Coherent Arbitrariness:

On Value Uncertainty for Environmental Goods

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Abstract

This paper investigates the role of coherent arbitrariness in non-market valuation. We examine whether people would rather state a range of values than a point estimate because they are unsure about the value they place on prospective changes in environmental goods. We focus on a parametric explanation of the determinants of this new type of "value gap"—the difference between the most someone is sure they would pay for an increase in an environmental good, and the smallest amount they are sure they would not pay. We also present a straightforward means of calculating aggregate willingness to pay from data on the range of willingness to pay expressed through a payment ladder.

Keywords: coherent arbitrariness; contingent valuation; uncertainty; quantile regression; coastal water quality.

I. Introduction

In their paper on *coherent arbitrariness*, Ariely et al. (2003, p. 77) state, but do not directly test, the proposition that ”rather than specific WTP [willingness to pay] values for products, consumers probably have some range of acceptable values.” The empirical validity of their presumption matters, especially for stated preference methods used in cost-benefit analyses of public goods. If such a range does exist, elicited statements of value in a contingent valuation survey, for instance, might arise arbitrarily from within an unknown range, triggered by uncontrolled cues or “anchors.” As Kahneman and Sugden (2005) note, an anchoring effect can arise when people are unsure of the true value they place on goods, or more worryingly, if stated preference methods measure attitudes rather than preferences. Moreover, even for private goods traded in real markets, evidence suggests that anchoring via ”incidental” information affects willingness to pay, implying an underlying uncertainty over the value of even common market-valued goods (Nunes and Boatwright, 2004).

This paper addresses three open questions: (i) do people actually prefer reporting a range of values rather than a specific value for a public good?, and if so, (ii) what affects the size of this range of values?; and (iii) how can we aggregate values which are stated as a range to estimate overall benefits? We design a valuation experiment that allows people to choose whether to report a single value or a range of values. Our results do not contradict the *coherent arbitrariness* notion—people invariably report a range rather than a specific value for the public good we consider, improvements in coastal water quality. Using a quantile regression approach, we find this value range is inversely related to the level of experience with the good, although this effect only kicks in once a certain minimal level of experience has been acquired. With regard to aggregation, we propose a method to measure mean willingness to pay from such interval responses.

II. Value uncertainty and stated preference methods.

The idea that people are uncertain over the value they place on private and public goods is not a new one, although *coherent arbitrariness* puts an appealing name to the general notion. Many possible reasons can explain such uncertainty. For instance, a person might believe the state of the environment is a random variable; he might also be uncertain about his future income; he might also be unfamiliar with the good in question (see for instance Crocker and Shogren, 1991). These factors could explain why he finds it difficult to state a single number as his valuation of a given change in public good supply. Such valuation uncertainty, however, maps into a point estimate of expected willingness-to-pay for an expected utility maximizer. Alternatively, the preference construction literature suggests that people construct their values in a context-specific way (Payne and Bettman, 1999), and for unfamiliar goods these constructed values might be easiest expressed as a range rather than a point – a bounded rationality argument for the existence of a value gap.

Consider recent attempts to address the valuation uncertainty issue. The stated preference literature has addressed the issue of value uncertainty in a number of different ways. Van Kooten et al. (2001) take a fuzzy number approach to the representation of the level of utility. Contrary to the usual assumption that people know their preferences for certain, they argue there is an "underlying vagueness of preferences" which, both theoretically and econometrically, can best be represented using fuzzy set theory, since this allows for uncertainty which cannot be resolved even with full information or experience. A related approach of explicitly adding a random variable in the utility function has been suggested by Svento (1993), Hanemann & Kriström (1995), Wang (1995), and Hanemann, Kriström and Li (2005).

Another interesting approach has been to use the idea of value uncertainty for a public good for which non-use benefits are thought to dominate total economic value to address the issue of hypothetical market bias. For example, Champ et al. (1997) asked questions about how certain respondents were concerning hypothetical donations to fund improvements in wilderness qualities in the Grand Canyon, and then related these responses to data on the relationship between actual and stated donations. They found respondents who were more certain about their donation had similar characteristics to those more likely to actually donate their stated amount if asked to do so. In a follow-up paper looking at donations for a green energy programme, Champ and Bishop (2001) found that using a question regarding how sure people were that they would donate the amount stated to filter responses allowed them to ”essentially eliminate hypothetical bias” in contingent donations for this public good (Champ and Bishop, page 384). A similar approach is reported in a provision-point mechanism context by Poe et al. (2002), although it is interesting that the desired effect on hypothetical market bias seems to be produced at a variable level of “payment certainty” (expressed on a 1-10 scale) across these three papers. Blumenschein et al. (1998) report comparable results comparing hypothetical and real payments for a private good, when a certainty of payment question is used to filter hypothetical responses. Notice, though, that this approach forces the researcher to make a judgment call about what respondents mean by varying degrees of stated payment uncertainty.

Ready, Navrud and Dubourg (2001) conditioned responses to both dichotomous choice and payment card designs for contingent valuation using statements concerning how sure respondents were about whether they would really pay the amount in question. Ready et al. found that the dichotomous choice design led to greater preference uncertainty, measured in this way, than the payment card design. An extension of this approach is given in Alberini et al. (2003) who build on the Welsh and Poe (1998) discrete choice approach, with multiple bids that allow respondents to express valuation uncertainty. A matrix was displayed to the respondent with suggested costs on the rows and categories of certainty of whether respondents would pay this cost in exchange for a public good in the columns. Alberini et al. observed that allowing for preference uncertainty increases welfare estimates for given environmental changes, the opposite result reported by Li and Mattsson (1995). But the difficulty with this "polychotomous choice" method to the representation of value uncertainty is that researcher must interpret how different respondents *think* about concepts such as " very uncertain", "not unlikely" and so on[1]. Alberini et al, for example, effectively assume all respondents interpret these concepts in the *same way*. This criticism also applies to those papers noted above where researchers use responses to uncertainty questions to re-classify WTP statements. But this homogeneity value uncertainty restriction is a strong assumption that is challenging to test directly.

We now describe an alternative approach, which avoids this problem, and allows us to explore why differences in value uncertainty exist across individuals. Our working hypothesis for this paper is that a person is uncertain about his preferences and finds it computationally costly to state a single number. Moreover, this uncertainty is reduced when a person has more experience with the good—the "value gap" might be inversely related to an empirical measure of experience with the

[1] Also see the results in Vossler and McKee (2006), who found formats designed to reveal value uncertainty seem to encourage people to over-state their true value uncertainty.

good. A parallel can be drawn with research which has found that differences between willingness to pay and willingness to accept compensation measures decline as experience in trading increases (e.g., Shogren et al., 1994).

III. Experimental design

Our experiment tests whether people prefer revealing a specific value or a range of values for a specific environmental public good by creating a two-way "payment ladder" (Figure 1 illustrates). Starting with the smallest value, each respondent considers each value in turn, ticking amounts they would definitely pay, crossing off amounts they would definitely not pay, and leaving blank those they cannot say either "definitely yes" or "definitely no" to. This format avoids the researcher having to interpret terms such as "possibly" and "probably". A person's WTP then is at least as great as the highest ticked value but is less than lowest crossed value. The uncertainty range over values for an individual is given by the gap between these highest and lowest amounts. Payment ladders have been used previously in the stated preference literature (Jones-Lee, Loomes and Philips, 1995; Maddison and Mourato, 2002), but not to explore the determinants of value uncertainty.

The environmental public good used in this experiment is coastal water quality in one area of Scotland. We examine uncertainty over the value of changes in this public good using an in-house valuation survey of nearly 800 local residents in two coastal towns, Ayr and Irvine, in South-West Scotland. These two towns are the major population centres within easy reach of this most polluted stretch of coastline in Scotland. People in the Ayr sample valued improved water quality at Ayr beach, people in the Irvine sample valued water quality at Irvine beach. Focus groups and a pilot study were used to develop the survey instrument. People are asked to value improved water quality, which has been problematic due to bacteriological contamination measured by faecal coliform counts. All seven major bathing beaches along the coast have failed the Bathing Waters Directive mandatory and guideline standards on frequent occasions over the last 10 years. Under the existing Bathing Waters Directive, responsible authorities must take action to bring water quality up to mandatory standards for total and faecal coliforms, whilst further improvements are likely to be required under the EU Water Framework Directive. The survey instrument explained how water quality could only be improved at a cost (increases in local water rates to pay for improved sewage treatment), then elicited respondents' willingness to pay for a certain improvement of water quality using the payment ladder described above. We employed a market research firm to collect the stated preference data. Data was collected on respondent's rating of local water quality, the number of trips they made to the beach per year, how long they had lived in the area, and socio-economic information. The final sample contained 351 and 432 useable responses from Ayr and Irvine. A copy of the questionnaire is available on request.

IV. Results

Our first research question was: do people actually prefer reporting a range of values rather than a specific value for a public good? Yes, we find people prefer providing a value range: our results support the idea that people have a range of acceptable values as presumed by Ariely et al. (2003). Table 1 presents the data generated by the payment ladder question. We see, for example, that 28 respondents have a LOWER value of £2 and an UPPER value of £7.5. We include cases when *UPPER* is greater than zero and the lower bound (*LOWER*) is zero. Such cases, in which the respondent simultaneously seems to be ”in the market” and out of it are not easily interpreted in a standard economic model. However, if the valuation is somewhere in the interval [0, UPPER], it is positive with some probability, which is sufficient for our goals.

Only 2 people (out of 498 respondents "in the market") revealed a specific value for improved water quality. Some 496 respondents reported their willingness to pay as a range. Data strongly support the notion that people do not want to pin down just exactly how much they want to pay for the improvement in local water quality, although we note that the format of our valuation question likely encourages people to report WTP as a range, rather than as a single point (Vossler and McKee, 2006).

Our second question was: what determines the size of this value range, or uncertainty gap? We begin by examining responses using a plot of all the data to be used in the regression analysis, as shown in Figure 2. We include those variables which we speculate, *a priori*, might have a possible impact on the value gap. As noted in Section 2, a key variable is expected to be experience of the good in question, which we approximate by the number of years a respondent has lived at the site (*YEARS*). We expect that the value gap shrinks with repeated exposure (greater familiarity) with the environmental good. Consumption of the good is further indicated by the number of trips the respondent takes to the beach each year (*TRIPS*), since consumption is another way to gain experience. Household income (*HHINCOME*) is included since a higher income allows a larger range to be stated. Furthermore, the literature on valuing public goods strongly suggests that income is positively correlated with environmental quality improvements. Because there are known quality differences (other than water quality) between the two beaches, a dummy (*LOCATION*) was included to explore this. Finally, we control for the amount of energy the respondent allegedly wanted to invest in reporting his valuation by including their assessment of the interest in the interview (*INTEREST*).

We *exclude* from Figure 1 those who explicitly were uninterested in the good, defining that subpopulation as those with an upper bound (*UPPER*) willingness-to-pay equal to zero. Furthermore, we also exclude outliers.[2]

Defining *Range* as [*UPPER-LOWER*], the top square of the matrix gives the histogram of Range. The remaining boxes in the diagonal provide histograms for the explanatory variables in our regression model. Several of the distributions are skewed, including income. The off-diagonal boxes have pair-wise plots of the corresponding variables along the diagonal. In addition, we have added two lines to visualize bivariate relationships; a dotted bivariate regression line and a lowness smoother (with the so-called smoother span set at 0.5).

We are interested in the variables that signal experience with the environmental good. These variables are *YEARS* and *TRIPS*. The bivariate plots of these variables against *Range* indicate negative and positive correlations, which is what we expect, given the way these variables are coded. First, the longer one lives at the site, the more certain one is about one's valuation of the prospective improvement in the public good. Second, fewer trips (represented by a *higher* value on the variable *TRIPS*), are positively correlated with a greater value of *Range*.

We now submit these preliminary findings to more formal testing. For reasons explained below, we use ordinary and quantile regressions for this purpose. Table 2 displays the regression results for the OLS model, in which the dependent variable is *Range*[3]. This suggests that household income (*HHINCOME*) and lack of experience as measured by number of trips (*TRIPS*) and the number of years the respondent has lived at the site (*YEARS*), lengthen the value interval, and increases our measure of

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[2] An outlier is defined here as a case when the valuation range is greater than £26 (true for less than 2 % of the individual responses in the sample). This ad-hoc definition of an outlier is used to produce figures that are more easily readable. We stress that including the outliers in the analysis does not change our major conclusions.

[3] We have also used robust regression approaches, and the results are similar to OLS.

value uncertainty. This confirms the visual impression given by Figure 2. The elasticity of YEARS, calculated at the means, is -0.16. A one-percent increase in YEARS decreases the Range by 0.16 percent[4]. Un-observed site characteristics measured by the site dummy *LOCATION* also significantly increases the uncertainty gap, with respondents living in Ayr being less certain about their Willingness to Pay than those living in Irvine. Finally, the extent to which the individuals find the interview "interesting" (*INTEREST*) has a positive impact on the range. The more interesting a person finds the interview, the larger the valuation gap. If degree of interest is positively related to how much mental effort one puts into responding to the valuation question, this suggests effort affects stated value uncertainty.

As noted, experience with an environmental good should affect the length of the valuation interval. We explore a regression model that consists only of the experience variables YEARS and TRIPS (called the *shorter* model). First, the coefficients are similar across specifications [(-0.04, -0.03) and (0.27, 0.27) for YEARS and TRIPS, in the longer/shorter model]. Second, the adjusted R-square drops from 9% to 1%. Third, heteroskedasticity adjusted t-values drop, in absolute value terms, from 2.58 to 2.14 for the YEARS variable in the shorter model. Interestingly, the same type of t-statistic for the TRIPS variable is 1.58 and 1.60 for the long/short model. In sum, the experience variables seem relatively robust across specifications, in the simple linear regression framework. We now extend our ordinary regression using quantile regression to explore in more detail heterogeneities in the data.

Quantile regression (Koekner and Bassett, 1978; Koekner and Hallock, 2001) is a useful complement to the standard regression analysis, because it allows an analysis of other points of the conditional distribution of interest. Standard regression

[4] Because HHINCOME and TRIPS are categorical variables, we have not calculated the elasticities.

analysis provides the conditional mean function, while quantile regression elicits, inter alia, the median regression estimator obtained by minimizing a sum of absolute errors. One can also obtain other conditional quantile functions by minimizing an asymmetrically weighted sum of absolute errors. Quantile regression allows insights that can easily be overlooked by using ordinary regression. For instance, Chamberlain (1994) estimates a union wage premium of 28 percent at the first decile of income, whilst the premium is small at the top deciles; the OLS estimate of the mean union wage premium is 15.8 percent. Consequently, it would be misleading to say that the wage premium typically increases with income; rather, unions affect wages at the lower deciles of the distribution. Born, Viscusi, and Baker (2006) examine tort reform using quantile regression, and find that the greatest effects are for firms at the high end of the loss distribution. As we will see, quantile regression applied to our data unmasks heterogeneities in the data.

In Figure 3, we display the result of a comprehensive quantile regression analysis, in which the quantiles vary from 0.02 to 0.98. All analysis has been undertaken using the statistical package R, available for free at r-project.org. The plots show the coefficients for each variable. Beginning with income (HHINCOME), we see a positive effect exists on Range across the income distribution. The value gap also seems to be influenced by the number of years living at the site (YEARS). The effect is more pronounced as time passes by. The regression coefficient on the other experience variable (TRIPS), was positive (and significant at the 85% level). The quantile regression picks up some of the heterogeneity, showing that Range increases with the infrequency of trips. Inspection of raw data shows that the mean of Range is highest for those who "rarely" go to the beach. At the same time, raw data shows that the median Range is lower for those who "rarely" go to the beach, compared to those who go to the beach "at least once a week". Consequently, some of the results are driven by a number of "very uncertain" respondents who rarely visit the beach. Before carrying this too far, we must caution that the confidence band is rather wide, as seen in Figure 3. The coefficient for the INTEREST variable is negative throughout, which here means that the less interest the respondent has shown in the interview, the smaller is Range. The quantile regression supported the results we obtain with the ordinary regression.

In sum, the answer to our second question "what determines the uncertainty gap?" is: increasing experience with the good, higher income, and how much mental effort one puts into responding to the valuation question.

V. Aggregating the benefits of water quality improvements

Our third question concerns the aggregation of uncertain willingness to pay values for the purposes of cost-benefit analysis. Since estimating the mean of the benefits of the improvement in the public good in our experiment is contingent on our interpretation of the respondents' answers, it is useful to recall exactly how the valuation question was phrased (see Figure 1):

> *Ask people if they would definitely pay £ 1 per year extra for improving water quality. If "yes", tick the first cell in column A, then ask if they would definitely pay £ 2. Keep going until the respondent says "no". Then ask them if they are sure £125 is too much for them. If yes, place a cross in the lowest cell of column B, and ask them if £ 104 is too much. Keep going up column B until they say that they are not sure if £ x is too much.*

Responses collected from this instruction have the following interpretation: with probability 1, a respondent is willing to pay the highest amount he accepted (*U*). With probability zero, he will pay lowest amount of those he said he would definitely not pay (*L*). Between *L* and *U* there is a probability between zero and one that the individual would actually be willing to pay a particular amount in that range. We have no information about the probability distribution of this range, but it seems plausible to assume that it is linear, given that the amounts are a small fraction of household income.

Let f(WTP) be the density function of the random variable WTP. If f(WTP) is linear, we can write the expected value of WTP as

$$E(WTP) \equiv \int_L^U wtp*f(wtp)dwtp = \frac{2}{3}*L + \frac{1}{3}*U \qquad (1)$$

Table 2 shows the calculations of the linear index for expected WTP given by (1), and compares this with a simple mid-point estimate, given by {1/2**L*+1/2**U*}. Our proposed estimate in (1) puts a higher weight on the lower bound compared to the mid-point estimate; as the price rises, the probability that people would be willing to pay it is assumed to fall linearly over the range of uncertainty. If we include the means of *L* and *U* values, one obtains a richer picture of sample values than is provided by the usual analysis. One could argue a conservative estimate of benefits to the sample is the mean of *L*, and an upper-bound estimate of benefits is the mean of *U*. Based on 112,000 households living in the area affected by the environmental improvement and the linear WTP index value for expected WTP, this implies an aggregate benefit of just under £1million per annum, once one allows for respondents with a zero willingness to pay. Basing the benefit aggregation on either the lower or upper bound instead implies benefits of £768,000 to £1.35 million.

6. Concluding remarks

We find strong evidence to support the key presumption underlying coherent arbitrariness – respondents did not reveal a single estimate of value, but rather provided a range of acceptable values, as posited by Ariely et al. (2003). We were also able to investigate, using the payment ladder approach, what determines this uncertainty range for individuals. This is the main contribution of this paper to the literature. Two measures of experience with the good in question - how long one has lived in the area, and how many trips one makes to the beach – turn out to influence the size of the uncertainty gap, along with income. This finding supports Plott's (1996) idea that experience is one aspect which influences the speed at which one can "discover" one's preferences in an internal search process. There are intriguing similarities with the effect of increased experience on the WTP/WTA gap. The magnitude of an anchoring effect, in the Ariely et al. sense, could be related to the magnitude of the uncertainty gap is for each person, or for the sample as a whole (Simonson and Drolet, 2004), although we cannot test this idea with our data. The extent of an anchoring effect might also depend on whether willingness to pay or willingness to accept compensation measures of value are being measured.

Samuelson (2005) argues that experimental economics is good at identifying situations in which economic theory does not predict well, and at suggesting ways in which theory can be improved. In a similar vein, we find that theory based on value certainty does not seem to describe values for this public good. Our work also suggests that thinking about the *determinants* of this value range would be a useful exercise, both in theory and practice. If further experiments confirm the idea that people prefer to state a range of values rather than a point, future theoretical research should embed such findings in a complete welfare theoretical set-up, which can then be tested empirically. Another potentially useful exercise would be to examine value uncertainty from the perspective of neuroeconomics, in terms of what triggers the size of the gap in a given context, and what learning process can we employ to narrow the uncertainty of values for public, environmental goods (see e.g., Camerer et al., 2004). For example, this might help us better understand why thresholds of experience exist – as we found in our data – and what determines these threshold values.

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Table 1. Responses generated by the payment-ladder. Upper bound = top row, Lower bound = first column.

	2	**3**	**5**	**7.5**	**10**	**13**	**15**	**20**	**26**	**34**	**40**	**52**	**60**	**65**	**70**	**125**
0	0	0	0	3	1	1	0	1	0	0	0	0	0	0	0	3
1	31	1	2	3	2	0	0	0	0	0	0	0	0	0	0	0
2	0	29	2	28	8	3	0	0	0	0	0	0	0	0	0	0
3	0	1	15	2	6	6	1	0	0	0	0	0	0	0	0	0
5	0	0	0	49	9	23	10	7	1	0	0	0	0	0	0	0
7.5	0	0	0	0	20	3	2	5	0	0	0	0	0	0	0	0
10	0	0	0	0	0	41	7	15	2	2	0	1	0	0	0	0
13	0	0	0	0	0	0	3	0	0	2	0	0	0	0	0	0
15	0	0	0	0	0	0	0	27	4	8	10	2	0	0	0	0
20	0	0	0	0	0	0	0	0	20	4	8	4	0	0	0	0
26	0	0	0	0	0	0	0	0	1	11	1	5	0	1	1	0
34	0	0	0	0	0	0	0	0	0	0	11	1	1	0	0	0
40	0	0	0	0	0	0	0	0	0	0	0	17	2	2	2	0
52	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0
60	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
104	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1

Table 2. OLS regression of *Range*

	Estimate	Std. Error	t value	Pr(> |t|)	White's t
(Intercept)	3.6793	1.8693	1.97	0.0497	1.97
hhincome	0.4534	0.2366	1.92	0.0560	2.00
years	-0.0405	0.0143	-2.83	0.0049	-2.58
trips	0.2714	0.1844	1.47	0.1419	1.58
interest	-1.1933	0.5193	-2.30	0.0221	-2.21
location	3.0296	0.6078	4.98	0.0000	5.03

Residual standard error: 5.5 on 424 degrees of freedom
Multiple R-Squared: 0.09971, Adjusted R-squared: 0.08909
F-statistic: 9.391 on 5 and 424 DF, p-value: 1.677e-08

Table 3: Expected willingness to pay figures, £ sterling per household per year.

Calculated over:	N	Based on *L*(Lower) values	Linear index	Midpoint index	Based on *U*(Upper) values
		Expected WTP values per household:			
Only those with positive WTP	498	10.78 (11.48)	13.53 (18.07)	14.91 (12.90)	19.02 (13.97)
All respondents	783	6.86 (10.52)	8.61 (17.07)	9.48 (12.18)	12.10 (13.25)

Figure 1: payment ladder

£ per annum increase	A: I would definitely pay per year (tick)	B: I would definitely NOT pay per year (cross)
1		
2		
3		
5		
7.5		
10		
13		
15		
20		
26		
34		
40		
52		
60		
65		
70		
93		
104		
125		

Instructions to interviewers:

"Ask people if they would definitely pay £1 per year extra for improving water quality. If yes, tick the first cell in column A, then ask if they would definitely pay £2. Keep going until the respondent says "no". Then ask them if they are sure £125 is too much for them. If yes, place a cross in the lowest cell of column B, and ask them if £104 is too much. Keep going up column B until they say that they are not sure if £x is too much."

Figure 2 Data used in the study. The histograms are displayed along the diagonal for each variable. The off-diagonals are the corresponding bivariate plots, that include lines indicating linear regression (bi-variate) line and a non-parametric smoothing line (a lowess smoother) indicating possibly non-linear bivariate relationship.

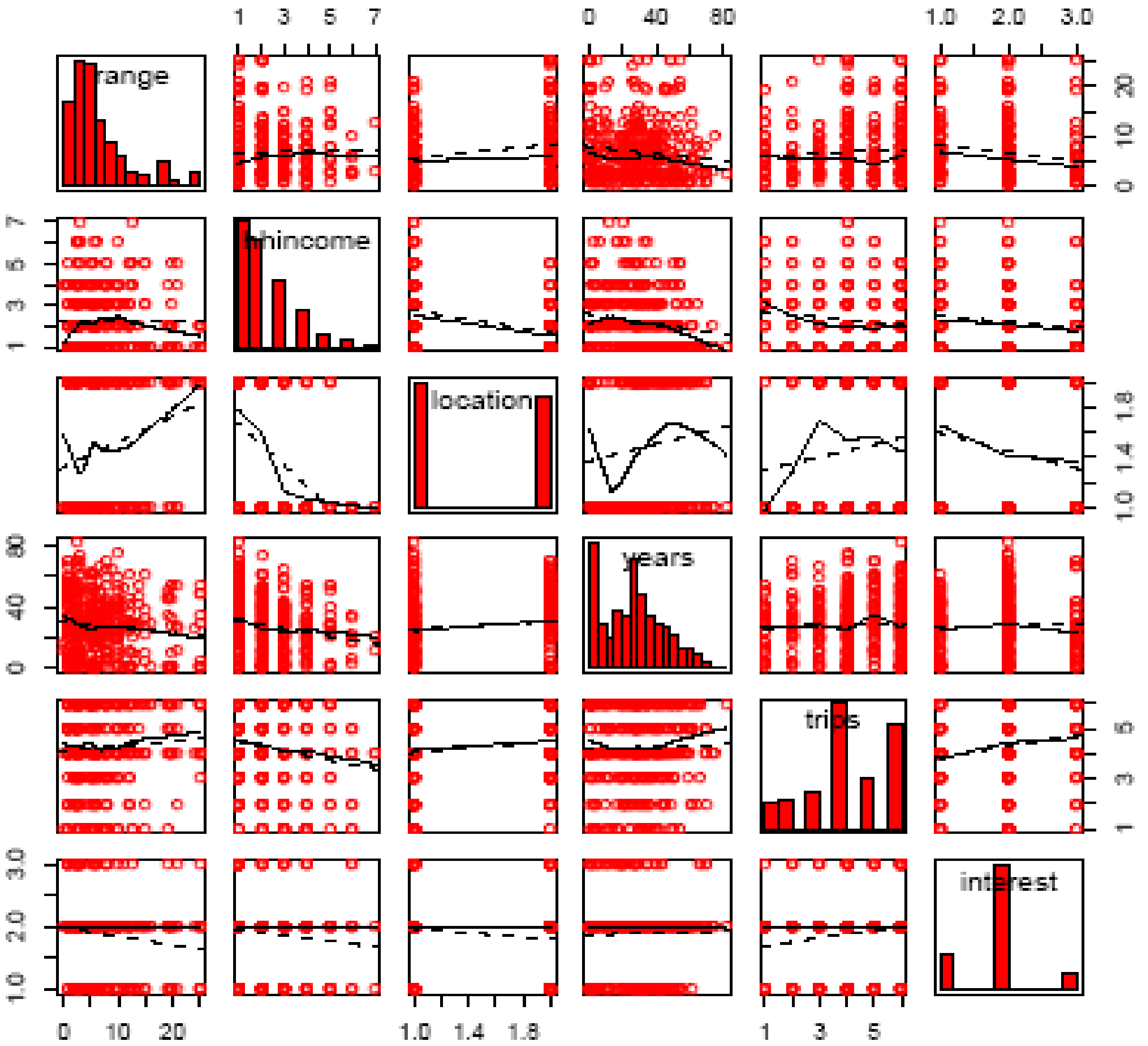

Figure 3. Quantile regression plot, with confidence bands for each parameter. The quantiles vary from 0.02 to 0.98. The computations are described in Koencker & Hallock (2001). The routine is implemented in R in the library quantreg.