CONSUMER INERTIA, CHOICE DEPENDENCE, AND LEARNING FROM EXPERIENCE IN A REPEATED DECISION PROBLEM

Eugenio J. Miravete and Ignacio Palacios-Huerta*

Abstract—Understanding when and how individuals think about real-life problems is a central question in economics. This paper studies the role of inertia (inattention), state dependence, and learning. The empirical setting is a tariff experiment, when optional measured tariffs for local telephone calls were introduced unanticipatedly. We find that consumers tend to align their choices of tariff and telephone use levels correctly. Despite low potential savings, mistakes are not permanent, as individuals actively engage in tariff switching in order to reduce the monthly cost of telephone service. Ignoring unobservable heterogeneity and the endogeneity of past choices would have reversed these results.

Errare humanum est, in errore perservare stultum. (To err is human, to persist in error is stupid.)

Lucius A. Seneca (4 BC–65 AD),
Ad Lucilium Epistolae Morales

I. Introduction

CHOOSING among alternatives is the quintessential economic decision that we routinely engage in. Depending on the nature of the specific good or service under consideration, it may also be a rather complex activity. In some cases, we revise our plans and previous decisions almost immediately, in others on a regular basis, and yet in others only when unexpected changes or extraordinary events compel us to reengage in such a decision process. The different frequency with which we revise our decisions may reflect our own optimizing behavior with respect to the decision process itself. As Stigler and Becker (1977) note, "The making of decisions is costly, and not simply because it is an activity that some people find unpleasant. In order to make a decision one requires information, and the information must be analyzed. The costs of searching for information and of applying the information to a new situation may be such that habit [and inertia] are sometimes a more efficient way to deal with moderate or temporary changes in the environment than would be a full, apparently utility-maximizing decision." Similarly, Knight (1921) observes, "It is evident that the rational thing to do is to be irrational where deliberation and estimation cost more than they are worth."

Consistent with these insights, recent research in the behavioral economics literature has documented a number of departures from the predictions of simple models of strict rational behavior (see DellaVigna, 2009, for a review). For instance, Heiss, McFadden, and Winter (2009) show how consumers make wrong choices when they first face complex alternatives; Abaluck and Gruber (2010) document how individuals appear to pay excessive attention to certain features of different insurance options, causing them not to choose the least expensive alternative. DellaVigna and Malmendier (2006) and Madrian and Shea (2001) point out that default options and inertia (time-independent conditions) are among the strongest determinants of individual choices in the dynamic settings they study. Attempts to explain observed behavior include loss aversion (Koscegi & Heidhues, 2008), reference-dependent preferences (Koscegi & Rabin, 2006), and consumer overconfidence (Grubb, 2009).

At the same time, a small but growing literature appears to provide support for the hypothesis of strict rationality of consumer choices over time. This research hints at learning as the corrective force fixing apparent choice inconsistencies. Examples include Agarwal et al. (2006), Ketcham et al. (2012), Miravete (2003). Learning effects are also studied in Choi et al. (2009).

This paper contributes to the literature by separating the effects of inertia (likely caused by inattention in our setting) from state dependence and learning. While we are not aware of any previous empirical study that attempts to do this, there is work, which we review in the next section, that relates to this study. Importantly, our econometric analysis also addresses the role of unobserved heterogeneity and the endogeneity of other decisions that may influence individuals' choices and their ability to learn. We show, in a spirit similar to the empirical contract study by Ackerberg and Botticini (2002), that the estimation bias resulting from ignoring unobserved heterogeneity arising from the endogenous sequence of choices that forms individual experiences may be—in fact, turns out to be—large enough to fully reverse the sign of the effects of past decisions on current choices.

We would expect that various decades of research would have produced systematic empirical evidence on the type of decision problems where consumers behave irrationally and the types of problems where they are rational, on how consumer behavior depends on the cost of acquiring and processing information relative to the benefits of better decision making, and on the types of situations where subjects tend to reason accurately or tend to make permanent errors. The

Received for publication November 4, 2009. Revision accepted for publication January 14, 2013.

* Miravete: University of Texas at Austin Centre for Competition Policy-UEA, and CEPR; Palacios-Huerta: London School of Economics, Athletic Club de Bilbao, and Ikerbasque Foundation at UPV/EHU.

We thank a coeditor, two anonymous referees, George Akerlof, Jordi Blanes-i-Vidal, David de Meza, Andrew Foster, Giuseppe Moscarini, Robert Porter, Ralph Siebert, Dan Silverman, Catherine Thomas, Johannes Van Biesebroeck, seminar participants at Berkeley and CEMFI, as well as audiences at the 2003 CEPR Conference on Applied Industrial Organization in Leuven, the 2007 Federal Trade Commission conference on Behavioral Economics and Consumer Policy in Washington, and the 2009 Workshop on Behavioral Models of Market Competition in Frankfurt for their helpful comments and suggestions. We are particularly grateful to Manuel Arellano and Raquel Carrasco for their assistance with the estimation of our dynamic discrete choice panel data model. Financial support from the Spanish Ministerio de Economia y Competitividad (ECO2012-31626) and from the Departamento de Educación, Política Lingüistica y Cultura of the Gobierno Vasco (IT869-13) is gratefully acknowledged. We alone are responsible for any remaining errors. An earlier version circulated as CEPR D.P. No. 3604 under the title "Rational Attention in a Repeated Decision Problem.

The Review of Economics and Statistics, July 2014, 96(3): 524–537
© 2014 by the President and Fellows of Harvard College and the Massachusetts Institute of Technology
doi:10.1162/REST_a_00386

fact is, however, that we are far from this ideal. There is a recent theoretical literature modeling rational inattention, as well as a theoretical and experimental literature on bounded rationality, but to the best of our knowledge, there is little empirical evidence from real-life settings.

A number of empirical problems justify the existing situation. In natural settings there are often great difficulties in finding individual decision-making situations, as opposed to aggregate market-level situations;[1] in observing all the relevant characteristics of individuals; in precisely determining individuals' choice and strategy sets; in measuring the exact incentive structures that individuals face; in our ability to address selection problems in settings where preferences are endogenous to the environment or to the behavior of others; and in knowing the determinants of the endogenous frequency of choices. One or more of these difficulties typically represent insurmountable obstacles for conducting convincing empirical research. In addition, sufficiently rich data sets with repeated individual choices that allow the study of dynamic learning effects, attention, and state dependence, while controlling for the effects of unobserved heterogeneity, are rarely available.

The main virtue of the natural setting we study is that none of these difficulties are present. South Central Bell (SCB) implemented a detailed tariff experiment for the Kentucky Public Service Commission in 1986. It collected demographic and economic information for about 2,500 households in Louisville. In spring 1986, all households in Kentucky were on mandatory flat rates, paying $18.70 per month with unlimited local telephone calls. This was the only payment plan available. In July 1986, optional measured services were introduced for the first time, in a way that was unanticipated by consumers. This alternative plan had a $14.02 monthly fixed fee, a $5.00 allowance, and a tariff per call that depended on its duration, distance, and period (time of the day and day of the week). The basic problem that households faced each month was to determine whether their expected demand for local phone calls next month would be above or below $19.02, as they would not be billed for the $5.00 allowance unless their usage level exceeded this limit. That is, an attentive household would have to think at time t about the expected consumption level at $t + 1$ and the tariff rate to be applied to that consumption level; consumption choices then take place at time $t + 1$. These choices were repeated every month. Tariffs could be switched at any time during the month and simply required a free phone call. A rich panel data set on the variables and characteristics of interest is available during the months of April to June and October to December 1986.

The analysis in this paper takes advantage of the opportunity that this unique setting provides. We have an individual decision-making situation where it is trivial to determine strategy sets and straightforward to observe individuals' choices over time. It is also relatively simple to measure the incentives and rewards that subjects face. Local telephone services represent a small share of consumers' budget, and hence we can rule out strategic and risk-aversion considerations. The monthly frequency of choices is exogenously given, and so there is no need to address any potential endogenous timing of decisions. Finally, there are no self-selection problems since the penetration of local telephone service is nearly universal (over 99% of the population) and the good in question (telephone services) is not subject to conspicuous motives.

In anticipation of the results, we find that telephone subscribers do not make permanent mistakes, and that while inertia exists, it is likely caused by rational inattention since individuals actively engage in tariff switching in order to reduce the monthly cost of local telephone service. We also find that the role of state dependence is crucial in that past individual decisions, rather than impulsiveness or random behavior, shape future individual actions. Finally, our results show that it is critical to address the bias from the endogeneity of lagged explanatory variables that identify inertia and state dependence. Failing to do this would have reversed the conclusions of the analysis.

The paper proceeds as follows. Section II briefly reviews relevant literature. Section III describes in detail the Kentucky tariff experiment and the data set, and reports some descriptive evidence. Section IV presents a conceptual framework. Section V presents our dynamic discrete choice panel data model and section VI the empirical results. Section VII concludes.

II. Related Literature

A large and growing literature on bounded rationality studies the importance of deliberation and processing costs in explaining deviations from the choices of rational, computationally unconstrained agents.[2] This literature includes various survey and experimental studies. Lusardi (1999, 2003) and Americks, Caplin, and Leahy (2003), for instance, find that a significant fraction of survey respondents make financial plans infrequently and that their behavior has a significant impact on the amount of wealth that they accumulate. In the experimental literature, Gabaix et al. (2006) study a cognition model that successfully predicts the aggregate empirical regularities of information acquisition both within

[1] At the market level or at other aggregate levels, downward-sloping demand functions can be derived even as consequences of agents' random choices subject to a budget constraint (Becker, 1962, and Gode & Sunder, 1993). As a result, it is generally not possible to distinguish rational from irrational behavior at any level of aggregation.

[2] These include the game theory literature (Rubinstein, 1998), behavioral industrial organization (Spiegler, 2011), learning and robustness in macroeconomics (Hansen & Sargent, 2008), the study of the demand for information in Bayesian decision theory (Moscarini & Smith, 2001, 2002), the study of cognitive dissonance and near-rational theories (Akerlof & Dickens, 1982; Akerlof & Yellen, 1982), and others. On the infinite regress problem, see Savage (1954) and Lipman (1991). Conslik (1996) reviews various experimental studies where subjects make errors in updating probabilities, display overconfidence, and violate several assumptions of unbounded rationality, as well as other studies where subjects reason accurately, especially after practice. Arrow (1987) and Lucas (1987) discuss some limitations of experiments to study bounded rationality.

and across experimental games. Costa-Gomes, Crawford, and Broseta (2006), and Costa-Gomes and Crawford (2006) also study cognition and behavior in different experimental games.

In macroeconomics, an important recent literature explores the potential of modeling rational inattention in consumers and producers. Reis (2006a,b), studies the consumption decisions of agents who face costs of acquiring, absorbing, and processing information,[3] and the same problem for producers and applies the results to a model of inflation. The resulting models are consistent with various puzzles and fit remarkably well with a number of quantitative facts.[4] Hellwig, Khols, and Veldkamp (2012) construct a unified framework that compares different information choice technologies (such as rational inattention, inattentiveness, information markets, and costly precision) and explain why some generate increasing returns while others generate multiple equilibria.

Finally, the asymmetry in the choice of tariffs that we study fits well into recent studies that focus on comparison friction defined as the wedge between the availability of comparative information and consumers' use of it. Economic models typically assume that it is inconsequential, that is, that consumers will access readily available information and will make effective choices. Kling et al. (2012) estimate the effect of reducing comparison friction in the market for prescription drug insurance plans for senior citizens in an experiment where they delivered personalized cost information in a letter. Their experimental results suggest that for senior citizens, comparison friction could be large even when the cost of acquiring information is low. Ketcham et al. (2012), however, find that these concerns are not substantiated in a large sample of senior citizens observed making actual real-life choices. Thanks to social interactions and the development of market-based institutions that ease learning among very old and even mentally ill patients, subjects significantly improved their choices and reduced overspending over time.[5]

Summing up, the literature shows that modeling inertia, learning, and attention and studying the predictions of limited rationality models experimentally offer a great deal of promise for improving our understanding of human decision making. Relative to the existing theoretical, survey, and experimental literature, this paper provides what, to the best of our knowledge, is the first empirical microeconometric study of rational attentiveness in a real-world setting using a large panel data set of a fully representative sample while controlling for unobserved heterogeneity and endogeneity of past choices at the same time that we separate inertia from the effect of state dependence.

III. Description of the Tariff Experiment

In the second half of 1986, SCB carried out a detailed tariff experiment aimed at providing the Kentucky Public Service Commission (KPSC) with evidence in favor of authorizing the introduction of optional measured tariffs for local telephone service. Prior to this experiment, in spring 1986, all households in Kentucky were on mandatory flat rates, and SCB collected demographic and economic information for about 2,500 households in the local exchange of Louisville. In July 1986, the tariff was modified in this city. Customers were given the choice of remaining in the previous flat tariff plan—paying \$18.70 per month with unlimited calls—or switch to the new measured-service option. The measured service included a \$14.02 monthly fixed fee and a \$5.00 allowance,[6] and it distinguished among setup, duration, peak periods, and distance.[7] Choices could be made every month; unless a household indicated to SCB otherwise, its current choice of plan would serve as the default choice for the following month.[8] The regulated monopolist also collected monthly information on use (number and duration of calls classified by time of the day, day of the week, and distance within the local loop) and payments during two periods of three months—one right before (March–May) and the other (October–December) three months after the measured tariff option was introduced.

Panel data sets that follow the repeated discrete choices of individuals and their subsequent decisions in environments where framing issues, risk aversion, or prior experiences can be ruled out for all individuals in a fully representative sample are not easy to find. It is thus not surprising that this data set has been used in the past. In chronological order, Miravete (2002) identifies the distributions of ex ante and ex post telephone use to evaluate the profit and welfare performance of sequential pricing mechanisms consisting of optimal two-part tariffs. The two sources of asymmetry of information, use and forecast ability, are identified by analyzing the choice of plan separately from the use decision. Next, Miravete (2003) evaluates the effect of expectations of future consumption as stated by consumers, as well as the role of potential savings in driving household tariff-switching

[3] Sims (2003) and Moscarini (2004) develop alternative models focusing on the information problem that agents face.

[4] Mankiw and Reis (2002) and Ball, Mankiw, and Reis (2005) study inattentiveness on the part of price-setting firms and find that the resulting model matches well the dynamics of inflation and output observed in the data. In the finance literature, Gabaix and Laibson (2002) assume that investors update their portfolio decisions infrequently and show how this can help explaining the equity premium puzzle.

[5] Other studies on comparison friction have examined the effect of the Internet in reducing this friction in various markets (Brynjolfsson & Smith, 2000; Scott-Morton, Zettelmeyer, & Silva-Risso, 2001; Brown & Goolsbee, 2002; Ellison & Ellison, 2009).

[6] Consumers on the measured option were not billed for the first \$5.00 unless their use exceeded that limit. Thus, depending on the accumulated telephone use over a month, a marginal second of communication could cost \$5.00.

[7] The tariff differentiated among three periods: peak was from 8 a.m. to 5 p.m. on weekdays, shoulder was between 5 p.m. and 11 p.m. on weekdays and Sunday, and off-peak was any other time. For the closer distance band A, measured charges were 2.0, 1.3, and 0.8 cents for setup and price per minute during the peak, shoulder, and off-peak period, respectively. For farther away distance band B, setup charges were the same, but duration was fixed at 4.0, 2.6, and 1.6 cents, respectively.

[8] Switching fee plans simply required a free phone call to request the change of service.

behavior. Interestingly, as consumers gain in experience, initial expectations become less and less relevant in determining the choice of tariff plan, and tariff switching appears to be motivated by a desire to reduce overpayment by an average of five dollars. While these two articles evaluate only the performance of the two-part tariffs that are offered, Miravete (2005) uses the empirical distribution of stated future expected consumption to evaluate the profit and welfare performance of sequential pricing mechanisms where options are fully nonlinear tariffs. Finally, Narayanan, Chintagunta, and Miravete (2007) estimate a structural discrete or continuous model of plan choice and demand of local telephone service where consumers update of future use expectation is conditioned by their choice of tariff. Relative to these articles, the contribution of this study is that it separates the role of inertia (or inattention) from state dependence while allowing for learning through the accumulated experience, something that makes individuals different from each other simply because they follow a different sequence of decisions over time.

The data set has a number of unique features to address the consequences of inertia (inattention), state dependence, and learning. First, local telephony is a basic service, and its market penetration is close to 100 percent in the United States. Thus, there are no potential self-selection problems or conspicuous consumption considerations that might lead us to obtain biased estimates because of selection into this market. Second, the low magnitude of the cost differences between the alternative tariff choices, relative to the average household income, allows us to rule out risk aversion as a potential determinant of permanent mistakes regarding the choice of tariffs. Third, it is valuable for the purpose of the analysis that in addition to demographic and economic variables, SCB also collected information on customers' own telephone use expectations in spring 1986 (before the experiment took place). That is, we have a good approximation of consumers' own expected satiation levels since the marginal tariffs were nil at that time.

Households receive the bill for their consumption every month. In this sense, the costs of searching for information are minimal, and thus the costs of deliberation and cognition relative to the expected payoffs would appear to be the main, and perhaps only, determinant of their behavior. For the purpose of the econometric analysis, we will assume that individuals know immediately whether their consumption exceeds or falls short of what is optimal for the tariff chosen. Further, there might be important asymmetries in search costs associated with the problem that a household faces. Households in the measured tariff simply need to compare their actual bill with the \$18.70 cost of the alternative flat tariff in order to ascertain whether they made a mistake. Households in the flat tariff option, however, would need to monitor every phone call they make and compute the total cost of all of their calls in the month in order to know if they would have spent above or below \$19.02 had they subscribed to the measured service (recall that each call is metered differently depending on its duration, distance, and period). Clearly this task is much more complex and demands a great deal of monitoring effort. Empirically, therefore, we would expect to find state dependence on tariff choices and telephone consumption that is associated with this asymmetry in monitoring effort and cognitive costs.

Table 1 defines the variables and presents basic descriptive statistics for the whole sample and for two groups of consumers split according to their choice of tariff in October. Only active consumers were considered and a number of observations with missing values for some variables were excluded.[9] These descriptive statistics initially suggest that individual heterogeneity in consumption and tariff subscription is important. Consumers who subscribe to the FLAT and MEASURED tariffs are in fact quite different. Households subscribing to the optional FLAT service tend to be larger, with teenagers, and with a lower level of education than those subscribing to the MEASURED tariff. Further, they not only differ in their level of local telephone usage, as captured by CALLS, but also in their expectations regarding future telephone use. Subjects tend to underestimate their demand for telephone services, especially those in the FLAT tariff in October. Further, there is an important self-selection effect (not reported in the table): the variability of demand of those who subscribe to the optional FLAT tariff, \$4.28 per month, is almost double that of those on MEASURED service, \$2.30 per month, as given by the measured tariff option in Louisville. This evidence will play a role when accounting for heterogeneity in use across zone and time bands.

Table 2 documents the joint distribution of tariff choice and use levels, as well as potential savings (had these individuals switched to the alternative option while keeping their consumption levels unchanged) and how many of the users, ended up switching tariffs. We again find important asymmetries among consumers. First, most households actually chose the right option for their realized telephone use. Most of those choosing the right tariff subscribed to the FLAT option (63% of the sample) as their demands clearly exceeded the use threshold beyond which the FLAT tariff is always the least expensive alternative. Had they chosen the MEASURED option, these individuals would have paid, on average, about \$17 more. Second, switching is more common among those who are overpaying: 14% of those on the MEASURED tariff with too high demand (and average potential savings of \$6.61 a month) and 17% of those on the FLAT tariff with too low use a level (and average potential savings of \$4.68 a month). Those choosing the right tariff option for their use level switch far less frequently: only 3.56% for those correctly choosing the FLAT tariff and none among those who, using the telephone only sparsely, chose the MEASURED option.

[9] Miravete (2002) documents that excluding households with missing information does not lead to biased results. The only variable with a substantial number of missing observations is income. In these cases, we recoded the missing observations to the yearly average income of the population in Louisville and also included a dummy variable, DINCOME, to control for nonresponses regarding household earnings.

TABLE 1.—VARIABLE DEFINITIONS AND DESCRIPTIVE STATISTICS

Variables	Description	All		Flat		Measured	
MEASURED	Optional measured service chosen this month	0.2971	(0.46)	0.0000	(0.00)	1.0000	(0.00)
EXPCALLS	Household own estimate of weekly calls	26.8884	(31.34)	30.1341	(35.05)	19.2104	(17.78)
CALLS	Current weekly number of calls	37.6093	(38.48)	44.4898	(42.62)	21.3326	(17.64)
BIAS	*CALLS—EXPCALLS*	10.7209	(39.92)	14.3558	(45.67)	2.1223	(18.04)
SWCALLS	Household average calls during spring	37.9434	(37.16)	44.0499	(40.80)	23.4980	(20.32)
SWBIAS	*SWCALLS—EXPCALLS*	11.0550	(39.37)	13.9158	(44.55)	4.2876	(21.39)
BILL	Monthly expenditure in local telephone service	19.4303	(4.41)	18.7000	(0.00)	21.1578	(7.82)
SAVINGS	Potential savings of switching tariff options	−9.9223	(16.53)	−15.1557	(16.45)	2.4578	(7.82)
SAVINGS-SPR	Pot. sav. of subscribing the measured option	−15.4206	(15.27)	−18.7859	(16.21)	−7.4596	(8.56)
SAVINGS-OCT	Potential savings in October	−9.4898	(16.99)	−14.2444	(17.61)	1.7578	(7.60)
SAVINGS-NOV	Potential savings in November	−9.2864	(15.03)	−13.6444	(15.30)	1.0230	(7.47)
SAVINGS-DEC	Potential savings in December	−10.9908	(17.41)	−16.4967	(17.22)	2.0340	(8.83)
INCOME	Monthly income of the household	7.0999	(0.81)	7.0767	(0.84)	7.1547	(0.74)
HHSIZE	Number of people who live in the household	2.6168	(1.51)	2.7858	(1.56)	2.2170	(1.28)
TEENS	Number of teenagers (13–19 years)	0.2440	(0.63)	0.2908	(0.68)	0.1336	(0.49)
DINCOME	Household did not provide income information	0.1577	(0.36)	0.1831	(0.39)	0.0977	(0.30)
AGE = 1	Household head between 15 and 34 years old	0.0632	(0.24)	0.0614	(0.24)	0.0676	(0.25)
AGE = 2	Household head between 35 and 54 years old	0.2686	(0.44)	0.2604	(0.44)	0.2880	(0.45)
AGE = 3	Household head above 54 years old	0.6682	(0.47)	0.6782	(0.47)	0.6444	(0.48)
COLLEGE	Household head is a college graduate	0.2240	(0.42)	0.1821	(0.39)	0.3230	(0.47)
MARRIED	Household head is married	0.5253	(0.50)	0.5342	(0.50)	0.5042	(0.50)
RETIRED	Household head is retired	0.2433	(0.43)	0.2417	(0.43)	0.2471	(0.43)
BLACK	Household head is black	0.1161	(0.32)	0.1295	(0.34)	0.0843	(0.28)
CHURCH	Telephone used for charity and church matters	0.1711	(0.38)	0.1785	(0.38)	0.1536	(0.36)
BENEFITS	Household receives federal or state benefits	0.3095	(0.46)	0.3282	(0.47)	0.2654	(0.44)
MOVED	Household head moved in the past five years	0.4025	(0.49)	0.3899	(0.49)	0.4324	(0.50)
Observations		1,344		949		395	

Mean and standard deviation of demographics and usage variables. This balanced sample contains 1,344 household observations. Income is measured in logarithms of thousands of 1986 dollars.

Switching therefore is not random and appears to respond to potential savings. A main goal of the empirical analysis is to determine whether the wrong combination of tariff choice and use level does indeed tend to induce this switching. Table 1 shows that potential savings from switching decrease slightly over time. This hints that learning is a potential driving force that must qualify the cross-section evidence showing that some individuals make mistakes. Descriptive statistics alone are, of course, far from sufficient to determine whether this is the case since the environment under study is not stationary (for example, demand may change over time).

Despite the remarkable features of the data, two issues are important to address econometrically. First, about 10% of consumers subscribed to the optional measured option when given that possibility. Our sample, however, includes 30% of those customers. Choice-based sampling bias can easily be dealt with using well-known methods (for example, Amemiya, 1985). All estimates reported in the analysis take into account this choice-based sampling as we use the weighting procedure of Lerman and Manski (1977) to obtain choice-based, heteroskedastic-consistent, standard errors. Second, when the tariff experiment began in July 1986, all households were assigned the preexisting FLAT tariff as the default option. Consumers may learn about their telephone use profile as they switch tariff options, and thus, over time, they will differ in their experience as summarized by the different sequences of past tariff choices and use levels. Evaluating the importance of inertia (inattention) and state dependence in the choice of tariff options therefore requires addressing the endogeneity of past choices and controlling for their induced individual heterogeneity. To this end, we use the semiparametric estimator suggested by Arellano and Carrasco (2003) in section V. Before undertaking this task, we present additional descriptive evidence.

TABLE 2.—JOINT DISTRIBUTION OF USE AND TARIFF CHOICE

	Low Usage = 1			Low Usage = 0		
	Share	Savings	Switchers	Share	Savings	Switchers
MEASURED = 1	0.0906	−4.68	0.0000	0.1961	6.61	0.1439
MEASURED = 0	0.0877	4.68	0.1695	0.6256	−16.76	0.0356

Data from October 1986. *Share* indicates the percentage of the sample in a particular tariff choice and use level combination. *Savings* shows the average dollar gain of choosing the other tariff option given the use level (positive values). *Switchers* indicates the percentage of those on a particular tariff choice and use combination who end up switching tariff options during fall 1986.

Next, we examine whether households may appear to choose *ex post* the correct tariff option for their use level by studying the pattern of correlations among tariff choice and use decisions using a simple static model of simultaneous choice. We estimate the following reduced-form model:

$$y_j^* = X\Pi_j + v_j, \qquad j = 1, 2, \tag{1}$$

where, conditional on observed demographics, we assume that

$$(v_1, v_2) \sim N(\mathbf{0}, \mathbf{\Sigma_v}); \qquad \mathbf{\Sigma_v} = \begin{pmatrix} 1 & \rho \\ \rho & 1 \end{pmatrix}. \tag{2}$$

These two equations are estimated simultaneously as a bivariate probit model, thus providing a consistent estimate of ρ conditional on all available household information and treating repeated observations for the same sample units as independent. In this model, $y_1 = 1$ if the household subscribes to the MEASURED tariff and $y_2 = 1$ if the household makes LOW USAGE of telephone service, defined as consumption below $19.02 when metered according to the MEASURED tariff rate. Thus, a significant positive estimate of ρ can be interpreted as the result of an unobservable element (for example, learning, rational inattention, or unbiased expectations) that induces the appropriate tariff choice for each use level. The model includes the same set of demographic variables in both equations to control for the effect of observable individual heterogeneity over the tariff choice and consumption decisions. The analysis also includes household-specific information from the spring months that is useful to control for the accuracy of predictions of individual future use. In particular, we include two dummies to indicate whether consumers significantly over- or underestimated future consumption when marginal consumption was not priced at all.[10] Similarly, we construct an indicator of use intensity for each household during the spring months, LOW USAGE$_{Spring}$, which equals 1 when the use level during spring (at marginal charge) is less than $19.02 had it been metered according to the measured tariff that would later become available during the fall. We include this variable in order to account for any systematic effect of demographics not included in our data on use levels. Table 3 reports the estimates of these reduced-form parameters.

TABLE 3.—CHOICE OF TARIFF AND USE LEVEL

	Measured		Low Usage	
CONSTANT	−0.6763	(5.56)	−0.8099	(7.06)
LOW INCOME	−0.0604	(0.57)	0.0418	(0.46)
HIGH INCOME	−0.2317	(1.79)	−0.0320	(0.32)
DINCOME	−0.4846	(4.23)	−0.1144	(1.43)
HHSIZE = 2	−0.3548	(3.32)	−0.3128	(3.46)
HHSIZE = 3	−0.5645	(4.29)	−0.3979	(3.81)
HHSIZE = 4	−0.4854	(3.17)	−0.3866	(2.97)
HHSIZE > 4	−0.7187	(4.04)	−0.6709	(4.22)
TEENS	−0.1768	(1.27)	0.0115	(0.11)
AGE = 1	−0.0216	(0.14)	0.1761	(1.38)
AGE = 3	−0.0491	(0.53)	0.1707	(2.03)
COLLEGE	0.2910	(3.42)	0.0709	(0.93)
MARRIED	0.2301	(2.47)	−0.0509	(0.66)
RETIRED	0.0497	(0.43)	−0.1967	(2.24)
BLACK	0.0287	(0.26)	−0.1845	(1.72)
CHURCH	−0.0274	(0.30)	−0.0084	(0.11)
BENEFITS	−0.2189	(2.03)	−0.0360	(0.42)
MOVED	−0.0542	(0.64)	0.0915	(1.24)
OVEREST	−0.3548	(2.42)	−0.7881	(5.17)
UNDEREST	−0.4164	(4.14)	−1.1597	(9.70)
LOW USAGE$_{Spring}$	0.6418	(4.87)	1.4125	(11.26)
ρ		0.2616	(5.05)	
$\ln \mathcal{L}$		−2,463.197		
Observations		4,032		

Estimates are obtained by weighted maximum likelihood (bivariate probit). Absolute, choice-biased sampling, heteroskedastic consistent, t-statistics are reported in parentheses.

We find a positive estimate of ρ, that is, a positive correlation between the choice of the measured service and a low demand realization. This finding suggests that consumers do not tend to make permanent mistakes when choosing among optional tariffs. However, this is a reduced-form estimate that at this stage cannot be attributed to a specific reason, be it inertia, rational inattention, state dependence, learning, or any other. In any case, this positive estimate is evidence that an unobservable process that aligns tariff choices and telephone use levels is at work.[11]

Various demographics also appear to contribute to the alignment of the choice of tariff plans and telephone use levels. For instance, larger households tend to subscribe to the flat tariff option and to have high use levels. Similarly, households with a low use profile during the spring months are also more likely to present a low use profile in the fall and, consequently, correctly choose the MEASURED tariff option. Finally, consumers who either over- or underestimated their future telephone use significantly are less likely to subscribe to the MEASURED option, but they are also far less likely to realize a low use level. Thus, households that made the largest absolute forecast errors are among those with very high levels of demand and, hence, are more likely to choose the right option by subscribing to the FLAT tariff.

Table 2 showed that all consumers not choosing the right tariff-use combination were equally likely to switch to the alternative option. Consumers were classified as having chosen correctly or incorrectly each tariff option ex post, keeping the use pattern unchanged, that is, independent of price responses. This provides an approximate upper bound to the gains of switching to a different tariff option. Therefore, those choosing the MEASURED service while experiencing high demand for telephone use were by far the most common among those making the wrong tariff choice for a given use pattern. It is interesting to note that consumers on the MEASURED option enjoy de facto negligible monitoring and deliberation costs since they just have to compare their past monthly bill to the cost of the FLAT option to decide whether to switch tariff plans. Among those households more likely to subscribe to the MEASURED option regardless of their telephone use are those whose head is married, holds a college degree, or does not receive any kind of benefits. At the other end, those experiencing high telephone use regardless of their tariff choice include older and retired households.

After this descriptive evidence, we turn toward the more substantive questions: Do consumers simply stay on their previously chosen tariff because of inertia (that is, rational inattention)? Do the consumption levels, tariff choices, and tariff switching that we observe in the data provide evidence that consumers are rationally attentive and respond to potential savings? What is the role of previous tariff choices and

[10] The UNDEREST dummy is equal to 1 if SWCALLS exceeds EXPCALLS by more than 50% of the standard deviation of SWBIAS. The OVEREST dummy is defined accordingly when EXPCALLS exceeds SWBIAS.

[11] The approach behind the estimates of table 3 is similar to that in Chiappori and Salanié (2000). A significant correlation coefficient in this estimation supports the idea of the existence of asymmetric information beyond the observable demographics of our data. The results regarding the sign and significance of all parameter estimates, including ρ, are robust to alternative specifications that exclude the spring use patterns and the individual expectation accuracy dummies.

demand realizations on the decision to subscribe to one of the two options? Do consumers learn from experience, or do they persist in making wrong choices? In order to answer these questions, we need more sophisticated econometric methods that allow us to account for state dependence, unobserved heterogeneity, and dynamic learning. We first provide a simple conceptual framework to visualize the problem under study.

IV. Conceptual Framework

The choice problem facing a household may be visualized with a simple framework. Borrowing from Kling et al. (2012), for instance, let $\widetilde{u}_{ij} \equiv (\widetilde{b}_{ij} - \widetilde{p}_{ij} - \widetilde{c}_{ij})$ denote the utility for increments to the utility from current consumption for household i from a given tariff choice j, where $\widetilde{b}_{ij}$ is the potential benefit to i from tariff j minus switching costs, $\widetilde{p}_{ij}$ is the potential cost of tariff j that can be predicted from comparative research based on extrapolations from consumption in the previous months, and $\widetilde{c}_{ij}$ is the potential cost that cannot be predicted from such extrapolations. Let r_i denote the comparison friction, that is, the costs of undertaking comparative research about all the available tariffs such as information, monitoring, and deliberation, which we assume is in the same units as, and is additively separable from, $\widetilde{u}_{ij}$.

Without research, the highest level of expected utility across all plans, taking the expectation over the joint distribution of all the random variables that determine $\widetilde{u}_{ij}$, is given by

$$v_i^1 = \max_j E(\widetilde{u}_{ij}).$$

If research is not undertaken, then the tariff that maximizes the expected utility in this equation will be chosen. Note that the current choice of tariff need not be the one that solves this problem, and so the individual may switch tariffs. Both current choices and switching depend on the effects of inertia (time-invariant determinants of choices), state dependence (time-varying endogenous determinants), and individual learning effects that are revised each period as information accumulates. Empirically, therefore, it will be important to differentiate among these three sources: inertia (which we denote by γ in the econometric model), state dependence (which we denote by β), and individual learning effects η_i.

When research is undertaken, however, the individual selects the plan j that solves

$$v_i^2(p_{i1}, \ldots, p_{ij}) = \max_j E(\widetilde{u}_{ij} | \widetilde{p}_{ij} = p_{ij}) - r_i,$$

where p_{ij} is a realization of $\widetilde{p}_{ij}$. The decision to undertake research therefore involves comparing v_i^1 to the expected value of v_i^2 taken over the joint distribution of the predictable cost component of all available tariffs, that is, comparing it to $v_i^3 = E[v_i^2(\widetilde{p}_{i1}, \widetilde{p}_{i2}, \ldots, \widetilde{p}_{ij})]$. In other words, the individual will undertake incremental research such as information gathering, consumption monitoring, and deliberation effort if the expected value of the maximum expected utility from doing that is greater than the maximum expected utility from the tariff that is chosen with no research. Otherwise the individual will not undertake such incremental research.

When r_i is lower for some households, this simple setting provides a straightforward testable implication: we would expect more of those households to undertake research and to find switching tariffs worthwhile. Thus, the asymmetry in the complexity and monitoring costs across tariffs means that we would expect to find corresponding differences in state dependence and learning effects. If the problems were exactly symmetric, we would expect no such differences.

V. A Model of Repeated Tariff Choice

In this section we first present a semiparametric, random effects, discrete choice model with predetermined variables. This model, based on Arellano and Carrasco (2003), controls for the effects of unobservable heterogeneity and for state dependence. The model is essentially a difference estimator in a repeated discrete choice environment, and as a result, the effect of time-invariant demographics is not identified. In section VI we estimate two specifications of this model to study the choices of tariffs and consumption levels over time and the persistence of wrong tariff-use-level combinations, respectively.

A. A Dynamic Discrete Choice Panel Data Model

A risk-neutral individual chooses one of two tariff options in order to minimize the expected cost of telephone services. The probability of subscribing to a given option may depend on some intrinsic characteristics of consumers, including their telephone use profiles and their expectation on the realization of demand. This can be written as

$$\begin{aligned} y_{it} &= \boldsymbol{I}\left\{\gamma + \beta z_{it} + E\left(\eta_i \mid w_i^t\right) + \varepsilon_{it} \geq 0\right\}, \\ \varepsilon_{it} &\mid w_i^t \sim N\left(0, \sigma_t^2\right), \end{aligned} \tag{3}$$

where $y_{it} = 1$ ($y_{it} = 0$) if the measured (flat) tariff option is chosen. The constant γ captures the effect of inertia—the result of all time-invariant determinants of the choice of individuals.[12] The set of predetermined variables z_{it} includes the past realization of demand x_{it} and the previous choices of tariffs $y_{i(t-1)}$, so that together, they define the particular realization of the state for each individual i when choosing a tariff option at time t: $w_{it} = \{x_{it}, y_{i(t-1)}\}$. Thus, the estimates of β identify the effect of state dependence separately from inertia as z_{it} includes time-varying regressors that are predetermined, that is, not directly correlated with the current or

[12] The specification of Arellano and Carrasco (2003) is more general in the sense that it also includes a time-varying component common to all individuals, γ_t. With the exception of monthly indicators, all of our available demographics are time invariant. We also included these monthly indicators in our empirical analysis, but they did not improve our estimations, even when interacted with past subscription decisions and past realizations of demand.

future values of the error ε_{it} (although lagged values of errors ε_{it} might be correlated with z_{it}).

The probability of subscribing to a given tariff option, and hence the probability of switching tariffs in the future, depends on the sequence of past choices and past realizations of demand for each consumer. As time goes by, individuals make different decisions and hence tend to become increasingly different as their experience diverges with every new choice made. These decisions can be summarized by $w_i^t = \{w_{i1}, \ldots, w_{it}\}$, which is the history of past choices represented by a sequence of realizations: $w_{it} = \{x_{it}, y_{i(t-1)}\}$. Addressing individual heterogeneity in this model adds up to controlling for the different observed sequence of decisions of each individual. As consumers choose differently, they accumulate different experiences and invest differently in information-gathering and deliberation efforts. These experiences in turn change the information set on which they decide in the future. For instance, consumers who have previously chosen the measured option may have learned that their demand is systematically high, so that in the future, they will be more likely to subscribe to the flat tariff option. Consumers who have always remained on the flat tariff option have accumulated different experiences, and this also affects their conditional probability of renewing their subscription to the flat tariff option.

The last element of the model is η_i, an individual effect whose forecast is revised each period t as the information summarized by the history w_i^t accumulates. In our case, η_i is the intrinsic individual value of tariff option $y_{it} = 1$. This value of choosing the measured option is not known to individuals; hence, only its expectation enters the decision rule. In other words, the probability of choosing the measured option is not only affected by inertia (γ) and state dependence (β), but also by the learning effect identified by $E\left(\eta_i \mid w_i^t\right)$ after controlling for individual heterogeneity.[13]

In our second application of this model, y_{it} does not represent the choice of tariff, but whether the joint combination of tariff choice and use level is the right one. In this second application, γ identifies all the elements conducive to inattention that induce individuals to make the wrong choice permanently, while the effect of state dependence β identifies whether individuals revise their choices to avoid making mistakes permanently depending on their experiences. Accounting for individual heterogeneity amounts to addressing the value of rational inattention—the cost of choosing wrong combinations that might eventually trigger switching tariffs.

Summing up, the model defines conditional probabilities for every possible sequence of realizations of state variables in order to deal with regressors that are predetermined but not exogenous, such as the previous choices of tariffs and the past realizations of demand. Then the estimator computes the probability of subscribing to a given tariff along every possible path of past realizations of demand and subscription decisions. The panel data structure allows us to identify the effect of individual unobserved heterogeneity since, in each period, consumers may make different decisions even if they have shared the same history of realizations of state variables until then.

Finally, note that the conditional distribution of the sequence of expectations $E\left(\eta_i \mid w_i^t\right)$ is left unrestricted and, hence, the process of updating expectations as information accumulates is not explicitly modeled. This is the only aspect of the model that makes it semiparametric. Although the assumption of normality of the distribution of errors is not essential, the assumption that the errors ε_{it} are not correlated over time is necessary for the estimation. Since errors are assumed to be normally distributed, conditional on the history of past decisions, the probability of choosing the measured option at time t for any given history w_i^t can be written as

$$\text{Prob}\left(y_{it} = 1 \mid w_i^t\right) = \Phi\left[\frac{\gamma + \beta z_{it} + E\left(\eta_i \mid w_i^t\right)}{\sigma_t}\right]. \quad (4)$$

B. *Econometric Implementation*

Since all our regressors are dichotomous variables, their support is a lattice with J points. The vector w_{it} has a support defined by $2J$ nodes $\{\phi_1, \ldots, \phi_{2J}\}$. The $t \times 1$ vector of regressors $z_i^t = \{z_{i1}, \ldots, z_{it}\}$ has a multinomial distribution and may take up to J^t different values. Similarly, the vector w_i^t is defined on $(2J)^t$ values, for $j = 1, \ldots, (2J)^t$. Given that the model has discrete support, any individual history can be summarized by a cluster of nodes representing the sequence of tariff choices and demand realizations for each individual in the sample. Thus, the conditional probability can be rewritten as

$$\begin{aligned} p_{jt} &= \text{Prob}\left(y_{it} = 1 \mid w_i^t = \phi_j^t\right) \\ &\equiv h_t\left(w_i^t = \phi_j^t\right), \qquad j = 1, \ldots, (2J)^t. \end{aligned} \quad (5)$$

In order to account for unobserved individual effects, we compute the proportion of customers with identical history up to time t who subscribe to the measured tariff option M at each time t. We then repeat this procedure for every available history in the data. For each history, we compute the percentage of consumers who subscribe to the measured option. This provides a simple estimate of the unrestricted probability $\hat{p}_{tj}$ for each possible history present in the sample. Then, by taking first differences of the inverse of the equation above, we get

$$\begin{aligned} &\sigma_t \Phi^{-1}\left[h_t\left(w_i^t\right)\right] - \sigma_{t-1}\Phi^{-1}\left[h_{t-1}\left(w_i^{t-1}\right)\right] \\ &\quad - \beta\left(z_{it} - z_{i(t-1)}\right) = \xi_{it}, \end{aligned} \quad (6)$$

[13] Since this distribution is conditional on the individual's history w_i^t, and thus on the observable subsets of histories available in our sample, estimates may be subject to the initial conditions problem (Heckman, 1981, see). Arellano and Carrasco (2003) point out that this feature of the model is shared by many other discrete choice panel data models when dealing with unobserved heterogeneity, including Chamberlain (1984) and Newey (1994).

and by the law of iterated expectations, we have

$$E[\xi_{it} \mid w_i^{t-1}] = E[E(\eta_i \mid w_i^t) - E(\eta_i \mid w_i^{t-1}) \mid w_i^{t-1}] = 0. \tag{7}$$

This conditional moment condition serves as the basis of the GMM estimation of parameters β after normalizing $\sigma_1 = 1$. To identify the effect of inertia, we make use of

$$E\left[E(\eta_i \mid w_i^{t-1})\right] = E\left[\Phi^{-1}\left[h_t\left(w_i^{t-1}\right)\right] - \gamma - \beta z_{it}\right] = 0. \tag{8}$$

Arellano and Carrasco (2003) show that there is no efficiency loss in estimating these parameters by a two-step GMM method where, in the first step, the conditional probabilities p_{tj} are replaced by unrestricted estimates $\hat{p}_{tj}$, the proportion of consumers with a given history that subscribe to the measured service. Then

$$\hat{h}_t\left(w_i^t\right) = \sum_{j=1}^{(2J)^t} \boldsymbol{I}\left\{w_i^t = \phi_j^t\right\} \cdot \hat{p}_{tj}, \tag{9}$$

which is used to define the sample orthogonality conditions of the GMM estimator:[14]

$$\frac{1}{N}\sum_{i=1}^{N}\left\{\sigma_t \Phi^{-1}\left[\hat{h}_t\left(w_i^{t-1}\right)\right] - \gamma - \beta z_{it}\right\} = 0, \quad t = 2, \ldots, T, \tag{10}$$

and

$$\frac{1}{N}\sum_{i=1}^{N} d_{it}\left\{\sigma_t \Phi^{-1}\left[\hat{h}_t\left(w_i^t\right)\right] - \sigma_{t-1}\Phi^{-1}\left[\hat{h}_{t-1}\left(w_i^{t-1}\right)\right] - \beta\left(x_{it} - x_{i(t-1)}\right)\right\} = 0, \quad t = 3, \ldots, T, \tag{11}$$

where d_{it} is a vector containing the indicators $\mathbf{1}\left\{w_i^t = \phi_j^t\right\}$ for $j = 1, \ldots, (2J)^{t-1}$.

VI. Empirical Evidence: Inertia, State Dependence, and Learning

Every month consumers choose their tariff option and use level. In section V, we argued that past choices are valid instruments to identify the effect of state dependence separately from the effects of inertia and learning. We begin this section by showing the transition matrices between tariff choices by previous telephone use levels in table 4 (top panel). Given the large probabilities along the diagonal, it might be tempting to conclude that tariff switching is not significant. However, that conclusion neglects some interesting results. For instance, if previous use was high, individuals are twice as likely to correctly switch from the measured service to the flat tariff than to incorrectly switch from the flat tariff to the measured service. If, on the contrary, previous demand was low, nobody switches from the measured service to the flat tariff, while among switchers, the largest probability occurs when consumers on the flat tariff correctly switch to the measured service. This asymmetric pattern is consistent with the idea advanced earlier that individuals face substantially lower information, monitoring, and deliberation costs when subscribing to the measured option.

Table 4.—Transition Matrices

	LOW USAGE$_{t-1}$		HIGH USAGE$_{t-1}$	
	MEASURED$_{t-1}$	FLAT$_{t-1}$	MEASURED$_{t-1}$	FLAT$_{t-1}$
MEASURED$_t$	1.0000	0.1123	0.9199	0.0451
FLAT$_t$	0.0000	0.8877	0.0801	0.9549
	MEASURED$_{t-1}$		FLAT$_{t-1}$	
	WRONG$_{t-1}$	RIGHT$_{t-1}$	WRONG$_{t-1}$	RIGHT$_{t-1}$
WRONG$_t$	0.7905	0.3259	0.5205	0.0866
RIGHT$_t$	0.2095	0.6741	0.4745	0.9134

Transition probabilities for each state.

Similarly, in order to characterize whether inattention is mainly rational, the bottom panel of table 4 shows the transition matrices between ex post right and wrong choices conditional on previous tariff choices. We find off-diagonal probabilities that are substantially greater than in the previous case, thus hinting at one of the main results: mistakes are not permanent. This is consistent with the hypothesis that inattention is rational, particularly among those who chose the flat tariff option since their demands are sufficiently large. First, most of those not paying attention remain in the right tariff-use combination. Second, the largest transition probability from wrong to right occurs among those who previously chose the FLAT tariff option. This 47% is much larger than the 11% of customers in the top panel who switched from the FLAT to the MEASURED service because their use was low, something that hints at temporary reductions of demand. In this case, not switching away from the flat option is optimal as demand would tend to return to its normal high level.

In order to account for the dynamic nature of the learning process where individuals may invest time, cognitive effort, and other resources to gain knowledge about their new options and about their own demand for telephone service, we next report the results of two dynamic discrete choice panel data models with predetermined variables that account for the existence of inertia, state dependence, and unobserved individual heterogeneity. The first model tests for inertia and the second for rational inattention. In both cases, we report the consistent GMM estimator of Arellano and Carrasco (2003). In addition, in order to have a sense of the extent to which properly dealing with state dependence plays a fundamental

[14] In practice, the number of moment conditions is smaller than $\sum_t (2J)^{t-1}$ because we consider only clusters with at least four observations. Also, we use the orthogonal deviations suggested by Arellano and Bover (1995) rather than first differences among past values of the state variables.

TABLE 5.—TARIFF SUBSCRIPTION

Method	CONSTANT		MEASURED_{t-1}		LOW USAGE_{t-1}	
GMM	−1.9751	(7.99)	−8.9011	(36.02)	−4.4181	(17.88)
ML	−1.7022	(77.82)	3.2177	(43.13)	0.5388	(10.54)

Consistent GMM random effects dynamic estimates of Arellano and Carrasco (2003) with predetermined regressors and inconsistent ML estimates. Absolute, choice-biased sampling, heteroskedastic-consistent *t*-statistics are reported in parentheses.

TABLE 6.—WRONG CHOICE OF TARIFFS

Method	CONSTANT		WRONG_{t-1}		MEASURED_{t-1}	
GMM	−1.5233	(7.02)	−1.3889	(6.40)	−7.9160	(36.49)
ML	−1.3560	(77.89)	1.3827	(34.11)	0.8354	(15.90)

Consistent GMM random effects dynamic estimates of Arellano and Carrasco (2003) with predetermined regressors and inconsistent ML estimates. Absolute, choice-biased sampling, heteroskedastic-consistent *t*-statistics are reported in parentheses.

role in the analysis, we also report the standard ML estimator that fails to address the endogeneity of lagged dependent variables and ignores individual heterogeneity.

A. *Testing for Inertia in Tariff Choices*

The first model studies whether households tend to remain subscribed to the same tariff option over time regardless of their past realized use levels:

$$\text{MEASURED}_t = \boldsymbol{I}\{\gamma + \beta_1\text{MEASURED}_{t-1} + \beta_2\text{LOW USAGE}_{t-1} + E(\eta_i \mid w_i^t) + \varepsilon_{it} \geq 0\}. \quad (12)$$

The first row in table 5 reports the GMM results accounting for predetermined regressors and unobserved individual heterogeneity. As indicated earlier, this estimator accounts for every potential path of use level and choice of tariffs over time. The estimates we obtain reveal that inertia is important, a finding that is consistent with the persistence of tariff choices along the diagonals of table 4. But we also find that choices vary significantly over time and are not exclusively determined by static considerations. In particular, we find that the GMM estimates of the predetermined variables LOW USAGE_{t-1} and MEASURED_{t-1} are both negative and significant.[15] The negative estimate of LOW USAGE_{t-1} captures the effect of the mistakes consumers made with sufficiently high use levels who still sign up for the optional measured tariff, a finding that is consistent with the transition probabilities shown in table 4. Similarly, the negative estimate of MEASURED_{t-1} indicates that consumers do switch tariffs significantly and that, contrary to the hypothesis of habit and inertia, automatic renewal of tariff subscription options does not necessarily mean that consumers will stay in the previously chosen tariff indefinitely.[16]

The second row of table 5 reports the estimates of a standard probit regression that fails to address the endogeneity of lagged endogenous regressors and ignores individual heterogeneity. These results show, quite remarkably, that the sign of the state dependence estimates is the opposite. According to this misspecified model, consumers with low demand would tend to subscribe to the optional measured service once and for all, since the choice of tariff option also appears to be correlated over time. These results would support the idea that consumers' choices are overwhelmingly characterized by inertia and that switching, if it existed, would not to be relevant or important.

The fact that the consistent GMM method and the static ML method produce opposite results means that they support very different theories of individual behavior. We could simply dismiss the ML estimates because they are inconsistent since they ignore the endogenous nature of regressors as well as unobserved individual heterogeneity. But we can go further and use the model to provide an explanation for the upward bias of the ML estimate. Remember that η_i, the value of subscribing to the optional measured service, is unknown to the consumer. Intuitively, as time elapses, the effects of accumulated experience, cognitive efforts, and other investments materialize by increasing the expected value of subscribing to that option: the updating of $E\left(\eta_i \mid w_i^t\right)$ increases with history w_i^t. In other words, experience should become a more important determinant of tariff choices over time. Therefore, by ignoring the effect of $E\left(\eta_i \mid w_i^t\right)$, what the ML estimates of β_1 and β_2 are in fact doing is pooling the effects of MEASURED_{t-1} and $E\left(\eta_i \mid w_i^t\right)$, and of LOW USAGE_{t-1} and $E\left(\eta_i \mid w_i^t\right)$, respectively. As in Ackerberg and Botticini (2002), it turns out that the bias caused by ignoring the endogeneity of regressors and unobserved heterogeneity is large enough to reverse the conclusions. We take this as an empirical warning and an important methodological result.

We thus conclude that individual heterogeneity and state dependence are crucial to interpret the choice of tariff data and that our consistent estimates do not support the idea that consumers' responses are determined exclusively by inertia or impulsiveness. Instead, they are consistent with the fact that consumers learn over time and tend to rationally change their choices based on their individual experiences.

B. *Rational Inattention in the Choice of Tariffs*

The second model addresses the learning process directly by evaluating whether households that made a mistake are more likely to continue making permanent mistakes in the future:

$$\text{WRONG}_t = \boldsymbol{I}\{\gamma + \beta_1\text{WRONG}_{t-1} + \beta_2\text{MEASURED}_{t-1} + E(\eta_i \mid w_i^t) + \varepsilon_{it} \geq 0\}. \quad (13)$$

Table 6 studies the extent to which ex post mistakes are permanent. The endogenous variable equals 1 whenever household *i* chooses the wrong tariff option ex post, that is, either the measured tariff and a high-use level or the flat tariff

[15] Results are robust across clusters defined by the different dummy demographic indicators employed in table 3.

[16] Impulsiveness or random behavior, such as consumers choosing tariffs by flipping a fair coin every month, would imply a coefficient for MEASURED_{t-1} equal to 0.

TABLE 7.—MARGINAL EFFECTS

Previous Transition	October	November	December	Average Fall
From (Flat,Right) to (Flat,Wrong)	−11.60	−6.52	−4.27	−7.46
From (Measured,Right) to (Measured,Wrong)	−0.01	−1.67	−2.13	−1.27
From (Flat,Right) to (Measured,Right)	−17.73	−17.82	−11.64	−15.73
From (Flat,Wrong) to (Measured,Wrong)	−6.13	−12.98	−9.49	−9.53

Percent change in the probability of choosing the current tariff option wrongly conditional on each transition among states.

and a low-use level. The predetermined variables in this case include whether households made the wrong tariff choice in the previous period and whether they subscribed to the measured tariff option.

The GMM estimates reported in the first row show that the effect of MEASURED_{t-1} is negative and significant, a result that is robust across all demographic strata (not reported). Consistent with the descriptive evidence presented in tables 3 and 4, we can conclude that the switching of tariffs is not symmetric: consumers who previously subscribed to the measured option are more likely to switch options than those who subscribed to the optional flat tariff. This asymmetric behavior is consistent with the differences in cognitive, monitoring, and deliberation costs across the tariff choices discussed earlier. In other words, this finding supports the hypothesis that households that face the less complex problem learn faster and make fewer mistakes. Importantly, we also obtain a negative estimate for WRONG_{t-1}, which is strongly significant across all demographic strata (not reported). Contrary to claims often made in the literature, this indicates that mistakes are not permanent and that the switching between tariff options is aimed at reducing the cost of local telephone service.

Interestingly, the inconsistent ML estimates also reported in table 6 are again in sharp contrast with these results (in fact, again with the opposite sign). The logic for the bias of the ML estimate is similar to the one described earlier. The unobserved cost of making the wrong choice of tariff-use level combination increases over time as consumers accumulate experience with longer histories ω_i^t. Thus, the estimates of state dependence β_1 and β_2 pool the effect of the state with the unaddressed component of the error conveying the effect of learning: $E\left(\eta_i \mid w_i^t\right)$. This bias is so large that the ML estimates of WRONG_{t-1} and MEASURED_{t-1} are positive and strongly significant. In other words, these estimates would incorrectly lead us to conclude that households make permanent mistakes. These mistakes would be a characteristic of households driven mostly by rational inattention or by households that think that they are going to consume below the threshold level but systematically consume above it (for example, naive hyperbolic discounters).

Summing up, individual heterogeneity and state dependence are again methodologically and empirically crucially important in interpreting the choice of tariff data and to qualify the effects of inertia. Despite the arguably low amounts of money at stake in these consumption decisions, consumer behavior is not characterized by permanent mistakes.

C. *Marginal Effects*

Before concluding, we pursue the result that mistakes are a transitory phenomenon and compute the marginal effects associated with the transition among different states. Arellano and Carrasco (2003) show that the probability of subscribing to the wrong tariff plan when we compare two states $z_{it} = z^0$ and $z_{it} = z^1$ changes by the proportion:

$$\hat{\Delta}_t = \frac{1}{N}\sum_{i=1}^{N}\left\{\Phi\left(\hat{\sigma}_t^{-1}\hat{\beta}\left(z^1 - z_{it}\right) + \Phi^{-1}\left[\hat{h}_t\left(w_i^t\right)\right]\right)\right. \left. -\Phi\left(\hat{\sigma}_t^{-1}\hat{\beta}\left(z^0 - z_{it}\right) + \Phi^{-1}\left[\hat{h}_t\left(w_i^t\right)\right]\right)\right\}. \quad (14)$$

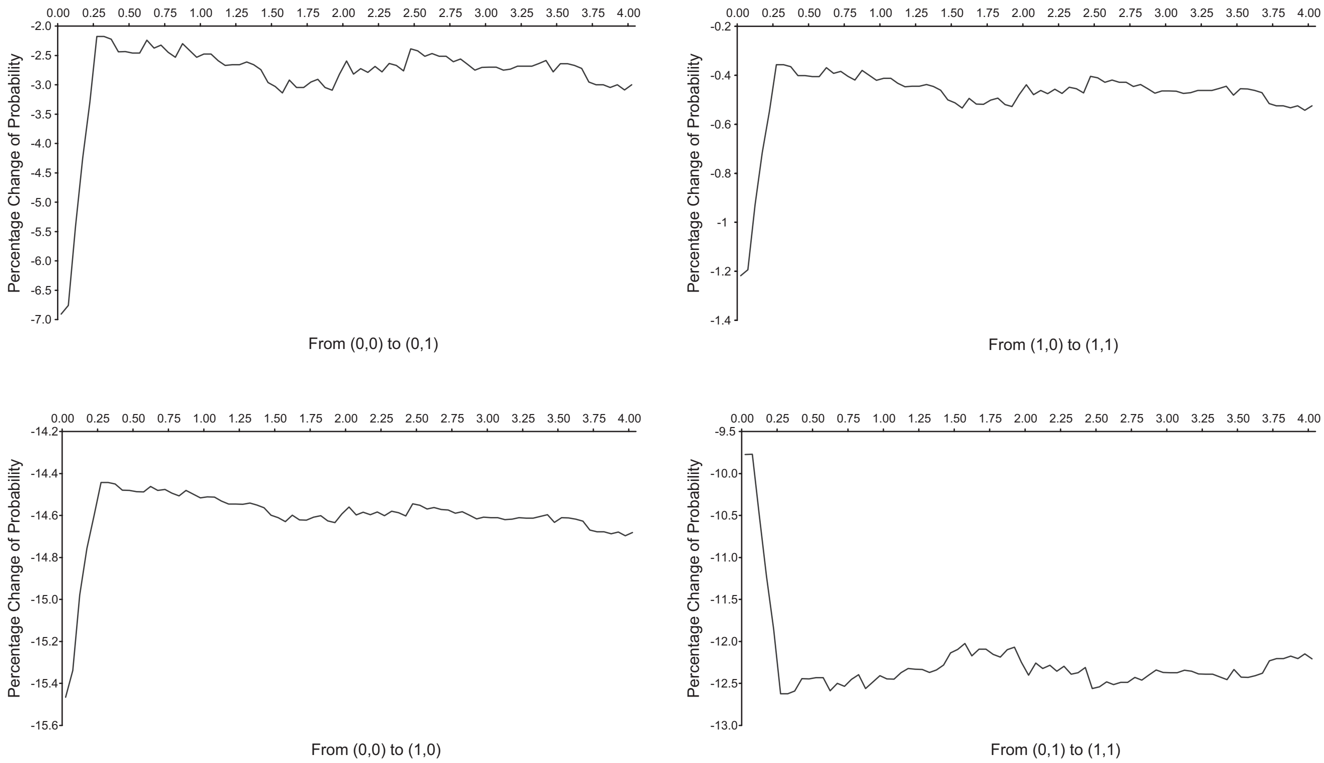
Since the evaluation depends on the history of past choices ω_i^t, these marginal effects are different for each month in the sample. Table 7 presents four marginal effects evaluated in October, November, and December and the average effect over the fall.[17] The first two rows show the change in probability of choosing incorrectly if consumers chose incorrectly in the previous month. The first row indicates that this probability decreases on average by 7.46% if consumers subscribed to the flat tariff option, while the second row shows that this probability decreases by 1.27% had they subscribed to the measured tariff option. Thus, regardless of the choice of tariff, it is less likely that they will make another mistake in their choice of tariffs.

Similarly, the last two rows report the change in probability of choosing incorrectly if consumers subscribed to the optional measured service in the previous month. This probability decreases by 15.73% if consumers subscribed correctly to the optional measured service in the previous month and decreases by 9.53% if they subscribed incorrectly to the optional measured service. Thus, consistent with the asymmetry in the complexity of the problems discussed earlier, the probability of making a mistake is substantially lower after subscribing to the measured option than after subscribing to the flat tariff. This decrease in probability is more important for those with low demand for whom the measured service is the least expensive option than for those with a use pattern above the threshold of $19.02.

Finally, it is important to note that in analyzing these marginal effects, WRONG is defined simply to be equal to 1 when consumers pay any positive amount above the cost of the alternative option. Rather than treating all mistakes equally,

[17] These four transitions exhaust the relevant effects to be reported. To compute the marginal effects of going in the opposite direction, just reverse the sign of the corresponding effect in table 7.

FIGURE 1.—MARGINAL EFFECTS AT DIFFERENT MISTAKE THRESHOLDS



we repeat the analysis for different thresholds in increments of five cents from $0.00 to $4.00. This allows us to measure whether this change in probability varies significantly with the magnitude of the mistake. Figure 1 reports the average marginal effects for the fall. Interestingly, we find that marginal effects experience an abrupt jump in the first 25 to 30 cents and remain basically constant once consumers realize a mistake above these 25 to 30 cents. Recall that under the measured service option, consumers are not billed for the allowance unless their use is above $19.02. This is 32 cents more than the $18.70 cost of the flat tariff option. We find it remarkable that this amount is almost identical to 25 to 30 cents.

VII. Conclusion

The systematic analysis of individual responses to changes in the environment is important for understanding the determinants of attention and inattention and the extent and formation of rationality. The natural setting of the Kentucky tariff experiment and a rich panel data set that is free from a number of critical obstacles have allowed us to uncover households' responses in isolation from a number of conflicting considerations that generally exist in other circumstances.

We find that households recognize that choices today affect their utilities in the future and actively react to a new option despite potential savings of very small magnitude. They make no permanent mistakes. Their reactions, however, are not symmetric. Households that face a more costly and cognitively more difficult tariff problem learn more slowly and are more likely to make mistakes than households that face a simpler tariff choice problem. The fact that the evidence turns out to be drastically different when lagged endogenous variables and unobserved heterogeneity are appropriately treated in the econometric analysis indicates that they play an important role in the dynamic learning process.

When and why people are attentive or inattentive and, when they are attentive, when and why people get it right or wrong, are fundamental questions for our understanding of human decision making. We do not claim that the results we have obtained will systematically generalize to other settings. This is an empirical question whose answer depends on the degree of complexity, the costs of monitoring and information, the size of incentives, and possibly other characteristics of the specific problem and environment under study. What we hope is that the analysis in this paper will contribute to an empirically based science of decision making that, together with theoretical and experimental work on cognitive processes, will improve our understanding of when and how decision makers think about real-life problems.

REFERENCES

Abaluck, Jason T., and Jonathan Gruber, "Choice Inconsistencies among the Elderly: Evidence from Plan Choice in the Medicare Part D Program," *American Economic Review* 101 (2010), 1180–1210.

Ackerberg, Daniel, and Maristella Botticini, "Endogenous Matching and the Empirical Determinants of Contract Form," *Journal of Political Economy* 110 (2002), 564–591.

Agarwal, Sumit, Souphala Chomsisengphet, Chunlin Liu, and Nicholas S. Souleles, "Do Consumers Choose the Right Credit Contracts?" mimeograph, Wharton School, University of Pennsylvania (2006).
Akerlof, George A. and William T. Dickens, "The Economic Consequences of Cognitive Dissonance," *American Economic Review* 72 (1982), 307–319.
Akerlof, George A., and Janet L. Yellen, "Rational Models of Irrational Behavior," *American Economic Review* 77 (1982), 137–142.
Amemiya, Takeshi, *Advanced Econometrics* (Cambridge, MA: Harvard University Press, 1985).
Americks, John, Andrew Caplin, and John Leahy, "Wealth Accumulation and the Propensity to Plan," *Quarterly Journal of Economics* 118 (2003), 1007–1047.
Arellano, Manuel, and Olympia Bover, "Another Look at the Instrumental Variable Estimation of Error-Components Model," *Journal of Econometrics* 68 (1995), 29–51.
Arellano, Manuel, and Raquel Carrasco, "Binary Choice Panel Data Models with Predetermined Variables," *Journal of Econometrics* 115 (2003), 125–157.
Arrow, Kenneth J., "Rationality of Self and Others in an Economic System," in R. M. Hogarth and M. W. Reder, eds., *Rational Choice: The Contrast between Economics and Psychology* (Chicago: Chicago University Press, 1987).
Ball, Laurence M., N. Gregory Mankiw, and Ricardo Reis, "Monetary Policy for Inattentive Economies," *Journal of Monetary Economics* 52 (2005), 703–725.
Becker, Gary S., "Irrational Behavior and Economic Theory," *Journal of Political Economy* 70 (1962), 1–3.
Brown, Jeffrey R., and Austan Goolsbee, "Does the Internet Make Markets More Competitive? Evidence from the Life Insurance Industry," *Journal of Political Economy* 110 (2002), 481–507.
Brynjolfsson, Erik, and Michael D. Smith, "Frictionless Commerce? A Comparison of Internet and Conventional Retailers," *Management Science* 46 (2000), 563–585.
Chamberlain, Gary, "Panel Data," in Z. Griliches and M. D. Intriligator, eds., *Handbook of Econometrics* (New York: North-Holland, 1984).
Chiappori, Pierre-André, and Bernard Salanié, "Testing for Asymmetric Information in Insurance Markets," *Journal of Political Economy* 108 (2000), 56–78.
Choi, J. J., D. Laibson, B. C. Madrian, and A. Metrick, "Reinforcement Learning and Savings Behavior," *Journal of Finance* 64 (2009), 2515–2534.
Conslik, J., "Why Bounded Rationality?" *Journal of Economic Literature* 34 (1996), 669–700.
Costa-Gomes, Miguel A., and Vincent P. Crawford, "Cognition and Behavior in Two-Person Guessing Games: An Experimental Study," *American Economic Review* 96 (2006), 1737–1768.
Costa-Gomes, Miguel A., Vincent P. Crawford, and Bruno Broseta, "Cognition and Behavior in Normal-Form Games: An Experimental Study," *Econometrica* 69 (2006), 1193–1235.
DellaVigna, Stefano, "Psychology and Economics: Evidence from the Field," *Journal of Economic Literature* 47 (2009), 315–372.
DellaVigna, Stefano, and Ulrike Malmendier, "Paying Not to Go to the Gym," *American Economic Review* 96 (2006), 694–719.
Ellison, Glenn, and Sara Fisher, Ellison, "Search, Obfuscation, and Price Elasticities on the Internet," *Econometrica* 77 (2009), 427–452.
Gabaix, X., D. Laibson, G. Moloche, and S. Weinberg, "Costly Information Acquisition: Experimental Analysis of a Bounded Rationality Model," *American Economic Review* 96 (2006), 1043–1048.
Gabaix, Xavier, and David Laibson, "The 6D Bias and the Equity Premium Puzzle" (pp. 257–311), in Ben Bernanke and Kenneth Rogoff, eds., *NBER Macroeconomics Annual 2001* (Cambridge, MA: MIT Press, 2002).
Gode, Dan K., and Shyam Sunder, "Allocative Efficiency of Markets with Zero-Intelligence Traders: Market as a Partial Substitute for Individual Rationality," *Journal of Political Economy* 101 (1993), 119–137.
Grubb, Michael D., "Selling to Overconfident Consumers," *American Economic Review* 99 (2009), 1770–1807.
Hansen, Lars P., and Thomas J. Sargent, *Robustness* (Princeton, NJ: Princeton University Press, 2008).
Heckman, James J., "The Incidental Parameters Problem and the Problem of Initial Conditions in Estimating a Discrete Time–Discrete Data Stochastic Process," in C. F. Manski and D. L. McFadden, eds., *Structural Analysis of Discrete Data with Applications* (Cambridge, MA: MIT Press, 1981).
Heiss, Florian, Daniel McFadden, and Joachim Winter, "Mind the Gap! Consumer Perceptions and Choices of Medicare Part D Prescription Drug Plans," in D. A. Wise, ed., *Research Findings in the Economics of Aging* (Chicago: University of Chicago Press, 2009).
Hellwig, Christian, Sebastian Khols, and Laura Veldkamp, "Information Choice Technologies," *American Economic Review Papers and Proceedings* 102 (2012), 35–40.
Ketcham, Jonathan, Claudio Lucarelli, Eugenio J. Miravete, and M. Christopher Roebuck, "Sinking, Swimming, and Learning to Swim in Medicare Part D," *American Economic Review* 102 (2012), 2639–2673.
Kling, Jeffrey R., Sendhil Mullainathan, Eldar Shafir, Lee C. Vermeulen, and Marian V. Wrobel, "Comparison Friction: Experimental Evidence from Medicare Drug Plans," *Quarterly Journal of Economics* 127 (2012), 199–235.
Knight, Frank W., *Risk, Uncertainty, and Profit* (Boston: Houghton Mifflin, 1921).
Koscegi, Botond, and Paul Heidhues, "Competition and Price Variation When Consumers Are Loss Averse," *American Economic Review* 98 (2008), 1245–1268.
Koscegi, Botond, and Matthew Rabin, "A Model of Reference-Dependent Preferences," *Quarterly Journal of Economics* 121 (2006), 1133–1166.
Lerman, Steven R., and Charles F. Manski, "The Estimation of Choice Probabilities from Choice Based Samples," *Econometrica* 45 (1977), 1977–1988.
Lipman, Barton L., "How to Decide How to Decide How to . . . : Modeling Limited Rationality," *Econometrica* 59 (1991), 1105–1125.
Lucas, Robert E. Jr., "Adaptive Behavior and Economic Theory," in R. M. Hogarth and M. W. Reder, eds., *Rational Choice: The Contrast between Economics and Psychology* (Chicago: University of Chicago Press, 1987).
Lusardi, Annamaria, "Information, Expectations and Savings," in H. Aaron, ed., *Behavioral Dimensions of Retirement Economics* (New York: Russell Sage Foundation, 1999).
——— "Planning and Saving for Retirement," mimeograph, Dartmouth College (2003).
Madrian, Brigitte C., and Dennis F. Shea, "The Power of Suggestion: Inertia in 401(k) Participation and Savings Behavior," *Quarterly Journal of Economics* 116 (2001), 1149–1187.
Mankiw, N. Gregory, and Ricardo Reis, "Sticky Information versus Sticky Prices: A Proposal to Replace the New Keynesian Philips Curve," *Quarterly Journal of Economics* 117 (2002), 1295–1328.
Miravete, Eugenio J., "Estimating Demand for Local Telephone Service with Asymmetric Information and Optimal Calling Plans," *Review of Economic Studies* 69 (2002), 943–971.
——— "Choosing the Wrong Calling Plan? Ignorance and Learning," *American Economic Review* 93 (2003), 297–310.
——— "The Welfare Performace of Sequential Pricing Mechanisms," *International Economic Review* 46 (2005), 1321–1360.
Moscarini, Giuseppe, "Limited Information Capacity as a Source of Inertia," *Journal of Economic Dynamics and Control* 28 (2004), 2003–2035.
Moscarini, Giuseppe, and Lones Smith, "The Optimal Level of Experimentation," *Econometrica* 69 (2001), 1629–1644.
——— "The Law of Large Demand for Information," *Econometrica* 70 (2002), 2351–2366.
Narayanan, Sridhar, Pradeep K. Chintagunta, and Eugenio J. Miravete, "The Role of Self Selection, Usage Uncertainty and Learning in the Demand for Local Telephone Service," *Quantitative Marketing and Economics* 5 (2007), 1–34.
Newey, Whitney K., "The Asymptotic Variance of Semiparametric Estimators," *Econometrica* 62 (1994), 1349–1382.
Reis, Ricardo, "Inattentive Consumers," *Journal of Monetary Economics* 53 (2006a), 1761–1800.
——— "Inattentive Producers," *Review of Economic Studies* 73 (2006b), 793–821.

Rubinstein, Ariel, *Modeling Bounded Rationality* (Cambridge, MA: MIT Press 1998).
Savage, Leonard J., *The Foundations of Statistics* (New York: Wiley, 1954).
Scott-Morton, Fiona, Florian Zettelmeyer, and Jorge Silva-Risso, "Internet Car Retailing," *Journal of Industrial Economics* 49 (2001), 501–519.
Sims, Christopher A., "Implications of Rational Inattention," *Journal of Monetary Economics* 50 (2003), 665–690.
Spiegler, Ran, *Bounded Rationality and Industrial Organization* (New York: Oxford University Press, 2011).
Stigler, George J., and Gary S. Becker, "De Gustibus Non Est Disputendum," *American Economic Review* 67 (1977), 76–90.