# FREQUENCY BIAS IN CONSUMERS' PERCEPTIONS OF INFLATION: AN EXPERIMENTAL STUDY $^{\dagger}$

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ABSTRACT. We investigate whether the perception of economy-wide inflation is affected by the frequency with which various goods' prices are observed. We provide novel experimental evidence that consumers' perceptions of aggregate inflation are systematically biased toward the perceived inflation rates of the frequentlypurchased items. This 'frequency bias' may affect consumers' consumption and investment decisions, and thus have important macroeconomic consequences. It may also explain why consumers typically over-estimate inflation in surveys during periods where frequently-purchased non-durable goods are inflating faster than durables.

**Key words**: Inflation perceptions; biases; laboratory experiment **JEL classification codes:** C91; E31; C82.

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## I INTRODUCTION

Macroeconomic phenomena emerge out of the decisions of individual decision makers. Individuals contemplating decisions in dynamic settings need to form beliefs about the current state of key economic variables and their evolution. The decision makers' perceptions of contemporaneous economic variables often have a bigger impact on final macroeconomic outcomes than the actual values of these variables. Situations with multiple equilibria provide well known, albeit striking examples. In a bank run, for example, the depositors' perceptions of a bank's creditworthiness determine the final outcome, not the actual creditworthiness of the bank. An authority wishing to guarantee financial stability has to control perceptions as much as actual economic variables.

Similarly, the efficacy of monetary policy typically depends more heavily on the anticipated inflation than on the actual realized inflation rate (Bernanke, 2007). To form expectations about future inflation, consumers often rely on *perceptions* about past price changes.<sup>1</sup> If those inflation perceptions and resulting expectations are systematically biased, so will be consumers' intertemporal decisions and responses to macroeconomic policies. The price inflation example illustrates the importance of understanding how economic agents perceive changes in economic variables, and uncovering any systematic mistakes they may exhibit in forming beliefs about the variables' evolution in the future.

The observation that people misperceive economic variables has been known at least as early as the early twentieth century.<sup>2</sup> The advent of normative game theory and the ubiquitous usage of perfect rationality assumptions led to the relative neglect of misperception issues. Interest in how the lay public views economic variables was revived in the 1980s, as researchers began testing the rational expectations hypothesis (e.g. Revankar, 1980; Lovell, 1986). To date, research has focused almost exclusively on the macroeconomic dimensions of expectations and not on individuals' perceptions and the associated behavioral implications. However, a behavioral analysis of the impact of biases on perceptions may help in understanding how policy makers can deal with both biased perceptions and expectations.

In this paper we conduct an experimental and behavioral analysis of misperceptions and biases in how humans perceive the evolution of variables over time. We focus on

<sup>&</sup>lt;sup>1</sup>Fluch and Stix (2005) provide evidence that inflation expectations grow with inflation perceptions. In fact, economists have used the past (weighted) inflation rates to approximate the expected rate, implicitly assuming that agents correctly perceive past inflation rates and then use those perceptions to form their expectations.

<sup>&</sup>lt;sup>2</sup>Keynes used the term 'money illusion' to describe workers misperceiving their real wage to be equal to their nominal wage. The term was coined by Irving Fisher, who later wrote a homonymous book (Fisher, 1928).

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the case of inflation, as both an interesting one in its own right and as representative of other cases of biased perceptions.<sup>3</sup> The argument is based on rigorous experimental evidence and fits with previous survey evidence. Jonung (1981) presents one of the first attempts to systematically document and explain misperceptions in the evolution of prices over time. He finds that women's perceptions are more biased than men's and attributes this to their more frequent retail shopping experiences and high food inflation at the time.<sup>4</sup> Jonung and Laidler (1988) show that perceptions are in general not rational. In general, average perceptions of inflation are too high, and perceptions tend to be higher for young people, women, unmarried individuals, minorities, and lower-income individuals. These demographic patterns have been documented in the U.S. (Bryan and Venkatu, 2001b), England (Blanchflower and MacCoille, 2009), Ireland (Duffy and Lunn, 2009) and New Zealand (Leung, 2009).

Without the control of all relevant variables that the laboratory affords, it is difficult to provide anything more than suggestive evidence about the existence and the type of biases. For example, many demographic variables are highly correlated so that causality is difficult to infer. Furthermore, information sets are difficult or impossible to measure and cannot be controlled.<sup>5</sup> Perceptions of inflation may also appear biased because the current representative basket of goods used to calculate official inflation estimates may not accurately represent the true purchases of many consumers in the economy. Consumers may substitute between goods, shifting the true basket composition away from the basket used by the statistical agency, or the quality of goods may change over time, affecting perceptions of inflation. There may be a disconnect between survey responses and the actual expectations used to make economic decisions (Mishkin, 1981), and survey subjects may have little incentive to make an accurate forecast. It is often difficult to disentangle these possible explanations. All of these factors can be controlled in a laboratory experiment, making inference much cleaner.

We study price-change perceptions in a specially-designed, contextually-framed laboratory experiment. The framing we use is that of a simulated shopping experience, where subjects have to choose among a variety of goods with potentially different rates

<sup>&</sup>lt;sup>3</sup>We do not contest the value of doing rationality-based theory. We do, however, argue that it cannot always be assumed that people perceive economically relevant variables correctly.

<sup>&</sup>lt;sup>4</sup>In a recent survey of Ohio consumers, Bryan and Venkatu (2001a) also find that women perceive higher rates of recent-past inflation than men do, even controlling for age, socioeconomic and educational differences.

<sup>&</sup>lt;sup>5</sup>To illustrate, consider the long literature testing the rational expectations hypothesis using survey data. Most studies generally reject the claim that expectations are rational (see Figlewski and Wachtel, 1981, e.g.), but such inquiries are ultimately inconclusive because nearly any expectation can be rationalized by some unobservable beliefs about unrealized events.

of inflation.<sup>6</sup> Therefore, information sets are both observed and manipulated. Resulting beliefs can be elicited in an incentive-compatible way. The basket of purchased goods is chosen by the experimenter in advance and perfectly observed. Quality of goods can be abstracted away. Accurately measuring biases is entirely feasible with this level of control and measurement.

When calculating economy-wide inflation rates, well calibrated individuals should weigh each individual good's inflation rate by the percentage of total expenditures on that good. Subjects in our experiment are given this information and should have no uncertainty about how individual inflation rates are aggregated. Regardless, subjects tend to overweight price changes of frequently-purchased goods when estimating economywide inflation rates. We refer to this phenomenon as the *frequency bias* in inflation perceptions. The existence of this bias in a controlled laboratory setting suggests that it may be a fundamental attribute of how individuals aggregate various price changes.

Linking it to real life experience, our experimental evidence implies that if the frequency of purchase is not perfectly correlated with the proportion of expenditure, the perception of the aggregate inflation is likely to be systematically biased. Items such as "food at home" and "gasoline" are frequently purchased and are the most visible and best publicized components of the CPI, but constitute only 8.9% and 3.7% of total aggregate expenditures, respectively.<sup>7</sup> Our findings suggest that consumers' perceptions of overall inflation are biased toward the inflation rates of high-frequency goods like gasoline and food. In fact, for this reason, macroeconomic policy makers often stress the importance of food prices "in determining the wage demands of labor and the inflationary expectations of all consumers" (p.34, 1976 *Economic Report of the President*).

Note that the frequency bias is a bias of *aggregation across goods*. It neither claims nor requires that perceptions of individual-good inflation rates be accurate. It is not caused by individuals remembering only the prices of more-frequently purchased goods and forgetting the prices of large, infrequent purchases. It only describes cognitive errors in aggregating the perceived individual-good rates to form a perception of the economy-wide inflation rate. It is the overall inflation rate, however, that individuals must use when making financial investment and savings decisions, and so the bias will manifest in distorted allocations of financial assets.

<sup>&</sup>lt;sup>6</sup>While the shopping framing seemed to be the most appropriate one for subjects to readily understand, we do not think it unduly affects behavior. Results should generalize to any setup where a set of objects exists with differing inflation rates; e.g. different assets in a financial market.

<sup>&</sup>lt;sup>7</sup>Expenditure shares are based on the average weight over 1980-2010 from the U.S. Bureau of Labor Statistics.

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Our experimental data clearly show that subjects also make errors in estimating individual-good rates. Specifically, the perceived individual-good rates are too highly correlated, relative to true rates. Since our experimental treatments assign more extreme inflation rates to the more frequently-purchased goods, the estimates for those goods contain the most error. This result refutes the claim that the frequency bias is simply a bias in memory; the most frequently-encountered goods are the ones for which subjects' inflation estimates are the most erroneous. The observed *correlation bias* in individual-good inflation rates is discussed briefly in Section III.

**Related Literature** Our paper is related to a number of works in the literature of inflation expectation/perception formation. To our knowledge, however, this is the first experimental study that directly investigates behavioral biases in the perception of past inflation. A handful of experimental studies have investigated how expectations of future individual prices are affected by past prices (e.g. Schmalensee, 1976; Garner, 1982; Camerer, 1992; Hey, 1994); in these contexts, the rational expectations hypothesis is generally rejected in favor of adaptive expectations models. More recently, Adam (2007) studies forecasts of future inflation rates in a simulated macroeconomic model and finds that subjects adopt a "Restricted Perceptions Equilibrium" in which agents use simple forecast functions only and outcomes and beliefs reinforce each other. Pfajfar and Zakelj (2009) find that, within a New Keynesian sticky price framework, subjects use various models of expectations formation of inflation, including sticky information, adaptive learning and rational rules. Burke and Manz (2011) study how economic literacy affects inflation expectations formation through two specific channels: the choice of information and the use of given information. None of these studies feature the aggregation of multiple prices to generate predictions or perceptions about economy-wide inflation rates. Thus, none has the scope to study issues related to the frequency bias. Malmendier and Nagel (2012) propose a personal experience-based model of expectations formation. Using cross-sectional survey data, they find differences in expectations across age groups can be explained by the variations in their life-time inflation experiences. Here, we identify a specific experience—shopping frequency—that affects the bias in inflation perceptions.

The rest of the paper is organized as follows. We formally define the frequency bias in Section II. In Section III we describe the experimental design and present the various results from the laboratory. In Section IV, we relate our findings in the lab to survey observations. Section V concludes.

## **II** THE FREQUENCY BIAS DEFINED

Economy-wide inflation rates are generally calculated as the rate of change in the total price of a representative basket of goods. Formally, if each good *i*'s price at some point in time *t* is given by  $p_{it}$ , and if a basket is comprised of  $q_i$  units of each good *i*, then the period-*t* price of the basket is given by

$$(1) P_t = \sum_i q_i p_{it}.$$

The inflation rate from period t-1 to t for each good is given by  $\pi_{it} = (p_{it} - p_{i,t-1})/p_{i,t-1}$ , and the economy-wide inflation rate is  $\Pi_t = (P_{t-1} - P_t)/P_{t-1}$ . A bit of algebra shows that the aggregate inflation rate must be a convex combination of individual-good inflation rates, with the weight on each good equal to its share of the total period-t expenditure. Thus, we must have

(2) 
$$\Pi_t = \sum_i \theta_{it} \pi_{it},$$

where

(3) 
$$\theta_{it} = \frac{q_i p_{it}}{\sum_j q_j p_{jt}}$$

We refer to  $\theta_{it}$  as the *expenditure weight* for good *i* at time *t*. For our experiments  $\theta_{it}$  does not vary with time, so we typically ignore the *t* subscript in the notation.

In reality, consumers may have perceptions of inflation for each good *i*, denoted  $\pi_i^p$ , that differ from the true good-*i* inflation rate  $\pi_i$ . Their perception of the economy-wide inflation rate ( $\Pi^p$ ) may also differ from the true economy-wide rate ( $\Pi$ ). We can relate these perceived rates by

(4) 
$$\Pi^p = \sum_i \omega_i \pi_i^p,$$

where  $\omega_i$  is the weight the consumer actually places on  $\pi_i^p$ . Regardless of the accuracy of each  $\pi_i^p$ , if a consumer understands that economy-wide inflation rates are calculated by constructing a basket of  $q_i$  units of each good *i*, then it must be that  $\omega_i = \theta_i$  for each *i*.<sup>8</sup>

A frequency bias occurs when the consumer's actual weights  $\omega_i$  deviate from  $\theta_i$ , with more weight put on goods that are more frequently purchased, and less weight put on

<sup>&</sup>lt;sup>8</sup>If the consumer knows that a basket is used to calculate inflation rates, but they do not know the quantities  $q_i$ , then it still must be true that  $\omega_i \in [0,1]$  for each i and  $\sum_i \omega_i = 1$ . In our experiment the quantities  $q_i$  are clearly shown.

goods that are less frequently purchased. To separate frequency of purchase from quantity purchased, we let  $q_i = n_i \mu_i$ , where  $n_i$  is the number of times good *i* was purchased in the given time period (measured as the number of distinct transactions), and  $\mu_i$  is the average quantity per purchase. The *frequency weight* of good *i* is given by

(5) 
$$\phi_i = \frac{n_i}{\sum_j n_j}$$

From these weights we can formally define the frequency bias:

**Definition.** A consumer's perceptions of inflation exhibit the **frequency bias** if there is some  $\alpha > 0$  such that, for each good *i*,

(6) 
$$\omega_i = \alpha \phi_i + (1 - \alpha) \theta_i,$$

where  $\phi_i = n_i / \sum_j n_j$  is the relative frequency with which good *i* is purchased and  $\theta_i = P_i / P$  is the fraction of total expenditures spent on good *i*.

The degree to which consumers use frequency weights versus expenditure weights is captured by the parameter  $\alpha$ . An unbiased consumer has  $\alpha = 0$ . Given  $\alpha$ , the perception of the overall inflation rate is calculated as

$$\Pi^{p} = \sum_{i} \omega_{i} \pi_{i}^{p}$$
$$= \sum_{i} \left[ \alpha \phi_{i} + (1 - \alpha) \theta_{i} \right] \pi_{i}^{p}$$

Letting  $\Pi_{\text{EXP}}^p = \sum_i \theta_i \pi_i^p$  be the correct expenditure-weighted inflation rate and  $\Pi_{\text{FREQ}}^p = \sum_i \phi_i \pi_i^p$  be the frequency-based inflation rate, we have that

(7) 
$$\Pi^p = \alpha \Pi^p_{\text{FREQ}} + (1 - \alpha) \Pi^p_{\text{EXP}}.$$

Thus, the frequency bias can equivalently be expressed as a bias in  $\Pi^p$  toward  $\Pi^p_{\text{FREQ}}$ .

Again, the parameter  $\alpha$  provides a simple way to measure the magnitude of the bias. It is this parameter that we measure in our controlled laboratory experiments.

The frequency bias represents an error in how individuals aggregate the inflation rates within their consumption basket. The individual-level frequency bias will be observed at an aggregate level (aggregating across individuals) as long as most individuals have similar relative frequencies of purchasing various goods.

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# **III THE LABORATORY EXPERIMENT**

# Experimental Design

The experiment is designed to measure perceived inflation rates in a simulated economy. The frequency bias can be estimated by comparing reported perceptions of economywide inflation against the reported perceptions of inflation for each individual good. If the frequency bias is strong, then economy-wide inflation reports will be biased toward the inflation rates of goods that are purchased more frequently; therefore, we compare a baseline treatment with fairly flat inflation (Treatment EQ) to two treatments where the most-frequently purchased goods inflation rates are either large and positive (Treatment POS) or large and negative (Treatment NEG).

Nine experimental sessions were conducted at Ohio State University in November and December of 2009.<sup>9</sup> All subjects were Ohio State undergraduate students recruited via e-mail.<sup>10</sup> All sessions took place in the Ohio State Experimental Economics Laboratory. In total, 186 subjects participated in the experiment in sessions of roughly 21 subjects per session. Each subject was only allowed to participate in one session of this experiment.

For each session, all subjects arrived at the laboratory simultaneously, were seated at computer terminals, and told to log into the experiment website.<sup>11</sup> The website then provided specific instructions regarding the procedures for the experiment, which subjects read at their own pace. They then proceeded to make a series of decisions through the experiment website. Once every subject had completed the experiment, each was paid in cash privately based on their earnings and left the laboratory. Earnings during the experiment were recorded in 'points', with each point being worth one penny of actual payout. Final earnings ranged from \$8.40 to \$22.59, with a mean of \$18.15. Sessions took roughly one hour to complete.

The experiment consists of two phases. The first phase is broken into 96 periods, referred to as 'days'. Sixteen days constitute a 'month', for a total of six months in the

<sup>&</sup>lt;sup>9</sup>One small pilot session and one session with a technical flaw are excluded. Results from these sessions appear qualitatively similar to the nine reported sessions. The data are available upon request.

 $<sup>^{10}</sup>$ Existing evidence shows that undergraduate students behave similarly to other populations in most economic decisions; there are some settings with systematic subject-pool differences, though there seems to be little guidance about which settings will generate differences and in which directions these differences will operate. Thus, from an *ex-ante* perspective, subject pool effects can be treated as unbiased noise. See Fréchette (2009) for details.

<sup>&</sup>lt;sup>11</sup>The website is available at http://healy.econ.ohio-state.edu/exp/shopping. To experience this experiment and view the instructions, log in using session password 'test'.

| Good                     | Α    | B   | С     | D     | Basket |
|--------------------------|------|-----|-------|-------|--------|
| Purchases per month      | 7    | 6   | 2     | 1     | 16     |
| Month 1 mean price       | \$1  | \$7 | \$122 | \$470 | \$763  |
| Monthly inflation rate:  |      |     |       |       |        |
| ${f Treatment} \ {f EQ}$ | 4%   | 4%  | 4%    | 4%    | 4%     |
| Treatment POS            | 10%  | 9%  | 7%    | 1%    | 3.63%  |
| Treatment NEG            | -10% | -2% | 1.5%  | 5.5%  | 3.80%  |

TABLE I. Frequencies of purchase, starting prices, and inflation rates for the four goods used in the experiment.

first phase. In each day subjects are shown a  $4 \times 3$  table of prices. An example table is shown in Figure I. Each row corresponds to a different type of good, labeled abstractly as goods A, B, C, and D, and each column corresponds to a different brand, labeled as 1, 2, and 3. Each day subjects are told which type of good they are to purchase (A, B, C, or D) and are asked to select the cheapest price for that good. They could then click on any of the twelve prices in the table. If they click on the lowest price of the correct good then they earn five points. The middle price of the correct good earns them three points, and the highest price earns them one point. Clicking on any price of an incorrect good earns them zero points. After clicking a price, the experiment proceeds to the next day, where a new table of twelve prices is shown and subjects are again told which good to buy. If a subject does not click any price within 30 seconds then they earn zero points for that 'day' and the experiment automatically proceeds to the next day (no time limit was imposed on the first day).

Over the 96 days, subjects shop for the different goods with different frequencies. Specifically, in each 16-day month they are asked to buy good A seven times, good B six times, good C two times, and good D one time; see Table I. We refer to each month's bundle of purchases as a 'basket'. The ordering of the purchases in the basket was randomized within each month.

The simulated shopping experience is designed to mimic key aspects of actual consumer purchases. When shopping for an item, consumers focus only on a single type of good, though other goods' prices are available for perusal. Some items—such as gasoline and food—are purchased more frequently than others. Multiple prices for the desired good may be offered, adding noise to inflation perceptions, and consumers benefit by choosing the lowest-priced option. No notion of quality is introduced so that prices need



FIGURE I. Phase I of the experiment: The shopping decision.

not be adjusted for varying quality levels. We reward purchases using a fixed point system rather than giving shoppers a total budget because recalling basket inflation rates with a fixed budget would amount to observing the total change in the budget. This would oversimplify the problem of recalling inflation rates since, in reality, liquid asset balances are affected by much more than expenditures.

Each of the four goods  $i \in \{A, B, C, D\}$  is given an initial mean price  $\bar{p}_{i1}$  for the first month; the values of  $\bar{p}_{i1}$  used in the experiment are given in the third row of Table I. In each subsequent month, the mean price for each good is inflated by a monthly inflation rate  $\pi_i^*$  that does not vary during the experiment. In Treatment EQ (Sessions 1–3) all four goods have an equal inflation rate  $\pi_i^* = 0.04$ . In Treatment POS (Sessions 4–6), the

inflation rates are positively correlated with the frequency of purchase, so that the more frequently-purchased goods have higher inflation rates. In Treatment NEG (Sessions 7–9) the inflation rates are negatively correlated with frequency of purchase, with goods A and B actually experiencing deflation on average.

Although inflation occurs from month to month, the mean price does not change within the month. Thus, for any day t in month m the mean price of good i is  $\bar{p}_{im}$ , and in every day of month m + 1 the mean price of good i is  $\bar{p}_{i,m+1} = \bar{p}_{im} (1 + \pi_i^*)$ .

The three daily prices for each good offered to the subject each day are uniform random draws centered at the current month's mean price. Specifically, in each day t of month m the realized price of brand  $b \in \{1,2,3\}$  is a value  $p_{ibmt}$  drawn from a uniform distribution over the interval  $[0.9 \bar{p}_{im}, 1.1 \bar{p}_{im}]$ , and then rounded to the nearest penny. Each brand's daily price is drawn independently of all other prices, conditional on that good's mean price for the month. All twelve prices (three brands of four goods) for each day are shown in a single table so subjects can easily see all prices for all goods each day. See Figure I for an example of the actual table presented to subjects in the experiment.

If  $\iota(m,t) \in \{1,2,3,4\}$  identifies the good a subject is asked to buy on day t of month m, and if  $p_{imt} = \min\{p_{i1mt}, p_{i2mt}, p_{i3mt}\}$  denotes the minimum price for good i on day t of month m, then the total expenditure on good i in month m is given by

$$P_{im} = \sum_{\{t:\iota(m,t)=i\}} p_{imt}.$$

The realized total basket price for month *m* is then the total expenditure for the month,  $P_m = \sum_i P_{im}$ .

The realized inflation rate for the entire basket of goods over the six months is given by  $\Pi = (P_6 - P_1)/P_1$ . The realized inflation rate for each good *i* over the six months is the change in total expenditures on good *i* between the first and last month, or  $\pi_i = (P_{i6} - P_{i1})/P_{i1}$ . Here, the realized inflation rates  $\pi_i$  may differ slightly from the fixed, underlying inflation rates  $\pi_i^*$  given in Table I because of randomness in the actual price draws observed by a subject.

As described in Section II, the basket inflation rate must be a convex combination of individual inflation rates, using the expenditure shares as weights. Thus, if  $\theta_i = P_{i1}/P_1$  is the expenditure weight of each good *i*, then

(8) 
$$\Pi = \sum_{i} \theta_{i} \pi_{i}.$$

Phase one of the experiment ends after all six months of shopping were complete, which typically takes about twenty minutes. At no point during the first phase are subjects told that they are buying an identical basket of goods each month—though an astute subject could deduce this fact—and subjects are never told in phase one that they will be asked inflation-related questions in phase two.

Phase two consists of two decisions made sequentially: A guess of the basket inflation rate and a guess of each good's inflation rate.

Before the first decision, subjects are told that they had just purchased an identical quantity of each good in each month, thus forming a 'basket' of goods that they had purchased in each month. They are then asked: "What was the TOTAL percentage change of the price of a basket of goods from month 1 to month 6?" Subjects then enter a guess of the six-month basket inflation rate, which we denote here by  $\Pi^{p}$ .<sup>12</sup> At the end of the experiment they are told the realized inflation rate  $\Pi$  and receive  $425 - 500 |\Pi^{p} - \Pi|$  points for their guess. Thus, a perfect guess earns \$4.25, while a guess that is off by ten percentage points (where  $|\Pi^{p} - \Pi| = 0.10$ ) earns \$3.75. Earnings are truncated below zero, so no subject can earn negative payoffs for this decision. Subjects do not learn the true inflation rate or their earnings for this guess until the experiment is complete.

After submitting their estimate of the basket inflation rate, subjects are asked to guess the six-month inflation rate for each of the four goods. At the end of the experiment, the subject is paid  $125 - 500 |\pi_i^p - \pi_i|$  points for each of their four guesses  $\pi_i^p$ . Thus, four perfect guesses earns \$5.00, and subjects lose five cents for every percentage point difference between a guess and that good's true inflation rate. Again, earnings were truncated below zero, so no subject could earn negative payoffs for this decision. Subjects do not learn the true inflation rate or their earnings for this guess until the experiment was completed.

At the end of the experiment subjects are shown their earnings in points from each decision in the experiment, along with the true inflation rates for each good and for the entire basket of goods. The point earnings are then converted to dollars (at a rate of one cent per point) and rounded up to the next whole dollar amount. Subjects are paid their earnings in cash privately, sign a receipt, and leave the laboratory individually.

In our analysis, eight subjects (out of 186) are removed from the data as outliers for having at least one guess whose error was greater than 100 percentage points. Analyzing medians without removing outliers yields qualitatively similar conclusions, but is less amenable to regression analysis.

<sup>&</sup>lt;sup>12</sup>Before continuing, subjects are asked to verify all decisions that require keyboard input in order to minimize the occurrence of typographic errors.

|   | Theoretical | Estimated | 95% Confidence |
|---|-------------|-----------|----------------|
|   | Weights     | Weights   | Interval       |
| Frequency-Based Inflation Rate          | 0.000       | 0.440     | [0.241, 0.639] |
| <b>Expenditure-Based Inflation Rate</b> | 1.000       | 0.560     | [0.361, 0.759] |

TABLE II. Estimate of the size of the frequency bias in reported inflation rates.

# Measuring the Frequency Bias

We begin by measuring the degree of frequency bias across all treatments. This is done by estimating the parameter  $\alpha$  in the relationship

$$\Pi^p = \alpha \,\Pi^p_{\rm FREQ} + (1 - \alpha) \,\Pi^p_{\rm EXP}$$

that was derived in equation (7) above. The values  $\Pi_{\text{EXP}}^{p}$  and  $\Pi_{\text{FREQ}}^{p}$  are calculated from the individual-good inflation reports for each subject. The announced basket rates ( $\Pi^{p}$ ) are then regressed on these two values. We constrain the two regression coefficients to sum to one, though we do not require that  $\alpha$  be between zero and one. The results are shown in Table II.

On average, subjects put 44% weight on the frequency with which goods are purchased and only 56% weight on the (theoretically-correct) expenditure weights. These estimates are significantly different from the theoretical predictions of 0% and 100%, respectively, with p-values less than 0.001. Thus, the frequency bias is both statically significant and economically meaningful in size; nearly half of agents' expectations are derived from their frequency of purchase.

This result is robust to the specification of the linear regression. Removing the constraint that the coefficients sum to one gives an estimated relationship of

$$\Pi^p = 0.528\Pi^p_{\text{EXP}} + 0.428\Pi^p_{\text{FREQ}}$$

Both coefficients are significantly different from both zero and one at the five-percent level. Also allowing for a constant gives an estimated relationship of

$$\Pi^{p} = 8.187 + 0.257\Pi_{\text{EXP}}^{p} + 0.419\Pi_{\text{FREQ}}^{p}$$

The positive constant is significant, indicating a general tendency to report basket rates that are high relative to the reported individual-good rates, and both slope estimates remain significantly different from both zero and one.<sup>13</sup>

<sup>&</sup>lt;sup>13</sup>Because  $\Pi_{\text{EXP}}^{p}$  and  $\Pi_{\text{FREQ}}^{p}$  have an estimated correlation coefficient of 0.723, one might worry that these regressions are impacted by multicollinearity problems. Diagnostic tests show that multicollinearity is



FIGURE II. Average errors (in percentage points) in economy-wide inflation perceptions by treatment. The dashed lines represent 95% confidence intervals.

Breaking the result down by treatment yields somewhat noisier results because the sample sizes are smaller. In Treatment POS the estimated  $\alpha$  (the weight on  $\Pi_{\text{FREQ}}^p$ ) is 0.387, with a *p*-value of 0.002. In Treatment NEG the estimated  $\alpha$  is 0.291 with an insignificant *p*-value of 0.124. In Treatment EQ the estimated  $\alpha$  is 1.01 with a *p*-value less than 0.001.

As is common in experimental studies, the exact magnitude of the effect is difficult to pin down, but its presence is apparent; the real power of the experimental method comes in studying treatment effects, which we analyze in the following subsection.

|                        |                           | Good         |              |              |              |            |
|------------------------|---------------------------|--------------|--------------|--------------|--------------|------------|
| Trt                    |                           | Α            | B            | С            | D            | Basket     |
|                        | Purchases/Period          | 7            | 6            | 2            | 1            |            |
| POS                    | <b>Reported Inflation</b> | 29.30        | 23.70        | 22.90        | 22.49        | 25.47      |
|                        | Actual Inflation          | 61.02        | 53.24        | 40.42        | 5.16         | 19.57      |
|                        | Average Error             | $-31.72^{*}$ | $-29.54^{*}$ | $-17.52^{*}$ | $17.33^{*}$  | $5.90^{*}$ |
|                        | <b>Reported Inflation</b> | 19.87        | 19.19        | 19.88        | 19.17        | 23.01      |
| $\mathbf{E}\mathbf{Q}$ | Actual Inflation          | 21.96        | 21.46        | 21.08        | 21.27        | 21.16      |
|                        | Average Error             | -2.09        | -2.27        | -1.21        | -2.10        | 1.86       |
| NEG                    | <b>Reported Inflation</b> | -2.08        | 7.57         | 8.62         | 12.62        | 10.47      |
|                        | Actual Inflation          | -40.99       | -9.75        | 8.28         | 30.33        | 20.37      |
|                        | Average Error             | $38.91^{*}$  | $17.32^{*}$  | 0.34         | $-17.71^{*}$ | -9.90*     |

Note: \*Average error is significantly different from zero at the 1% level.

TABLE III. Mean six-period inflation rates for each good and for the entire basket.

## Treatment Differences

Figure II presents the difference between actual and reported inflation for each treatment. It shows that people overestimate basket inflation rates when the frequentlypurchased goods have the highest inflation rates (Treatment POS), and that people underestimate overall inflation rates when the frequently-purchased goods have the lowest inflation rates (Treatment NEG). When all goods have the same inflation rate, subjects are reasonably well calibrated (Treatment EQ).

Table III shows the average reported and actual inflation rates in each treatment for each individual good and for the total basket, as well as the average error for each. The treatment effects from Figure II are apparent in the last column of the table; reported rates for the basket are too high in Treatment POS, roughly accurate in the Treatment EQ, and too low in Treatment NEG. The average errors (reported rates minus true rates) are significantly different from zero (at the 5% level) in Treatments POS and NEG, but not in EQ. Errors in Treatment NEG are significantly lower than in the other two treatments (Wilcoxon rank-sum test *p*-values of < 0.001 and 0.004, respectively), though errors in Treatments POS and EQ are not significantly different (*p*-value of 0.202).

not a serious problem here: The variance inflation factor of the last regression is 2.09 and the tolerance of  $\alpha$  is is 0.478. Both are below most thresholds for concern. Finally, regressing  $\Pi^p$  on  $\Pi^p_{\text{FREQ}}$  alone gives an estimated relationship of  $\Pi^p = 10.286 + 0.568 \Pi^p_{\text{FREQ}}$  with a *p*-value of less than 0.001 on the slope coefficient.

## Individual-Good Inflation Rates

The frequency bias is one of aggregation. Table III also reveals a systematic bias in the accuracy of individual-good inflation rates: Subjects report individual-good inflation rates that are biased toward the overall basket rate. For example, in Treatment POS, subjects grossly underestimate the rate of the highest-inflating good and overestimate the rate of the lowest-reporting good. In Treatment NEG the same phenomenon occurs. In Treatment EQ, however, each individual good's inflation rate equals the basket rate, and so subjects' individual-good reports are well calibrated.

We refer to this bias in the accuracy of individual good reports as the *correlation bias*, since reported individual-good rates are more correlated than the true individual-good rates.<sup>14</sup> In all three treatments, the actual prices are independently drawn for each good, and so no correlation exists between the true inflation rates of the four goods.<sup>15</sup> Subjects' reports, however, are highly correlated. For every treatment and for every pair of goods, the subjects' reported inflation rates for those two goods have a positive correlation coefficient that is significant at the five-percent level. The estimated coefficients are all greater than thirty percent. Figure III shows the relationship between actual inflation rates and reported rates for the four goods. A linear regression shows a relationship of 0.27, significantly less than the one-to-one relationship that would be exhibited by a well-calibrated individual.

It is possible that the correlation bias is driving the treatment differences observed in Figure II. Suppose subjects exhibit the correlation bias but not the frequency bias, so that their individual-good rates are correlated but, given those incorrect rates, they form their perceptions of the basket rate using the (correct) expenditure weights on each good. In Treatment POS, the infrequently-purchased Goods C and D have the lower inflation rates, so such a subject would overestimate those rates. But those goods also constitute 93 percent of total expenditures, so these two overestimates would result in an overestimation of the basket rate. Similarly, in Treatment NEG, Goods C and D have high inflation rates and would be underestimated, leading to an underestimated basket

<sup>&</sup>lt;sup>14</sup>A simple explanation for the correlation bias is that subjects have a prior over inflation rates that is common across goods and correct when averaging across goods. This is particularly justifiable in a context-free laboratory experiment with fictitious goods. If subjects observe the true inflation rate with noise (perhaps due to inattention) then, assuming the distributions of the prior and noise are symmetric and quasiconcave (see Chambers and Healy, 2010), the average posterior expectation of each good's inflation rate will lie between its true rate and the common prior. Perceived inflation rates will be biased toward the overall mean, generating the correlation bias.

<sup>&</sup>lt;sup>15</sup>Pairwise tests for correlation confirm this expected result in our data.



FIGURE III. Reported versus actual inflation rates across the four individual goods.

rate. In Treatment EQ all goods' rates would be correctly perceived, as would the basket rate. These predictions exactly match Figure II.

To disentangle the correlation bias from the frequency bias, we regress basket inflation reports on individual-good inflation reports to estimate the weights subjects place on each good. These estimates can then be compared to the (average) expenditurebased weights that subjects would use if they exhibit no frequency bias, as well as the frequency-based weights for each good. The results appear in Table IV.

Indeed, subjects' actual weights differ from the correct expenditure-based weights, with *p*-values less than five percent for goods A, C, and D, and a *p*-value of 0.070 for good B. In all four goods, the actual weight used is biased toward the frequency weight. Thus, we find that both the frequency bias and the correlation bias operate simultaneously, and both work together to generate the treatment effects seen in Figure II.

Finally, we observe that subjects' precision of their perceptions is affected by the frequency of purchase. For each subject, we ask whether their relative ordering of reported inflation rates for goods A and B matches the true ordering of inflation rates for goods A and B. We then regress this binary variable on the absolute difference between the

|                           | Reported Individual Inflation in Good: |         |         |         |  |
|---------------------------|--|---------|---------|---------|--|
|                           | Α                                      | B       | С       | D       |  |
| Reported Basket Inflation | 0.214                                  | 0.234   | 0.102   | 0.450   |  |
| (Standard Error)          | (0.075)                                | (0.121) | (0.119) | (0.088) |  |
| Expenditure Weights       | 0.009                                  | 0.055   | 0.319   | 0.616   |  |
| Frequency Weights         | 0.438                                  | 0.375   | 0.125   | 0.063   |  |

TABLE IV. Estimates for reported basket inflation regressed on reported individual-good inflation rates, compared to the expenditure-based and frequency-based weights.

two goods' inflation rates using a probit regression. The estimated coefficient (0.0236) is highly significant (*p*-value of 0.002), indicating some sensitivity between the rates of these most frequently-purchased goods. When we perform the same regression on the infrequently-purchased goods C and D, however, the estimated coefficient (0.0012) is not significant (*p*-value of 0.858). Thus, subjects appear unaware of differences between infrequently-purchased goods' inflation rates. These results are consistent with the suggestion that subjects focus attention on frequently-purchased goods and virtually ignore infrequently-purchased goods' prices.

# IV EXPLAINING OVERESTIMATES OF INFLATION IN SURVEY DATA

Recent surveys of inflation perceptions and expectations show a general tendency for individuals to over-perceive and over-estimate inflation rates. We argue that this may be a result of the frequency bias, given that frequently-purchased non-durable goods have seen greater inflation rates than durable goods.

In practice, economy-wide inflation is measured through the changes in a consumer price index (CPI), most often the All Items CPI for All Urban Consumers (CPI-U), reported by the United States Bureau of Labor Statistics. The CPI-U is calculated by forming a basket of goods that represents the purchases of a typical American consumer living in an urban area. The price for each good in the basket is surveyed, the total price of the entire basket is calculated, and the resulting total expenditure is normalized to that of some base year. The Chain Weighted CPI (C-CPI) updates the base year frequently, but is only available for limited time period.<sup>16</sup>

<sup>&</sup>lt;sup>16</sup>The 1996 Boskin Commission Report concluded that reported CPI-U inflation is systematically overestimated mainly due to quality improvement in consumption goods. Since the Commission's report, many improvements were introduced into the CPI. Nevertheless, today's upward bias in the reported CPI-U is still estimated to be at least 1.0 percent per year (Gordon, 2006).



Sources: Bureau of Labor Statistics and University of Michigan, CbUcl d SLBSPabMI Ua

FIGURE IV. Actual inflation and consumers' inflation expectations in the U.S.

Figure IV compares the actual quarterly CPI inflation rates (both CPI-U and the C-CPI) to the average household's inflation expectation taken by the Survey Research Center at the University of Michigan, from 1985Q1 to 2009Q4. It reveals a general trend of expectations significantly exceeding actual inflation over the past twenty years.<sup>17</sup> A monthly survey in Ohio of consumers' perceptions of past price increases confirms this pattern. Respondents reported about 6 percent on average for the period where the actual increase in CPI was only 2.7 percent (Bryan and Venkatu, 2001b). There have been several attempts to rationalize the systematic error in consumers' expectations. For example, the "Peso problem" explanation (see Rogoff, 1980; Krasker, 1980; Lizondo, 1983; Campbell and Shiller, 1991; Bekaert et al., 2001, e.g.) claims that agents rationally believe there is a small probability of a very large increase in inflation, leading to expectations that almost always look biased, *ex post*.

We suggest instead that this systematic error in inflation expectations can potentially be explained by the frequency bias in inflation perceptions. Inflation rates for non-durable goods have been systematically higher than inflation rates for durable goods over the past twenty years, with the difference becoming large after 2002. Since

<sup>&</sup>lt;sup>17</sup>Lower income groups typically report higher perceived inflation than higher income groups. It appears that the higher inflation perception of the average consumer is an artifact of disproportionately overvaluing the inflation opinion of the lower-income respondents. However, Kokoski (2000) shows that using population demographics as an alternative weight to construct CPI does not significantly affect the calculation result, suggesting that one needs to look elsewhere for explanations.



FIGURE V. Actual inflation vs. a qualitative indicator of perceived Inflation in the Euro area

non-durable goods are purchased more frequently, the frequency bias predicts that consumers' perceptions of inflation over this time period are greater than the inflation rate calculated using an expenditure-weighted index like the CPI-U or C-CPI. Although this correlation is merely suggestive, it does support the claim that the experimental results may have macroeconomic consequences.<sup>18</sup>

To expand on this argument, consider consumer experiences in the United States from 1985–2009. There have been notable increases in the prices of low-price, everyday goods, e.g. food and beverage (3.1 percent), energy (4 percent), and transportation (2.6 percent), and a much smaller rise or even decline in the prices of the relatively expensive consumer goods, e.g. apparel (0.58 percent), audio-visual devices (0.4 percent), and information technology (-11.1 percent). The aggregate effect is a relatively low overall inflation rate, according to the CPI. Consumers more frequently experienced the goods with higher inflation rates, however, leading to the apparent upward biases in inflation perceptions and expectations.

<sup>&</sup>lt;sup>18</sup>It is interesting to note that although we observe frequency bias in average consumers, professional forecasters do *not* appear to exhibit any such bias. In fact, professional inflation forecasts are generally accurate (Keane and Runkle, 1990, e.g.). However, consumers only occasionally pay attention to news reports of inflation forecasts (Carroll, 2003). In most macro policy applications, what matters is consumers inflation perceptions. It is in the failure to predict the consumers' responses that policymakers' models may suffer in predictive power. It is for this reason that policymakers should care about the existence of the frequency bias.

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Similarly, a survey of European consumers' perceptions of recent inflation shows significant over-estimation of recent inflation in the years 2002–06 following the introduction of the euro (Figure V).<sup>19</sup> In general, prices of goods were rounded up after the conversion from local currencies to the euro. This meant that the prices of low-value but frequently-purchased goods increased significantly (e.g. from 1.70 to 2 euro) while for more valuable but infrequently shopped goods the increase was insignificant (e.g. from 980.70 to 981 euro). In terms of total expenditure, this rounding effect was trivial; however, for individuals whose daily purchases became noticeably more expensive, the perceived effect was large.<sup>20</sup>

The main point we highlight here is that frequency bias has the potential to help us reconcile survey based inflation perceptions or expectations to actual inflation. While a thorough investigation of the "frequency weighted" price statistics using micro-data on inflation perception and shopping frequency of individual goods may be interesting, it is beyond the scope of this paper and is left for future studies.

# V DISCUSSION AND FUTURE RESEARCH

We have shown that people misperceive inflation in a controlled lab experiment, biasing their perceptions of economy-wide inflation toward the inflation rates of the morefrequently purchased goods. One implication is that adjusting for the frequency bias in inflation expectations might be more suitable for macroeconomic analysis. Even economic research that is interested in inflation *expectations* rather than current perceptions should take these findings into consideration, since the frequency bias in perceptions likely extends to a bias in expectations.

An open question is whether the frequency bias is attenuated with experience. Although our experiment cannot address this question, we conjecture that adjustments in perceptions would be very slow. Learning is fastest when feedback about mistakes is clear (see Weber, 2003, e.g.). Small mistakes in consumption-savings decisions, however, are unlikely to provide informative negative feedback. Slight over- or under-investments in housing, for example, are unlikely to cause foreclosure or financial distress. Thus, consumers will feel little to no pressure to adapt their method of aggregation. As evidence that the bias may not attenuate, recall that the over-estimation of inflation observed in

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<sup>&</sup>lt;sup>19</sup>In this survey, participants are asked "How do you think prices have developed in the last 12 months?" and are given possible answers "risen a lot", "risen moderately", "risen slightly", "stayed about the same", and "fallen". The reported indicator is a linear combination of the frequency of responses given to each answer.

<sup>&</sup>lt;sup>20</sup>See Del Giovane and Sabbatini (2008), for example.

the field (Figure IV) has persisted over the past 25 years, suggesting little learning from experience. We hypothesize that the accuracy of expert forecasts (Keane and Runkle, 1990) does not come from recalling past shopping experiences, but rather from considering prices and inflation analytically.

The frequency bias that was documented in the present study may also be present in other situations where agents have to aggregate different pieces of relevant information to form a perception of current trends. Investors in financial markets observe the movement of individual prices in multiple occasions over a given time period. As far as the frequency of price information they get about specific shares is not equal to the weight they have in the general index, investors' perceptions of the general trends in the stock market can be biased. Another example can be found in the field of mass media: Receivers of news will get the same news item multiple times, which might bias their perception of reality. Such a phenomenon can be relevant in the field of political economy. Suppose a given candidate has one good and one bad characteristic. Even voters with neutral priors might underestimate the relative merits of this candidate if they receive reminders about the negative characteristic more frequently than they receive reminders about the positive one. This justifies the extensive use of advertising in political campaigns. An extensive study of such questions remains for future research.

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