Online Appendix:
Mental Accounting and Consumer Choice

Justine Hastings
Brown University and NBER
Jesse M. Shapiro*
Chicago Booth and NBER

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1 Additional Findings and Specifications

Figure 1 shows the dynamics of the effect of a change in the price of regular gasoline on the share of gasoline that is regular grade. Out to a six month horizon, the effects are fully persistent, indicating that a permanent increase in the regular price would increase the share of regular gasoline for at least six months.

Figure 2 shows that the premium-regular price gap tends to compress when the regular-grade price rises. Figure 3 shows evidence on the dynamics of this compression. After an increase in the regular price, the gap in prices falls, but the decrease dissipates within two months.

Figure 4 illustrates the findings of our placebo analysis. In each panel we estimate a logit model with a product-specific constant, allowing the marginal utility of money to depend on household income and to vary flexibly across weeks in the data. Using this model we can calculate the household income implied by purchasing behavior in each week: the household income level that would rationalize the average household's behavior in a given week with the model estimated in a baseline week. For gasoline, the implied income series moves inversely with prices. This is simply another representation of our main finding: as the gas price rises, households act far poorer, poorer than can be reconciled with the plausible income effect of gasoline. For orange juice and milk purchases, we do not observe such behavior. Indeed, during the large fall in gasoline prices in the autumn of 2008, households act, if anything, slightly poorer when choosing orange juice or milk brands, consistent with the onset of the financial crisis but not with their behavior at the pump.

Figure 5 shows the predictions of the model of loss aversion that we estimate in the paper alongside the predictions of a model that allows for diminishing sensitivity. Formally, we assume that the universal gain-loss function is a power function (Tversky and Kahneman 1992). Under this assumption it follows that per-gallon utility is given by

$$\begin{aligned} u_{ijt} = {} & \alpha_{ij} - \mu p_{jt} + \varepsilon_{ijt} \\ & + \eta\theta^{\nu}\frac{(q_{it}g_j - q_{it}\tilde{g}_{it})^{\nu}}{q_{it}}1_{g_j \geq \tilde{g}_{it}} + \gamma\theta^{\nu}\frac{\left(\left|q_{it}g_j - q_{it}\tilde{g}_{it}\right|\right)^{\nu}}{q_{it}}1_{g_j < \tilde{g}_{it}} \\ & - \eta\mu^{\nu}\frac{\left(\left|q_{it}p_{jt} - q_{it}\tilde{p}_{it}\right|\right)^{\nu}}{q_{it}}1_{p_j \leq \tilde{p}_{it}} - \gamma\mu^{\nu}\frac{(q_{it}p_{jt} - q_{it}\tilde{p}_{it})^{\nu}}{q_{it}}1_{p_j > \tilde{p}_{it}} \end{aligned} \tag{1}$$

*E-mail: justine_hastings@brown.edu, jesse.shapiro@chicagobooth.edu.

We set $\nu = 0.88$ (Tversky and Kahneman 1992) and estimate the separately identified parameters.

Figure 6 plots the average automobile speed, respectively, against the price of regular gasoline. We use data from the National Automotive Sampling System General Estimates System (NASS-GES) to construct a monthly time series of traveling speeds for 1990-2009 (National Highway Traffic Safety Administration 2009). The data come from a nationally representative sample of police-reported motor vehicle accidents. We construct a monthly series of the average traveling speed for automobiles traveling more than 0 miles per hour and at or below 95 miles per hour that were struck by another vehicle. (We exclude automobiles that struck other vehicles because these automobiles are likely to be less representative of vehicles on the road.) A regression in first differences reveals no statistically significant relationship between gasoline prices and traveling speeds.

Table 1 presents five specifications. The first is our baseline model that assumes that α_{ij} and μ_i are constant across households. The second, also presented in the body of the paper, assumes that α_{ij} are independently normally distributed, and is estimated with quadrature accuracy 9 on a subsample of the data. The third specification repeats the second using the full sample and a lower quadrature accuracy. (Accuracy and sample size trade off due to memory constraints.) The fourth specification allows for unobserved heterogeneity in μ_i instead of α_{ij}. The fifth specification relaxes the distributional assumptions on α_{ij} and μ_i by estimating the model separately for each household and estimating parameters η^M and η^G via FGLS from the household-specific estimates, under the assumption that μ_i is uncorrelated with m_{it} conditional on α_{ij}. This specification restricts attention to households that buy all three grades of gasoline at some point in the sample period. (For households that do not buy all grades, the constants α_{ij} are unidentified.)

Table 2 presents our placebo models of orange juice and milk purchases for both the full sample of transactions and a subsample of transactions that occur on the same day as a gasoline purchase. Results are similar in the two samples.

Table 3 presents our placebo models of orange juice and milk purchases for both the full sample of transactions and a subsample of transactions that are made by frequent buyers, defined as households that buy at least 12 times in the respective category in each of the full years in our sample (2006, 2007, and 2008). In the case of orange juice, the point estimate on η^G changes meaningfully but remains well within the confidence interval of the original estimate, and the estimate on η^M becomes less precise due to the smaller number of households in the subsample. In the case of milk, point estimates are similar between the full sample and the subsample. In both cases our substantive conclusion is unchanged: we cannot reject the null hypothesis of fungibility in any specification.

2 Estimates from State-Level Data

For each state and quarter we obtain state aggregate personal income from the Bureau of Economic Analysis (BEA), which we convert into aggregate expenditures by scaling by the US ratio of quarterly consumer expenditures to quarterly personal income from the National Income and Product Accounts (NIPA). We obtain state aggregate gasoline gallons purchased and the average retail price of regular gasoline from the Energy Information Administration (EIA). We estimate the number of households in each state and quarter by multiplying BEA midyear population estimates by the US ratio of households to population (from the Census). We transform all incomes, expenditures and prices into 2005 dollars using the NIPA price index for personal consumption expenditures excluding food and energy.

To estimate our model we assume that expenditures, gasoline quantities, and preferences are identical (up to taste shocks ε_{ijt}) across households within a state. We measure m_{it} as total expenditures divided by the number of households. We measure $q_{it}p_{0t}$ as the product of state gasoline gallons purchased and state average retail price of regular gasoline, divided by the number of households. We transform the market share of each grade of gasoline into the mean utility of that grade in a given state and quarter, relative to the share of regular gasoline (Berry 1994). We estimate the model via 2SLS, treating state per-capita income and the national price of gasoline as excluded instruments and treating the key interactions between total and gasoline expenditures and the price gap as endogenous. (This approach ensures that our key parameters are identified only by variation in income and in national prices.) We allow for a state-quarter-grade utility shock that is mean zero conditional on instruments and controls.

Appendix table 4 presents our results. The format is identical to the presentation of our main results in the paper. Column (1) presents our baseline results and column (2) presents a specification including state fixed effects. In both specifications we confidently reject the null hypothesis of fungibility.

3 Category Budgeting Model

We estimate a model that incorporates the idea that households keep track of category-specific budgets (Heath and Soll 1996) and try to maintain category spending at a target level. An existing theoretical literature argues that such mental accounts may be an effort to economize on optimization or memory costs (Gilboa and Gilboa-Schechtman 2003, Gilboa, Postlewaite and Schmeidler 2010). Because we do not know of an existing model that delivers parametric predictions for our setting, we adopt an ad-hoc empirical specification. We assume that utility is quasilinear in non-gasoline consumption with marginal utility μ and that households experience a utility loss equal to the square of the difference between actual gasoline expenditure and a target expenditure r_{it}. It follows that household i's per-gallon utility from purchasing grade j at time t is

$$u_{ijt} = \alpha_{ij} - \mu p_{jt} - \gamma \frac{(q_{it} p_{jt} - r_{it})^2}{q_{it}} + \varepsilon_{ijt} \tag{2}$$

where γ denotes the importance of maintaining a category budget. We operationalize the model by assuming that r_{it} is equal to the household's sample mean transaction expenditure.

Figure 7 presents the model's predictions. This model fits the data well. Households seek to minimize variability in their expenditures around a target amount. When prices are high, this leads households to switch to cheaper grades of gasoline, and the reverse occurs when prices are low. We stress, however, that unlike our models of loss aversion and price salience, the category budgeting model is not derived from an existing body of theory, and should therefore be taken only as an ad-hoc specification designed to illustrate a possible mechanism.

References

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Gilboa, Itzhak and Eva Gilboa-Schechtman. 2003. Mental accounting and the absentminded driver, in I. Brocas and J.D. Carrillo (eds.), *The Psychology of Economic Decisions, Vol. 1: Rationality and Well-Being*. Oxford: Oxford University Press.

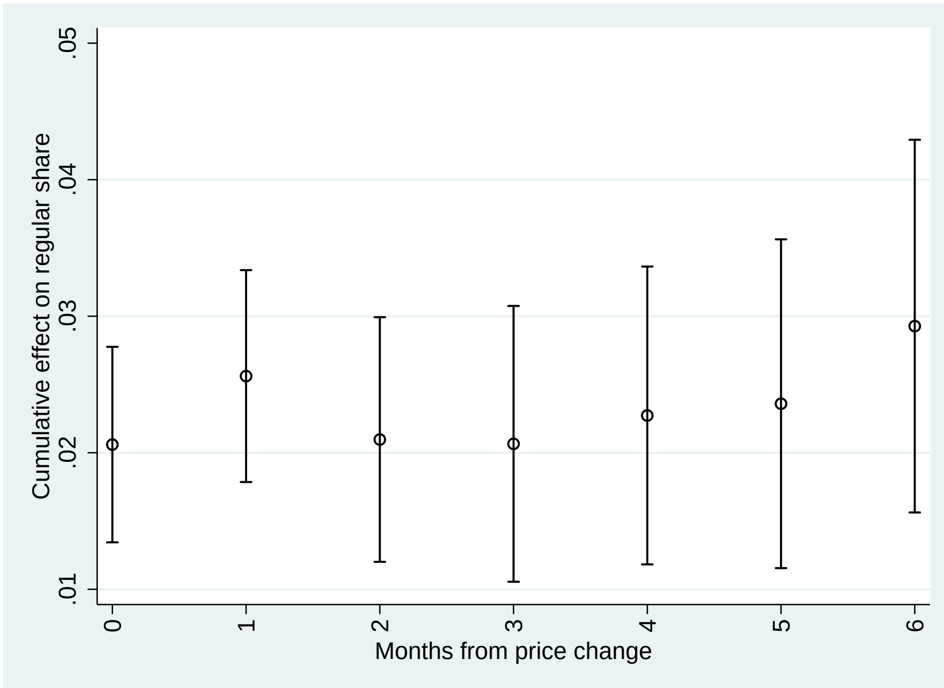
Gilboa, Itzhak, Andrew Postlewaite and David Schmeidler. 2010. The complexity of the consumer problem and mental accounting. *University of Pennsylvania Working Paper*.

Heath, Chip and Jack B. Soll. 1996. Mental budgeting and consumer decisions. *The Journal of Consumer Research* 23(1): 40-52.

National Highway Traffic Safety Administration. 2009. *National Automotive Sampling System General Estimates System*. Accessed at <http://www.nhtsa.gov/NASS> on July 13 2011.

Tversky, Amos and Daniel Kahneman. 1992. Advances in prospect theory: Cumulative representation of uncertainty. *Journal of Risk and Uncertainty* 5: 297-323.

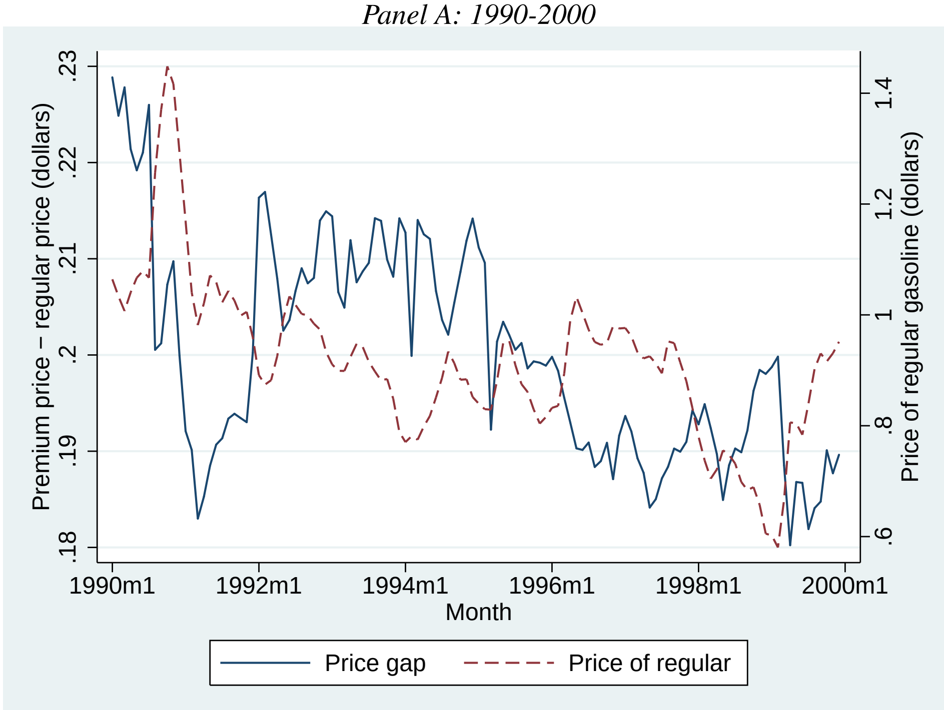
Figure 1: Persistence of the effect of the regular price on the share of regular gasoline



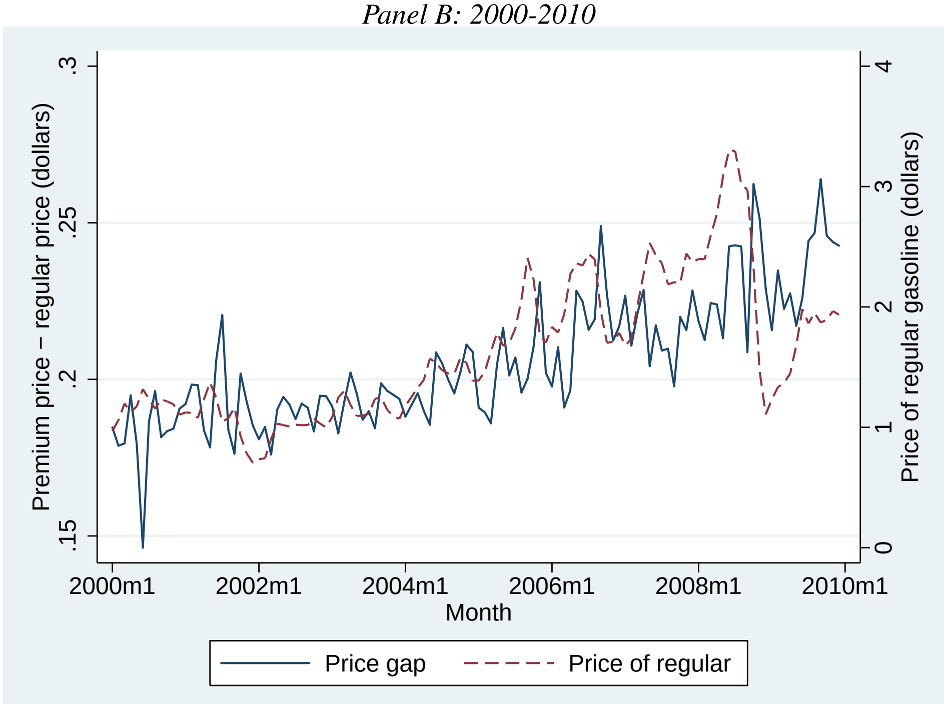
Notes: Data are from the EIA. The plot shows the cumulative effect of a $1 increase in the regular price on the share of regular gasoline. The bars show a 95 percent confidence interval. The plot is based on a regression of the change in the regular share on the change in the regular price and six lags of the change in the regular price.

Figure 2: Price gap and price of regular gasoline

Panel A: 1990-2000

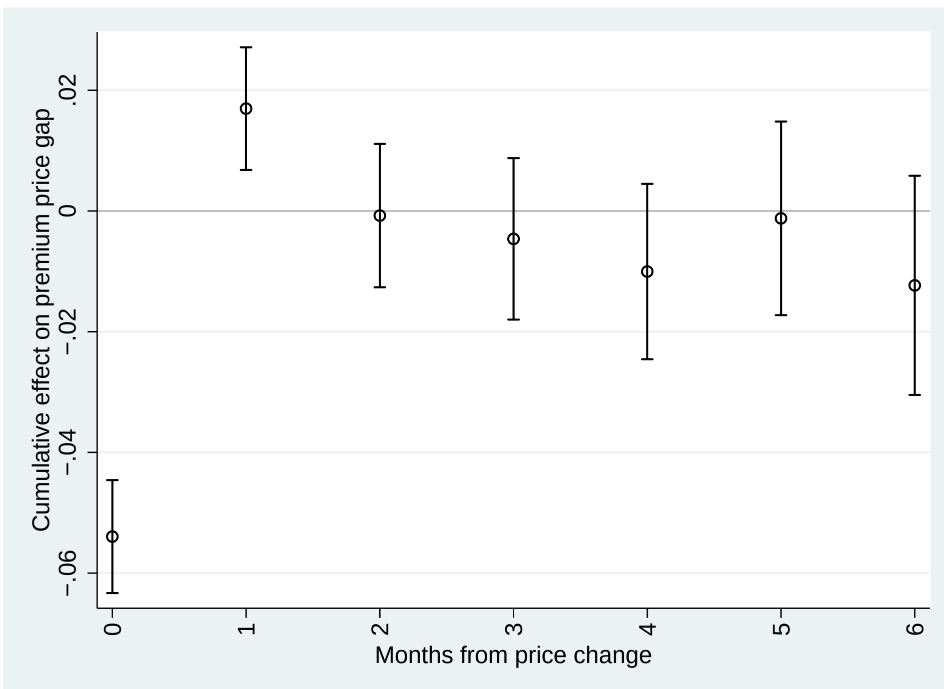


Panel B: 2000-2010



Notes: Data are from the EIA. Each panel plots the monthly US average price of regular gasoline (in 2005 US dollars) and the monthly average price difference between premium and regular gasoline (in 2005 US dollars).

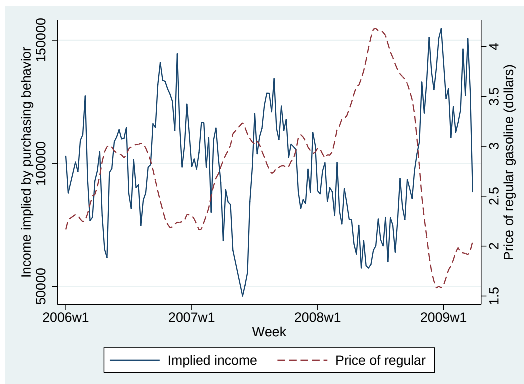
Figure 3: Decay in the effect of regular price on the price gap



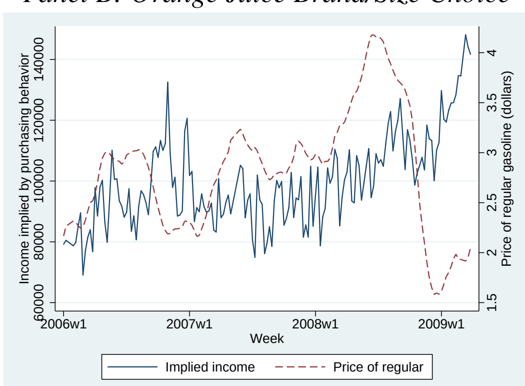
Notes: Data are from the EIA. The plot shows the cumulative effect of a $1 increase in the regular price on the price gap between premium and regular gasoline. The bars show a 95 percent confidence interval. The plot is based on a regression of the change in the price gap between premium and regular gasoline on the change in the regular price and six lags of the change in the regular price. All prices are in 2005 US dollars.

Figure 4: Income implied by purchasing behavior: gasoline vs. placebo categories

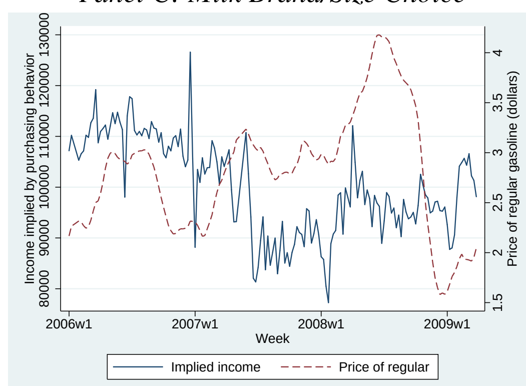
Panel A: Gasoline Grade Choice



Panel B: Orange Juice Brand/Size Choice

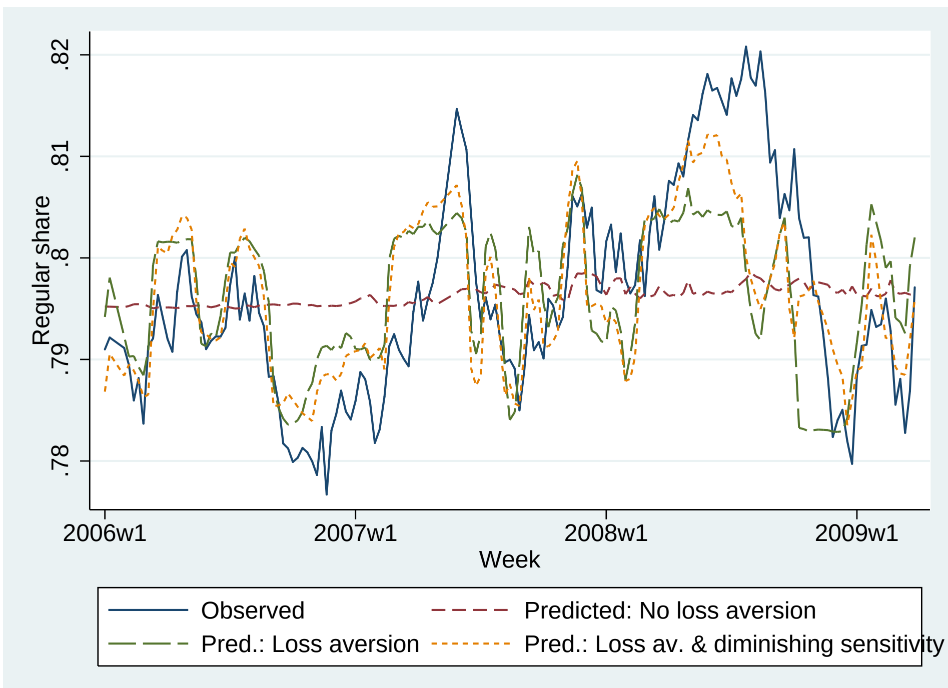


Panel C: Milk Brand/Size Choice



Notes: Data are from the retailer and exclude stores with significant changes to the milk assortment during the sample period. We estimate a logit model allowing for a product-specific constant, a product-specific linear time trend (for orange juice and milk), and a store-week-product-level utility shock that is mean zero conditional on the included variables. We assume that the marginal utility of money is a linear function of income and includes a week-level shock common to all households. We define the "income implied by purchasing behavior" in a given week as the household income such that the marginal utility of money in a baseline week is equal to the marginal utility of money in the given week. (We choose the baseline week so that mean implied income is equal to the sample mean income.) To estimate the model, we aggregate the data to the store-week level and assume household income is equal to mean household income in the store-week. We transform the market share of each product (grade of gasoline, brand/size of orange juice or milk) into the mean utility of that grade in a given store-week, relative to the share of a base product (regular gasoline, private label one-gallon orange juice or milk) and estimate via OLS (Berry 1994).

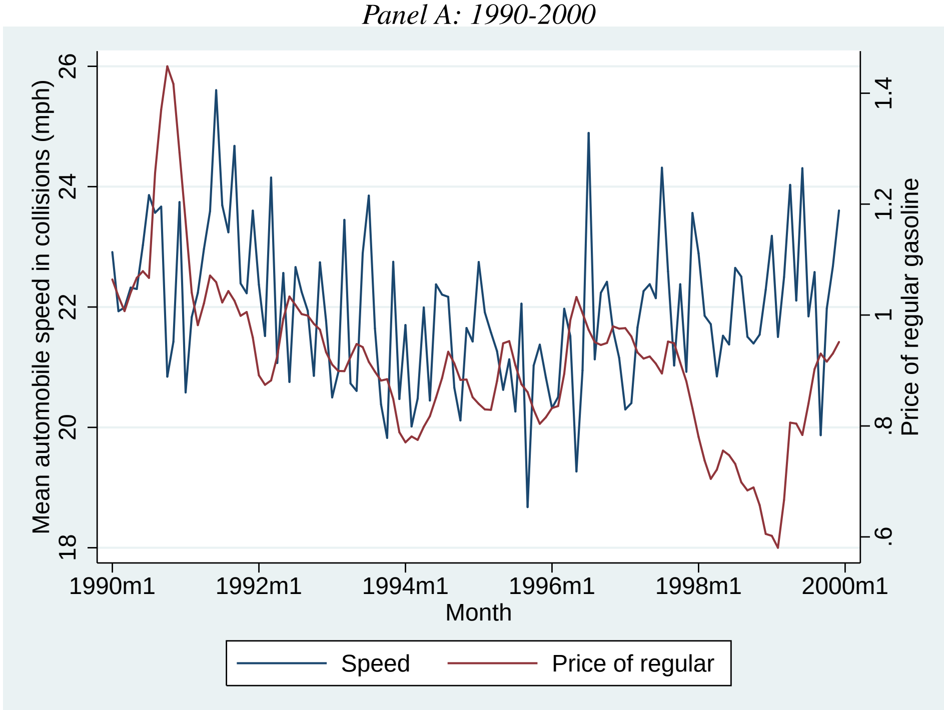
Figure 5: Loss aversion: allowing for diminishing sensitivity



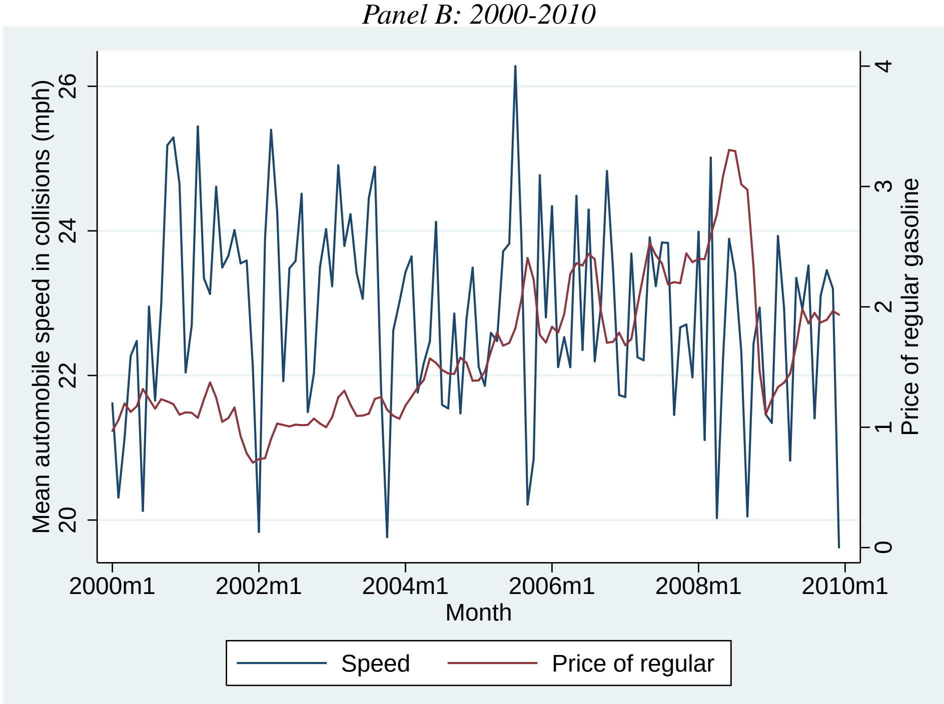
Notes: Data are from the retailer. The line labeled "observed" shows the weekly share of transactions that go to regular gasoline. The line labeled "Price of regular" shows weekly average transaction price of regular gasoline (in current US dollars). The lines labeled "predicted: no loss aversion" and "predicted: loss aversion" show the average predicted probability of buying regular gasoline from the no-loss-aversion and loss-aversion models presented in the body of the paper. The line labeled "predicted: loss aversion and diminishing sensitivity" shows the average predicted probability of buying regular gasoline from the model in equation (1) with $\nu = 0.88$.

Figure 6: Traveling speed of automobiles in collisions

Panel A: 1990-2000

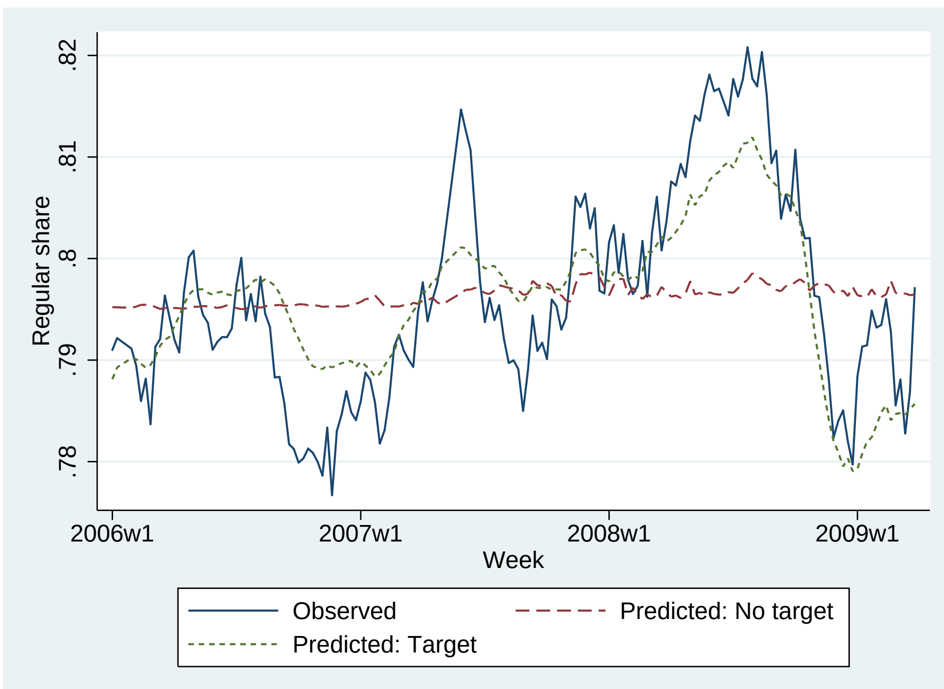


Panel B: 2000-2010



Notes: Each panel plots the average traveling speed for automobiles in the US that are struck during a motor vehicle accident (from the NASS-GES) and the monthly US average price of regular gasoline (from the EIA, in 2005 US dollars).

Figure 7: Category budgeting model



Notes: Data are from the retailer. The line labeled "observed" shows the weekly share of transactions that go to regular gasoline. The lines labeled "predicted: no target" and "predicted: target" show the average predicted probability of buying regular gasoline from the model in equation (2) estimated with γ constrained to 0 and with γ unconstrained, respectively.

Table 1: Additional models with unobserved heterogeneity

Dependent variable: Choice of gasoline grade					
	(1)	(2)	(3)	(4)	(5)
Effect on marginal utility of:					
$1000 increase in gasoline expenditures	0.4306	0.7145	0.7434	0.7721	1.0477
(Parameter η^G)	(0.0314)	(0.0317)	(0.0188)	(0.0340)	(0.0133)
$1000 decrease in total expenditures	0.0293	0.0416	0.0250	0.0204	0.0159
(Parameter η^M)	(0.0008)	(0.0042)	(0.0036)	(0.0087)	(0.0040)
Average marginal effect on regular share of:					
$1 increase in price of regular gasoline	0.0142	0.0140	0.0335	0.0217	0.0349
	(0.0010)	(0.0006)	(0.0008)	(0.0010)	(0.0004)
$1000 decrease in gasoline expenditures	-0.0120	-0.0118	-0.0283	-0.0184	-0.0295
	(0.0009)	(0.0005)	(0.0007)	(0.0008)	(0.0004)
$1000 increase in total expenditures	-0.0008	-0.0007	-0.0010	-0.0005	-0.0004
	(0.0000)	(0.0001)	(0.0001)	(0.0002)	(0.0001)
p-value of Wald test for fungibility $\left(\eta^G = \eta^M\right)$	0.0000	0.0000	0.0000	0.0000	0.0000
Unobservable variation in...		α_{ij}	α_{ij}	μ_i	α_{ij}, μ_i
Quadrature accuracy	–	9	3	9	—
Sample	All	1/10th	All	1/10th	Buy all grades
Number of transactions	10548175	1082486	10548175	1082486	4556308
Number of households	61494	61494	61494	61494	24643

Note: Data are from retailer. Table reports estimates of the model described in the body of the paper. Standard errors in parentheses allow for correlation in residuals by month. Sample "1/10th" is a sample of every 10th transaction for each household. Sample "Buy all grades" restricts to households who buy each grade of gasoline at least once during the sample period. In specification (1) we assume that α_{ij} and μ_i are constant across households and estimate via maximum likelihood. In specifications (2) and (3) we assume that α_{ij} are distributed independently normal across households and choices. In specification (4) we assume that μ_i are distributed independently normal across households and choices. We estimate the models in specifications (2), (3) and (4) via maximum likelihood, approximating the likelihood using sparse grid integration with given accuracy (Heiss and Winschel 2008). In specification (5) we estimate the model separately for each household and estimate parameters η^M and η^G via FGLS from the household-specific parameter estimates, under the assumption that μ_i is uncorrelated with m_{it} conditional on α_{ij}. The Wald test for specification (5) assumes no covariance in the estimates of η^G and η^M.

Table 2: Placebo models: gas days vs all days

Dependent variable: Choice of brand

	(1)	(2)	(3)	(4)
Effect on marginal utility of:				
$1000 increase in gasoline expenditures	-0.0141	-0.0039	-0.0128	-0.0117
(Parameter η^G)	(0.0250)	(0.0275)	(0.0197)	(0.0225)
$1000 decrease in total expenditures	0.0044	0.0044	0.0034	0.0036
(Parameter η^M)	(0.0002)	(0.0003)	(0.0001)	(0.0001)
Average marginal effect on private label share of:				
$1 increase in price of regular gasoline	-0.0169	-0.0047	-0.0055	-0.0050
	(0.0299)	(0.0327)	(0.0084)	(0.0096)
$1000 decrease in gasoline expenditures	0.0143	0.0039	0.0046	0.0042
	(0.0252)	(0.0276)	(0.0071)	(0.0081)
$1000 increase in total expenditures	-0.0045	-0.0044	-0.0012	-0.0013
	(0.0002)	(0.0003)	(0.0000)	(0.0000)
p-value of Wald test for fungibility $(\eta^G = \eta^M)$	0.4571	0.7617	0.4115	0.4977
Category	OJ	OJ	Milk	Milk
Sample	All	Gas day	All	Gas day
Number of transactions	411161	97684	2210312	514449
Number of households	13493	12760	34128	33756

Note: Data are from retailer. Table reports estimates of the model described in the paper but applied to choice of orange juice or milk brand rather than choice of gasoline grade. Standard errors in parentheses allow for correlation in residuals by month. We assume that α_{ij} and μ_i are constant across households. “Gas day” means that the purchase was made on the same day as a gasoline purchase.

Table 3: Placebo models: restricting to frequent buyers

Dependent variable: Choice of brand

	(1)	(2)	(3)	(4)
Effect on marginal utility of:				
$1000 increase in gasoline expenditures	-0.0141	0.0082	-0.0128	-0.0191
(Parameter η^G)	(0.0250)	(0.0219)	(0.0197)	(0.0192)
$1000 decrease in total expenditures	0.0044	0.0046	0.0034	0.0033
(Parameter η^M)	(0.0002)	(0.0003)	(0.0001)	(0.0001)
Average marginal effect on private label share of:				
$1 increase in price of regular gasoline	-0.0169	0.0100	-0.0055	-0.0076
	(0.0299)	(0.0266)	(0.0084)	(0.0076)
$1000 decrease in gasoline expenditures	0.0143	-0.0084	0.0046	0.0064
	(0.0252)	(0.0225)	(0.0071)	(0.0064)
$1000 increase in total expenditures	-0.0045	-0.0047	-0.0012	-0.0011
	(0.0002)	(0.0003)	(0.0000)	(0.0000)
p-value of Wald test for fungibility $(\eta^G = \eta^M)$	0.4571	0.8676	0.4115	0.2443
Category	OJ	OJ	Milk	Milk
Sample	All	Frequent buyer	All	Frequent buyer
Number of transactions	411161	164742	2210312	1659129
Number of households	13493	2287	34128	17044

Note: Data are from retailer. Table reports estimates of the model described in the paper but applied to choice of orange juice or milk brand rather than choice of gasoline grade. Standard errors in parentheses allow for correlation in residuals by month. We assume that α_{ij} and μ_i are constant across households. “Frequent buyer” means that the household made a purchase in the category at least 12 times in each of 2006, 2007, and 2008.

Table 4: Estimates from state-level data

Dependent variable: log(share of grade) minus log(share of regular)

	(1)	(2)
Effect on marginal utility of:		
$1000 increase in gasoline expenditures	0.7877	0.8327
(Parameter η^G)	(0.0842)	(0.1679)
$1000 decrease in total expenditures	0.0719	0.0608
(Parameter η^M)	(0.0190)	(0.0707)
Average marginal effect on regular share of:		
$1 increase in price of regular gasoline	0.0293	0.0309
	(0.0031)	(0.0062)
$1000 decrease in gasoline expenditures	-0.0232	-0.0245
	(0.0025)	(0.0049)
$1000 increase in total expenditures	-0.0021	-0.0018
	(0.0006)	(0.0021)
p-value of Wald test for fungibility $\left(\eta^G = \eta^M\right)$	0.0000	0.0000
State fixed effects?		X
Number of state-quarter-grades	7377	7377
Number of states	50	50

Note: All specifications include decade fixed effects, quarter (season) fixed effects, and decade-specific linear time trends, all interacted with gasoline grade fixed effects. Specification (2) adds state fixed effects interacted with gasoline grade fixed effects. All models are estimated via two-stage least squares, with state per-capita income and the national average price of regular gasoline treated as excluded instruments and the interaction between total expenditures and the grade price gap, and between gasoline expenditures and the grade price gap, treated as endogenous.