, which are calculated with the delta method, are proportionally large. In column four (PWL-FE model), the estimated CV from the second segment is statistically significant and similar to the CV estimate from the PWL-OLS model. The reason for the zero effect of income in the FE-spline regression is the lack of within-variation in the first and third income splines. However, because this estimator works well for the second spline of the income distribution, we include it because of preference for FE-models in the literature. Comparing CVs from PWL-OLS and PWL-FE models, the estimated CV from the second segment is statistically significant in

Table 3
Point estimates and corresponding CV estimates by choice of model estimator and functional form of income.

Panel A	OLS		PWL-OLS		FE		PWL-FE		OLS-IV	
	Coeff.	CV	Coeff.	CV	Coeff.	CV	Coeff.	CV	Coeff.	CV
Pain	−0.2123***		−0.2081***		−0.0563***		−0.0562***		−0.1999***	
	(0.0089)	910***	(0.0088)		(0.0093)	1,044**	(0.0093)		(0.0103)	129***
Income	0.0064***	(115)			0.0015***	(425)			0.0426***	(42)
	(0.0008)				(0.0006)				(0.0131)	
Income										
1. spline (<$30 K)			0.0312***	183***			0.0017	NV		
			(0.0068)	(40)			(0.0073)			
2. spline[1] ($30K-$50 K)			0.0598***	95***			0.0275***	56***		
			(0.0062)	(11)			(0.0065)	(16)		
3. spline (>$50 K)			0.0033***	1,720***			0.0005	NV		
			(0.0006)	(301)			(0.0005)			
BIC	155,825		155,599		95,098		95,090		146,668	

Panel B	OLS		FE		OLS-IV	
	Coeff.	CV	Coeff.	CV	Coeff.	CV
Pain	−0.2089***		−0.0561***		−0.1922***	
	(0.0089)	2,377***	(0.0093)	4,137	(0.0107)	152**
ln(income)	0.0704***	(611)	0.0160***	(5,519)	0.2529***	(72)
	(0.0049)		(0.0053)		(0.0753)	
BIC	155,687		95,091		142,672	

N=64,205 person-years observations. N=58,588 in OLS-IV models. PWL: Piecewise linear. *p<0.10, ** p<0.05, *** p<0.01. Models include age, age squared, number of children in household, year dummies, dummies for comorbidities, marital status, census division, labor force status, gender, education, race, Hispanic and health insurance. FE models include age, age squared, year dummies, dummies for comorbidities, marital status, census division, labor force status, children in household and health insurance as covariates in addition to pain and income. Knots are at income values 3 and 5 in PWL-OLS and PWL-FE models (income variable is in 10,000 USD). CVs are reported in USD, 2015 price level and are calculated with coefficients from adjusted models. [1]t-value for difference in slope between 1. and 2. segment in PWL-OLS model is -2.54. Results are unweighted. Weighted results are in Appendix. NV=no CV value as the income coefficient was not different from zero. Mean income in CV formula in Panel B=47,088. Standard errors (in parentheses) are clustered on individuals.

Table 4
Point estimates and corresponding CV estimates by model estimator and functional form of income, by gender.

	Men			Women		
Panel A	OLS	FE	OLS-IV	OLS	FE	OLS-IV
Pain	−0.2129***	−0.0741 ***	−0.2058***	−0.2094***	−0.0450***	−0.1904***
	(0.0140)	(0.0150)	(0.0151)	(0.0115)	(0.0120)	(0.0138)
Income	0.0056***	0.0021**	0.0204	0.0072***	0.0010	0.0630***
	(0.0010)	(0.0009)	(0.0172)	(0.0011)	(0.0007)	(0.0192)
CV	1,035***	969**	276	796***	1,182	83***
	(197)	(445)	(236)	(126)	(840)	(28)
BIC	64,757	39,091	58,521	91,341	56,265	89,062
Panel B	**OLS**	**FE**	**OLS-IV**	**OLS**	**FE**	**OLS-IV**
Pain	−0.2092***	−0.0738***	−0.2010***	−0.2068***	−0.0448***	−0.1827***
	(0.0139)	(0.0150)	(0.0158)	(0.0115)	(0.0120)	(0.0146)
ln(income)	0.0797***	0.0243***	0.1310	0.0635***	0.0103	0.3562***
	(0.0074)	(0.0083)	(0.1085)	(0.0065)	(0.0068)	(0.1063)
CV	1,865***	2,898	551	2,932**	9,084	81**
	(608)	(3726)	(930)	(1167)	(28,766)	(36)
BIC	64,665	39,000	57,909	91,295	56,264	86,022

Men: N = 26,876 person-years observations. N = 24,342 in OLS-IV models. Women: N = 37,329 person-years observations. N = 34,246 in OLS-IV models.*p < 0.10, ** p < 0.05, *** p < 0.01. Models include age, age squared, number of children in household, year dummies, dummies for comorbidities, marital status, census division, labor force status, gender, education, race, Hispanic and health insurance. FE models include age, age squared, year dummies, dummies for comorbidities, marital status, census division, labor force status, children in household and health insurance as covariates in addition to pain and income (income variable is in 10,000 USD). CVs are reported in USD, 2015 price level. Results are unweighted. Weighted results are in Appendix. Mean income in CV formula in Panel B = 53,088 for men and 42,769 for women. Standard errors (in parentheses) are clustered on individuals.

both models (95 USD vs 56 USD) suggesting a much smaller CV than estimates from models with ln(income) (Panel B) and from the third segment of the spline regressions.

Precision in fixed-effects models depends on within-person variation. Fortunately, 12,461 individuals change status in the life-satisfaction variable, 6,421 change status in the pain variable and 18,421 change status in the income variable during the observation period. This resulted in only 4,546 individuals changing status in all three variables. In the spline regression, 3,238 individuals change life satisfaction, pain, and the first income spline (1,819 if conditional on change in third income spline). These numbers are more than sufficient for identification, but also explain the somewhat large standard errors for the first and third income splines.

Our results from a FE model assuming well-being to be linear in income suggest that an individual with average equivalised total household income of 125 USD per day would need an extra 1,044 USD per day to achieve the same level of life satisfaction as someone who is not often troubled with pain. This is eight times the average equivalised household income per day. These results

Table 5
Point estimates and corresponding CV estimates by choice of model estimator and functional form of income. 65 years and older.

Panel A	OLS		PWL-OLS		FE		PWL-FE		OLS-IV	
	Coeff.	CV	Coeff.	CV	Coeff.	CV	Coeff.	CV	Coeff.	CV
Pain	−0.1965***		−0.1943***		−0.0340***		−0.0339***		−0.1903***	
	(0.0113)	1,256***	(0.0112)		(0.0123)	2,861	(0.0123)		(0.0127)	116**
Income	0.0043***	(259)			0.0003	(5,824)			0.0451**	(47)
	(0.0008)				(0.0007)				(0.0180)	
Income										
1. spline (<$30K)			0.0286***	186***			0.0026	NV		
			(0.0089)	(59)			(0.0103)			
2. spline1 ($30K-$50K)			0.0431***	123***			0.0140	67		
			(0.0078)	(23)			(0.0084)	(47)		
3. spline (>$50K)			0.0019***	2,776***			−0.0003	NV		
			(0.0007)	(954)			(0.0007)			
BIC	92,089		92,021		55,392		55,407		87,392	

Panel B	OLS		FE		OLS-IV	
	Coeff.	CV	Coeff.	CV	Coeff.	CV
Pain	−0.1946***		−0.0339***		−0.1820***	
	(0.0112)	2,777**	(0.0123)	NV	(0.0123)	112**
ln(income)	0.0602***	(1,185)	0.0057		0.2735***	(63)
	(0.0068)		(0.0080)		(0.1058)	
BIC	92,028		55,391		84,498	

N=38,010 person-years observations. N=34,656 in OLS-IV models. PWL: Piecewise linear.*p<0.10, ** p<0.05, *** p<0.01. Models include age, age squared, number of children in household, year dummies, dummies for comorbidities, marital status, census division, labor force status, gender, education, race, Hispanic, religious preference and health insurance. FE models include age, age squared, year dummies, dummies for comorbidities, marital status, census division, labor force status, children in household and health insurance as covariates in addition to pain and income. Knots are at income values 3 and 5 in PWL-OLS and PWL-FE models (income variable is in 10,000 USD). CVs are reported in USD, 2015 price level and are calculated with coefficients from adjusted models. Results are unweighted. Weighted results are in Appendix. NV=no CV value as the income coefficient was not different from zero. Mean income in CV formula in Panel B=47,097. Standard errors (in parentheses) are clustered on individuals.

are similar to those from McNamee and Mendolia (2014), who used FE models with log of income and found the daily CV for pain to be nine times the average income per day using Australian data. Graham et al. (2011) found CV for extreme pain to be five times the income for the corresponding period using cross-sectional data. Results from our piecewise-linear models however suggest a much smaller CV for pain than previous research, compensation of as low as 56 USD per day.

We next turn to the 2SLS models to control for possible endogeneity of income. We explored three possible instruments for income: mother's education, father's education, and spouse's education (Howley, 2017; Knight et al., 2009). A valid instrument must be highly correlated with income and have no direct effect on life satisfaction, after conditioning on the other included variables (and individual fixed effects in the FE models). Spouse's education was not significant in the first stage and was therefore discarded. Both father's and mother's education was relevant based on the F-test of instruments in the first stage. However, father's education did not pass the weak-instrument test (Anderson-Rubin Wald test). Thus, we instrument for income with mother's education, defined as the highest grade she completed in school. This variable has a significant relationship of the expected sign with the income variable with an *F*-test of the excluded instrument equal to 80 (Stock et al., 2002). The H_0 of whether the endogenous variable can be treated as exogenous was rejected ($p = 0.0047$ for the linear income model and $p = 0.0183$ for the ln(income) model). The positive relationship between mother's education and her children's income as adults is well documented Howley (2017).

The downward bias of the income coefficient in models without instruments, as documented in previous research, is likely explained by a willingness to substitute leisure for working hours now as an investment in future happiness, thereby increasing current income at the expense of current happiness. Another explanation is that the 2SLS estimator corrects for attenuation bias as a result of measurement error in the income variable. Furthermore, as reviewed by Powdthavee (2010), not being able to control for other people's income or rate of adaptation and aspiration to income may cause this downward bias.

Compared to the OLS results, the ln(income) coefficient in Panel B, is 3.6 times larger in the model with instrumented income. This is in line with previous research. The calculated CV of 129 USD per day (Table 3, panel A) may however still be biased by unobserved individual heterogeneity because we could not estimate FE-IV models as mother's education is time-invariant. We address this by considering the proportional reduction of the coefficients for pain and income once individual fixed effects are controlled for (coefficients in first vs third column) of 73 % for the pain coefficient and 76 % for the income coefficient and applying those to the coefficients from the 2SLS model in column five. This results in a CV estimate of 145 USD per day, an amount very close to the CV estimates of 129 in panel A and 152 in panel B.

Comparing genders shows that the estimated CVs are similar for men and women (Panel A of Table 4) but the CV estimate from the OLS model in panel B for women is larger than men's by 1,067 USD per day. Results from 2SLS suggest a much larger CV for men than for women, explained by smaller marginal utility of income for men in column three.

The results for the subsample of 65 years and older are in line with the results for the full age sample, in particular for OLS, PWL-OLS and OLS-IV models (compare Table 5 to 3). CV estimates from FE models have large standard errors and this may be due to less within-individual variation in income (and/or life satisfaction) in a restricted sample.

Finally, we explored the sensitivity of the estimated CVs to the severity of pain. As would be expected, the monetary amount needed to compensate for well-being losses due to pain suffering increases by level of pain severity (see Table 6).

We provide results tables in an Appendix that include all coefficients for OLS, FE and OLS-IV models (Table A1 and A2). Looking at results from the FE model, the coefficients are of the expected sign and in accordance with previous research. Life satisfaction increases with age at a diminishing rate with a decline

Table 6
CV estimates by pain severity.

Panel A: linear income	(1) OLS	(2) FE	(3) OLS-IV
Pain			
Mild	434***	639**	65***
	(72)	(318)	(23)
Moderate	1,008***	1,030**	144***
	(128)	(432)	(47)
Severe	1,547***	2,511**	225***
	(203)	(1,003)	(75)
Panel B: log(income)	**(1) OLS**	**(2) FE**	**(3) OLS-IV**
Pain			
Mild	409***	962	63**
	(106)	(1,095)	(27)
Moderate	3,510***	3,940	180**
	(1,029)	(5,387)	(88)
Severe	20,658**	594,172	357
	(9,682)	(1,796,554)	(219)

*p < 0.10, ** p < 0.05, *** p < 0.01.

in life satisfaction starting at age 70 (in accordance with U-shaped relationship between life-satisfaction and age in samples including all ages as our sample includes 50 years and older). Comparison of unadjusted and adjusted (all controls included) models revealed that as expected, the coefficients for chronic pain and income decrease when more control variables are added in the OLS models but stay mostly unchanged in the FE models, suggesting that the fixed effects capture an important part of the relationship between pain and life satisfaction on one hand and income and life satisfaction on the other (Table A3). Comparison of weighted and unweighted results yielded similar results for other models (Table A4).

In an attempt to identify the effect of pain on life-satisfaction, we excluded pain from our models and used the point estimates for arthritis instead in our CV calculations (Table A5). As expected, the point estimates for arthritis in Table A5 are of negative sign and considerably smaller in absolute value than the pain coefficients in Table 3. It is not unlikely that pain directly related to arthritis can be treated with specific drugs/pain treatment and thus would not capture other and often unexplained origins of chronic pain, albeit the smaller sized coefficients in Table A5 compared to those in Table 3. Moreover, because of an intrinsic lack of within variation in the arthritis variable (8 % of individuals in our sample change status in arthritis compared to 29 % who change status in the pain variable) we were unable to produce point estimates from the FE models in Table A5. The possible endogeneity of the pain variable is thus best addressed by controlling for individual fixed effects, and the same would apply for arthritis. CV estimates were generally robust to the exclusion of psychological conditions as a control variable although an increase in the OLS-IV models from 129 to 164 USD in panel A and from 152 to 221 USD per day in panel B was noted.

6. Discussion

By using improved econometric methods, we provide new information on the value of pain relief among people older than 50. Our results suggest a lower CV for pain than previously reported. More importantly, we contribute to the literature by using a PWL model as a more flexible method to express WTP across income ranges, instead of the traditional log transformation of income. Results from IV-models also yield CVs that are considerably lower than previous research suggests.

We compared our income coefficients to coefficients previously reported for life-satisfaction equations from four different countries; Britain, Germany, Australia and USA (Clark et al., 2018) and found that our income coefficients correspond to the lower end of the range of coefficients. This is true after adjusting the income coefficients for different scaling of the life-satisfaction variable in the two studies (11/5), with our coefficients (times 2.2) closely reflecting those found using data from Britain (see Clark et al., Table 2.2). This comparison, although limited to model specifications where well-being is assumed to be linear in log income in OLS and FE models, is helpful to benchmark our income coefficients.

The two studies that use exogenous lottery wins to estimate the treatment effects of income on life-satisfaction — Lindqvist et al. (2018) and Apouey and Clark (2015) — have starkly different results. The treatment effect of \$100 K on life-satisfaction is estimated to be 0.037 SD units by Lindqvist et al. and 1.369 SD units by Apouey and Clark. We choose the former as an alternative for our income coefficient in Table 3 (column 1, OLS) because Lindqvist et al. use a larger sample size and have stronger internal validity. Lindqvist et al. approximate a lifetime income effect on life-satisfaction using lottery prizes annuitized over 20 years at a 2 % interest rate. To calculate a CV for our linear income model in Table 3, we take the estimate 0.062 from Table A10 in Lindqvist et al., which, after adjustment to different scaling of the life-satisfaction variable (0.062/2.2 = 0.028) and to USD prices between 2011 and 2015, we can apply an estimate of 0.028/1.0537 = 0.027. Using the income coefficient of 0.027 and our pain coefficient of -0.0563 that is adjusted for individual heterogeneity (FE model in Table 3), the corresponding CV is 57 USD per day.

We did two additional sensitivity tests. First, instead of using a pain coefficient from an experimental setting, we used the pain coefficient from our estimate of the effect of pain on life-satisfaction through transitions into and out of arthritis status (see Table A5). Using the pain coefficient of -0.0793 from Table A5 and the lifetime income effect estimate from Lindqvist et al. (0.027) generates a CV of 80 USD per day. Second, we compared the CV by income coefficients across the two studies for the case of ln (income). The corresponding Lindqvist estimate (adjusted) is 0.16 (0.377 in Table A10 in Lindqvist et al.) and applying the FE coefficient of -0.0561 the estimated CV is 54 USD per day. Both CV estimates, 57 and 80 USD per day, are within our estimated range of 56–145 USD per day. The CV using lifetime log-income effect from Lindqvist et al. of 54 USD per day is lower.

Because there is some variability across countries in the income gradient for life-satisfaction equations (Clark et al., 2018), an income effect estimate based on a sample of Swedish lottery players may not apply to US data. Furthermore, there is inherent uncertainty in the annuity-adjustment parameter used to rescale the lifetime income gradient. However, the comparison is helpful and will hopefully stimulate similar research in other countries. This sensitivity analysis points towards the lower part of our estimated range of 56–145 USD per day as the most credible CV estimate. We note that using income estimates from lottery studies instrinsically produces willingness to accept (WTA), whereas by using variation in household income the estimated CV is between WTA and WTP.

Our paper has several limitations. Pain can be a consequence of neurological diseases, diabetes, or of musculoskeletal origin, but we did not have controls for those conditions that we found validated by a doctor's diagnosis. However, any possibility of omitted-variable bias should be mitigated by controlling for age because neurological disease and diabetes likelihood (Type 2) increases with age. Furthermore, the numerous other health controls included should capture the effect of musculoskeletal conditions on pain and life satisfaction, in particular psychiatric problems, lung disease, cancer and arthritis. External validity may be limited by the age range used, in particular if the marginal utility of income for those over 50 is lower than in the younger population, which would result in higher CV-estimates than in a sample with lower mean age. Responses to life-satisfaction questions may be liable to situational influences, such as the site of the interview, the weather, one's mood and the interviewer, but those differences can be considered as random error (Veenhoven, 1993).

The value of pain is likely overestimated in previous research using the well-being valuation method, with our best approximation to a WTP estimate being in the range of 56–145 USD per day. This range of estimates is derived from models where we take into account the effects of individual heterogeneity (by applying FE models), the leveraging effect of the highest income levels (by applying PWL models) and the endogeneity of the income variable with mother's education as an instrument (by applying OLS-IV models). Those are issues that previous research and our analysis alike have highlighted as issues that should be taken into consideration when finding as reliable estimates as possible for the CVs. Furthermore, the value of pain relief is positively related to severity of pain. Our research also has implications for the CV literature as a whole. We show the importance of controlling for the endogeneity of income and allowing the effect of income to vary flexibly across income levels. To this end, PWL models are promising because they perform well econometrically and allow for easier exploration of results across income groups than log transformations of income.

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Appendix Valuing pain using the subjective well-being method

Table A1
Point estimates from OLS, FE and OLS-IV models with linear income.

Dependent variable: Life satisfaction	OLS	FE	OLS-IV	
			First-stage	IV
Real equivalized household income	0.0064***	0.0015***		0.0426***
	(0.0008)	(0.0006)		(0.0131)
Mother's education			0.1245***	
			(0.0136)	
Pain	−0.2123***	−0.0563***	−0.2349***	−0.1999***
	(0.0089)	(0.0093)	(0.0886)	(0.0103)
Age	0.0510***	0.0504***	0.0614	0.0494***
	(0.0098)	(0.0152)	(0.1051)	(0.0108)
Age squared	−0.0014	−0.0051***	−0.0239**	−0.0004
	(0.0009)	(0.0014)	(0.0094)	(0.0011)
Second wave	−0.0133*	−0.0160*	−0.2715***	−0.0025
	(0.0076)	(0.0086)	(0.0740)	(0.0091)
Third wave	−0.0263***	−0.0185*	−0.2735***	−0.0173*
	(0.0080)	(0.0112)	(0.0748)	(0.0093)
Fourth wave	−0.0050	0.0055	−0.0488	−0.0038
	(0.0085)	(0.0148)	(0.0833)	(0.0094)
Ever reported cancer	−0.0358***	−0.1049***	−0.0076	−0.0278**
	(0.0124)	(0.0261)	(0.1018)	(0.0132)
Ever reported lung disease	−0.1128***	−0.0058	−0.3710***	−0.1053***
	(0.0159)	(0.0308)	(0.0867)	(0.0176)
Ever reported heart problems	−0.0775***	−0.0536***	−0.0023	−0.0731***
	(0.0108)	(0.0203)	(0.0987)	(0.0117)
Ever reported stroke	−0.0831***	−0.0605*	−0.3187***	−0.0796***
	(0.0178)	(0.0327)	(0.1093)	(0.0197)
Ever reported psychological problems	−0.3542***	−0.1765***	−0.3744***	−0.3306***
	(0.0133)	(0.0305)	(0.0885)	(0.0148)
Ever reported arthritis	−0.0203**	−0.0020	−0.1936**	−0.0136
	(0.0096)	(0.0185)	(0.0934)	(0.0108)
Ever reported high blood pressure	0.0086	−0.0411**	−0.4048***	0.0244**
	(0.0092)	(0.0183)	(0.0972)	(0.0115)
Do you smoke cigarettes now?	−0.1488***	0.0414*	−0.7781***	−0.1261***
	(0.0139)	(0.0229)	(0.0895)	(0.0178)
Divorced or separated	−0.3151***	−0.1145***	−1.6364***	−0.2625***
	(0.0142)	(0.0309)	(0.1072)	(0.0260)
Widowed	−0.2425***	−0.2194***	−0.6860***	−0.2203***
	(0.0131)	(0.0242)	(0.1085)	(0.0170)
Single	−0.2484***	−0.1803***	−1.8204***	−0.1843***
	(0.0229)	(0.0652)	(0.3917)	(0.0368)
Unemployed	−0.2507***	−0.1367***	−2.4110***	−0.1735***
	(0.0261)	(0.0241)	(0.1486)	(0.0415)
Partly retired	0.0973***	0.0396**	−1.3083***	0.1412***
	(0.0148)	(0.0163)	(0.1848)	(0.0239)
Retired	0.0635***	0.0063	−2.5102***	0.1516***
	(0.0122)	(0.0152)	(0.1402)	(0.0357)
Out of the labor force	−0.0151	−0.0640***	−1.8077***	0.0512*
	(0.0188)	(0.0223)	(0.1523)	(0.0310)
Number of resident children	−0.0155**	−0.0002	−0.8023***	0.0085

Table A1 (*Continued*)

Dependent variable: Life satisfaction	OLS	FE	OLS-IV	
			First-stage	IV
	(0.0068)	(0.0106)	(0.0525)	(0.0129)
Female	0.0631***		−0.2982***	0.0727***
	(0.0096)		(0.0958)	(0.0112)
GED and high school graduate	−0.0087		0.2146***	−0.0171
	(0.0145)		(0.0704)	(0.0170)
Some college	−0.0513***		1.0231***	−0.1000***
	(0.0155)		(0.0904)	(0.0245)
College and above	−0.0071		3.8386***	−0.1612***
	(0.0161)		(0.1394)	(0.0580)
Black/African American	−0.0589***		−1.3026***	−0.0085
	(0.0134)		(0.0817)	(0.0237)
Other	0.0222		−0.4982***	0.0584**
	(0.0208)		(0.1803)	(0.0246)
Hispanic= = 1	−0.0220		−1.2094***	0.0410
	(0.0184)		(0.1451)	(0.0301)
Health insurance	0.0795***	0.0605***	0.1828*	0.0763***
	(0.0121)	(0.0141)	(0.1102)	(0.0132)
Constant	3.7789***	3.8503***	7.0925***	3.4849***
	(0.0359)	(0.1254)	(0.4303)	(0.1163)
Observations	64,205	64,205	58,588	58,588
Adjusted R-squared	0.1259	0.0097	0.1407	0.0368
F-statistic of excluding instrument				83.95
Anderson-Rubin F-test (p-value)				0.0008

Standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$". Reference groups are married or partnered, employed, less than high school and white. Census division controls not shown for parsimony.

Table A2
Point estimates from OLS, FE and OLS-IV models with ln(income).

Dependent variable: Life satisfaction	OLS	FE	OLS-IV	
			First-stage	IV
Real equivalized household income(ln)	0.0704***	0.0160***		0.2529***
	(0.0049)	(0.0053)		(0.0753)
Mother's education			0.0210***	
			(0.0017)	
Pain	−0.2089***	−0.0561***	−0.0702***	−0.1922***
	(0.0089)	(0.0093)	(0.0092)	(0.0107)
Age	0.0487***	0.0503***	0.0358***	0.0429***
	(0.0097)	(0.0152)	(0.0106)	(0.0105)
Age squared	−0.0011	−0.0051***	−0.0052***	−0.0001
	(0.0009)	(0.0014)	(0.0010)	(0.0011)
Second wave	−0.0135*	−0.0158*	−0.0247***	−0.0079
	(0.0076)	(0.0086)	(0.0076)	(0.0082)
Third wave	−0.0245***	−0.0177	−0.0485***	−0.0167*
	(0.0079)	(0.0112)	(0.0078)	(0.0089)
Fourth wave	−0.0033	0.0064	−0.0286***	0.0013
	(0.0085)	(0.0148)	(0.0087)	(0.0090)
Ever reported cancer	−0.0380***	−0.1051***	0.0303**	−0.0358***
	(0.0124)	(0.0261)	(0.0126)	(0.0131)
Ever reported lung disease	−0.1083***	−0.0058	−0.0916***	−0.0979***
	(0.0159)	(0.0308)	(0.0158)	(0.0183)
Ever reported heart problems	−0.0764***	−0.0533***	−0.0186*	−0.0685***
	(0.0108)	(0.0203)	(0.0111)	(0.0115)
Ever reported stroke	−0.0784***	−0.0599*	−0.0978***	−0.0684***
	(0.0178)	(0.0327)	(0.0168)	(0.0205)
Ever reported psychological problems	−0.3510***	−0.1759***	−0.0798***	−0.3264***
	(0.0132)	(0.0305)	(0.0134)	(0.0151)
Ever reported arthritis	−0.0213**	−0.0020	−0.0030	−0.0211**
	(0.0095)	(0.0185)	(0.0106)	(0.0101)
Ever reported high blood pressure	0.0096	−0.0411**	−0.0524***	0.0204*
	(0.0092)	(0.0183)	(0.0103)	(0.0106)
Do you smoke cigarettes now?	−0.1421***	0.0415*	−0.1618***	−0.1184***
	(0.0138)	(0.0229)	(0.0151)	(0.0189)
Divorced or separated	−0.2887***	−0.1095***	−0.5252***	−0.1994***
	(0.0143)	(0.0309)	(0.0161)	(0.0422)
Widowed	−0.2235***	−0.2161***	−0.3312***	−0.1658***
	(0.0132)	(0.0242)	(0.0137)	(0.0286)
Single	−0.2149***	−0.1749***	−0.6358***	−0.1011*
	(0.0229)	(0.0652)	(0.0288)	(0.0532)
Unemployed	−0.2253***	−0.1346***	−0.5725***	−0.1315***

Table A2 (*Continued*)

Dependent variable: Life satisfaction	OLS	FE	OLS-IV	
			First-stage	IV
	(0.0261)	(0.0241)	(0.0305)	(0.0510)
Partly retired	0.1105***	0.0413**	−0.3085***	0.1635***
	(0.0147)	(0.0163)	(0.0175)	(0.0279)
Retired	0.0885***	0.0094	−0.5728***	0.1895***
	(0.0124)	(0.0152)	(0.0141)	(0.0452)
Out of the labor force	0.0151	−0.0608***	−0.5720***	0.1188**
	(0.0189)	(0.0223)	(0.0230)	(0.0474)
Number of resident children	−0.0043	0.0017	−0.2234***	0.0308*
	(0.0068)	(0.0106)	(0.0077)	(0.0185)
Female	0.0647***		−0.0478***	0.0721***
	(0.0096)		(0.0106)	(0.0107)
GED and high school graduate	−0.0272*		0.2661***	−0.0753***
	(0.0146)		(0.0148)	(0.0278)
Some college	−0.0775***		0.4336***	−0.1661***
	(0.0157)		(0.0166)	(0.0406)
College and above	−0.0409**		0.7874***	−0.1967***
	(0.0164)		(0.0182)	(0.0669)
Black/African American	−0.0427***		−0.3346***	0.0206
	(0.0135)		(0.0150)	(0.0306)
Other	0.0282		−0.1089***	0.0647***
	(0.0208)		(0.0256)	(0.0246)
Hispanic= = 1	−0.0001		−0.3913***	0.0884**
	(0.0184)		(0.0213)	(0.0408)
Health insurance	0.0723***	0.0598***	0.1190***	0.0540***
	(0.0120)	(0.0141)	(0.0153)	(0.0156)
Constant	3.7258***	3.8389***	1.3094***	3.4560***
	(0.0361)	(0.1253)	(0.0440)	(0.1202)
Observations	64,205	64,205	58,588	58,588
Adjusted R-squared	0.1277	0.0098	0.3731	0.1003
F-statistic of excluding instrument				160.07
Anderson-Rubin F-test (p-value)				0.0008

Standard errors in parentheses. * p < 0.10, ** p < 0.05, *** p < 0.01″. Reference groups are married or partnered, employed, less than high school and white. Census division controls not shown for parsimony.

Table A3
CV estimates from unadjusted and adjusted models.

Panel A	OLS		FE	
	Unadjusted	Adjusted	Unadjusted	Adjusted
Pain	−0.3113***	−0.2123***	−0.0575***	−0.0563***
	(0.0092)	(0.0089)	(0.0093)	(0.0093)
Income	0.0091***	0.0064***	0.0017***	0.0015***
	(0.0009)	(0.0008)	(0.0006)	(0.0006)
CV	932***	910***	932***	1,044**
	(102)	(115)	(343)	(425)
Panel B	**OLS**		**FE**	
	Unadjusted	Adjusted	Unadjusted	Adjusted
Pain	−0.2926***	−0.2089***	−0.0570***	−0.0561***
	(0.0091)	(0.0089)	(0.0094)	(0.0093)
ln(income)	0.1057***	0.0704***	0.0236***	0.0160***
	(0.0043)	(0.0049)	(0.0052)	(0.0053)
CV	1,925***	2,377***	1,317***	4,137
	(299)	(611)	(970)	(5,519)

*p < 0.10, ** p < 0.05, *** p < 0.01. Unadjusted models include pain and real equivalized household income in panel A and ln (real equivalized household income) in panel B. Adjusted models also include age, age squared, number of children in household, year dummies, dummies for comorbidities, marital status, census division, labor force status, gender, education, race, Hispanic and health insurance. FE models include age, age squared, year dummies, dummies for comorbidities, marital status, census division, labor force status, children in household and health insurance as covariates in addition to pain and income. CVs are reported in USD, 2015 price level. Unweighted results. Standard errors (in parentheses) are clustered on individuals.

Table A4
CV estimates with and without weights.

Models with linear income	OLS		PWL-OLS		OLS-IV	
	No weights	With weights	No weights	With weights	No weights	With weights
	910***	893***			129***	144***
	(115)	(121)			(42)	(52)
Income						
1. spline			183***	185***		
			(40)	(56)		
2. spline[1]			95***	76***		
			(11)	(9)		
3. spline			1,720***	1,533***		
			(301)	(274)		

Models with ln(income)	OLS		OLS-IV	
	No weights	With weights	No weights	With weights
	2,377***	1,513***	152**	137**
	(611)	(427)	(72)	(68)

*p < 0.10, ** p < 0.05, *** p < 0.01. Compensating variation (CV) is calculated from models including age, age squared, number of children in household, year dummies, dummies for comorbidities, marital status, census division, labor-force status, gender, education, race, Hispanic and health insurance. Knots are at income values 30,000 and 50,000 in PWL-OLS model. CVs are reported in USD per day at 2015 price level. Standard errors (in parentheses) are clustered on individuals.

Table A5
Point estimates and corresponding CV estimates by choice of model estimator and functional form of income: Arthritis.

Panel A	OLS		PWL-OLS		FE		PWL-FE		OLS-IV	
	Coeff.	CV	Coeff.	CV	Coeff.	CV	Coeff.	CV	Coeff.	CV
Arthritis	−0.0793***		−0.0778***		−0.0066		−0.0072		−0.0677***	
	(0.0095)	329***	(0.0094)		(0.0185)	124	(0.0185)		(0.0112)	41***
Income	0.0066***	(57)			0.0015***	(348)			0.0458***	(15)
	(0.0008)				(0.0005)				(0.0133)	
Income										
1. spline			0.0351***	60***			0.0019	NV		
			(0.0069)	(14)			(0.0073)			
2. spline[1]			0.0620***	35***			0.0275***	7		
			(0.0062)	(5)			(0.0065)	(18)		
3. spline			0.0033***	638***			0.0005	NV		
			(0.0006)	(137)			(0.0005)			

Panel B	OLS		FE		OLS-IV	
	Coeff.	CV	Coeff.	CV	Coeff.	CV
Arthritis	−0.0793***		−0.0067		−0.0735***	
	(0.0094)	156***	(0.0185)	66	(0.0101)	42**
ln(income)	0.0747***	(35)	0.0162***	(224)	0.2708***	(16)
	(0.0050)		(0.0053)		(0.0759)	

N = 64,205 person-years observations. N = 58,588 in OLS-IV models. PWL: Piecewise Linear. *p < 0.10, ** p < 0.05, *** p < 0.01. Models include age, age squared, number of children in household, year dummies, dummies for comorbidities, marital status, census division, labor force status, gender, education, race, Hispanic and health insurance. FE models include age, age squared, year dummies, dummies for comorbidities, marital status, labor force status, children in household and health insurance as covariates in addition to arthritis and income. Knots are at income values 3 and 5 in PWL-OLS and PWL-FE models (income variable is in 10,000 USD). CVs are reported in USD, 2015 price level and are calculated with coefficients from adjusted models. [1]t-value for difference in slope between 1. and 2. segment in PWL-OLS model is -2.54. Results are unweighted. Weighted results are in Appendix. NV = no CV value as the income coefficient was not different from zero. Mean income in CV formula in Panel B = 47,088. Standard errors (in parentheses) are clustered on individuals.

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