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# Measuring uncertainty based on rounding: New method and application to inflation expectations

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ABSTRACT

The literature on cognition and communication documents that people use round numbers to convey uncertainty. This paper introduces a method of quantifying the uncertainty associated with round responses in pre-existing survey data. I construct micro-level and time series measures of inflation uncertainty since 1978. Inflation uncertainty is countercyclical and correlated with inflation disagreement, volatility, and the Economic Policy Uncertainty index. Inflation uncertainty is lowest among high-income consumers, college graduates, males, and stock market investors. More uncertain consumers are more reluctant to spend on durables, cars, and homes. Round responses are common on many surveys, suggesting numerous applications of this method.



## 1. Introduction

The Great Recession has drawn increased attention to the potentially harmful consequences of heightened uncertainty, prompting new measurement efforts. Surveys that elicit respondents' probabilistic expectations provide the most direct measure of uncertainty, but are relatively uncommon, as most surveys simply ask for point forecasts. Thus, most empirical research relies on time series uncertainty proxies that lack a micro-level dimension. This paper posits that surveys asking for point predictions can convey some indication of individual respondents' uncertainty. Researchers in cognition, linguistics, and communication note that the use of a round number often signals more uncertainty than the use of a non-round number. Krifka (2009) names this observation the *Round numbers suggest round interpretations (RNRI)* principle. Building on this principle, I develop a novel method of exploiting rounding behavior to construct micro-level uncertainty measures.

The association between rounding and uncertainty may vary over time and across contexts. The new methodology is flexible and based on the assumption that agents that are sufficiently uncertain about their forecast choose from a set of round numbers when responding to the survey; call these "type *h*," for high uncertainty. Less uncertain agents ("type *l*") choose from a larger set of possible responses. Responses in a given month come from a mixture of two distributions: one

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distribution of type-*h* responses with support on round numbers, and another of type-*l* responses with support on both round and non-round numbers. The mixture weight is the fraction of type-*h* consumers. For each survey date, maximum likelihood estimates of the parameters of each distribution and the mixture weight can be used to compute the *probability* that a consumer is type *h* given her response and the survey date. This probability is a proxy for her uncertainty, and estimates of the share of type-*h* agents at time *t* provide an uncertainty index.

This new method of measuring uncertainty has several major benefits. It provides a measure with a micro-level dimension, allowing cross-sectional and panel analyses that are impossible with many other uncertainty measures. Newer surveys that collect density forecasts do provide micro-level uncertainty measures, but it may be time consuming or mentally taxing for subjects to report their subjective probability distribution. The new method does not rely on assumptions about expectations *formation*, only about expectations *reporting*, and thus can be used to test and develop models of expectations formation. The method can be applied to *pre-existing* datasets containing point estimates or forecasts, allowing analysis of uncertainty even for time periods and variables for which we lack probabilistic survey data. The method is flexible enough to be used for many different types of survey data with prevalent round responses, such as surveys of health, time and energy use, and income and gas price expectations.

I use inflation expectations data as a proof-of-concept, since inflation uncertainty is of long-standing interest to economists and policymakers. A large share of respondents to the Michigan Survey of Consumers (MSC) and the Federal Reserve Bank of New York Survey of Consumer Expectations (SCE) report inflation forecasts that are a multiple of five. Since SCE respondents also provide density forecasts for inflation, I use the SCE data to validate that multiple-of-five point forecasts are indeed associated with larger density forecast interquartile ranges, and that the uncertainty measure constructed by my methodology is a stronger proxy for uncertainty than is a simple dummy variable indicating a multiple-of-five point forecast. Following this validation test, I construct micro-level and time series inflation uncertainty measures using the MSC data, which is available for a much longer time sample.

The inflation uncertainty index constructed from MSC data is countercyclical and was especially high in the early 1980s recession and the Great Recession. It is also high when inflation is either very high or very low. The inflation uncertainty index is positively correlated with alternative time-series proxies for uncertainty, including the Economic Policy Uncertainty index and, most strongly, with the Jurado et al. (2015) macro uncertainty index. It is positively correlated with inflation disagreement, but the correlation weakens after the Volcker disinflation. Inflation uncertainty varies more in the cross-section than over time and displays expected demographic patterns, with lower uncertainty for more educated and higher-income consumers, males, and people with investments in the stock market. More uncertain consumers also make larger forecast errors and revisions, and uncertainty is persistent at the individual level. Similar properties are exhibited by the SCE density forecast-based inflation uncertainty measure, providing further support for the validity of the rounding-based uncertainty proxy.

The new micro-level inflation uncertainty measure allows closer study of the link between uncertainty and reported behavior. Bachmann et al. (2015) find that MSC respondents with higher inflation expectations report less favorable attitudes toward spending on cars, homes, and other durable goods. Including the rounding-based uncertainty measure in similar regressions shows that more uncertain consumers also express less favorable spending attitudes, and the coefficient on expected inflation remains small and negative.

The paper is organized as follows. Section 2 discusses the association between round numbers and uncertainty. Section 3 details the methodology for constructing a micro-level measure of uncertainty. Section 4 applies this methodology to inflation expectations data, provides support its validity, and describes properties of the uncertainty measures. Section 5 explores the link between inflation uncertainty and consumption of cars, homes, and other durables. Section 6 describes other applications of the inflation uncertainty measure and of the method of estimating uncertainty based on rounding and concludes.

## 2. Round numbers and the expression of uncertainty

The method of measuring uncertainty introduced in this paper exploits a well-documented association between round numbers and uncertainty. Round numbers play a prominent role in communication and cognition (Albers and Albers, 1983). According to communication and linguistic theory, round numbers—typically multiples of five or of a power of ten, depending on context— are frequently used to convey that a quantitative expression should be interpreted as imprecise (Dehaene and Mehler, 1992; Jansen and Pollmann, 2001; Sigurd, 1988). This is known as the *Round Numbers Suggest Round Interpretation* (RNRI) principle, and is quite intuitive (Krifka, 2009). If a headline reports that 500 people attended a rally, this is interpreted as some number in the vicinity of 500. If the headline reports that 497 attended, this is interpreted as exactly 497. Likewise, someone who says she weighs 150 pounds may just have a rough idea; if she says 151 pounds, she has probably stepped on a scale recently. Indeed, self-reported body weight is less accurate for adults who report round numbers than for those who do not (Rowland, 1990). Experimental studies asking subjects to report quantitative estimates confirm that round responses are associated with imprecise estimates (Baird et al., 1970; Selten, 2002). Huttenlocher et al. (1990) find that, when asked to estimate the days elapsed since an event occurred, subjects have a tendency to report round numbers, especially for events remembered with less precision.

In the finance literature, Harris (1991) finds that stock traders' bids and offers are clustered at round numbers, especially when market volatility is high. Similarly, Zhao et al. (2012) find that cognitive limitations lead to limit order clustering