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# Connecting the dots: continuity in the relationship between income and emotional well-being

Manja Derlin\*      Carina Keldenich†      Andreas Knabe‡

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## Abstract

We examine how functional-form assumptions affect conclusions about the existence of satiation in the relationship between income and emotional well-being. Previous studies have estimated a piecewise log-linear model with one structural break in both intercept and slope, which may lead to discontinuities in the estimated relationship. We show that imposing continuity in this type of model in OLS and quantile regressions substantially alters inferences about income satiation. At commonly applied thresholds, satiation disappears. The threshold shifts upwards when determined by best statistical fit and satiation re-emerges only at very high incomes. These findings demonstrate that the presence and location of satiation are highly sensitive to modeling choices.

**Keywords:** income, emotional well-being, experience sampling method

**JEL codes:** I31, C21, D12

## 1 Introduction

Several studies have examined the relationship between income and emotional well-being, among them the influential works of Kahneman and Deaton (2010) and Killingsworth (2021).<sup>1</sup> Using US survey data, Kahneman and Deaton (2010) find that the association between income and emotional well-being is log-linear up to an annual income of \$75,000, beyond which the relationship

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<sup>1</sup>Other relevant studies on income and emotional well-being include, e.g., (Hudson et al., 2016; Kushlev et al., 2015; Jebb et al., 2018; Stone et al., 2018). For a survey on the even larger literature on income and cognitive well-being, see Clark et al. (2008).

plateaus. By contrast, Killingsworth (2021), using experience sampling method (ESM) data that capture emotional states in real time, does not find evidence for income satiation beyond this threshold.

In a joint effort to reconcile these findings, Killingsworth et al. (2023) identify two key explanations. First, the plateau reported by Kahneman and Deaton (2010) partly reflects a ceiling effect, as their binary measure cannot capture further improvements once the higher category is selected. Second, quantile regressions reveal substantial heterogeneity: at the lower end of the well-being distribution (around the 15th percentile), a plateau re-emerges above \$100,000 (an inflation-adjusted equivalent to the threshold found by Kahneman and Deaton, 2010); at the median, the log-linear relationship persists; and at the upper end (e.g. at the 85th percentile), the association becomes even stronger above \$100,000.

Bennedsen (2024) notes that the aforementioned studies by Killingsworth (2021) and Killingsworth et al. (2023) rest on two strong assumptions: (i) the income–well-being relationship is piecewise log-linear with one structural break in both intercept and slope, and (ii) this structural change occurs at some predetermined threshold. He suggests relaxing the second assumption and determines the threshold endogenously by selecting the value that minimizes the residual sum of squares (RSS). This method identifies an optimal threshold around \$200,000, above which both mean and quantile regressions indicate satiation.

In this paper, we focus on the first of these two assumptions. In comparison to models enforcing continuity, estimating the intercept and slope separately below and above the threshold (i.e., allowing for a jump) provides more flexibility and therefore better statistical fit. However, discontinuities in the estimated relationship raise conceptual concerns (unless they can be motivated by real-world breakpoints, e.g., in economic policy), because small income changes across the threshold would correspond to sudden well-being changes.

To investigate this issue, we analyze how imposing a continuity restriction affects the empirical assessments of income satiation. Using the same ESM data, we replicate the analyses of Killingsworth et al. (2023) and Bennedsen (2024) and extend them by estimating continuous piecewise log-linear models. For both thresholds employed in the reference studies (\$100,000 and \$200,000, respectively), the positive log-linear relationship also extends beyond the threshold after enforcing continuity. When the threshold is determined endogenously, the optimal value shifts substantially upward (to around \$500,000) under continuity, and evidence of satiation appears only at very high income levels.

We contribute to the existing literature by demonstrating that the presence, location, and distributional pattern of satiation are highly sensitive to functional-form assumptions, in this case

regarding continuity. Consequently, these results suggest that threshold-based findings should be interpreted with caution and that continuity restrictions deserve consideration as a robustness check in future research.

## 2 Data

This study draws on the ESM data published by Killingsworth et al. (2023), which also forms the basis of the analysis in Bennedsen (2024).<sup>2</sup> The data comprise 1,725,944 momentary affect reports from 33,391 adults (aged 18–65) residing in the United States, collected via smartphone prompts. Respondents answered the question “How do you feel right now?” using a continuous response scale, subsequently transformed to a numeric value ranging from 0 (“Very bad”) to 100 (“Very good”). The publicly available version of the dataset provides within-person averages of these well-being reports, yielding 33,391 individual-level observations. The only additional information included in the dataset is annual pre-tax household income, reported in 15 discrete brackets, which serves as the sole explanatory variable in the present analysis, as in both earlier studies using the same dataset. The brackets are defined in \$10,000 increments up to \$100,000, followed by thresholds at \$125,000, \$150,000, \$200,000, \$300,000, and \$500,000. For further details on the data, see Killingsworth (2021).

## 3 Empirical analysis

### 3.1 Methods

To facilitate comparisons across studies, we begin by replicating the Ordinary Least Squares (OLS) results reported by Killingsworth et al. (2023) and Bennedsen (2024). Following these studies, we standardize each individual’s mean well-being level to a  $z$ -score, denoted by  $w_i$ , and estimate the following piecewise log-linear model (henceforth, the *jump specification*):

$$w_i = (\alpha + \beta \ln y_i) I(y_i \leq \tau) + (\gamma + \delta \ln y_i) I(y_i > \tau) + \varepsilon_i, \quad (1)$$

where  $y_i$  represents the household income of individual  $i$  (approximated by the midpoint of the reported income bracket, and \$625,000 for everyone with income  $>$  \$500,000),  $\tau$  denotes the income threshold at which the structural break in the log-linear income–well-being relationship is located,  $I(\cdot)$  is an indicator function, and  $\varepsilon_i$  is an idiosyncratic error term. This specification permits considerable flexibility by allowing a discontinuity in the conditional mean of well-being

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<sup>2</sup>The dataset is publicly available at <https://osf.io/qye4a/> (last accessed August 21, 2025).

at  $\tau$ .

The reference studies differ in how they determine the threshold  $\tau$ . Killingsworth et al. (2023) adopt the threshold originally proposed by Kahneman and Deaton (2010), setting  $\tau = \$100,000$  (after adjusting for inflation). In contrast, Bennedsen (2024) determines  $\tau$  endogenously, selecting  $\tau = \$200,000$  as this minimizes the RSS and thus provides the best statistical fit.

To assess whether the results are robust to imposing continuity, we allow only a change in the slope - but no jump - at the threshold in our adjusted model (henceforth, the *kink specification*):

$$w_i = a + b \ln y_i + c (\ln y_i - \ln \tau) I(y_i > \tau) + \varepsilon_i. \quad (2)$$

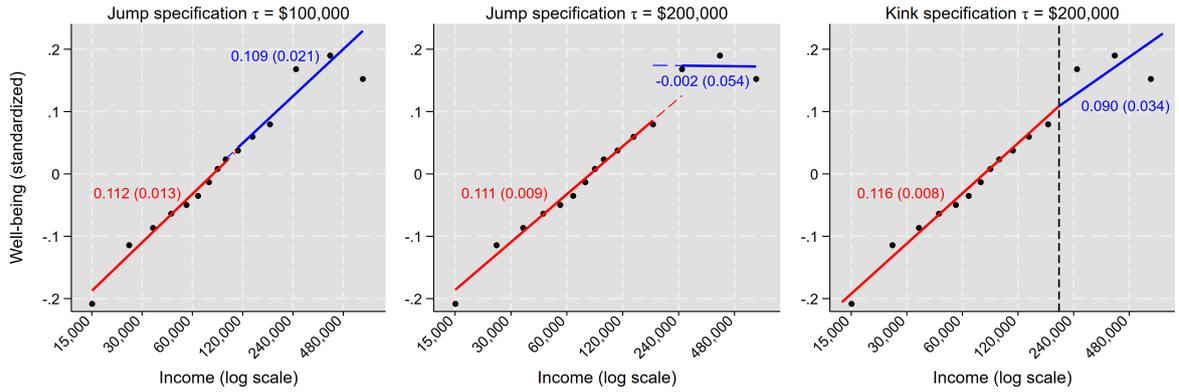
Here,  $a$  is the intercept,  $b$  is the slope below the threshold, and  $c$  captures the change in slope at  $\tau$ . Hence,  $(b + c)$  is the slope above the threshold. Following Bennedsen (2024), the optimal threshold is identified by considering all income-bracket boundaries as potential thresholds and selecting the threshold value that minimizes the RSS.

For both specifications, we test for evidence of income satiation. We define a *weak* form of satiation as diminishing marginal returns to (log) income. We evaluate this by testing whether the slope of the income–well-being relationship declines significantly at the threshold ( $\beta > \delta$  in the jump specification;  $c < 0$  in the kink specification). A *strong* form of satiation additionally requires that well-being does not increase beyond the threshold. We interpret our results as consistent with this stronger form if we fail to reject  $\delta \leq 0$  and  $b + c \leq 0$ , respectively. To evaluate how enforcing continuity alters the estimated income–well-being relationship, we compare results across the two models.

Finally, in line with Killingsworth et al. (2023) and Bennedsen (2024), we also estimate quantile regressions for the kink specification at the 15%, 30%, 50%, 70%, and 85% quantiles, using unstandardized well-being as the dependent variable.

### 3.2 OLS results

The left and middle panels of Figure 1 show the results from the jump specification, in the left panel for  $\tau = \$100,000$  (exactly replicating Killingsworth et al., 2023) and in the middle panel for  $\tau = \$200,000$  (exactly replicating Bennedsen, 2024). In their graphical expositions, the original studies left a gap between the midpoints of the income intervals surrounding the threshold  $\tau$ , thereby remaining agnostic about the precise point within this interval at which the relationship switches from the lower to the upper segment. In our exposition, we extend both segments of the piecewise log-linear function into this gap (shown as dashed lines). If these dashed lines do not intersect, it is impossible to generate a continuous function based on the parameter estimates,



Note: The figure shows the best-fit lines (and their slopes) obtained from piecewise log-linear regressions. Black dots indicate sample averages of well-being levels within each income bracket. Standard errors in parentheses.

Figure 1: Results of OLS regressions

indicating a discontinuity — or “jump” — in the estimated income–well-being relationship.

Since only a minimal discontinuity is apparent in the left panel of Figure 1, imposing continuity has little effect when  $\tau = \$100,000$ .<sup>3</sup> By contrast, the middle panel reveals a pronounced jump if  $\tau = \$200,000$ , and the right panel of Figure 1 demonstrates that enforcing continuity through the kink specification substantially alters the results with this threshold. There is no longer evidence of a significant change in slope at the threshold ( $c = -0.026$ ,  $p = 0.491$ ), and the income–well-being relationship remains positive even above the threshold ( $b + c = 0.090$ ,  $p = 0.008$ ).

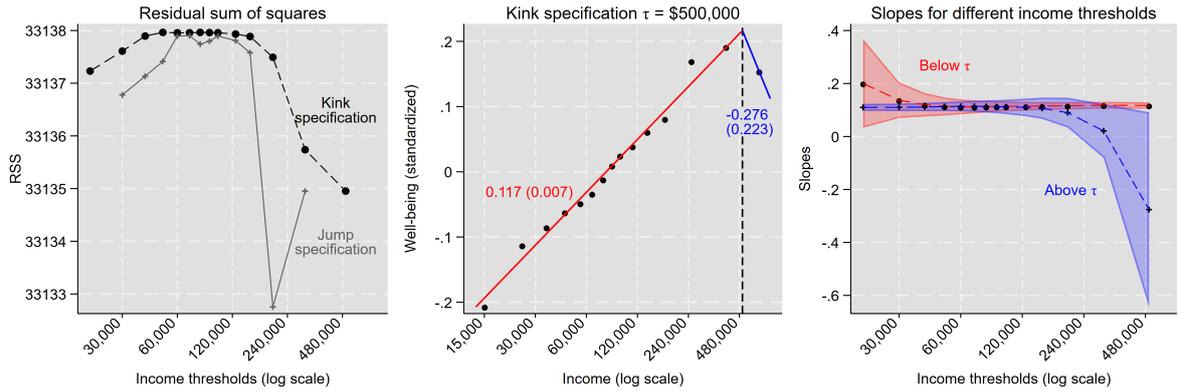
Next, following Bannedsen (2024), we select  $\tau$  endogenously such that it minimizes the RSS. The left panel of Figure 2 plots the RSS across all candidate values of  $\tau$  for both the jump specification — exactly replicating the results of Bannedsen (2024) — and the kink specification. Because the kink specification imposes an additional continuity constraint, its RSS is necessarily higher for every value of  $\tau$ . This indicates a somewhat poorer fit relative to the jump specification, although the difference appears modest. Notably, under the kink specification, the RSS-minimizing threshold is substantially higher (\$500,000 rather than \$200,000).

The middle panel of Figure 2 presents the results of the kink specification with  $\tau = \$500,000$ . At this higher threshold, a statistically significant change in slope re-emerges ( $c = -0.393$ ,  $p = 0.082$ ), and the estimated slope above the threshold becomes negative, but is statistically not significantly different from zero ( $b + c = -0.276$ ,  $p = 0.217$ ).<sup>4</sup>

However, the fact that  $\tau = \$500,000$  yields the best statistical fit for a single-kink specification does not necessarily imply that this is the point at which satiation begins. To examine how the estimated slopes depend on the choice of  $\tau$ , the right panel of Figure 2 plots the estimated

<sup>3</sup>The estimates from the kink specification with  $\tau = \$100,000$  are virtually identical; regression results are reported in the Appendix.

<sup>4</sup>Estimation of the jump specification is not feasible at this threshold, as only a single income category lies to the right of  $\tau$ .



*Note:* Left panel: residual sum of squares (RSS) of OLS regressions with different income thresholds. Middle panel: best-fit line for the RSS-minimizing threshold. Black dots indicate sample averages of well-being levels within each income bracket. Standard errors in parentheses. Right panel: estimated slopes of regression line below and above the threshold for different income thresholds. Shaded areas represent the 90% confidence bands.

Figure 2: Results for alternative thresholds

slopes below and above the threshold for each candidate value of  $\tau$ . The pattern suggests that satiation may begin at substantially lower income levels. For instance, if the threshold were set at  $\tau = \$300,000$ , the estimated slope above the threshold would also be small and statistically insignificant ( $b + c = 0.021, p = 0.736$ ).

### 3.3 Quantile regressions

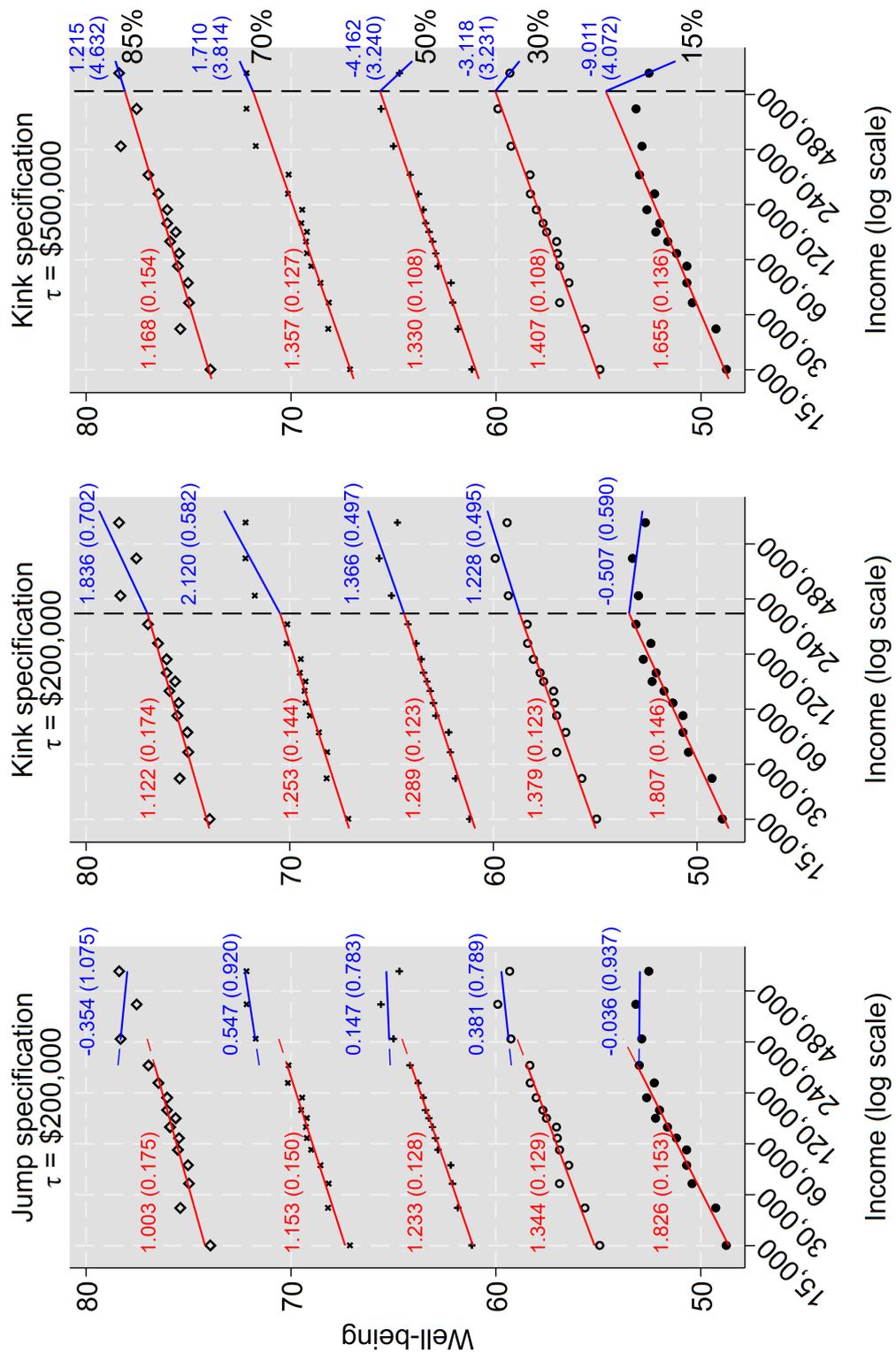
Following Killingsworth et al. (2023) and Bennedsen (2024), we report quantile regression results in Figure 3.

The left panel displays results for the jump specification with  $\tau = \$200,000$ , exactly replicating Bennedsen (2024).<sup>5</sup> Consistent with the OLS results, the estimates indicate discontinuities for all displayed quantiles. When continuity is enforced via the kink specification (middle panel) with the same threshold, results resemble those reported by Killingsworth et al. (2023) for a lower threshold value. Evidence consistent with strong satiation is found only at the lowest quantile (15th percentile). For all other examined quantiles (30th and above), we do not find significant changes in the slopes, and the slopes above the threshold remain significantly positive.<sup>6</sup>

Finally, the right panel of Figure 3 presents the results from the kink specification with  $\tau = \$500,000$ . At this higher threshold, evidence of satiation is no longer confined to the lower quantiles but extends to the median as well. For the 15th percentile and for the median, we find significant reductions in the slopes ( $c = -10.67, p = 0.009$  for the 15th percentile;  $c = -5.49, p = 0.093$  for the median). For the 15th percentile, we even find statistically

<sup>5</sup>The quantile regression results of Killingsworth et al. (2023) can also be exactly replicated, but are not reported here.

<sup>6</sup>We conduct the same analysis with  $\tau = \$100,000$  (cf. Killingsworth et al., 2023). Because the jump specification does not yield substantial discontinuities at this threshold for any of the considered quantiles, enforcing continuity does not qualitatively alter the results. For completeness, these estimates are reported in the Appendix.



Note: Quantile regressions for the 15th, 30th, 50th, 70th, and 85th percentiles. Black dots indicate sample quantiles of well-being levels within each income bracket. Standard errors in parentheses.

Figure 3: Quantile Regressions

significant evidence of a slope reversal ( $b + c = -9.011$ ,  $p = 0.027$ ). For the 70th and 85th percentiles, we do not find evidence for a change in the slope at the threshold. The point estimate for the slope beyond the threshold is positive, but we cannot reject the null hypothesis that it is equal to zero.<sup>7</sup>

## 4 Conclusion

We have shown that when estimating a piecewise log-linear relationship between income and emotional well-being, enforcing continuity — i.e. switching to a specification allowing for a kink rather than a jump at the threshold — substantially alters conclusions about income satiation. However, it is important to emphasize that the true relationship between income and well-being is unlikely to be exactly piecewise log-linear with a single threshold at which either a kink or a jump occurs, and results may be similarly sensitive to changing other assumptions about the functional form. Besides this shared limitation, the two specifications offer different advantages: while the jump specification provides a closer fit to the observed data, the kink specification imposes continuity, which is arguably a feature of the underlying relationship. Consequently, the key contribution of the paper is to highlight the sensitivity of results to functional form assumptions, rather than to provide conclusive evidence of the presence or absence of satiation. Future research should explore more flexible functional forms — such as models with multiple kinks or smooth nonlinear specifications — to obtain a more accurate characterization of the income-well-being gradient.

## Data availability

Data have been made publicly available by Matthew Killingsworth at <https://osf.io/qye4a/>.

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<sup>7</sup>For completeness, results for the kink specification with  $\tau = \$300,000$  are reported in the Appendix. As expected, they represent an intermediate case between the middle and right panels of Figure 3.

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# Appendices

## A Regression Results

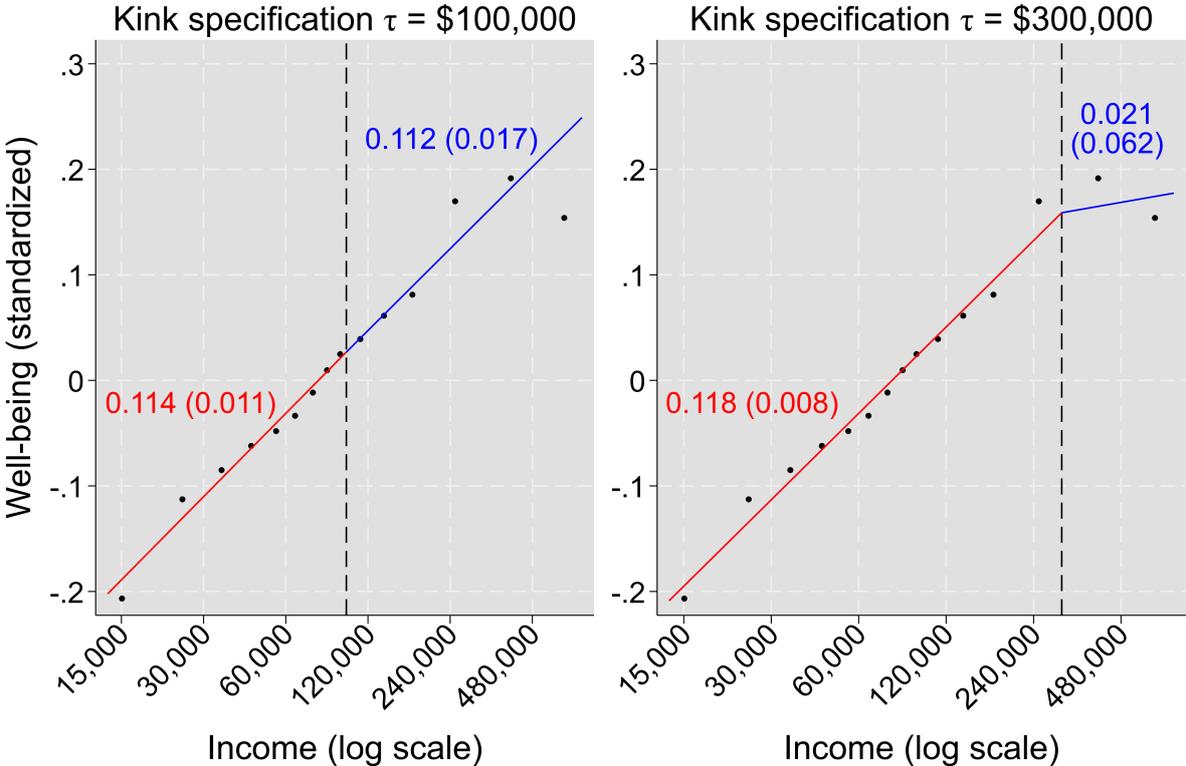
Table A.1: Regression Results

	(1)	(2)	(3)	(4)
	Kink at \$100k	Kink at \$200k	Kink at \$300k	Kink at \$400k
$\ln y_i$	0.114*** (0.011)	0.116*** (0.008)	0.118*** (0.008)	0.117*** (0.007)
$(\ln y_i - \ln \tau) I(y_i > \tau)$	-0.002 (0.024)	-0.026 (0.038)	-0.097 (0.065)	-0.393* (0.226)
Constant	-1.283*** (0.125)	-1.310*** (0.095)	-1.331*** (0.088)	-1.319*** (0.084)
Observations	33391	33391	33391	33391
Slope above kink ( $b + c$ )	0.112 (0.017)	0.090 (0.034)	0.021 (0.062)	-0.276 (0.223)
$H_0: b + c = 0$ (p-value)	0.000	0.008	0.736	0.217

Notes: Standard errors in parentheses.

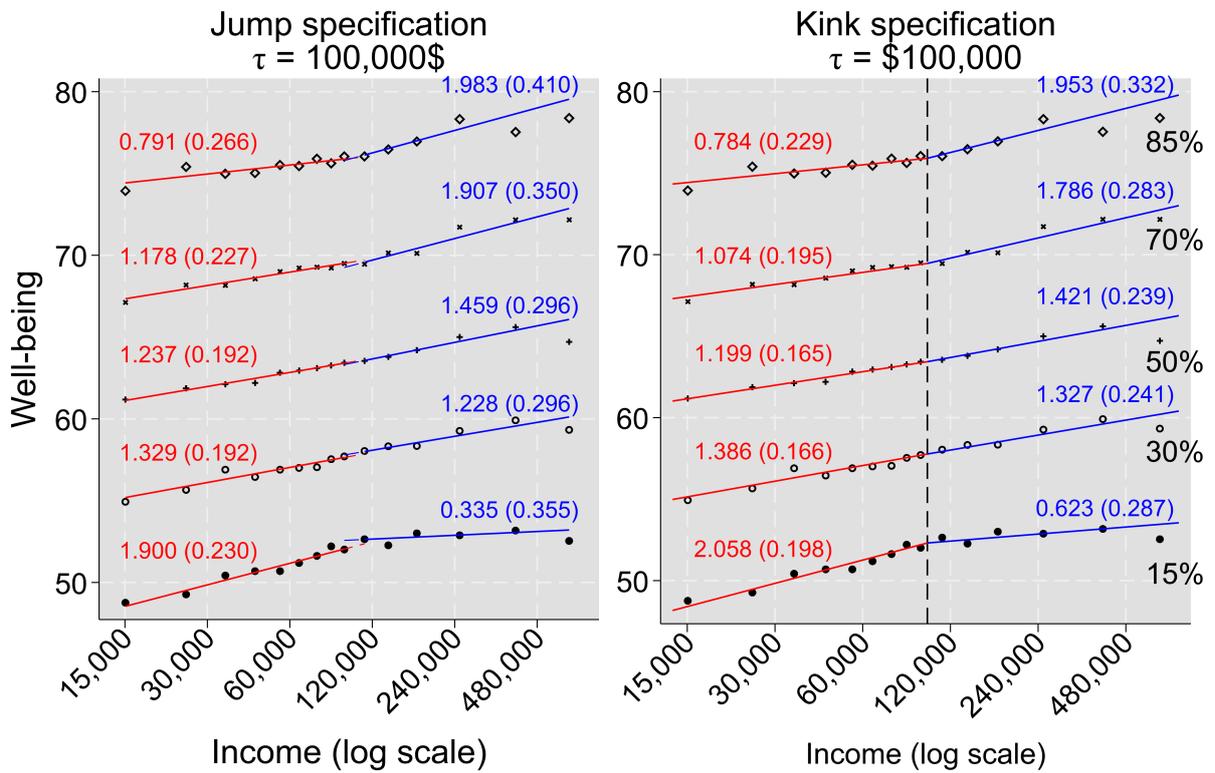
\*\*\*  $p < 0.01$ , \*\*  $p < 0.05$ , \*  $p < 0.1$ .

## B Additional Figures



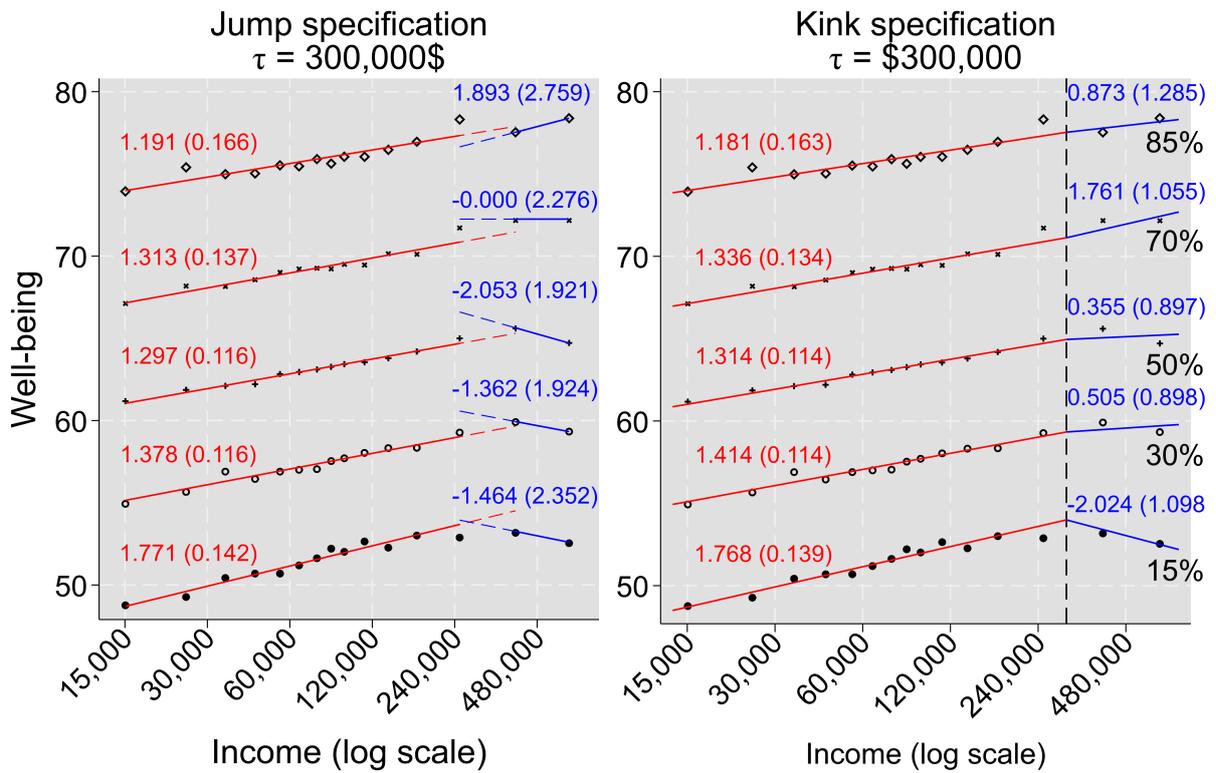
Note: The figure shows the best-fit lines (and their slopes) obtained from piecewise log-linear regressions. Black dots indicate sample averages of well-being levels within each income bracket. Standard errors in parentheses.

Figure A.1: Kink specification, other thresholds, OLS



Note: Quantile regressions for the 15th, 30th, 50th, 70th, and 85th percentiles. Black dots indicate sample quantiles of well-being levels within each income bracket. Standard errors in parentheses.

Figure A.2: Comparison jump vs. kink specification,  $\tau = \$100,000$ , quantile regression



Note: Quantile regressions for the 15th, 30th, 50th, 70th, and 85th percentiles. Black dots indicate sample quantiles of well-being levels within each income bracket. Standard errors in parentheses.

Figure A.3: Comparison jump vs. kink specification,  $\tau = \$300,000$ , quantile regression



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