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"On the Welfare Cost of Consumption Fluctuations in the Presence of Memorable Goods," Second Version

by

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On the Welfare Cost of Consumption Fluctuations in the Presence of Memorable Goods*

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Abstract

We propose a new category of consumption goods, memorable goods, that generate a flow of utility after consumption. We analyze an otherwise standard consumption model that distinguishes memorable goods from other nondurable goods. Consumers optimally choose lumpy consumption of memorable goods. We empirically document differences between levels and volatilities of memorable and other goods expenditures. Memorable goods expenditures are about twice durable goods expenditures and half the volatility. The welfare cost of consumption fluctuations driven by income shocks are overstated if memorable goods are not accounted for and estimates of excess sensitivity of consumption might be due to memorable goods.

Keywords: Memorable Goods, Consumption Volatility, Welfare Cost

JEL Codes: D91, E21

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We can entertain ourselves with memories of past pleasures ... (Adam Smith [1759])

Much of the pleasure and pain we experience in daily life arises not from direct experience - that is, "consumption" - but from contemplation of our own past or future or from a comparison of the present against the past or future. The fact that experiences are carried forward in time through memory enables them to affect welfare at later times. (Loewenstein and Elster [1992])

In this paper we propose to augment the canonical distinction of consumption goods into nondurable and durable goods by a third category which we call memorable goods. Conceptually, a good is *memorable* if a consumer draws utility from her past consumption experience, that is, through memory. A dinner at a three star restaurant on your anniversary will be enjoyed for months, and possibly years, afterward.[1] In addition to generating immediate utility, the meal contributes to a stock of memories that may depreciate over time but generate utility in the meantime.

Based on this idea we construct a novel consumption-savings model of nondurable and memorable goods. As in the example, memorable goods consumption impacts future utility through the accumulation of the stock of memory. We demonstrate that in the model households optimally choose a non-smooth consumption profile of memorable goods and that delaying current memorable goods consumption may increase life-time utility. Our model predicts that in the presence of a negative income shock households optimally postpone their memorable goods consumption and reduce the size of memorable goods expenditure spikes. Finally, we show that these expenditure patterns have important consequences for two applied questions: the welfare losses from consumption fluctuations and the excess sensitivity of consumption to expected tax rebates.

In terms of its *defining* characteristics a good is memorable (as opposed to durable) if, even though it is not physically present anymore, the consumer derives utility from its past consumption.[2] In order to make the concept of a memorable good empirically operational, we utilize observed purchase and consumption patterns. Traditionally, consumption goods are differentiated only according to whether or not they have a physically durable component. For a nondurable consumption good, expenditures on the good and the physical, utility-generating consumption act typically occur frequently and coincide. After the act of consumption the good is physically fully depreciated. Durable goods are typically purchased infrequently, but their utility-yielding continuous service flow lasts as long as the durable good is physically present. In contrast, the defining characteristic of a memorable good is that it can potentially create a flow of utility from the memory generated by some consumption paths. A property of a memorable good (as implied by consumers' optimal choices) is that there is often infrequent expenditure *and* infrequent physical consumption of

[1] Work in psychology and marketing finds evidence of utility from memories. Using fMRI Speer et al. (2014) show that the same neural circuitry that responds to monetary rewards is stimulated by positive memories. They also find that participants were willing to sacrifice monetary rewards to activate positive memories. Zauberman et al. (2009) find a connection between recall of positive memories and responses to monetary rewards; participants were willing to sacrifice more tangible rewards in order to activate positive memories: "When people make decisions about experiences to consume over time, they treat their memories of previous experiences as assets to be protected."

[2] Since memorable goods are not physically present anymore after their consumption they also cannot serve as collateral. Thus, and in stark contrast to durable goods, memorable goods may be harder to purchase on credit.

the good (after which the good is physically fully depreciated), combined with the continued utility flow (via memory) from the consumed good. See Figure 1 for a representation of expenditure and consumption patterns implied by our classification. A memorable good (as opposed to nondurable good) is often *infrequently purchased and infrequently consumed*, while nondurable goods are frequently purchased and frequently consumed.[3] Goods we classify as memorable include dining out, food for catered affairs, trips and vacations, photographic rental and services, clothes and jewelry, and religious and welfare activities. These goods are typically classified as nondurables, see e.g., Cutler and Katz (1992) or Souleles (1999).

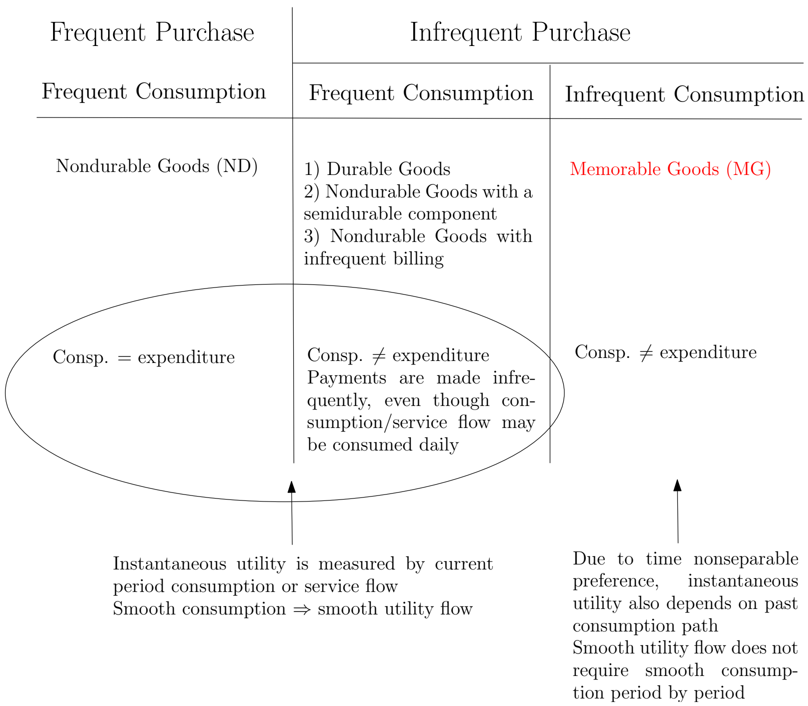


Figure 1: Purchase and Consumption Patterns

By introducing the concept of memorable goods, one can explain observed lumpy consumption choices without introducing indivisibilities in consumption for many nondurable consumption categories.[4] Examples of memorable goods include consumption on various festive events and ceremonies. In our model with memorable goods, households that have large celebrations and associated spikes in expenditures (instead of smoothing expenditures) enjoy the

[3] For example, a luxurious dinner on a trip occurs infrequently while an ordinary dinner at home happens on a daily basis.

[4] For example, on Christmas in the UK, the average number of presents that children receive is eighteen. Traditional consumption theory predicts that parents should have given their children one or two gifts every month instead of giving many gifts at the same time, while our model suggests that households choose lumpy consumption expenditures in order to make this consumption experience memorable: only an extraordinary consumption experience contributes to the stock of memory from Christmas.

memory long after the event has taken place.[5,6]

The above observation suggests that although memorable goods bear some resemblance to durable goods, there are fundamental differences between them. In the standard durable goods model an expenditure on a durable good generates a stream of future utilities. However, absent non-convex adjustment costs or indivisibilities durable goods don't lead to *consumption* spikes, and will not be able to accommodate some of the observable behavior that memorable goods can. For example, the flow of benefits from the purchase of a sixty inch flat screen television is the same whether this is the first television ever owned or if it is a replacement of a previous sixty inch flat screen television that just broke. The case of memorable goods as modeled here is fundamentally different: for an expenditure to be memorable it must differ substantially from past expenditure.[7] Thus, a necessary ingredient for a dinner at a three star restaurant to be memorable is that it is out of the ordinary. There would likely be no fond memories of the meal a month from now if one ate at this restaurant every day. Consequently, part of the appeal a meal at this restaurant is its "specialness", and one may forgo frequent visits even if the restaurant is nearby and the cost is not prohibitive. Our treatment of memorable goods as a third expenditure category therefore differs substantively from that of durable goods because whether a consumer's expenditure generates memories and thus long-lasting utility will depend on her pattern of previous consumption; *a fortiori* an expenditure that is memorable today may not be memorable next week.

Our model of memorable goods also differs fundamentally from habit formation models. The latter models strengthen the desire to smooth consumption expenditures over time.[8] In sharp contrast, our model with memorable goods emphasizes the memorability of "unusual" consumption and predicts infrequent and lumpy memorable good consumption expenditures. The essential difference between both models lies in the way a given stream of consumption expenditures generates a stream of period utility. In standard habit formation models, any increase in current consumption raises the habit stock and reduces future utility from a given consumption expenditure below the habit. In our model of memorable goods, only unusual current consumption expenditures add to the memory stock, but these memories generate future utility. It is this aspect of memory utility that generates the desire for spikes in consumption expenditures, rather than the additional incentives to smooth expenditures inherent in habit formation models.

It is important to note that we do not model memory *formation* explicitly. There are many fond memories that are not accompanied by unusual expenditure.[9] Conversely, some unusual expenditures are unlikely to generate memories that one can draw upon later. Instead we use proxies for consumption events that would plausibly generate memories.

[5] There are evolutionary foundations supporting the notion that agents pay special attention to out-of-the-ordinary consumption events. Rayo and Becker (2007) present evidence from biology for the importance of greater utility from sudden increases in consumption and argue that an agent will experience a high level of happiness if and only if his current experience exceeds what he achieved one period ago. See also Robson (2001), Samuelson (2004), and Robson and Samuelson (2011) for related models and biology references.

[6] In this paper we do not discuss the possibility of "negative memories", such as the memory from a bad vacation experience. It is possible to model bad memories using regret theory, but this is beyond the scope of this paper.

[7] If one Googles *memorable, definition* the first thing that shows up is "...being special or unusual". The online site *thesaurus.com* includes the following synonyms for memorable: extraordinary, historic, momentous, monumental, notable, remarkable.

[8] See, for example, Abel (1990), Campbell and Cochrane (1999), Chapman (1998), Boldrin et al. (2001), and Ljungqvist and Uhlig (2009).

[9] One may have very warm feelings of watching on television the seventh game of the world series at age ten despite there having been no expenditure associated with the event.

We focus on consumption categories that we feel intuitively could generate memories such as vacations and special restaurant meals. We then look for consumers who spend an unusually large amount in a given period, relative to their usual consumption, and count the above-normal part of expenditure as contribution to memory by memorable good consumption.[10]

Based on our heuristic definition of memorable goods we turn to the CEX and classify goods into three categories (nondurable goods, durable goods and memorable goods; see Table E.I for a summary and see Tables E.II-E.IV for detailed information) and document salient features of their monthly and quarterly expenditure patterns for individual households over a 12 month time period. We show that memorable goods display more expenditure volatility than nondurable goods, and a higher incidence of zero expenditures over the observed 12 month time period across households (which we term inactivity). In contrast, memorable goods expenditures are less volatile and display a lower incidence of zero expenditures than durable goods, both on a monthly basis and on a quarterly basis. In particular, memorable goods expenditures are about twice the magnitude and display half of the volatility of the durable goods expenditure.

In our theoretical model of memory goods, households face income risk and choose expenditures on nondurable and memorable goods.[11] The model captures the salient empirical features of memorable consumption goods: the timing of the physical act of consumption and the utility this act generates are de-coupled, and both expenditures and physical consumption occur infrequently as part of the *optimal* household consumption plan, and in lumps when they occur. Note that the incidence of lumpy expenditures in our model is not the result of any indivisibility or non-convex adjustment cost, but rather is a deliberate choice to do something out of the ordinary that creates memory.

An immediate implication of our model is that although expenditures on memorable goods are volatile, the associated utility flow that they generate is not. This implication of the model may matter greatly for applied questions as we demonstrate through two applications. First, this property of the theory has profound consequences for the calculation of the welfare cost of consumption expenditure fluctuations because the infrequent and lumpy expenditure profile of memorable goods, as implied by the optimal choices of households, might contribute little, if anything, to the welfare losses associated with volatile consumption expenditures for risk-averse households.[12] When we use the model with memorable goods, in our first application, to quantify the welfare losses of consumption fluctuations induced by uninsurable idiosyncratic income risk, we find that the presence of memorable goods overstates this cost by 1.7

[10]We focus on specific consumption categories rather than specific instances of consumption experiences such as watching the seventh game of the world series at age ten because data on memory formation is not available and there might not be much of economic interest in such memory formation even if data were available on such events.

[11]We abstract from durable goods in the model because incorporating them is not needed for our applications. It is conceptually straightforward to augment the model to include these goods in exactly the same way the sizable literature on consumer durables has done.

[12]One prominent example is the expenditure on weddings. Web sites dealing with wedding finances show that the average budget for a wedding amounts to about $\$20,000$, while the average household income of a newly married couple is $\$55,000$ annually. Many expenditures, such as those for the honeymoon, the reception site rental, outlays for photography and video services or the rehearsal dinner are commonly categorized as nondurable consumption expenditures. We suggest that due to the memorable component in wedding consumption, there is no significant welfare loss associated with the nonsmoothness of household consumption expenditures due to the incidence of a wedding.

percentage points, relative to the benchmark in which memorable goods are lumped together with nondurable goods, as commonly done in the literature. This finding stems directly from the facts that a) memorable goods expenditure constitutes a significant share of the sum of expenditures on both nondurable and memorable goods (about 16%), b) expenditures on memorable goods are very volatile over time, and c) according to our model this volatility in expenditures is not associated with a significant welfare loss, relative to a smooth consumption profile. Indeed, according to our model a smooth consumption expenditure profile of memorable goods is pointedly suboptimal.[13] Second, we show that the rejection of the permanent income hypothesis (PIH) based on the excess sensitivity of consumption to expected tax refund receipts documented in the literature (and concretely, by Souleles, 1999) might be entirely due to the presence of memorable goods. Specifically, we find that after separating memorable goods from traditionally defined nondurable goods, nondurable goods consumption does not respond to predictable federal income tax refunds, as the standard PIH theory predicts. However, as we argued above, a lumpy change in expenditures on memorable goods in response to an expected income change is fully consistent with our theoretical model, which we view as a natural extension of the standard PIH style consumption-savings model that incorporates memorable goods.

The paper is organized as follows. In the next subsection we briefly relate our work to the existing literature before turning to a description of our model in Section 2. In that section we develop our model of memorable goods and characterize its properties theoretically and numerically via simulations. Section 3 contains the results of a descriptive empirical analysis using CEX consumption data. The purpose of this section is to empirically validate the basic predictions of the theoretical model of Section 2. In the next two sections we turn to two applications of our theory. In Section 4 we analyze the welfare cost of consumption fluctuations in the presence of memorable goods, first using reduced form regressions, and then employing our structural model. In Section 5, we revisit Souleles's (1999) empirical evidence against the permanent income hypothesis when distinguishing between nondurable and memorable goods. Section 6 concludes. Details about the theoretical properties of the model, the numerical solution procedure and the CEX data used in the empirical analysis are relegated to the separate appendix.

0.1 Relation to the Literature

Our paper is related to several strands of the empirical and theoretical literature on household consumption and its response to income shocks. On the empirical side a recent set of papers uses disaggregate household-level data to document stylized facts about the detailed composition of consumption expenditures across different categories. For example, Aguiar and Hurst (2008) document that the behavior of total expenditures on nondurable goods over the life cycle masks substantial heterogeneity in the profiles of individual consumption sub-components.

[13] For some memorable goods such as vacations, one might worry that there are alternative explanations for the infrequency of purchases. For example, one could think of there being a fixed cost to going to Greece, hence it may be optimal to go one time for a long period rather than make frequent trips. The existence of motivations beyond memory formation for the infrequency doesn't preclude the expenditure being memorable, however. Our basic notion is that pleasurable out-of-the-ordinary consumption adds to the stock of memory stock. The thrust of our welfare analysis would be unaffected, subject to the good generating memories as the model assumes.

On the theoretical side, our paper contributes to the literature on modeling household dynamic consumption and savings choices, by proposing and analyzing a novel consumption-savings model with memorable goods. Our paper therefore complements the large literature, starting from Friedman (1957) and Modigliani and Brumberg (1954), that models nondurable consumption choices, as well as the literature on modeling expenditures and consumption on durable goods (see e.g. Mankiw [1982]) and the work that proposes non-time-separable preferences over streams of consumption (see e.g. the habit persistence models of Abel [1990] or Campbell and Cochrane [1999] or models with recursive preferences as in Epstein and Zin [1989] or the rational addiction models of Becker and Murphy[1988]).

We build on the literature stressing individuals may care about past consumption because of the memories associated with past consumption. See, for example, the quotations of Smith (1759) and Loewenstein and Elster (1992) at the beginning. The formal incorporation of utility derived from past consumption dates (at least) back to Strotz's classic paper on dynamic consistency (Strotz [1955]). His formulation incorporated utility from past consumption to allow for "the possibility that a person is not indifferent to his consumption history but enjoys his memories of it".[14]

When we revisit Souleles's (1999) empirical test of the permanent income hypothesis using income tax return data, we contribute to the work that assesses the extent to which consumption responds to expected changes in income (starting with Hall [1978]) as well as income shocks.[15] Hamermesh (1982) notes that if agents cut back on total expenditure there will be a bigger proportional impact on luxuries. Zeldes (1989) tests the permanent income hypothesis and finds that an inability to borrow against future labor income affects the consumption of a significant portion of the population. Nelson (1994) has pointed out that many nondurable goods feature lumpy consumption and infrequent purchases. Parker (1999) finds consumers do not perfectly smooth their consumption expenditure across expected income changes; moreover, the consumption goods that have larger intertemporal elasticity of substitution respond more to predictable income changes. Souleles (1999) produces significant evidence of excess sensitivity in the response of households' nondurable consumption to their income tax refunds. Browning and Crossley (2000) show that luxuries have a high intertemporal substitution elasticity and thus are easy to postpone. Browning and Crossley (1999) show that liquidity constrained agents cut back on expenditures on small durables during a low income spell much more than would be suggested by the income elasticities of these goods in 'normal' times, while nondurable expenditures flows are much smoother than would be predicted in a model without durables. Charles and Stephens (2006) find that in bad

[14]In Strotz (1955), individuals compare all possible life-long consumption paths, but at different points in life. In this framework the individual at some given date t may strictly prefer a consumption path c to path $\hat{c}$, when the paths c and $\hat{c}$ are identical from t onward if consumption path c generated fond memories prior to period t that are absent in path $\hat{c}$. Strotz's model is very general and can easily accommodate the notion of memories, but is overly general for our purposes. He puts little structure on the connection between individuals' preferences at different points in his life over life-long consumption paths. This lack of restrictions can lead to time inconsistency, which is what Strotz wanted to point to. Agents' preferences in our model fit into Strotz's framework: an agent will have well-defined preferences over any set of life-long consumption paths, and those preferences will evolve over time. At any given point in time, an agent will have preferences over consumption paths, and the preferences over future consumption will depend on previous consumption. Unlike the general case in Strotz, however, in our formulation preferences are time consistent. Thus, we separate the consequences of agents enjoying memories of past consumption from the conceptually different issue of time inconsistency. We view as one advantage of our approach that our model is a straightforward extension of standard consumption-savings models, which allows a clear understanding of the role memories play for optimal dynamic consumption decisions.

[15]See Hall and Mishkin (1982) for a seminal contribution and Jappelli and Pistaferri (2010) for a recent survey of the literature.

economic times the lower income groups reduced the shares of their total outlays, and these downward adjustments are primarily concentrated among reductions in outlays devoted to entertainment and personal care expenditures.

Finally, our paper contributes to the literature that measures the welfare cost of consumption fluctuations. Using aggregate consumption data, Lucas (1987) calculates that the welfare gains from eliminating all aggregate consumption fluctuations is less than one-hundredth of one percent of consumption when preferences are logarithmic. However, using micro-level consumption data, the welfare losses of *idiosyncratic* consumption fluctuations are orders of magnitude larger, following the same Lucas (1987) approach. Gorbachev (2011) argues that the welfare losses of household-level nondurable consumption fluctuations equal 4.15% of annual nondurable consumption, under log preferences and using Panel Study of Income Dynamics (PSID) data on food expenditures. These results are in the same order of magnitude as the ones documented in this paper when we use CEX data and ignore memorable goods.

1 The Model

We now set out the consumption-savings model with memorable goods and discuss its qualitative predictions. Denote by C_{mt} and C_{nt} real contemporaneous consumption expenditures on memorable goods and nondurable goods, respectively. Households have preferences defined over contemporaneous consumption C_{mt} and C_{nt}, and the stock of memory M_t from past memorable consumption expenditures, represented by a period utility function of the form[16]

$$U(C_{nt}, C_{mt}, M_t) = \xi \frac{C_{nt}^{1-\gamma}}{1-\gamma} + (1-\xi)\frac{(\alpha C_{mt} + (1-\alpha)M_t)^{1-\gamma}}{1-\gamma}. \tag{1}$$

The utility from memorable goods consumption is the weighted sum of the direct utility obtained from the act of consumption C_{mt} and the stock of memory M_t from past memorable goods consumption, with weight α controlling the importance of immediate memorable goods consumption C_m relative to the stock of memory M_t. When $\alpha = 1$, memorable goods become standard nondurable goods. The parameter ξ governs the relative importance of nondurable goods consumption to memorable goods consumption, and $1/\gamma$ measures the intertemporal elasticity of substitution, assumed to be the same for nondurable and memorable goods.

In addition to specifying how instantaneous utility depends on the stock of memory we need to take a stance on how it is updated over time. In order to capture the idea proposed in the introduction that only an unusual consumption experience contributes to the stock of memory, we introduce a variable, N_t, to represent the threshold value for a consumption experience to be indeed memorable. We assume that memorable goods expenditure C_{mt} only adds to the

[16] A more general specification relaxing the additive separability between nondurable and memorable goods is given by

$$U(C_{nt}, C_{mt}, M_t) = \frac{(\xi C_{nt}^{\nu} + (1-\xi)(\alpha C_{mt} + (1-\alpha)M_t)^{\nu})^{\frac{1-\gamma}{\nu}}}{1-\gamma}$$

with $\nu \neq 1$. The separable formulation leads to predictions that are more easily interpretable and is flexible enough to provide a good fit of the data.

stock of memory M_t if it exceeds the threshold value of being memorable N_t at time t. Specifically, the law of motion of the stock of memory M_t is characterized by

$$M_{t+1} = (1 - \delta_m)M_t + \max\{C_{mt} - N_t, 0\} \tag{2}$$

where $\delta_m \in [0,1]$ measures the speed with which the stock of memory depreciates.

The threshold value N_t itself could in principle depend on the individual's complete history of past consumption experiences, but we parameterize the evolution of N_t as an AR(1) process in the following parsimonious way,

$$N_{t+1} = (1 - \rho)N_t + \rho C_{mt} \tag{3}$$

where $\rho \in [0,1]$ controls the weight of current memorable goods consumption on the threshold value. When $\rho = 1$, only the most recent immediate memorable goods consumption matters for the past consumption experience, that is, $N_t = C_{m,t-1}$. In contrast, when ρ is close to 0, the impact of C_{mt} on the threshold value of being memorable is small.

To illustrate the conceptual difference in the stock of memories M and the threshold value of being memorable N, we take a completely smooth consumption plan, $C_{m,t} = \bar{C}_m$ for all t, as an example. In this case, the threshold value of being memorable is $N_t = \bar{C}_m$ while the stock of memories is $M_t = 0$.

The standard CRRA utility function that does not differentiate between memorable goods and nondurable goods and has no memorable goods stock is a special case of our utility function with $\xi = 1$, $C_t = C_{nt} + C_{mt}$ and

$$U(C_t) = \frac{C_t^{1-\gamma}}{1-\gamma} \tag{4}$$

Given the period utility function, the intertemporal household consumption-savings problem is completely standard. The household faces a stochastic income process $\{Y_t\}$ and maximizes time zero expected lifetime utility

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t U(C_{nt}, C_{mt}, M_t) \tag{5}$$

subject to a sequence of budget constraints

$$C_{mt} + C_{nt} + S_{t+1} \leq Y_t + (1+r)S_t \tag{6}$$

where S_t is the beginning of the period position of riskless assets. The exogenous net return r on these assets is assumed to be constant. Furthermore, we assume that the household faces the borrowing constraint, $S_{t+1} \geq 0$.

For the stochastic process governing monthly income, we assume that Y_t is determined as the sum of a permanent component $\bar{y}$ and an income shock z_t that follows an $AR(1)$ process

$$\ln Y_t = \bar{y} + z_t \tag{7}$$

$$z_t = \rho_z z_{t-1} + \varepsilon_t \tag{8}$$

where $\bar{y}$ is the average log-income of the household, ρ_z measures the persistence of the income shock, and the shock itself is distributed normally with variance σ_ε^2, that is $\varepsilon_t \overset{iid}{\sim} N(0,\sigma_\varepsilon^2)$. Therefore, the conditional distribution of z_t is given by $z_t \sim N(\rho_z z_{t-1}, \sigma_\varepsilon^2)$, and the unconditional distribution of z_t is given by $z_t \sim N(0, \frac{\sigma_\varepsilon^2}{1-\rho_z^2})$. Moreover, the unconditional expected income is given by $\mathbb{E}(Y_t) = \mathbb{E}(\exp(\bar{y}+z_t)) = \exp(\bar{y} + \frac{1}{2}\frac{\sigma_\varepsilon^2}{1-\rho_z^2})$. In addition, we assume that $(1+r)\beta \leq 1, \quad 0 < \rho \leq 1$ and $\quad 0 < \delta_m < 1$.

The model has no analytical solution, so we need to solve it numerically. The dynamic programming problem of the household has state variables (M,N,S,z) and is given by

$$V(M,N,S,z) = \max_{C_m,S' \geq 0} \left\{ U(C_n,C_m,M) + \beta\mathbb{E}[V(M',N',S',z')|z] \right\} s.t. \tag{9}$$

$$\begin{aligned}
C_n &= Y + (1+r)S - C_m - S' \\
M' &= (1-\delta_m)M + \max\{C_m - N, 0\} \\
N' &= (1-\rho)N + \rho C_m \\
\ln Y &= \bar{y} + z \\
z' &= \rho_z z + \varepsilon.
\end{aligned}$$

The main challenge is that with 4 continuous state variables (M,N,S,z) the state space is fairly large. In addition, our specification of memorable good results in a maximization that is not a convex programming problem, and the resulting policy functions (especially for C_m) are not continuous in the state variables, especially the memory stock M and the threshold of being memorable N. To deal with the large state space we use a Smolyak sparse grid collocation algorithm and approximate the *value function* (but not the policy functions) by a linear combination of polynomials at each grid point.[17] Further details on the solution algorithm are provided in Appendix B.

1.1 Discussion of Model Assumptions and Qualitative Features

Our model departs from traditional consumption models in the dynamics of the memory stock M_t (Equation 2) and the endogenous evolution of threshold value N_t (Equation 3). Memorable goods consumption c_{mt} adds to the stock

[17] See Barthelmann et al. (2000) and Malin et al. (2007) for the details of Smolyak's algorithm.

of memory M_t to the extent that it exceeds an endogenous threshold N_t that is determined by past expenditures. This threshold property is the key mechanism that generates the intermittent spikes of memorable goods consumption even in the *absence* of nonconvex adjustment costs and indivisibilities.[18]

In order to derive insights into the qualitative features of our model it is instructive to investigate individuals' optimal consumption profile in a "frictionless" case where there is no income risk and no binding borrowing constraints, before turning to numerical simulations of the full model. Absent income risk and a binding borrowing constraint, and under the assumption of $(1+r)\beta = 1$, the standard consumption-savings model without memorable goods predicts that households optimally choose a constant consumption plan. However, in the presence of memorable goods, this changes. Consider a special case where $\rho = 1$ and the threshold value of being memorable depends only on the previous period memorable goods consumption expenditure, $N_t = C_{m,t-1}$. Using the first order conditions of an individual's optimization problem, we show in appendix A that a smooth consumption plan $C_{m,t} = \overline{C}_m$ for all t, is never optimal, given $M_0 > 0$. Furthermore, for large discount factor β and moderate risk aversion coefficient γ, there exists an $\varepsilon > 0$, such that the consumption plan that delays current consumption $\{\overline{C}_m - \varepsilon, \overline{C}_m + \varepsilon, \overline{C}_m, \ldots\}$ strictly dominates the smooth consumption plan $C_{m,t} = \overline{C}_m$ in terms of lifetime utility.[19]

1.2 Simulation Results

When $\rho < 1$, the dynamics of $C_{m,t}$ and S_{t+1} are more complicated. To gain some insights into the mechanics of the model we report its key quantitative features, obtained via simulations, in the remainder of this section. The parameters used are the same as in the quantitative welfare analysis in Section 4, and thus their calibration is discussed in detail there. We summarize the parameter choices in Table 1. The model is calibrated at a monthly frequency.

Table 1: Parameter Values for Simulation

Param.	Interpr.	Value
ρ_z	Pers. of Income Shock	0.9900
σ_ε	Std. of Income Shock	0.0797
$\bar{y}$	$\mathbb{E}(y) = 1$	-0.1598
r	Interest Rate	4% (p.a.)
$1/\beta - 1$	Time Discount Rate	7% (p.a.)
ξ	Weight on C_n in U	0.7598
α	Weight on C_m in U	0.8836
ρ	Weight on C_m in N	0.2881
δ_m	Deprec. of Memory	0.0861

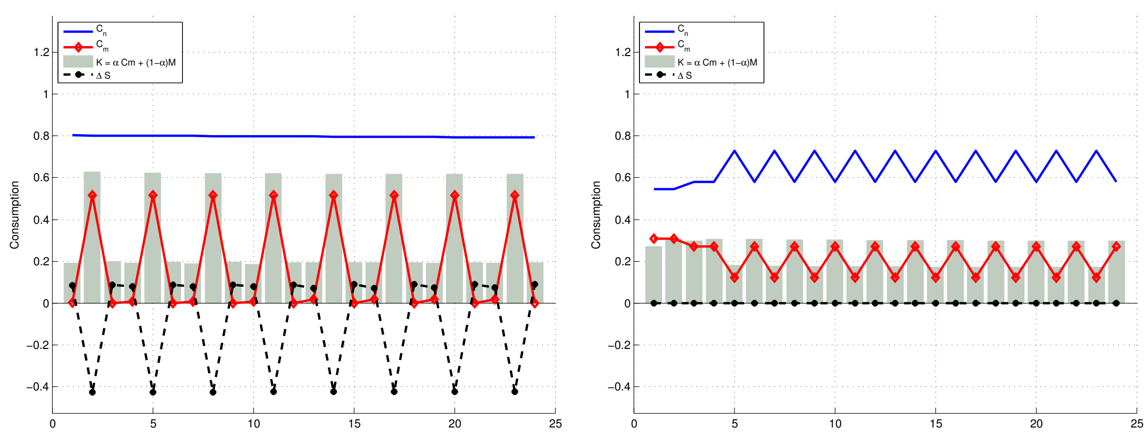
[18]This feature of the model also implies that a consumer may have higher utility if she postponed further expenditures to a later period since by doing so she may obtain a greater increment to her memory stock. In addition, making this consumer a gift of a memorable good in a period just prior to an unusually large memorable goods purchase may make her *worse off*; this that cannot happen in a standard model with durable goods.

[19]The sufficient condition for such ε is the following inequality condition: $(\alpha\overline{C}_m + (1-\alpha)M_0)^{1-\gamma} + \beta(\alpha\overline{C}_m + (1-\alpha)(1-\delta)M_0)^{1-\gamma} < (\alpha\overline{C}_m + (1-\alpha)M_0 - \alpha\varepsilon)^{1-\gamma} + \beta(\alpha\overline{C}_m + (1-\alpha)(1-\delta)M_0 + (\Delta+\alpha)\varepsilon)^{1-\gamma}$, where $\Delta = 2(1-\alpha) > 0$.

In order to characterize the key qualitative features of the model we display simulated consumption and asset time paths for 24 periods (months), for three different realized paths of income shocks. In the benchmark scenario (I) we set the realization of all income shocks to be zero, that is $\varepsilon_t = 0$ for $t = 1, \ldots, 24$ and $z_0 = 0$. This thought experiment shows the consumption and savings dynamics of the model in the absence of shocks.[20] The second scenario (II) explores the response of the household to a negative income shock; 12 months of zero income shocks are followed by a one-time, two-standard deviation, negative income shock at period 13, and no subsequent shocks thereafter.[21] Finally, scenario (III) investigates whether the households' consumption-savings response to income shock features asymmetries by simulating a positive income shock symmetric to that of the negative income shock scenario (II).[22]

To assess the importance of binding borrowing constraints we report simulations for two sets of initial conditions, one in which the endogenous state variables (M, N, S) are set to their long run average, and one in which $M_0 = N_0 = 0$ and $S_0 = 0$. Last, to understand the role of memories on households' optimal consumption-savings decisions, we report the simulated consumption and savings response in the special case when $\alpha = 1$. In this case, the stock of memory does not enter households' utility function, and memorable goods become standard nondurable goods.

First, turning to household behavior in the absence of *realized* income shocks (benchmark scenario), we observe from Figure 2(a) that for households with liquid wealth nondurable consumption is smooth over time (and slightly decreasing, since $\beta(1+r) < 1$), whereas memorable consumption expenditures exhibit a positive spike every three months. Although the frequency and size of these spikes depends on the exact values of the parameters of the model (and especially on how fast memories depreciate measured by δ_m, and how important current expenditures C_m are in refreshing them, measured by ρ), the existence of spikes and periods of inactivity does not.



(a) $S_1 = \bar{S}, M_1 = \bar{M}, N_1 = \bar{N}$ (b) $S_1 = 0, M_1 = 0, N_1 = 0$

Figure 2: Changes in Consumption and Savings (Benchmark Scenario)

[20] The policy functions on which these simulations are based fully take into account the stochastic structure of the model.

[21] That is, the sequence of $\{\varepsilon_t\}_{t=1}^{24}$ is given by $\varepsilon_t = 0$ for all $t \neq 13$, and $\varepsilon_{13} = -2\sigma_\varepsilon = -0.16$. Therefore the absolute change in income at period 13 is $\Delta Y_{13} = \exp(\bar{y} - 0.16) - \exp(\bar{y}) = -0.1260$. Recall that mean income is normalized to one.

[22] To ensure that the increase in income in scenario III is of the same magnitude as the decrease in income in scenario II ($\Delta Y_{13} = \exp(\bar{y} + \varepsilon_{13}) - \exp(\bar{y}) = 0.1260$), we set the one-time positive income shock to be $\varepsilon_{13} = 0.1379$.

Moreover, although the dynamics of nondurable consumption is largely unaffected by the presence of memorable goods for asset-rich households,[23] the same is not true for liquidity constrained households, as Figure 2(b) demonstrates. For a household without financial wealth, it is still optimal to consume memorable goods in spikes; however, they become smaller and more frequent. For an asset-rich household, the positive spikes are two times as large as the household's 24-month average memorable goods expenditure, whereas for a household which is at or near borrowing constraint, the relative size of a positive memorable goods expenditure is significantly smaller. Interestingly, if the borrowing constraint is binding a positive spike in memorable consumption must be met by a fall in nondurable consumption (given that income is constant). Consequently nondurable consumption fluctuates as well, even in the absence of any realized income shocks, and even with utility from nondurable and memorable consumption being additively separable.[24]

Next we turn to household behavior in response to negative and positive income shocks (scenarios II and III, respectively). Table 2 Panel A summarizes the simulated consumption and savings response to negative and positive income shocks, and Figures 3 and 4 display the simulated time paths for consumption and savings. For comparison, Table 2 Panel B reports the simulated consumption and savings response in the special case when memorable goods are standard nondurable goods ($\alpha = 1$).

There is a significant difference in the nondurable consumption response to income shocks between households at or near the borrowing constraints and those with significant positive wealth. Furthermore, this difference is asymmetric with respect to positive and negative income shocks. Households far removed from the borrowing constraint behave in a way that is typical in standard consumption-savings models without memorable goods (as shown in Figures 3(a) and 4(a)). They reduce nondurable consumption in response to a (persistent, but not permanent) negative income shock and increase it (somewhat less) when facing a positive income shock of the same magnitude.[25]

The presence of memorable goods has a much more significant impact on the dynamics of consumption in response to income shocks for asset-poor households. As discussed above, nondurable consumption fluctuates for these households even in the absence of shocks (see Figure 2(b)), and the occurrence of income movements modifies this behavior. To interpret the figures and the table, note that the period of the shock ($t = 13$) was planned to be a period of memorable goods abstention for asset-constrained households, and the subsequent period ($t = 14$) would display a memorable goods spike in the *absence* of a shock.

From Figure 3(b), we observe that a negative income shock leads to a delay in a memorable consumption spike by one month (to $t = 15$) and a decline in the spike (compare Figure 3(b) with Figure 2(b)). A positive income

[23] If the utility function was not separable between nondurable consumption and memorable goods this statement would not apply, since then spikes in memorable consumption would affect the marginal utility from nondurable consumption.

[24] Figures 7 and 8 in the appendix plot the time paths of the state variables in the benchmark scenario for asset-rich households and liquidity-constrained households respectively.

[25] The magnitude of these changes is smaller in the model with memorable goods than in the model without them (compare panel A and panel B) since future consumption of memorable goods responds to the income shocks as well in the former model.

Table 2: Consumption Response to Unanticipated Income Shocks

Panel A: Benchmark Model

	Scenario II ($\Delta Y < 0$)		Scenario III ($\Delta Y > 0$)	
Variable	not constrained	constrained	not constrained	constrained
percent change in income $\frac{\Delta Y}{Y}$	-0.148	-0.148	0.148	0.148
absolute change in income $\lvert\Delta Y\rvert$	0.126	0.126	0.126	0.126
$\frac{\Delta C_n}{\lvert\Delta Y\rvert}$	-0.450	0.366	0.410	0.415
$\frac{\Delta C_m}{\lvert\Delta Y\rvert}$	0.000	-1.366	4.465	0.585
$\frac{\Delta S'}{\lvert\Delta Y\rvert}$	0.153	0.000	-3.171	0.000
$\frac{\Delta C_n}{\lvert\Delta Y\rvert}+\frac{\Delta C_m}{\lvert\Delta Y\rvert}+\frac{\Delta S'}{\lvert\Delta Y\rvert}$	-0.297	-1.000	1.703	1.000
$\frac{\Delta K}{\lvert\Delta Y\rvert}$	-0.133	-1.169	3.812	0.555
$\frac{\Delta M'}{\lvert\Delta Y\rvert}$	-1.045	-0.388	2.086	0.688
changes in the timing of the spike	0	-1	1	1

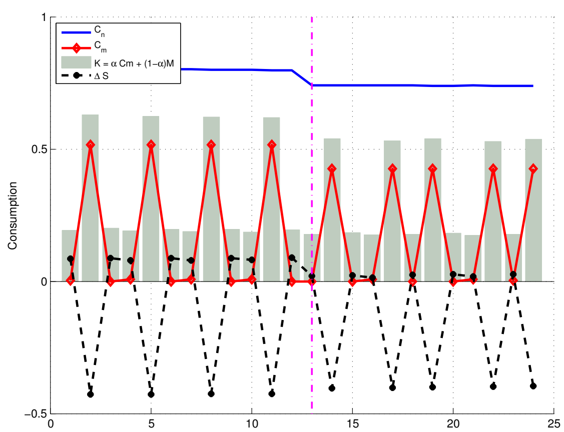
Panel B: $\alpha = 1$ (a special case: memorable goods are standard nondurable goods)

	Scenario II ($\Delta Y < 0$)		Scenario III ($\Delta Y > 0$)	
Variable	not constrained	constrained	not constrained	constrained
percent change in income $\frac{\Delta Y}{Y}$	-0.148	-0.148	0.148	0.148
absolute change in income $\lvert\Delta Y\rvert$	0.126	0.126	0.126	0.126
$\frac{\Delta C_n}{\lvert\Delta Y\rvert}$	-0.504	-0.764	0.458	0.747
$\frac{\Delta C_m}{\lvert\Delta Y\rvert}$	0.000	-0.236	0.269	0.253
$\frac{\Delta S'}{\lvert\Delta Y\rvert}$	-1.578	0.000	-0.809	0.000
$\frac{\Delta C_n}{\lvert\Delta Y\rvert}+\frac{\Delta C_m}{\lvert\Delta Y\rvert}+\frac{\Delta S'}{\lvert\Delta Y\rvert}$	-2.083	-1.000	-0.083	1.000
$\frac{\Delta K}{\lvert\Delta Y\rvert}$	0.000	-0.236	0.269	0.253
$\frac{\Delta M'}{\lvert\Delta Y\rvert}$	-0.393	-0.224	-0.125	0.056
changes in the timing of the spike	N/A	N/A	N/A	N/A

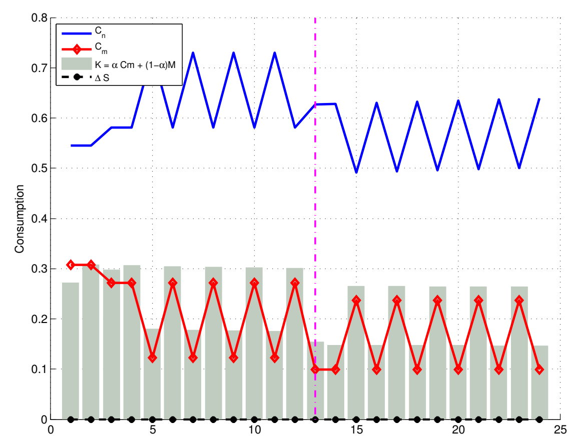
Note: Households who are not constrained start from the long run average of the state variable level $(\bar{S}, \bar{M}, \bar{N})$, the constrained households refer to households that start from $(S_1 = 0, M_1 = 0, N_1 = 0)$; and $K = \alpha C_m + (1-\alpha)M$. The first 8 rows compare the changes in consumption and savings immediately before and after the income shock. The last row compares the timing of the spike immediately after the income shock to the timing in the case with zero income shocks: -1 for a one period delay, 0 for no change, 1 for one period forward.

shock induces an anticipation of the memorable goods spending spike by one month (to $t = 13$, compare Figure 4(b) with Figure 2(b)). The budget constraint for borrowing-constrained households, in conjunction with the abstention of memorable goods consumption in period $t = 13$ then implies an *increase* in nondurable consumption in the period of the negative income shock[26], although this increase is smaller than what was planned prior to the shock (see again Figure 3). In the period following the shock the fall in nondurable consumption is again smaller than "planned" as the abstention in memorable purchases is extended by one period, relative to the no-shock benchmark.

Thus a negative income shock reduces the planned increase in nondurable consumption since the current month features abstention in memorable consumption purposes (compare again Figures 3(b) to Figure 2(b) respectively). This result bears resemblance to Browning and Crossley's (1999) analysis of the role of semi-durable goods in coping with income losses. Here households let their stock of memories depreciate longer in response to a negative income shock. In this sense they access their internal "memory capital market" to smooth out the negative income shock (see Figure 9 in the appendix for the time paths of state variables in the case of a negative income shock).



(a) $S_1 = \bar{S}, M_1 = \bar{M}, N_1 = \bar{N}$



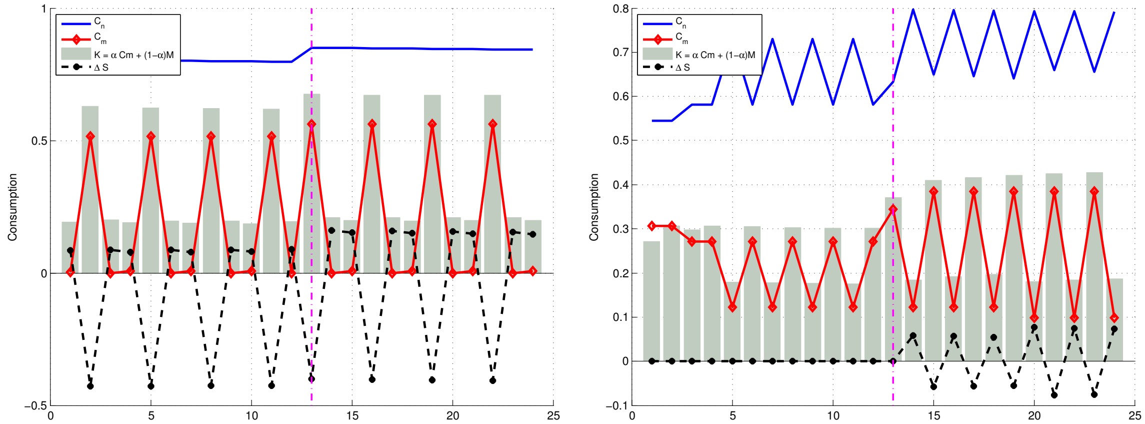
(b) $S_1 = 0, M_1 = 0, N_1 = 0$

Figure 3: Changes in Consumption and Savings (Scenario II: Negative Shock)

This mechanism also works in the reverse direction in that households move the purchase of memorable goods forward for a positive income shock. In the period of the shock they also respond by increasing nondurable consumption, with a spike that is smaller than in the absence of the positive income innovation. As standard PIH logic dictates nondurable consumption is persistently higher from then on and continues to fluctuate to permit memorable consumption spikes for households near the borrowing constraint.

The previous discussion suggests that the introduction of the *memory stock* into the utility function plays a key role in determining households' consumption and savings behavior. In the special case with $\alpha = 1$, the stock of memories does not enter households' utility functions, and memorable goods become standard nondurable goods. As seen in

[26] This explains the perhaps surprising sign on the nondurable consumption response to an income decline documented for the liquidity-constrained households in Table 2 (Panel (a), second column).



(a) $S_1 = \bar{S}, M_1 = \bar{M}, N_1 = \bar{N}$ (b) $S_1 = 0, M_1 = 0, N_1 = 0$

Figure 4: Changes in Consumption and Savings (Scenario III: Positive Shock)

Figures 13 to 19 in the appendix, not surprisingly households then optimally choose a smooth consumption plan both for C_n and C_m in the absence of income shocks. Both memorable consumption and nondurable goods consumption fall in response to a negative income shock and increase in response to a positive income shock.

Before using this model for an evaluation of the welfare cost of consumption fluctuations we now employ household consumption data from the CEX to document that expenditure patterns indeed differ significantly between nondurable and memorable (as well as durable) consumption goods in the way predicted by the theory. We also use these data to structurally estimate the model in Section 4 as well as to conduct the empirical analysis of the consumption response to anticipated tax rebates in Section 5 of the paper.

2 Data

In this section we describe the US Consumer Expenditure data (CEX) that we use for our empirical analysis.

2.1 Sample and Consumption Categories

2.1.1 Consumer Expenditure Survey (CEX)

The data is obtained from the Consumer Expenditure Survey (CEX) for the period 1980-2003.[27] The CEX, constructed by the Bureau of Labor Statistics (BLS) contains comprehensive measures of consumption expenditures and earnings for a large cross section of households. In addition, and crucially for our purposes, it has a limited panel dimension.[28]

[27] Starting in 2004 the CEX introduced many changes in both income and consumption expenditure variables that reduce the comparability with the data from the earlier period.

[28] The Panel Study of Income Dynamics (PSID) has extended its coverage of consumption in recent years, but the higher frequency of observations in the CEX (as well as the longer overall sample with comprehensive consumption data) make us prefer the CEX over the PSID consumption data for this study.

The CEX is a rotating panel of households that are selected to be representative of the U.S. population. Each household is interviewed every three months over five calendar quarters, and in every quarter 20 percent of the sample is replaced by new households. In the first preliminary interview the CEX procedures are explained to the members of the household, and they are asked to keep track of their expenditures for future interviews. After this first interview, each household is subsequently interviewed for a maximum of four more times, once every three months. In each of these interviews, detailed information is collected on household consumption expenditures for the last three months. In the second and fifth interviews, demographic and income data are collected for each household, including earnings and income information for the previous 12 months.

We include in our sample only households that are classified as complete income reporters in the CEX. We also drop observations that report zero food expenditures, and those who report only food expenditures. In addition, we exclude all observations of households for which the household reference person is below 21 or above 64, and those households with negative or zero disposable income (as defined later in this section). Finally, we exclude households classified as rural, and those households who do not have consecutive 12 months of consumption expenditure reports. Our final sample consists of $28,969$ households with the full 12 months of consecutive consumption expenditure observations. Table E.V and Table E.VI report selected summary statistics of our sample.

2.1.2 Consumption Categories

In this section we provide an empirical classification of the set of memorable goods (MG), nondurable goods (ND) and durable goods. The set of memorable goods (MG) is meant to comprise goods for which the timing of the physical act of consumption and the utility this act generates are typically de-coupled, and for which both expenditures as well as physical consumption occur infrequently. [29]

We categorize memorable goods (MG) as food away from home, food for catered affairs, alcohol out, nondurable expenditure on trips and vacations, clothing and shoes, jewelry and watches, photographic rental and services, and religious and welfare activities.[30] Nondurable expenditure on trips and vacations includes nondurable expenditure of food, alcohol, entertainment, and transportation on trips and vacations. For a complete and detailed list of memorable goods, see Table E.III. Our definition of nondurable goods (ND) encompasses most, but not all, of the goods traditionally classified as nondurable goods (Lusardi (1996), Parker (1999), Krueger and Perri (2006), Aguiar and Hurst, 2008). We include in ND food at home, food at school, meals received as pay, tobacco, alcohol at home, utility, house-

[29] We pointed out in the introduction that the choice of which goods to include in the set of memorable goods is subjective. We emphasize that the categorization of a good as memorable does not imply that a specific consumer will necessarily have memorable consumption from this good; whether or not she does will depend on the pattern of her consumption of the good.

[30] Prior to 2001Q2, expenditures on religious and welfare activities were recorded only in the 5th interview, and the amounts have been divided by 12 to transform the data into a monthly expenditure in the ITAB files. Starting from 2001Q2, households are asked to report their religious and welfare expenditures made for the previous three month prior to the month of the interview in MTAB file. Thus by construction, the expenditure of religious and welfare activities are very “smooth” across the year for each individual before 2001Q2, and there is an upward “jump” before and after interview quarter 2001Q2.

hold operation, rents for the primary residence (including rental equivalent), local transportation, business services, education, and health care. For more detailed information on nondurable consumption goods, refer to Table E.II.

Finally we include in the set of durable goods furniture, motor vehicles (net outlays and car loans), and recreation equipment. The durable goods expenditure does not include expenditures on housing assets, since we have already included a measure of the service flow from housing assets (the rental equivalent) in our nondurable goods expenditure variable. More detailed information is contained in Table E.IV. Total household consumption expenditures is the sum of memorable goods, nondurable goods and durable goods.

2.1.3 CEX Data Frequencies

Because we are interested in how households change expenditures in different consumption categories over time, a panel dimension with a reasonably high frequency of observations is desirable. Although the CEX interview is conducted at quarterly frequency, the highest frequency for consumption data is monthly. Specifically, each expenditure reported by a household is identified by Universal Classification Code (UCC) and the month in which the expenditure occurred in CEX Monthly Expenditure (MTAB) file. The algorithm that BLS uses to construct MTAB files for each interview quarter is called the Time Adjustment (TA henceforth) process. It maps each UCC into a monthly time frame. In general, whenever the reference month information is available, the TA algorithm maps the UCC to the exact month in which the expenditure occurs (e.g. trip related expenditures, expenditures on jewelry, food for catered affairs and cars). There are many UCCs (mostly nondurables) where only quarterly information is available. The TA algorithm converts monthly expenditure by dividing quarterly expenditure by 3 (e.g. food at home).

The TA algorithm is complex. Moreover, because it is based on the very detailed UCCs, when we aggregate more than 600 UCCs into 57 consumption categories, many of these consumption categories contain "mixed" frequency information.[31] Based on the 2006 TA mapping algorithm,[32] we report the underlying frequencies of our consumption expenditure categories as an illustration (Table E.VII). We say a consumption category contains monthly information, if any of the UCCs contained in this category has information on specific expenditure month in CEX data. As we can see from Table E.VII, most of the consumption categories contains monthly information, and this is especially true for memorable goods and durable goods expenditures. In addition, as a robustness check, in Section 2.2 we conduct our empirical analysis both for data at monthly frequency (our preferred data) and for data at quarterly frequency.

2.2 Descriptive Analysis

Before turning to the two applications of our theory we briefly document the salient descriptive facts for expenditures on memorable goods from the data. Specifically we provide measures of volatility and the frequency and size of

[31] The mapping between CEX UCCs and detailed consumption and income categories is available upon request.

[32] We thank Jeffrey Crilley from BLS for providing us with the file.

spikes in consumption expenditures for different consumption categories. We will demonstrate that expenditures on memorable goods are more volatile, more infrequent and lumpy, relative to expenditures on nondurable goods. Section 2.2.1 documents the expenditure shares, volatility measures and inactivity of different consumption categories, and Section 2.2.2 displays summary measures of lumpiness of expenditures on different consumption goods.

2.2.1 Consumption Expenditure Volatility

In this section, we document the extent of household-level consumption expenditure volatility associated with each of the three consumption goods categories. Specifically, monthly consumption expenditure volatility of good i for household h is measured as the standard deviation of household consumption expenditures over 12 months, divided by the household-specific 12 month average consumption expenditure,[33]

$$\text{vol}_i^h = \frac{\sqrt{\sum_l (E_{i,l}^h - \bar{E}_i^h)^2}}{\bar{E}_i^h} = \frac{\text{standard deviation}_i^h}{\text{mean}_i^h} \tag{10}$$

where $E_{i,l}^h$ denotes household h's expenditure on good i in month l, and $\bar{E}_i^h$ is the average consumption expenditure for household h over the 12 months for that good i. If $\bar{E}_i^h = 0$, then household h has zero expenditure over 12 months in category i, and we assign $\text{vol}_i^h = 0$.[34] We call a household who did not incur any expenditure on consumption good i over the 12-month observation period an "inactive household" for good i. The inactive ratio is the number of inactive households divided by the number of all households. It is a descriptive measure of the purchasing frequency associated with a particular consumption category i.

The first three columns of Table 3 report the average consumption share, volatility measures and the inactive ratio, for the entire sample and also for selected subsamples of households with low and with high cash at hand. Specifically, we measure cash at hand as the sum of the amount in checking and savings and disposable income. We then sort households by cash at hand and report results for those households in the bottom and the top quintiles of the cash at hand distribution. We think of the first group of households as likely to be liquidity-constrained and the latter group as very unlikely to be liquidity-constrained.

As seen in Table 3, nondurable goods constitute 77.94% of the total outlays and have the lowest average volatility. Memorable goods constitute 14.19% of the total outlays and are 3 times as volatile as nondurable goods. Durable goods expenditures account for 7.9% of total outlays, and are 7 times as volatile as those on nondurable goods. Compared to durable goods, memorable goods expenditures are about twice the magnitude and display half of the

[33] This measure is analogous to that of Davis and Kahn (2008). They measure volatility of consumption as the absolute value of the log change in 6 month consumption expenditures for each household, and then average over households. However, because we need to allow for zero expenditures in some consumption categories for our analysis, instead of taking log changes for each household we calculate the coefficient of variation.

[34] Note that our volatility measure is a conservative measure of consumption volatility for memorable and durable goods with infrequent expenditures because we assign a zero volatility to households for which we do not observe any positive expenditure during the 12 month observation period (inactive households). If we drop the households who have zero expenditure throughout the 12 month periods, the measured volatility of memorable goods and durable goods expenditures would be significantly higher.

Table 3: Consumption Expenditure Statistics (Monthly Frequency)

	Ave Share	Ave Vol	Inactive Ratio	Freq Spikes	Size Spikes
Full Sample					
Outlays	1.0000	0.5251	0.0000	0.0853	2.4704
ND	0.7794	0.2786	0.0000	0.0471	1.3350
Memorables	0.1419	1.0107	0.0048	0.1930	0.3660
Durables	0.0787	2.0475	0.0389	0.1687	0.7392
Cash at Hand $\leq$ 20 pct					
Outlays	1.0000	0.4085	0.0000	0.0694	2.2619
ND	0.8617	0.2612	0.0000	0.0436	1.5073
Memorables	0.0923	1.2033	0.0170	0.1988	0.2625
Durables	0.0460	2.0534	0.1199	0.1474	0.5137
Cash at Hand $\geq$ 80 pct					
Outlays	1.0000	0.6079	0.0000	0.1041	2.4976
ND	0.7083	0.3197	0.0000	0.0601	1.2411
Memorables	0.1882	0.9360	0.0012	0.1890	0.4814
Durables	0.1035	2.0025	0.0063	0.1766	0.8740

Note: Cash at hand is the sum of total amount in checking and savings and disposable income. The percentiles of cash at hand are calculated for each reference year. We say that an expenditure is a spike if the expenditure exceeds the household-level average. Average inactivity records the fraction of households who did not incur any expenditure during the 12-month reference period. The average frequency of consumption spikes is the average number of consumption expenditure spikes divided by 12. The relative size of consumption spikes is the consumption expenditure spikes normalized by household-level 12-month average outlays.

volatility. We also report the measured expenditure volatilities based on data at quarterly frequency (Table E.VIII). As one can see from tables 3 and E.VIII, the relative magnitudes of the volatility measures of these consumption goods groups do not change as we move from monthly to quarterly frequency. Quarterly memorable goods expenditures are 3 times as volatile as nondurable goods, and durable goods expenditures are 6 times as volatile as expenditures on nondurable goods. 0.48 percent of households do not have any memorable goods purchase over the 12 month periods, 3.89 percent of households do not have any durable goods purchase in the sample period. For completeness, Table E.IX and Table E.X in the appendix report the measured volatility of 57 detailed consumption goods categories based on monthly expenditures and quarterly expenditures respectively.

Comparing expenditure patterns between liquidity-constrained and asset-rich households, memorable goods constitute a much larger share of total outlays for asset-rich (18.8%) than for liquidity-constrained households (9.2%). The measured volatility of both memorable goods and durable goods is smaller for asset-rich households. 1.7% of liquidity-constrained households did not have any memorable goods expenditure during the 12 month reference periods and 0.1% of asset-rich households did not have any memorable goods consumption in the reference periods.

Our theoretical model also predicts that households optimally choose to have zero expenditure in memorable goods in certain periods (which we refer as inactive periods). To further investigate whether such expenditure patterns exist in our defined memorable goods categories, we document the frequency of expenditure inactivity for the following six detailed memorable goods categories: food for catered affairs, food on trips and vacations, entertainment on trips and vacations, total expenditure on trips and vacations, clothes and shoes, jewelry and watches. We also report the inactivity patterns for two durable goods categories, new and used vehicles (net outlay), and tires, tubes, accessories and other parts, as a comparison with memorable goods. From Figure 20 we observe that indeed, memorable goods, as well as durable goods, display infrequent monthly expenditures. In fact, with the exception of the clothes and shoes categories the mode of the distribution of months of inactivity is 12, that is, most households are expenditure-inactive for a given consumption category for each of the twelve months the household spends in the sample.

2.2.2 Consumption Expenditure Spikes

Another salient expenditure pattern for memorable goods, as shown in our model simulation, is that when expenditures on memorable goods occur, they occur in lumps. To investigate the lumpy expenditure patterns in memorable goods expenditure, we denote by $n_i^h \in \{0, 1, \ldots, 11\}$ the number of expenditure spikes of size $\kappa \geq 1$ relative to household i's mean expenditure on good i. Thus n_i^h is defined as:

$$n_i^h = \sum_{l=1}^{12} \mathbf{1}\{l : E_{i,l}^h > \kappa \cdot \bar{E}_i^h\}, \quad \kappa \geq 1.$$

For each consumption category i we now plot the frequency distribution of the number of expenditure spikes n_i^h of at least size $\kappa = 1.5$ among households who report at least one positive expenditure on goods i within the 12-month periods. This statistic gives us a measure of expenditure lumpiness for different consumption categories. Figure 21 shows that most households have at least one consumption expenditure spike within a 12 month period for these selected memorable and durable goods, and the expenditure on these goods tends to be quite lumpy.

We also summarize frequencies of spikes and relative size of spikes for total consumption outlays, as well as separately for nondurables, memorable goods and durables in the last two columns of Tables 3 and E.VIII, for the entire sample but also for selected subsamples of households with low and with high cash at hand. We measure the average frequency of consumption spikes as the average number of consumption spikes divided by the total number of reference periods. To measure the relative size of consumption spikes, we normalize households' expenditure spikes by household-level 12-month average total consumption outlays. One prediction from our model simulations is that liquidity constrained households choose more frequent spikes of memorable goods expenditures. This is indeed the case as the fourth column of tables 3 and E.VIII show. A related prediction holds that asset rich individuals experience larger consumption spikes when they occur, which holds true in the data (see the last column of tables 3 and E.VIII).

To summarize our descriptive empirical findings, expenditures on memorable consumption goods are a significant share of a typical household's budget, and they display substantially larger fluctuations at a monthly (and quarterly) frequency than nondurable consumption goods. Furthermore, memorable goods expenditures in each category spike once or twice during the year, and are otherwise characterized by a higher inactive ratio. However, as argued in Section 2 these spikes and spells of inactivity might well be optimal *even in the absence* of idiosyncratic income shocks or/and incomplete financial markets, and thus might not contribute to welfare losses from inefficient consumption fluctuations. We will now turn to a formal quantitative investigation of this point, using the CEX data described above.

3 Welfare Cost Analysis

One immediate implication of our model of memorable goods is that the observed large consumption expenditure fluctuations of memorable goods does not necessarily lead to welfare losses from volatile consumption. A household's underlying utility flow from memorable goods may be smoother than the per-period memorable goods consumption expenditure because of the substitutability between contemporaneous memorable goods consumption and the stock of memory accumulated in the past. The optimal consumption of memorable goods depends on both the stock of memory and the average level of recent past memorable goods consumption. Hence, households adjust their memorable goods consumption over time based on their memory stock and the average level of past memorable goods consumption. This is the case even in the absence of income risk and incomplete financial markets.

To demonstrate the potential biases of measured welfare cost associated with consumption fluctuations when the presence of memorable goods is not accounted for, we proceed in two steps. First we conduct a reduced-form analysis of the welfare cost of consumption fluctuations whose aim is to show that the bias due to incorrectly ascribing welfare losses to expenditure fluctuations of memorable consumption can be substantial. Second, we use a structurally estimated version of our consumption model developed in Section 1 to give a more precise answer, grounded in economic theory, to the question of how much the welfare losses of consumption fluctuations might be overstated by not accounting for the fact that memorable goods expenditure fluctuations are part of optimal household consumption choices, even in the absence of uninsurable shocks (to income, say) that may make consumption volatile otherwise.

3.1 Welfare Cost of Consumption Fluctuations: A Reduced Form Comparison

In this section, to carry out welfare analysis, we continue to assume that a typical household's flow utility function is given by equation (1) from Section 2. However, in this subsection we do not specify the *underlying source* of the consumption fluctuations that lead to welfare losses, relative to a smooth consumption profile. Instead, we directly take advantage of the empirically observed consumption expenditure data to estimate statistical consumption processes, which we then evaluate in terms of their welfare properties (relative to smooth profiles) using the utility function (1).

To do this, we need to assume a specific stochastic process for the observed consumption expenditures. The advantage of this approach is that it does not rely on specific model frictions; however, the disadvantage of this approach is that without observing the stock of memory and the parameters that govern the evolution of the memory stock, we cannot calculate the welfare losses associated with memorable goods expenditure fluctuations (if there are any). Nevertheless, this approach can give us an upper bound on the possible bias in calculating welfare cost of consumption fluctuations that one gets when failing to distinguish memorable goods from nondurable goods, under the maintained assumption that the empirically estimated consumption expenditure process is specified correctly.

Suppose the empirical process for household h's nondurable goods expenditures $C^h_{n,t}$ in month t is described as

$$\begin{aligned} \ln(C^h_{n,t}) &= \sum_{l=2}^{12} \alpha_l d_l + \alpha_{13} \cdot year + X_{h,t}\beta + \sigma_c z^h_t, \quad z^h_t \sim N(0,1) && (11) \\ &= P^h_t + \sigma_c z^h_t && (12) \end{aligned}$$

where d_l is a dummy variable for month l, the term $\alpha_{13} \cdot year$ allows long-run yearly consumption growth, and $X_{h,t}$ is a vector of known individual characteristics of household h, including education, marital status, race and sex of the reference person, family size, and regional dummies. The term σ_c measures the size of shocks to household consumption. Thus the process in (11) decomposes monthly consumption expenditures into a predictable component P^h_t and a consumption shock $\sigma_c z^h_t$.

To obtain an upper bound for the bias that is generated by ignoring the potential optimality of memorable consumption fluctuations, we now assume that there are *no* welfare losses from fluctuations in memorable consumption expenditures. As demonstrated in Section 2, such fluctuations are part of an optimal consumption plan, and we therefore implicitly assume that the empirically observed fluctuations of expenditures on memorable goods are optimal.

Following Lucas (1987), we define the *welfare cost* of nondurable goods consumption fluctuations as the percentage increase in consumption, uniform across all dates and states, required to leave the consumer indifferent between the stochastic consumption process $\{(1+g(\sigma_c))C^h_t\}$ and the deterministic process $\{\mathbb{E}\{C^h_t\}\} = \exp(P^h_t + \frac{1}{2}\sigma^2_c)$. It can be shown that $g(\sigma_c)$ is a function of the coefficient of relative risk aversion γ and is given by[35]

$$g(\sigma_c) \approx \frac{1}{2}\gamma\sigma^2_c. \tag{13}$$

Let σ^2_{ND} be the variance of nondurable consumption obtained when estimating (11) with data for nondurable consumption expenditures alone. Denote by σ_{NDMG} as the estimated value from equation (11), with $C^h_{n,t}$ constituting the sum of expenditures on both nondurables and memorable goods. Therefore, with σ_{NDMG} corresponding to the measured volatility of nondurable goods without distinction between nondurable and memorable consumption, this is just a special case of our utility function (1) with $\xi = 1$.

The bias from misclassifying memorable goods predicted by this reduced-form welfare cost calculation thus de-

[35]The proof of this is in appendix A.

pends on the relative magnitude of household-level residual consumption volatility of nondurable and memorable goods (σ^2_{NDMG} and σ^2_{ND}), and is directly proportional to the coefficient of relative risk aversion γ. The estimated average consumption volatility for the combined (nondurable and memorable) consumption expenditures is $\bar{\sigma}_{NDMG} = 0.28$, and is $\bar{\sigma}_{ND} = 0.25$ for nondurable consumption alone. The fact that $\bar{\sigma}_{NDMG}$ is three percentage points larger than $\bar{\sigma}_{ND}$ comes from the fact that the average volatility of memorable goods expenditure is $\bar{\sigma}_{MG} = 1.01$, significantly larger than $\bar{\sigma}_{ND} = 0.28$, but that, on the other hand, the expenditure share of memorable goods is only 16% of the combined expenditure, on average across households.[36]

The welfare cost of fluctuations in total consumption of memorable goods and nondurable goods can be calculated using equation 13. Using the estimated average household consumption volatility (0.28), the associated welfare cost of household-level consumption fluctuations is reported in Table E.XI. With logarithmic preferences the estimated welfare cost of consumption fluctuations is 3.95% of total consumption of memorable and nondurable goods, and is 3.64% of total outlays. Evidently this loss increases linearly with risk aversion γ as equation (13) implies.

In order to assess the extent to which the potential misclassification of memorable goods might bias the calculations above, Table E.XII reports the estimated welfare cost of household nondurable consumption alone. Not surprisingly, given the reported volatile expenditure patterns of memorable goods in Section 2.2, the estimate of $\bar{\sigma}_{ND}$ is lower than that of $\bar{\sigma}_{NDMG}$. This difference has significant consequences for the welfare cost of consumption fluctuations calculations. As shown in Table E.XII the welfare cost falls considerably. Again with logarithmic preferences they now amount to 3.19% of nondurable goods consumption and only 2.49% of total outlays. Compared to the case where the distinction between memorable goods and nondurable goods is ignored, the estimated welfare cost is reduced by about 32% in terms of total outlays on account of the presence of memorable goods. We stress again that we interpret this number as an *upper bound* on the bias in the welfare cost calculations.[37]

3.2 Welfare Cost of Consumption Fluctuations: A Structural Approach

The previous section stipulated an empirical consumption process and used an empirical estimate of consumption volatility and a utility function, to determine the welfare cost of these consumption fluctuations. We did not take a stance on what underlying shocks might induce these fluctuations and made rather stark assumptions about the degree to which they might be optimal (not at all for nondurable consumption, perfectly optimal for memorable consumption).

In our structural model the only source of suboptimal consumption fluctuations stems from uninsurable idiosyncratic *labor income* risk; recall that households could only self-insure through building up and drawing down their

[36]Note that the same argument also applies to durable goods (although we are obviously not the first ones to point it out for durable goods). Thus our quantitative conclusions are not necessarily invalidated even if we mis-classify some durable goods as memorable goods in our analysis.

[37]We also calculate volatility and the welfare cost under a different categorization, adopting a more conservative approach of what constitutes memorable goods. For that we now group clothes & shoes, and jewelry & watches into nondurable goods (as opposed to memorable goods) and call the resulting aggregate "ND Plus". The estimated consumption volatility is 0.27 and the associated welfare cost is displayed in Table E.XIII. With this classification the (upper bound for the) bias for the welfare cost of consumption fluctuations amounts about 17% (the welfare cost falls from from 3.64 to 3.02 as a percent of total outlays).

balance of risk free assets.[38] We now ask, in the context of our structural model, how large are the welfare losses from consumption fluctuations induced by idiosyncratic income shocks, and how these losses are affected by explicitly modeling memorable goods. To do this, we compare (both in the model with, and in the model without memorable goods) household welfare in two scenarios: one in which households in the model face a stochastic income process and one in which households receive deterministic incomes with the same mean as in the stochastic world. In order to implement these calculations we first have to parameterize our structural model, which we do through a combination of calibration and structural estimation. We describe this procedure next. We need a fully parameterized version of our model to carry out the welfare cost of income shock-induced consumption fluctuations calculations, but we also view it as informative to provide structural estimates especially of those preference parameters associated with memorable goods consumption for which there is little evidence in the existing literature.

3.2.1 Externally Calibrated Parameters

Table 4: Externally Calibrated Parameters

Parameters	Interpretation	Value	Target
ρ_z	Persistence of log income process	0.9900	
σ_ε	Volatility of log income process	0.0797	Covariance of $\ln Y_t$ and $\ln Y_{t-12}$ = 0.28 (CEX)
$\bar{y}$	Average log income	-0.1598	$\mathbb{E}(Y) = 1$ (Normalization)
r	Monthly real interest rate	0.33%	Annual real interest rate 4%
γ	Relative risk aversion coefficient	1.0	Log Utility as Benchmark

We first calibrate a subset of the parameters as follows. In line with the frequency of our CEX data a model period is one month. We specify the monthly income process to be highly persistent[39] and set $\rho_z = 0.9900$. We set the standard deviation of the log income process to be $\sigma_\varepsilon = 0.0797$ so that the covariance of current income and last year's income matches CEX data.[40] We normalize the deterministic component of log income to $\bar{y} = -0.1598$ so that the unconditional expectation of an individual's monthly income is normalized to 1. We use an annual real interest rate of 4%, and thus the monthly real interest rate in our model is set to be 0.33%. In our benchmark parameterization we assume a log utility function, $\gamma = 1$. The parameter values from the outside sources are reported in Table 4.

3.2.2 Internal Calibration Results

Internal calibration is by simulated method of moments (SMM). The average distance between five CEX data sample moments and simulated model moments is minimized with respect to the five model parameters $(\beta, \xi, \alpha, \delta_m, \rho_n)$.

[38] In Lucas' (1987) representative agent endowment economy household income and consumption fluctuations are identical.

[39] Our value implies an annual persistence of labor income of 0.89 which is at the lower end of the spectrum of the empirical estimates, see e.g. Guvenen (2009). Note that less persistent labor income shocks are easier to insure through precautionary saving, and thus the welfare costs from these shocks are bound to be lower that fluctuations with even higher persistence.

[40] Under the assumption of our income process, $\text{cov}(\ln Y_{t-12}, \ln Y_t) = \rho_z^{12}\text{var}(\ln Y_t) = \frac{\rho_z^{12}}{1-\rho_z}\sigma_\varepsilon$.

Notice that the five parameters specify the preferences for and the law of motion associated with memorable goods. The five moments we use consist of the (liquid) asset to income ratio, the average expenditure share of ND out of total consumption expenditures ($ND+MG$), and the average volatilities of ND, of memorable, and of total expenditures.

The internal calibrated values of model parameters $(\beta, \xi, \alpha, \delta_m, \rho)$ are reported in Table 5. The relative importance of nondurable goods is fairly large, $\xi = 0.7598$, relative to the weight $1-\xi = 0.2402$ on memorable goods. Although immediate memorable consumption C_m constitutes the most important component of the utility flow from memorable goods consumption ($\alpha = 0.8836$), the memory stock M_t is also significant. The weight of current memorable goods consumption on future memory threshold N is moderate ($\rho = 0.2881$). Last, after one year $2/3$ of the memorable shock is depreciated, absent spending, and thus only $1/3 = (1-.0861)^{12}$ remains. We also report the values of targeted moments and the simulated moments under the parameter estimates[41] in Table 6.

Table 5: Internal Calibrated Parameters

	Interpretation	Value
β	Subjective discount factor	0.9944
ξ	Weight on C_n in U	0.7598
α	Weight on C_m in U	0.8836
ρ	Weight on C_m in N	0.2881
δ_m	Deprec. of Memory	0.0861

Table 6: Model Fit

Targeted Moments	Data	Model
Median Liquid Assets/Annual Income	0.25	0.26
Average Share of ND/(ND+Memorable)	0.84	0.83
Average Freq of Memorable Goods Spikes	0.19	0.27
Average Volatility of (ND+Memorable)	0.31	0.25
Average Volatility of Memorable	1.01	1.16

3.2.3 Welfare Cost Calculation

Equipped with the structurally estimated model we now can calculate the welfare losses from uninsurable income shocks, both in the presence and absence of memorable goods. Denoting by Φ the normal cdf with zero mean and variance σ_ε^2, we can rewrite the household's value function, equation 9) as:

$$V(M,N,S,z) = \max_{C_n,C_m,S'\geq 0} \left\{ \xi \frac{C_n^{1-\gamma}}{1-\gamma} + (1-\xi)\frac{(\alpha C_m + (1-\alpha)M)^{1-\gamma}}{1-\gamma} + \beta \int V(M',N',S',\rho_z z + \varepsilon')d\Phi(\varepsilon') \right\} s.t.$$

$$C_n = Y + (1+r)S - C_m - S' \tag{14}$$

$$M' = (1-\delta_m)M + \max\{C_m - N, 0\} \tag{15}$$

$$N' = (1-\rho)N + \rho C_m \tag{16}$$

$$\ln Y = \bar{y} + z. \tag{17}$$

This dynamic programming problem yields value and policy functions $V(M,N,S,z)$, $C_n(M,N,S,z)$, $C_m(M,N,S,z)$,

[41] Although the fit of the moments is satisfactory, it is not perfect, due to the inability of the model to generate, jointly, sufficiently volatile nondurable consumption and sufficiently smooth memorable consumption expenditures in the model, relative to the data. Note, however, that household consumption in the CEX is likely measured with substantial error which might overstate the empirical expenditure volatility for a given household over a twelve month interval.

$S'(M,N,S,z)$. Similarly, define the dynamic programming problem for a household facing no income risk as

$$\bar{V}(M,N,S) = \max_{C_n,C_m,S'} \left\{ \xi \frac{C_n^{1-\gamma}}{1-\gamma} + (1-\xi)\frac{(\alpha C_m + (1-\alpha)M)^{1-\gamma}}{1-\gamma} + \beta \bar{V}(M',N',S') \right\}$$

subject to equations (14) to (16), and with income

$$\ln Y = \bar{y} + \sigma_\varepsilon^2 [2(1-\rho_z^2)]^{-1}. \tag{18}$$

The last equation ensures that the household faces the same expected income as with income risk. Denote value and policy functions from this dynamic program as $\bar{V}(M,N,S)$, $\bar{C}_n(M,N,S)$, $\bar{C}_m(M,N,S)$, $\bar{S}'(M,N,S)$. Further define

$$W(S,z) = \max_{C_n,S' \geq 0} \left\{ \frac{C_n^{1-\gamma}}{1-\gamma} + \beta \int W(S', \rho_z z + \varepsilon') d\Phi(\varepsilon') \right\}$$

subject to equation (14) and (17) as the dynamic programming problem in the presence of income risk, but *absent* memorable goods, with value and policy functions $W(S,z), C_n^W(S,z), S^{W\prime}(S,z)$. Finally, in the absence of both income risk and memorable goods the dynamic program reads as

$$\bar{W}(S) = \max_{C_n,S' \geq 0} \left\{ \frac{C_n^{1-\gamma}}{1-\gamma} + \beta \bar{W}(S') \right\}$$

subject to equation (14) and (18), with associated value and policy functions $\bar{W}(S), \bar{C}_n^W(S), \bar{S}^{W\prime}(S)$.

For each state (M,N,S), we define the welfare cost of consumption fluctuations induced by uninsurable income shock as the permanent percent reduction in consumption that would make a household living in a world without income risk indifferent to living in a world with income risk. As Appendix A shows, that these numbers can be calculated from the value functions alone:

$$\begin{aligned} g(M,N,S) &= \left[\frac{V(M,N,S,z=0)}{\bar{V}(M,N,S)}\right]^{\frac{1}{1-\gamma}} - 1 \\ g^W(S) &= \left(\frac{W(S,z=0)}{\bar{W}(S)}\right)^{\frac{1}{1-\gamma}} - 1 \end{aligned} \tag{19}$$

where $\bar{V}(M,N,S;g)$ is lifetime utility in the no-risk economy with memorable goods, but with nondurable and memorable consumption scaled up by a factor g at all future dates. The function $\bar{W}(S;g)$ has a similar interpretation.[42]

[42] For $\gamma = 1$, a similar derivation yields

$$\begin{aligned} g(M,N,S) &= \exp[(1-\beta)(V(M,N,S,z=0) - \bar{V}(M,N,S))] - 1 \\ g^W(S) &= \exp[(1-\beta)(W(S,z=0) - \bar{W}(S))] - 1. \end{aligned}$$

Table 7: Aggregate Welfare Cost

	Interpretation	Estimated Value
$\bar{g}$	Welfare cost with memorable goods	-11.9%
$\bar{g}^W$	Welfare cost without memorable goods	-13.6%

By construction, the welfare cost function $g(M,N,S)$ in the model with memorable goods depends on the state variables M, N and S. Let $F(M,N,S)$ denote the invariant marginal distribution over state variables (M,N,S) in the model with memorable goods and income risk. Similarly, let $F^W(S)$ denote the invariant marginal distribution over wealth in the model with income risk but without memorable goods. Therefore,

$$\begin{aligned} F(M,N,S) &= \int_z H(M,N,S,z)d\Phi^z(z) \\ F^W(S) &= \int_z H^W(S,z)d\Phi^z(z) \end{aligned}$$

where $H(M,N,S,z)$ and $H^W(S,z)$ are the invariant distributions over the states in models with memorable goods and without memorable goods respectively, Φ^z is the normal cdf with zero mean and variance $\sigma_\varepsilon^2/(1-\rho^2)$. We can then calculate two aggregate welfare cost measures as follows:

$$\begin{aligned} \bar{g} &= \int_{M,N,S} g(M,N,S)dF(M,N,S) \\ \bar{g}^W &= \int_S g^W(S)dF^W(S). \end{aligned}$$

The difference between the welfare costs calculated in the two cases, $\bar{g}^W - \bar{g}$, is then our measure of the overstatement of the welfare cost of consumption fluctuations that stem from ignoring memorable goods.

Table 7 reports the estimated aggregate welfare cost measures $\bar{g}$ and $\bar{g}^W$ from the structurally estimated model. The reduction in the welfare cost of consumption fluctuations amounts to a significant 1.7 percentage points, or to approximately 13% of the overall welfare cost in the absence of memorable goods. To further interpret this result, Figure 5 compares the welfare cost in the model with memorable goods with the welfare cost in the model without memorable goods at each asset level (S) averaged across states M and N. We observe that the magnitude of the welfare costs of consumption fluctuations, is significantly smaller in the model with memorable goods than in the model without memorable goods, at *each* asset level. Note that the average asset level is lower in the model with memorable goods, because the memorable goods stock is used as an alternative asset to smooth adverse income shocks.[43]

[43] In the presence of income risk and borrowing constraints, both the models with memorable and without memorable goods have a non-degenerate invariant distribution over their respective state variables. In the model with uninsurable income risk but without memorable goods, asset accumu-

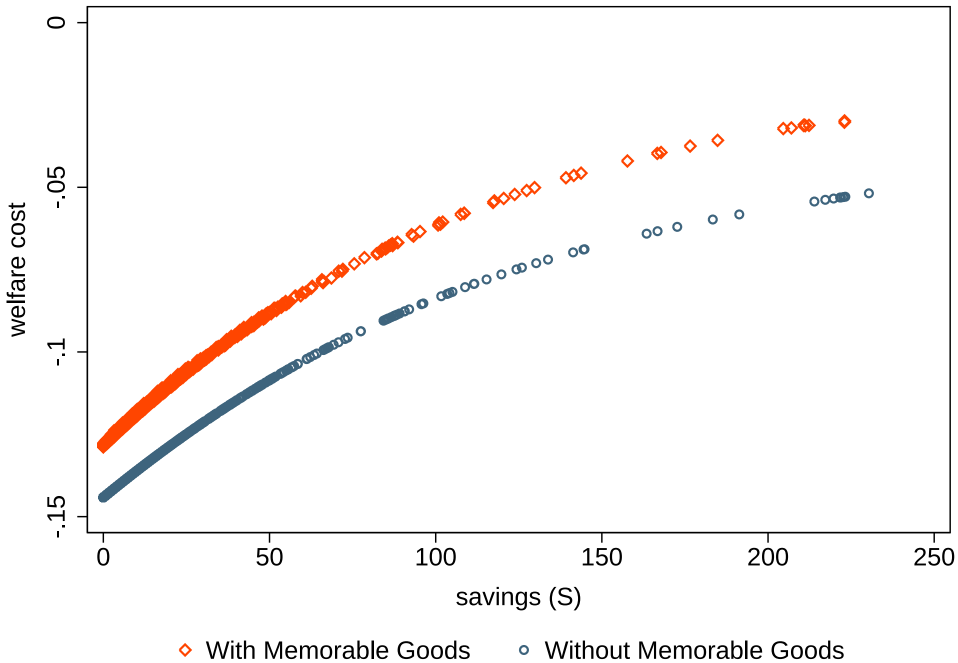


Figure 5: Welfare Cost Comparison

4 Revisiting an Excess Sensitivity Test of Consumption

In the previous section we demonstrated that accounting for and explicitly modeling memorable consumption goods may significantly change our quantitative assessment of the welfare cost of consumption fluctuations induced by uninsurable income shocks. Now we provide a second application from the empirical consumption literature that is sensitive to the exclusion of memorable consumption. The standard consumption-savings model predicts that, absent borrowing constraints, consumption should not respond to predictable changes in income. If it does, consumption exhibits excess sensitivity (to predictable income changes).

Our goal here is not to rewrite the huge empirical literature on excess sensitivity of consumption. We simply want to demonstrate that one important piece of evidence for excess sensitivity stemming from the consumption response to predictable federal income tax refunds, as documented in the important paper by Souleles (1999), could be entirely due to the response of memorable consumption expenditures to these tax refunds. In our empirical analysis we indeed find that nondurable consumption, *not* including memorable consumption expenditures, does not exhibit any excess sensitivity with respect to predictable income tax refunds.

lation is the only option available for households to smooth consumption and insure against income risk. However, in the model with memorable goods, under a moderate depreciation rate ($\delta_m = 0.0861$), memorable goods serve as an alternative buffer to insure against income shocks. When faced with negative income shocks households access their internal capital market by delaying expenditure spikes of memorable goods and letting the stock of memories depreciate. In the model with income shocks but no memorable goods, the average savings rate is 11.88; in the model with income shocks and memorable goods, the average savings rate is 11.13.

4.1 Implications of Model for Consumption Responses to Expected Income Changes

Prior to conducting our empirical analysis we briefly want to demonstrate that the model with memorable goods is consistent with the observation of excess sensitivity of consumption to expected income changes. Suppose the household learns the stochastic part z of her income $T+1$ periods in advance, with $T \geq 0$. Now the current information set includes current income z and future incomes in the T periods ahead, and the state space of the dynamic programming problem includes $(z, z_{+1}, z_{+2}, \ldots, z_{+T})$ and the program reads as

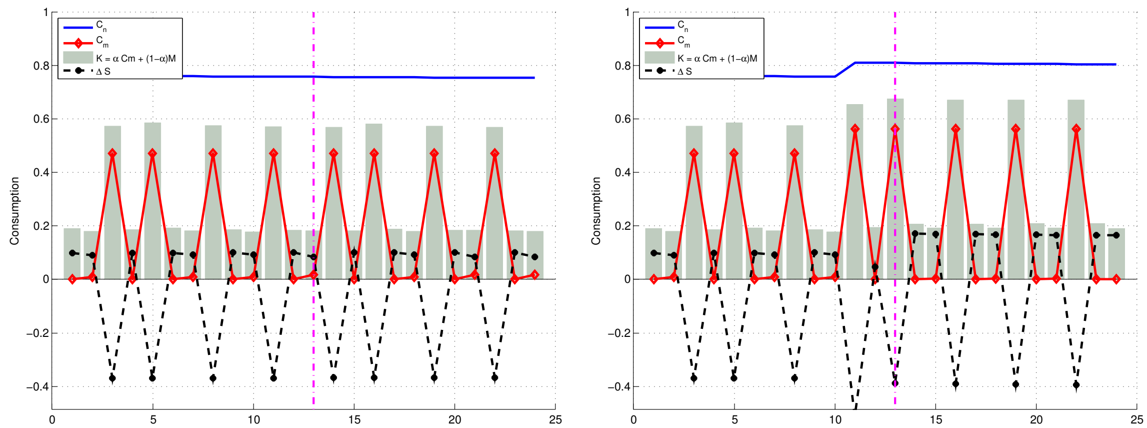
$$\begin{aligned}
V(M,N,S,z,z_{+1},z_{+2},\ldots,z_{+T}) &= \max_{C_m, S' \geq 0} \left\{ U(C_n, C_m, M) + \beta \mathbb{E}_{\hat{\varepsilon}'} [V(M', N', S', z', z'_{+1}, z'_{+2}, \ldots, z'_{+T})] \right\} s.t. \\
z' &= z_{+1} \\
z'_{+1} &= z_{+2} \\
&\vdots \\
z'_{+T-1} &= z_{+T} \\
z'_{+T} &= \rho z_{+T} + \hat{\varepsilon}'
\end{aligned}$$

and subject to (14)-(17). In order to characterize the consumption response when there is prior knowledge of income shocks, we present simulated consumption and asset responses over a 24-month period when households learn their stochastic income two periods in advance (an empirically plausible assumption for the tax rebate application below, given that a period is one month). The realized path of the positive income shocks considered here is the same as in the numerical scenario (III) in Section 1.2, and the specific household has a nontrivial amount of initial assets.[44] In the left panel of figure 6 we plot simulated the consumption and savings path in the absence of income shocks (to provide a benchmark especially for the memorable consumption dynamics), and in the right panel we display the same paths in case of an income shock in period 13 (the vertical dashed line) anticipated two periods in advance (in period 11).

The key observations are two-fold. First, *nondurable* consumption expenditures respond to the income shock as soon as the information about it is received (in period 11). In the period in which the income shock (in our application, the tax refund) is actually received (period 13) nondurable consumption displays no further response. This is of course what standard permanent income theory predicts: there is no excess nondurable consumption sensitivity to an expected (in period 13) income increase. Second, the situation is distinctly different for memorable consumption expenditures: the receipt of extra income in period 13 induces an expenditure spike, and crucially, one that would not have happened in the absence of the anticipated (by period 13) income increase, as the comparison of the right with the left panel indicates. These results demonstrate that excess sensitivity of memorable consumption expenditures, but the absence of such excess sensitivity of nondurable consumption expenditures is exactly what our model predicts. In the next

[44] The initial savings $\bar{S} = 2.3$.

section we argue that the empirical evidence from tax refund data displays precisely this pattern.[45]



(a) Zero Income Shock

(b) Positive Income Shock

Figure 6: Changes in Consumption and Savings (Learning 2 Periods in Advance)

4.2 Empirical Test Using CEX Tax-Refund Data

The idea of consumption excess sensitivity tests is to investigate whether consumption expenditures respond to predictable changes in disposable income. According to the standard intertemporal consumption-savings model with rational expectation it should not, absent binding borrowing constraints. The basic test for excess sensitivity of nondurable consumption to predictable income changes can then be conducted by estimating the following specification:

$$C_{n,t+1} - C_{n,t} = \beta_0 + \sum_i \beta_{1,i} X_{i,t} + \beta_2 \Delta Y_t \tag{20}$$

where $X_{i,t}$ is a set of household characteristics and ΔY_t is a change of income between period t and $t+1$ that is predictable at time t. In Appendix A we show how this equation can be derived from a linearization of the Euler equation for nondurable consumption expenditures.[46] Thus, absent binding borrowing constraints, the standard consumption-savings model based on the permanent income hypothesis implies that nondurable consumption changes should not be sensitive to predictable income changes, or $\beta_2 = 0$. However, for memorable goods consumption $C_{m,t}$, even in the absence of borrowing constraints, expenditures on memorable goods $C_{m,t+1}$ may still respond to predictable income

[45] For households with zero wealth, our model (as well as the standard model) will exhibit excess sensitivity of both nondurable and memorable consumption expenditures, and for very wealthy households the expected income change will leave expenditures of both categories unchanged.

[46] See Parker and Preston (2005) and Parker (1999) for similar analyses.

changes, since typically ΔY_t is correlated with $C_{m,t}$ in our model,[47] it does *not* predict that $\tilde{\beta}_2 = 0$ in the regression[48]:

$$C_{m,t+1} - C_{m,t} = \tilde{\beta}_0 + \sum_i \tilde{\beta}_{1,i} X_{i,t} + \tilde{\beta}_2 \Delta Y_t. \tag{21}$$

4.2.1 Data and Sample Selection

To insure comparability with Souleles (1999) our empirical strategy, as well as crucial sample selection choices and variable definitions, follows his as much as possible. The data used in this section are drawn from the CEX surveys from 1980 to 1991, which covers exactly the same time period as in Souleles (1999). Our definition of nondurable and memorable goods is the same as in previous sections. Furthermore we define strictly nondurable goods (Strictly ND) as all nondurable goods, but excluding health, education and reading. Finally we define strictly memorable goods as memorable goods excluding clothes and jewelry. Thus our definition of nondurable and memorable goods combined is equivalent to Souleles (1999)'s nondurable goods (ND+MG), and our definition of strictly nondurable and strictly memorable goods combined equals Souleles (1999)'s definition of strictly nondurable goods (Strictly (ND+MG)).[49]

The sample was selected in a way that closely follows the selection criteria provided in Souleles (1999).[50] The CEX asks about tax refunds twice, in a household's first and final interview. Each time what is recorded is the value of federal tax refunds received by the households in the 12 months before the interview month. Thus the refund variable in the CEX has a reference period of 12 months. About 80 percent of the refunds were mailed in March, April and May during the years 1980-1991,[51] and thus following Souleles (1999), we deflate refunds by the average of the monthly CPI for all items averaged over March, April, and May. All nominal variables were deflated to 1982-1984 dollars.

4.2.2 Empirical Specification and Estimation

Souleles (1999) provides evidence for excess sensitivity in consumption by estimating two regressions, both of which we will revisit here. The first specification to be estimated is (based on the general idea of excess sensitivity tests exposited in equation 20):

$$C^h_{t,II} - C^h_{t,I} = \sum_t \beta_{0t} * \text{year}^h_t + \beta_1' X^h_t + \beta_2 * \text{refund}^h_t + u^h_t. \tag{22}$$

[47] The same is true if ΔY_t is correlated with the Lagrange multiplier attached to the law of motion for memorable goods; see (33) in the appendix.

[48] A linear approximation of the Euler equation for memorable consumption goods expenditure is derived in appendix A that displays the explicit form on which this regession equation is based.

[49] The major components of strictly nondurables, defined in Souleles (1999), are food; household operations, including monthly utilities and small-scale rentals; apparel services and rentals; transportation fuel and services; personal services; and entertainment services and high-frequency fees. We further break down the above consumption groups into two consumption categories: strictly nondurable and strictly memorable goods by introducing memorable goods.

[50] A household was dropped from the sample if there were multiple consumer units in the household, or if the household lived in student housing or the head of household was a farmer; a household quarter was dropped if the household lacked basic food expenditure for any month of the quarter, or if any food was received as pay in the quarter. A household quarter is dropped if the age of household head increased by more than one or decreased moving into next quarter. The sample was restricted to households with heads aged 24-64. Finally, a household is dropped if the income report is incomplete or any of the income or financial records are invalid. We thank Nick Souleles for sharing the data appendix of Souleles (1999).

[51] Refer to Table 2 in Souleles (1999).

The dependent variable $C^h_{t,II} - C^h_{t,I}$ is the change in a given household h's real consumption expenditures (in levels) between quarter I (January through March) and quarter II (April through June) of a given year t. The variable year^h_t is the year dummy that is included to control for aggregate shocks and interest rates across time. The variable refund^h_t measures the tax refund received by household h in year t. As discussed in Appendix A, with $\beta_2 = 0$ equation (22) can be derived as a linearized version of the standard household consumption Euler equation; no linearization is necessary if the period utility function is quadratic. The vector X^h_t contains demographic variables (the age of the household head and changes in the number of adults and in the number of children) and is included in the regression to control for basic changes in household preferences.

The refund variable in the CEX, refund^h_t, has a reference period of 12 months. To make sure that the refund reference period covers the consumption change period (quarter I and quarter II of year t), we restrict the interview month of the final interview to be either January or July-December, so that the the key regressor refund^h_t, which records the real value of refunds (in levels) that household h received in the past 12 months before the final interview, covers the first two quarters of year t (when about 90 percent of the refunds are received).[52] This sample restriction ensures that the regressor refund^h_t is predetermined, and thus under the permanent income hypothesis β_2 should be zero.

An alternative to the standard frictionless intertemporal consumption model in which households might not display excess smoothness is a model proposed by Campbell and Mankiw (1990) and adopted by Souleles (1999) in which households simply consume a fraction μ of their tax refunds, upon the receipt of the refund check. The number μ can then be interpreted as the marginal propensity to consume (MPC) out of tax refunds. One could estimate μ by replacing $\beta_2 * \text{refund}^h_t$ in equation (22) with $\mu * \Delta\text{refund}^h_t$, where $\Delta\text{refund}^h_t = \text{refund}^h_{t,II} - \text{refund}^h_{t,I}$, the value of refunds received in quarter II of year t minus the value of refunds received in quarter I of year t. The CEX however, does not record refunds at quarterly frequency. Therefore following Souleles (1999), we use the information on the distribution of aggregate refund disbursement to account for the difference between refund^h_t and Δrefund^h_t.

Specifically, we calculate an 'attenuation factor' π from the distribution of aggregate refund disbursements: $\pi^h_t = p^{t,II}_h - p^{t,I}_h$, where $p^{t,II}_h (p^{t,I}_h)$ is the proportion of the refunds disbursed during h's refund reference period that was disbursed in particular in quarter I (quarter II) of year t. Multiplying the regressor refund^h_t by these factors to correct for the probability that some of refunds have been received in the second quarter of the reference year instead of first, essentially, we use approximation $\Delta(\text{refund}^h_t) \approx \text{refund}^h_t * \pi^h_t$. The attenuation factors used in this paper are taken directly from Souleles (1999) and are reported in Table 9. The equation for estimating the MPC μ is then given by,

$$C^h_{t,II} - C^h_{t,I} = \sum_t \beta_{0t} * \text{year}^h_t + \beta_1' X^h_t + \beta_2 * \text{refund}^h_t * \pi^h_t + u^h_t. \tag{23}$$

[52]With this sample restriction, our final sample size is larger than that of Souleles (1999) because we use monthly reference periods whereas Souleles (1999) uses quarterly reference periods. For example, a consumption record that covers from Dec. 1996 to Feb. 1997, is dropped from Souleles (1999) because it does not exactly cover the calendar quarter I, whereas in our sample, we use 12 months consumption data to construct the consumption record in quarter I and quarter II.

4.2.3 Results

Equation (22) is estimated by ordinary least squares (OLS), with standard errors corrected for heteroskedasticity. The estimation is undertaken including households that report no refund. A statistically significant and positive coefficient β_2 indicates, using the terminology of the literature, that consumption is excessively sensitive to changes in after-tax incomes (due to the tax rebates) that could have been anticipated by households. The results are reported in Table 8. As comparison, we also report the results from Souleles (1999) for the same consumption categories in Table 8.

Table 8 first displays the impact of federal income tax refunds on consumption categories for which memorable goods and nondurable goods are not differentiated from each other. For consumption defined as the sum of strictly nondurable and memorable goods (corresponding to the definition of strictly nondurable consumption used in Souleles [1999]), the coefficient of the refund variable refund_t^h is 0.023 and is statistically significant. However, once we exclude memorable goods from this consumption measure, the excess sensitivity of nondurable consumption to tax refunds becomes economically small and statistically insignificant: β_2 equals 0.007 and 0.001 for strictly nondurable and nondurable consumption goods (but now *excluding* memorable goods), respectively. Furthermore, we find that the coefficient on the refund variable for memorable goods and durable goods is both economically and statistically significant, 0.023 and 0.134 respectively. Thus the excess sensitivity of strictly nondurable consumption expenditure found in Souleles (1999) can entirely be attributed to the response of memorable consumption expenditure.

The OLS estimation results of equations (23) are reported in Table 9, with the standard errors corrected for heteroskedasticity. We first report the estimated MPC for consumption categories that do not differentiate between nondurable and memorable goods, but rather lump them together. We then display results if memorable goods are treated as a separate consumption category. The MPC of strictly nondurable consumption, including memorable goods, is positive and significant, as Souleles (1999) finds. However, once memorable goods are excluded from the definition of nondurable goods, the MPC of both strictly nondurable and nondurable goods again becomes economically modest and statistically insignificant (β_2 is estimated as 0.036 and 0.028 respectively). Moreover, as before memorable goods and durable goods display a large and significantly positive MPC (0.081 and 0.467 respectively) out of the tax refunds.

4.2.4 Robustness Check

In the previous section we conducted the excess sensitivity test and marginal propensity test for different consumption categories following Souleles (1999). These tests were also conducted for *strictly* nondurable and *strictly* memorable goods that do not include expenditures on health, education, reading, clothes, and jewelry. Our definition of nondurable and memorable goods combined is equivalent to Souleles (1999)'s nondurable goods, and our definition of strictly nondurable and strictly memorable goods combined equals Souleles (1999)'s definition of strictly nondurable goods. Items such as clothes and jewelry are classified as nondurable goods in Souleles (1999). We include these goods in

Table 8: Excess Sensitivity Tests

This table shows results for the excess sensitivity of consumption to tax refund by estimating the following regression model: $C^h_{t,II} - C^h_{t,I} = \sum_t \beta_{0t} * \text{year}^h_t + \beta_1' X^h_t + \beta_2 * \text{refund}^h_t + u^h_t$, where $C^{II} - C^{I}$ is the change in consumption between the first and second quarters.

	Strictly (ND+MG)		ND+MG		Total consumption		Strictly ND	ND	MG	Durables
	Souleles (1999)	Our Sample	Souleles (1999)	Our Sample	Souleles (1999)	Our Sample				
Refund	0.024**	0.023*	0.025	0.024	0.184**	0.158**	0.007	0.001	0.023*	0.134**
	(0.012)	(0.014)	(0.018)	(0.017)	(0.067)	(0.065)	(0.011)	(0.014)	(0.012)	(0.065)
Age	1.12	1.211	1.43	1.873	2.07	2.147	0.050	0.746	1.127	0.273
	(0.77)	(1.056)	(1.21)	(1.224)	(3.43)	(3.011)	(0.845)	(0.980)	(0.713)	(2.725)
d(adults)	164.4**	102.798**	145.7*	113.054**	323.9**	293.923**	84.005**	76.374**	36.680	180.870*
	(45.7)	(35.970)	(62.4)	(43.115)	(134.9)	(107.969)	(28.570)	(34.799)	(27.324)	(96.328)
d(kids)	51.9	65.685*	14.3	101.207**	116.2	339.047**	57.758*	82.735**	18.473	237.839*
	(45.5)	(37.009)	(103.6)	(48.981)	(207.6)	(140.693)	(32.795)	(41.167)	(26.267)	(126.651)
Observations	7622	9399	7525	9399	7525	9399	9399	9399	9399	9399

We define strictly memorable goods (Strictly MG) as memorable goods excluding clothes and jewelry, and we define strictly nondurable goods (Strictly ND) as our nondurable goods excluding health, education and reading. Our definition of consumption categories is consistent with Souleles (1999). Specifically, our definition of nondurable and memorable goods combined is equivalent to Souleles (1999)'s nondurable goods (ND+MG), and our definition of strictly nondurable and strictly memorable goods combined equals Souleles (1999)'s definition of strictly nondurable goods (Strictly (ND+MG)). Coefficients on time dummies are not reported. The sample includes the households not receiving refunds (the control group).

Heteroskedasticity-corrected standard errors are in parentheses.

* $p < 0.10$, ** $p < 0.05$

Table 9: The Marginal Propensity To Consume

This table shows results for the marginal propensity to consume by estimating the following model: $C^h_{t,II} - C^h_{t,I} = \sum_t \beta_{0t} * \text{year}^h_t + \beta_1' X^h_t + \beta_2 * \text{refund}^h_t * \pi^h_t + u^h_t$, where $C^{II} - C^I$ is the change in consumption between the first and second quarters.

	Strictly (ND+MG)		Total consumption		Total consumption-Strictly (ND+MG)		Strictly ND	ND	MG	Durables
	Souleles (1999)	Our Sample	Souleles (1999)	Our Sample	Souleles (1999)	Our Sample				
Refund*π	0.093**	0.094**	0.640**	0.577**	0.537**	0.482**	0.036	0.028	0.081**	0.467**
	(0.037)	(0.046)	(0.224)	(0.216)	(0.225)	(0.209)	(0.038)	(0.043)	(0.037)	(0.211)
Observations	7622	9399	7525	9399	7525	9399	9399	9399	9399	9399
Refund*$\pi_{2\text{ week}}$	0.045**	0.044*	0.344**	0.301**	0.294**	0.257**	0.015	0.006	0.041*	0.253**
	(0.021)	(0.025)	(0.116)	(0.114)	(0.122)	(0.114)	(0.020)	(0.023)	(0.022)	(0.115)
Observations	7622	9399	7525	9399	7525	9399	9399	9399	9399	9399

The attenuation factors π and $\pi_{2\text{ week}}$ represent the probability the refund came in April-June minus the probability the refund came in January-March, as described in the text. $\pi_{2\text{ week}}$ allows for a two-week delay before the refund is received and spent. The average of the π's across households by year, for 1980-1991 respectively, are: 0.13, 0.16, 0.20, 0.36, 0.34, 0.55, 0.32, 0.28, 0.30, 0.21, 0.15, 0.16. For $\pi_{2\text{ week}}$ the respective averages are: 0.42, 0.45, 0.47, 0.56, 0.60, 0.73, 0.57, 0.57, 0.56, 0.55, 0.50, 0.50. $\pi_{2\text{ week}}$ were computed allowing for a two-week delay after the disbursement of refunds. This should conservatively accommodate any delay while refund checks were in the mail and before households cashed them.

We define strictly memorable goods (Strictly MG) as memorable goods excluding clothes and jewelry, and we define strictly nondurable goods (Strictly ND) as our nondurable goods excluding health, education and reading. Our definition of consumption categories is consistent with Souleles (1999). Specifically, our definition of nondurable and memorable goods combined is equivalent to Souleles (1999)'s nondurable goods (ND+MG), and our definition of strictly nondurable and strictly memorable goods combined equals Souleles (1999)'s definition of strictly nondurable goods (Strictly (ND+MG)).

Coefficients on time dummies and demographic variables are not reported. The sample includes the households not receiving refunds (the control group).

Heteroskedasticity-corrected standard errors are in parentheses.

* $p < 0.10$, ** $p < 0.05$

Table 10: Robustness Check: Excess Sensitivity and Marginal Propensity To Consume

	MG	Strictly MG	Strictly MG Subcategory 1	Strictly MG Subcategory 2
Refund	0.023* (0.012)	0.017** (0.005)	0.017** (0.005)	0.013** (0.005)
Refund*π	0.081** (0.037)	0.050** (0.018)	0.051** (0.018)	0.036** (0.017)
Refund*$\pi_{2\text{ week}}$	0.041* (0.022)	0.030** (0.009)	0.031** (0.009)	0.023** (0.009)
Observations	9399	9399	9399	9399

Strictly MG is MG excluding Clothing, Shoes, Jewelry and Watches.
Strictly MG subcategory 1 is defined as Strictly MG excluding Alcohol Out and Alcohol on Trips.
Strictly MG subcategory 2 is defined as Strictly MG subcategory 1 excluding Religious and Welfare Activities.
Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$

our memorable goods classification (instead of our nondurable goods category) because they can potentially generate memories, although the memory generation itself depends on one's own past consumption experience.[53]

One might worry, however, that the detected excess sensitivity in memorable goods consumption is mainly driven by income-elastic luxury goods or semi-durable goods that are included in our broadly defined memorable goods category. To address this concern, in this section we conduct a robustness check by excluding these goods from our memorable goods category. Ait-Sahalia et al. (2004) defines luxury goods consumption based on luxury goods manufacturers sales such as Tiffany sales, as well as charitable giving. We therefore exclude the following consumption goods from our memorable goods category: clothing and shoes, jewelry and watches, religious and welfare activities (charitable giving), and alcohol. We then repeat our empirical analysis and report the results in Table 10. As shown in Table 10, although the magnitudes of the consumption response of these subcategories of memorable goods are reduced, the qualitative results remain: the response of memorable goods consumption to expected income change is positive and significant. Note that our analysis here provides a plausible lower bound as many of the expenditures in the excluded categories may not be luxury goods.

To summarize, our results show that nondurable goods, memorable goods, and durable goods may have distinct responses to income tax refunds. After excluding memorable goods from the traditionally defined nondurable goods category, nondurable goods consumption does not respond to income tax refunds in an economically and statistically significantly way, whereas memorable goods consumption responds to these refunds in a fairly sizeable way. Last, durable goods consumption displays the most pronounced response.

[53]For example, consider a pair of Prada shoes and Dom Pérignon champagne. If consumed, both generate long-lasting memories for an average consumer, because such consumption is out of ordinary for her. However, for a Hollywood star actress whose wardrobe is filled with designer branded shoes, a pair of Prada shoes, still a memorable good, does not generate memory for her. However, if she only purchases Dom Pérignon champagne for special occasions, the consumption of Dom Pérignon champagne generates memories that can impact her future utility.

5 Conclusion

In this paper we propose a novel consumption model that augments the canonical categorization of consumption goods into nondurable and durable goods by a third category which we call memorable goods. Memorable goods consumption impacts future utility through the accumulation process of memory stock. We show that households optimally choose a non-smooth consumption profile of memorable goods. We then estimate the welfare costs associated with consumption fluctuations, and find that relative to the benchmark model, in which all nondurable consumption is lumped together, an explicit distinction and modeling of memorable goods reduces the estimated welfare costs significantly. We further argue that the rejection of the PIH based on the excess sensitivity of consumption to predictable income changes documented in the literature might be entirely due to the presence of memorable goods.

With the development of our theory we hope to have laid the foundations for other applied work, beyond the two applications presented in this paper, using the concept of memorable goods. For example, it is sometimes suggested that people under-save for retirement, as evidenced by a decline in consumption when they are old. To the extent that early-life consumption includes goods with long-lasting memories, models that ignore such memory formation will overstate the decline in utility accompanying decreased consumption later in the life cycle. Breaking the direct link between consumption expenditures (on memorable goods) and the marginal utility of consumption from such expenditures may also have additional implications for asset prices, which we plan to explore in future work.

Finally, as pointed out in the introduction, we restrict attention to positive memories in this work. However, it seems obvious that out-of-the-ordinary negative experiences can result in unpleasant memories, the consequences of which affect future welfare. While positive memories can generate expenditures that seem anomalous from the perspective of the standard model (e.g. infrequent expenditure spikes), negative memories would more likely be linked to avoiding or postponing certain expenditures. Although it is outside the scope of this paper, we think that an analysis of the impact of negative memories on consumption-savings dynamics is an interesting research area to pursue.

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Appendix: For Review and Online Publication Only

A Derivations

Derivation of Euler Equations. The household's maximization problem is given by

$$
\begin{aligned}
V(M,N,S,z) &= \max_{C_m,S'} \left\{U(C_n,C_m,M)+\beta \mathbb{E} V(M',N',S',z')|z\right\} \\
& \quad s.t. \\
C_n &= Y+(1+r)S-C_m-S' \\
M' &= (1-\delta_m)M+\max\{C_m-N,0\} \\
N' &= (1-\rho)N+\rho C_m \\
S' &\geq 0 \\
\ln Y &= \bar{y}+z \\
z' &= \rho_z z+\varepsilon.
\end{aligned}
$$

We could rewrite the household's maximization problem as

$$
\begin{aligned}
V(M,N,S,z) &= \max_{N',S'} \left\{U(C_n,(N'-(1-\rho)N)/\rho,M)+\beta \mathbb{E} V(M',N',S',z')|z\right\} \\
& \quad s.t. \\
C_n &= Y+(1+r)S-S'-\frac{1}{\rho}(N'-(1-\rho)N) \\
M' &= (1-\delta_m)M+\frac{1}{\rho}\max\{N'-N,0\} \\
S' &\geq 0 \\
\ln Y &= \bar{y}+z \\
z' &= \rho_z z+\varepsilon.
\end{aligned}
$$

The first order conditions imply that the following two equations must hold at optimum,

$$
\begin{aligned}
\frac{\partial U}{\partial C_n}(C_n,C_m,M) &= \beta \mathbb{E}\frac{\partial V}{\partial S}(M',N',S',z')+\lambda_{S'} \\
\frac{\partial U}{\partial C_n}(C_n,C_m,M)-\frac{\partial U}{\partial C_m}(C_n,C_m,M) &= \mathbf{1}_{C_m>N}\cdot \beta \mathbb{E}\frac{\partial V}{\partial M}(M',N',S',z')+\rho\beta \mathbb{E}\frac{\partial V}{\partial N}(M',N',S',z')
\end{aligned}
$$

where $C_n = Y+(1+r)S-C_m-S'$, $\lambda_{S'}$ is the Lagrange multiplier associated with the borrowing constraint $S'\geq 0$, and

$\mathbf{1}_{C_m>N}$ is an indicator function that equals to 1 if and only if $C_m > N$.

The envelope theorem implies that the following conditions hold at the optimum,

$$
\begin{aligned}
\frac{\partial V}{\partial M}(M,N,S,z) &= \frac{\partial U}{\partial M}(C_n,C_m,M)+(1-\delta_m)\beta\mathbb{E}\frac{\partial V}{\partial M}(M',N',S',z') \\
\frac{\partial V}{\partial N}(M,N,S,z) &= \frac{1-\rho}{\rho}\frac{\partial U}{\partial C_n}(C_n,C_m,M)-\frac{1-\rho}{\rho}\frac{\partial U}{\partial C_m}(C_n,C_m,M)-\mathbf{1}_{C_m>N}\cdot\beta\mathbb{E}\frac{\partial V}{\partial M}(M',N',S',z') \\
\frac{\partial V}{\partial S}(M,N,S,z) &= (1+r)\frac{\partial U}{\partial C_n}(C_n,C_m,M).
\end{aligned}
$$

The Euler equation for the optimal consumption path of nondurable goods C_n is standard,

$$
\frac{\partial U}{\partial C_n}(C_n,C_m,M)-(1+r)\beta\mathbb{E}\frac{\partial U}{\partial C_n}(C_n',C_m',M')=\lambda_{S'}
$$

where $\lambda_{S'}$ is the Lagrange multiplier associated with the borrowing constraint $S'\geq 0$.

Under our utility specification, the Euler equation of $C_{n,t}$ is given by the following equation

$$
C_{n,t}^{-\gamma}-(1+r)\beta\mathbb{E}_t C_{n,t+1}^{-\gamma}=\frac{\lambda_{S_{t+1}}}{\xi}.
$$

The optimal consumption path of memorable goods C_m rely on not only the borrowing constraint and the interest rate but also the memory stock M and the past experience level of memorable goods consumption N,

$$
\begin{aligned}
&\frac{\partial U}{\partial C_n}(C_n,C_m,M)-\frac{\partial U}{\partial C_m}(C_n,C_m,M) \\
=\;& (1-\rho)\beta\mathbb{E}\left(\frac{\partial U}{\partial C_n}(C_n',C_m',M')-\frac{\partial U}{\partial C_m}(C_n',C_m',M')\right) \\
&+\mathbf{1}_{C_m>N}\cdot\beta\mathbb{E}\frac{\partial V}{\partial M}(M',N',S',z')-\rho\beta^2\mathbb{E}\left(\mathbf{1}_{C_m'>N'}\cdot\mathbb{E}\frac{\partial V}{\partial M}(M'',N'',S'',z'')\right).
\end{aligned}
$$

Under our current utility specification, the above equation can be rewritten as

$$
\begin{aligned}
&\alpha(1-\xi)(1-\rho)\beta\mathbb{E}_t((\alpha C_{m,t+1}+(1-\alpha)M_{t+1})^{-\gamma})-\alpha(1-\xi)(\alpha C_{m,t}+(1-\alpha)M_t)^{-\gamma} \\
=\;& \xi(1-\rho)\beta\mathbb{E}_t C_{n,t+1}^{-\gamma}-\xi C_{n,t}^{-\gamma} \\
&+\mathbf{1}_{C_{m,t}>N_t}\cdot\beta\mathbb{E}_t\frac{\partial V}{\partial M}(M_{t+1},N_{t+1},S_{t+1},z_{t+1})-\rho\beta^2\mathbb{E}_t\left(\mathbf{1}_{C_{m,t+1}>N_{t+1}}\cdot\mathbb{E}\frac{\partial V}{\partial M}(M_{t+2},N_{t+2},S_{t+2},z_{t+2})\right).
\end{aligned}
$$

■

Proof that $C_{m,t}=\overline{C}_m$ is suboptimal . The Euler equation for the optimal consumption path of nondurable goods C_n

is standard, and is given by the following equation

$$C_{n,t}^{-\gamma} - (1+r)\beta\mathbb{E}_t C_{n,t+1}^{-\gamma} = \frac{\lambda_{S_{t+1}}}{\xi} \tag{24}$$

where $\lambda_{S_{t+1}}$ is the Lagrange multiplier associated with the borrowing constraint $S_{t+1} \geq 0$. Thus the dynamics of nondurable consumption is affected by the presence of memorable goods only through the impact of the latter on the binding patterns of the borrowing constraint. We will show below that for households far away from the constraints, the nondurable consumption dynamics and response to income shock are substantially identical to that of the standard consumption-savings model[54], the same is not true for households with little or no financial wealth.

The optimal consumption choice for memorable goods consumption C_m depends strongly on the current period stock of memories M and the average level of past memorable goods consumption N. The first order condition for $C_{m,t}$ is

$$\begin{aligned} & \alpha(1-\xi)(1-\rho)\beta\mathbb{E}_t((\alpha C_{m,t+1}+(1-\alpha)M_{t+1})^{-\gamma}) - \alpha(1-\xi)(\alpha C_{m,t}+(1-\alpha)M_t)^{-\gamma} \\ = \; & \xi(1-\rho)\beta\mathbb{E}_t C_{n,t+1}^{-\gamma} - \xi C_{n,t}^{-\gamma} \\ & + \mathbf{1}_{C_{m,t}>N_t} \cdot \beta\mathbb{E}_t \frac{\partial V}{\partial M}(M_{t+1},N_{t+1},S_{t+1},z_{t+1}) - \rho\beta^2\mathbb{E}_t(\mathbf{1}_{C_{m,t+1}>N_{t+1}} \cdot \mathbb{E}\frac{\partial V}{\partial M}(M_{t+2},N_{t+2},S_{t+2},z_{t+2})) \end{aligned}$$

where the dynamics of marginal value of M_t and N_t along the optimal consumption path are given by the following two equations

$$\begin{aligned} \frac{\partial V}{\partial M}(M,N,S,z) &= \frac{\partial U}{\partial M}(C_n,C_m,M) + (1-\delta_m)\beta\mathbb{E}\frac{\partial V}{\partial M}(M',N',S',z') \\ \frac{\partial V}{\partial N}(M,N,S,z) &= \frac{1-\rho}{\rho}\frac{\partial U}{\partial C_n}(C_n,C_m,M) - \frac{1-\rho}{\rho}\frac{\partial U}{\partial C_m}(C_n,C_m,M) - \mathbf{1}_{C_m>N}\cdot\beta\mathbb{E}\frac{\partial V}{\partial M}(M',N',S',z'). \end{aligned}$$

To show that $\forall \overline{C}_m \geq 0$, a consumption plan $C_{m,t} = \overline{C}_m$ for all t is never optimal, it is sufficient to prove that $C_{m,t} = \overline{C}_m$ does not satisfy the optimality condition derived from the dynamic programming problem.

First, notice that when $\rho = 1$,

$$\frac{\partial V}{\partial N}(M_t,N_t,S_t,z_t) = -\mathbf{1}_{C_{m,t}>N_t}\cdot\beta\mathbb{E}\frac{\partial V}{\partial M}(M_{t+1},N_{t+1},S_{t+1},z_{t+1}).$$

When there is no income uncertainty and no borrowing constraint, and $(1+r)\beta = 1$, the optimal consumption

[54] And of course in the frictionless case when there is no income uncertainty and no borrowing constraint, and if $(1+r)\beta = 1$, the household's optimal consumption profile satisfies $C_{n,t}^* = \overline{C}_n$ for some $\overline{C}_n > 0$.

profile must satisfies the following equation,

$$\begin{aligned}&\xi C_{n,t}^{-\gamma}-\alpha(1-\xi)(\alpha C_{m,t}+(1-\alpha)M_t)^{-\gamma}\\ =\ &\mathbf{1}_{C_{m,t}>N_t}\cdot\beta\mathbb{E}_t\frac{\partial V}{\partial M}(M_{t+1},N_{t+1},S_{t+1},z_{t+1})-\beta^2\mathbb{E}_t(\mathbf{1}_{C_{m,t+1}>N_{t+1}}\cdot\mathbb{E}\frac{\partial V}{\partial M}(M_{t+2},N_{t+2},S_{t+2},z_{t+2})).\end{aligned}$$

Because $\rho=1$, under the smooth consumption plan $C_{m,t}=\overline{C}_m$ for all t, $N_t=\overline{C}_m$ for $t\geq 1$. Thus the optimality principle implies the following condition must be true for all t

$$\xi C_{n,t}^{-\gamma}-\alpha(1-\xi)(\alpha C_{m,t}+(1-\alpha)M_t)^{-\gamma}=0.$$

The Euler equation of $C_{n,t}$ implies that $C_{n,t}^{-\gamma}=C_{n,t+1}^{-\gamma}$, therefore the above condition implies that at optimum $(\alpha C_{m,t}+(1-\alpha)M_t)^{-\gamma}$ must be constant. However, under the smooth consumption plan $C_{m,t}=\overline{C}_m$, $M_{t+1}=(1-\delta_m)M_t<M_t$. Thus a consumption plan $C_{m,t}=\overline{C}_m$, $\forall\overline{C}_m\geq 0$, for all t is never optimal. ■

Derivation of Equation 13. The welfare cost of consumption fluctuations, $g(\sigma_c)$, is implicitly defined by the following equation,

$$\mathbb{E}\frac{\left((1+g(\sigma_c))C_{n,t}^h\right)^{1-\gamma}}{1-\gamma}=\frac{\left(\mathbb{E}(C_{n,t}^h)\right)^{1-\gamma}}{1-\gamma}. \tag{25}$$

Because

$$\begin{aligned}\mathbb{E}\{U((1+g(\sigma_c))C_{t,l}^h)\} &= \frac{(1+g(\sigma_c))^{1-\gamma}}{1-\gamma}\mathbb{E}\{\exp((1-\gamma)P_{t,l}^h+(1-\gamma)\sigma_c z_{t,l}^h)\}\\ &= \frac{\exp((1-\gamma)P_{t,l}^h)}{1-\gamma}(1+g(\sigma_c))^{1-\gamma}\exp(\frac{1}{2}(1-\gamma)^2\sigma_c^2)\end{aligned}$$

and $U(\mathbb{E}\{C_{t,l}^h\})=\frac{1}{1-\gamma}\exp((1-\gamma)P_{t,l}^h+\frac{1}{2}(1-\gamma)\sigma_c^2)$, $g(\sigma_c)$ satisfies

$$(1+g(\sigma_c))^{1-\gamma}\exp(\frac{1}{2}(1-\gamma)^2\sigma_c^2)=\exp(\frac{1}{2}(1-\gamma)\sigma_c^2).$$

Thus

$$\ln(1+g(\sigma_c))=\frac{1}{2}\gamma\sigma_c^2,$$

but since $\ln(1+g(\sigma_c))\approx g(\sigma_c)$ when g_i is small, then the welfare cost function associated with σ_{ic} is given by,

$$g(\sigma_c)\approx\frac{1}{2}\gamma\sigma_c^2.$$

■

Derivation of Equation 19. Define as

$$\begin{aligned}\bar{V}(M,N,S;g) &= \xi\frac{\left[(1+g)\bar{C}_n(M,N,S)\right]^{1-\gamma}}{1-\gamma}+(1-\xi)\frac{(\alpha(1+g)\bar{C}_m(M,N,S)+(1-\alpha)(1+g)M)^{1-\gamma}}{1-\gamma}\\ &\quad+\beta\bar{V}(\bar{M}',\bar{N}'(M,N,S),\bar{S}'(M,N,S);g).\end{aligned}$$

Note that

$$\bar{V}(M,N,S;g)=(1+g)^{1-\gamma}\bar{V}(M,N,S;g=0)=(1+g)^{1-\gamma}\bar{V}(M,N,S). \tag{26}$$

As for $\bar{V}$, we can define $\bar{W}(S;g)$ by

$$\bar{W}(S;g)=\frac{\left((1+g)\bar{C}_n^W(S)\right)^{1-\gamma}}{1-\gamma}+\beta\bar{W}(\bar{S}^{W\prime}(S);g).$$

Note that

$$\bar{W}(S;g)=(1+g)^{1-\gamma}\bar{W}(S;g=0)=(1+g)^{1-\gamma}\bar{W}(S). \tag{27}$$

For $\gamma=1$, a similar calculation yields

$$\begin{aligned}\bar{V}(M,N,S;g) &= \frac{\log(1+g)}{1-\beta}+\bar{V}(M,N,S;g=0)=\frac{\log(1+g)}{1-\beta}+\bar{V}(M,N,S)\\ \bar{W}(S;g) &= \frac{\log(1+g)}{1-\beta}+\bar{W}(S;g=0)=\frac{\log(1+g)}{1-\beta}+\bar{W}(S).\end{aligned}$$

The welfare cost of consumption fluctuations for a household in state (M,N,S) is then defined (in the model with and without memorable goods, respectively) as the solution to

$$\begin{aligned}\bar{V}(M,N,S;g(M,N,S)) &= V(M,N,S,z=0)\\ \bar{W}(S;g^W(S)) &= W(S,z=0)\end{aligned}$$

where setting $z=0$ in the model with risk again assures that households have the same income today and same expected income from tomorrow on in both worlds. Solving for $g(M,N,S)$ and $g^W(S)$ gives, exploiting equations (26) and (27),

$$\begin{aligned}g(M,N,S) &= \left[\frac{V(M,N,S,z=0)}{\bar{V}(M,N,S)}\right]^{\frac{1}{1-\gamma}}-1\\ g^W(S) &= \left(\frac{W(S,z=0)}{\bar{W}(S)}\right)^{\frac{1}{1-\gamma}}-1.\end{aligned}$$

■

Derivation of Euler Equations. Define

$$\lambda_{n,t} = \frac{\lambda_{S_{t+1}}}{\xi(1+r)\beta\mathbb{E}_t C_{n,t+1}^{-\gamma}}$$

$$\lambda_{m,t} = \frac{\left(\begin{array}{l}(1-\frac{(1-\rho)}{1+r})\xi C_{n,t}^{-\gamma} - \xi\frac{(1-\rho)}{1+r}\lambda_{S_{t+1}} - \mathbf{1}_{C_{m,t}>N_t}\cdot\beta\mathbb{E}_t\frac{\partial V}{\partial M}(M_{t+1},N_{t+1},S_{t+1},z_{t+1}) \\ +\rho\beta^2\mathbb{E}_t(\mathbf{1}_{C_{m,t+1}>N_{t+1}}\cdot\mathbb{E}\frac{\partial V}{\partial M}(M_{t+2},N_{t+2},S_{t+2},z_{t+2}))\end{array}\right)}{\alpha(1-\xi)(1-\rho)\beta\mathbb{E}_t((\alpha C_{m,t+1}+(1-\alpha)M_{t+1})^{-\gamma})}$$

Then the Euler equations for optimal consumption choices can be rewritten as

$$\mathbb{E}_t\frac{(1+r)\beta C_{n,t+1}^{-\gamma}}{C_{n,t}^{-\gamma}}(1+\lambda_{n,t}) = 1 \tag{28}$$

$$\mathbb{E}_t\frac{(1-\rho)\beta\mathbb{E}_t((\alpha C_{m,t+1}+(1-\alpha)M_{t+1})^{-\gamma})}{(\alpha C_{m,t}+(1-\alpha)M_t)^{-\gamma}}(1+\lambda_{m,t}) = 1. \tag{29}$$

Rational expectations implies that at optimum the following equation must be true[55]:

$$\frac{(1+r)\beta C_{n,t+1}^{-\gamma}}{C_{n,t}^{-\gamma}}(1+\lambda_{n,t}) = 1+e_{n,t+1} \tag{30}$$

$$\frac{(1-\rho)\beta[(\alpha C_{m,t+1}+(1-\alpha)M_{t+1})^{-\gamma}]}{(\alpha C_{m,t}+(1-\alpha)M_t)^{-\gamma}}(1+\lambda_{m,t}) = 1+e_{m,t+1} \tag{31}$$

where $e_{n,t+1}$ and $e_{m,t+1}$ can be interpreted as the expectation error, and by construction $e_{n,t+1}$ and $e_{m,t+1}$ are uncorrelated with information known at time t. Taking logs on both side and taking a linear approximation[56] of equation 30, we obtain the linearized Euler equation for nondurable consumption:

$$C_{n,t+1} - C_{n,t} = \frac{1}{\tilde{\gamma}}[\log((1-\rho)\beta) + \log(1+\lambda_{n,t}) - \log(1+e_{n,t+1}))]. \tag{32}$$

Note that when the borrowing constraint is not binding at period t ($\lambda_{S_{t+1}} = 0$) $\lambda_{n,t} = 0$.

Doing the same with equation 31 yields

$$C_{m,t+1} - C_{m,t} = \frac{1}{\alpha\gamma'}[\log((1-\rho)\beta) + \log(1+\lambda_{m,t}) - \log(1+e_{n,t+1}))] - \frac{1-\alpha}{\alpha}(M_{t+1}-M_t)$$

and plugging in the law of motion for M_{t+1} delivers the linearized Euler equation for memorable consumption expen-

[55] See Parker and Preston (2005) and Parker (1999) for similar analyses for nondurable goods expenditure.

[56] The linear approximation used here is $\log y_{t+1} - \log y_t = (y_{t+1} - y_t)/\bar{y}$ for some $\bar{y}$.

ditures:

$$C_{m,t+1}-C_{m,t}=\frac{1}{\alpha\gamma'}[\log((1-\rho)\beta)+\log(1+\lambda_{m,t})-\log(1+e_{n,t+1}))]-\frac{1-\alpha}{\alpha}(-\delta_m M_t+\max\{C_{m,t}-N_t,0\}) \quad (33)$$

In these equations the constants $\tilde{\gamma},\hat{\gamma}$ are products of the risk aversion coefficient γ and approximation constants. ■

B Model Solution Algorithm

The model solution algorithm is as follows:

Step 1. Guess an initial value of value function $V^{(0)}$ at each grid point of the state space, use OLS regression to calculate the Smolyak coefficients associated with value function $V^{(0)}$.

Step 2. At each state space grid point, value function at the i-th iteration, $V^{(i)}$, is maximized by searching memorable goods consumption C_m over a discrete grid

$$V^{(i)}(M,N,S,z)=\max_{C_m\in\text{Grid of } C_m}\{W^{(i)}(M,N,S,z,C_m)\}$$

where $W^{(i)}(M,N,S,z,C_m)$ is the value function associated with memorable goods consumption C_m for given state space variables (M,N,S,z), i.e.,

$$W^{(i)}(M,N,S,z,C_m)=\max_{S'}\left\{U(C_n,C_m,M)+\beta\mathbb{E}[V^{(i-1)}(M',N',S',z')|z]\right\}.$$

The solution of optimal savings S'^* associated with memorable goods consumption C_m is characterized by the following equation

$$-\frac{\partial U(Y+(1+r)S-C_m-S'^*,C_m,M)}{\partial C_n}+\beta\frac{\partial\mathbb{E}[V^{(i-1)}(M',N',S'^*,z')|z]}{\partial S'}=0$$

and $S'^*=0$ if $-\frac{\partial U(Y+(1+r)S-C_m,C_m,M)}{\partial C_n}+\beta\frac{\partial\mathbb{E}[V^{(i-1)}(M',N',0,z')|z]}{\partial S'}\leq 0$.

For (M',N',S',z') outside the state space grid, the value of value function $V^{(i-1)}(M',N',S',z')$ is calculated via interpolation using Smolyak coefficients. Furthermore, $\mathbb{E}[V^{(i-1)}(M',N',S'^*,z')|z]$ is calculated using quadratic rule numerical integration method.

Step 3. Update Smolyak coefficients associated with value function $V^{(i)}$.

Step 4. Repeat Step 2 to 3 until the value of value function at each state space grid point and associated Smolyak coefficients converge.

C Computation of Stationary Distribution

Our model predicts that there is a cross-sectional stationary distribution of state variables. There is no analytical solution to the household's consumption-savings problem, so we characterize the cross-sectional distribution of (M_t, N_t, S_t, z_t) numerically using Markov chain Monte Carlo (MCMC) simulation method. Specifically our procedure is as follows:

Step 1: At period $t = 0$, we randomly simulate state variables (M_0, N_0, S_0) for each household $h \in \{1, \ldots, H\}$ from an arbitrary initial distribution $F^{(0)}(M, N, S)$, and draw z_0 from the distribution $N(0, \sigma^2/(1-\rho^2))$ for each household.

Step 2: At period $t = 0$, for given state variables (M_t, N_t, S_t, z_t), households optimally make their current memorable goods consumption $C^*_{m,t}$ and period $t+1$ savings decisions S^*_{t+1}. Households' period $t+1$ state variables M^*_{t+1} and N^*_{t+1} are updated according to Equations 2 and 3 respectively. Households' period $t+1$ income shock z_{t+1} is randomly drawn according to the conditional distribution $N(\rho_z z_t, \sigma^2)$. The updated state variables $(M^*_{t+1}, M^*_{t+1}, M^*_{t+1})$ for H households yield the numerical distribution $F^{(1)}(M, N, S)$.

Step 3: Check if whether distribution $F^{(1)}(M, N, S)$ converges to $F^{(0)}(M, N, S)$ by checking whether the mean and variance of the state variable M, N, S are the same under these two distributions. If the distribution is not converged, then repeat step 2 for $t = 2, \ldots$.

D Data

D.1 Income Categories

We define disposable income as income before tax minus reported federal, state and local income taxes payments, property tax not reported elsewhere and other tax (net of tax refunds), deductions for social security and pension plans. Household income before tax includes wages and salaries, net business income, net farm income, rents income, dividend income, interest income, pension income, social security and railroad retirement income, supplemental security income, unemployment compensation, workers' compensation and veterans benefits, welfare received, scholarship, food stamps, contributions received from others with alimony/child support, meals received as pay, rent received as pay, and lump sum receipts and lump sum child support payment.

E Tables and Figures

Table E.I: Purchase and Consumption Patterns of Detailed Consumption Categories

Frequent Purchase	Infrequent Purchase	
Frequent Consumption	Frequent Consumption	Infrequent Consumption
Nondurable Goods	**Durable Goods**	**Memorable Goods**
Food At Home	Durable Household Furnishing and Equipment	Food Away from Home Excl. on Trips
Food at School	New and Used Motor Vehicles (Net Outlay)	Food for Catered Affairs
Meals Received as Pay	Tires, Tubes, Accessories, and Other parts	Food on Trips/Vacations
Tobacco Products	Recreation and Sports Equipment	Alcohol Out Excl. on Trips/Vacations
Alcohol Home		Alcohol on Trips
Personal Care Services	**Nondurable Goods with a semidurable component**	Lodging on Trips/Vacations
Tenant-Occupied Nonfarm Dwelling – Rent	College Tuition and Fees	Entertainment Fees and Admissions on Trips/Vacations
Rental Equivalence of Owned Home	Nursery, Elementary, and Other School Tuition and Fees	Other Entertainment Services and Rental on Trips
Rent Received as Pay	Educational books and supplies	Vehicle Maintenance, Rental etc on Trips/Vacations
Lodging at School	Prescription Drugs (Net Outlay)	Gasoline and Oil on Trips/Vacations
Electricity	Medical Supplies (Net Outlay)	Public Transportation on Trips/Vacations Excl. Airline
Gas	Medical Services (Net Outlay)	Airline Fares
Water and other sanitary services		Photographic Services and Rental
Fuel Oil and Coal	**Nondurable Goods with infrequent billing**	Religious and Welfare Activities
Telephone Service	Vehicle Registration	Clothing and Shoes
Domestic Service	Life and other Personal Insurance	Jewelry and Watches
Other Household Operation	Health Insurance	
Vehicle Maintenance, Rental etc	Auto Insurance	
Gasoline and Oil	Maintenance, Insurance etc - Owned Housing	
Local Public Transportation		
Reading		
Entertainment Fees and Admissions		
Other Entertainment Services and Rental		
Clothing Services, including watch and jewelry repair		
Business Services		
Lotteries and Pari-mutuel Losses		

Table E.II: Nondurable Goods

Number	Categories	CPI used to deflate	CPI
1	Food At Home	Food at home	SAF11
2	Food at School	Food away from home	SEFV
3	Meals Received as Pay	Food away from home	SEFV
4	Tobacco Products	Tobacco and smoking products	SEGA
5	Alcohol Home	Alcoholic beverages at home	SEFW
6	Personal Care Services	Personal care services	SEGC
7	Maintenance, Insurance etc - Owned Housing	Shelter	SAH1
8	Tenant-Occupied Nonfarm Dwelling – Rent	Rent of primary residence	SEHA
9	Rental Equivalence of Owned Home	Owners' equivalent rent of primary residence	SEHC
10	Rent Received as Pay	Lodging away from home	SEHB
11	Lodging at School	Lodging away from home	SEHB
12	Electricity	Electricity	SEHF01
13	Gas	Utility (piped) gas service	SEHF02
14	Water and other sanitary services	Water, sewer and trash collection services	SEHG
15	Fuel Oil and Coal	Fuel oil and other fuels	SEHE
16	Telephone Service	Telephone services	SEED
17	Domestic Service	Household operations	SEHP
18	Other Household Operation	Household operations	SEHP
19	Vehicle Registration	Motor vehicle fees	SETF
20	Vehicle Maintenance, Rental etc	Transportation services	SAS4
21	Gasoline and Oil	Motor fuel	SETB
22	Auto Insurance	Motor vehicle insurance	SETE
23	Local Public Transportation	Intracity transportation	SETG03
24	Reading	Recreational reading materials	SERG
25	Entertainment Fees and Admissions	Recreation services	SERF
26	Other Entertainment Services and Rental	Recreation	SAR
27	Clothing Services, including watch and jewlry repair	Miscellaneous personal services	SEGD
28	Business Services	Miscellaneous personal services	SEGD
29	Lotteries and Pari-mutuel Losses	Miscellaneous personal services	SEGD
30	Life and other Personal Insurance	All items	SA0
31	Prescription Drugs (Net Outlay)	All items	SA0
32	Medical Supplies (Net Outlay)	Medical care commodities	SAM1
33	Medical Services (Net Outlay)	Medical care services	SAM2
34	Health Insurance	Medical care	SAM
35	College Tuition and Fees	College tuition and fees	SEEB01
36	Nursery, Elementary, and Other School Tuition and Fees	Tuition, other school fees, and childcare	SEEB
37	Educational books and supplies	Educational books and supplies	SEEA

Table E.III: Memorable Goods

Number	Categories	CPI used to deflate	CPI
1	Food Away from Home Excl. on Trips	Food away from home	SEFV
2	Food for Catered Affairs	Food away from home	SEFV
3	Food on Trips/Vacations	Food away from home	SEFV
4	Alcohol Out Excl. on Trips/Vacations	Alcoholic beverages away from home	SEFX
5	Alcohol on Trips	Alcoholic beverages away from home	SEFX
6	Lodging on Trips/Vacations	Lodging away from home	SEHB
7	Entertainment Fees and Admissions on Trips/Vacations	Recreation services	SERF
8	Other Entertainment Services and Rental on Trips	Recreation	SAR
9	Vehicle Maintenance, Rental etc on Trips/Vacations	Transportation services	SAS4
10	Gasoline and Oil on Trips/Vacations	Motor fuel	SETB
11	Public Transportation on Trips/Vacations Excl. Airline	Other intercity transportation	SETG02
12	Airline Fares	Airline fare	SETG01
13	Photographic Services and Rental	Photographers and film processing	SERD02
14	Religious and Welfare Activities	All items	SA0
15	Clothing and Shoes	Apparel	SAA
16	Jewelry and Watches	Jewelry and watches	SEAG [a]

[a]The BLS CPI for Jewelry and watches starts from December 1997. We extend it back to January 1986 using the CPI for Apparel (SAA).

Table E.IV: Durable Goods

Number	Categories	CPI used to deflate	CPI
1	Durable Household Furnishing and Equipment	Household furnishings and operations	SAH3
2	New and Used Motor Vehicles (Net Outlay[a])	New and used motor vehicles	SETA[b]
3	Tires, Tubes, Accessories, and Other parts	Motor vehicle parts and equipment	SETC
4	Recreation and Sports Equipment	Recreation	SAR

[a]This is based on the EXPN variable QTRADEX in the OVB file which is the "Amount paid for vehicle after trade-in allowance minus amount of cost paid by employer". It includes loans taken out. It represents the total final cost to the consumer of buying the car not just the down payment they make when purchasing the vehicle. In this case, it essentially means the total amount committed to new and used motor vehicles by the consumer not just the immediate out of pocket expenditure.

[b]The BLS CPI for New and used motor vehicles starts from January 1993. We extend it back to January 1986 using the CPI for New Vehicles (SETA01).

Table E.V: Average Monthly Income and Consumption Expenditures - Sample

	Disp Income	Total Outlays	ND+Memorables	ND	Memorables	Durables
mean	1972.32	1484.61	1193.87	965.68	228.19	290.74

Note: Averages are weighted using average CU replicate weights. Average CU weight is derived by summing the weight of each CU (FINLWT21) across four quarters and then dividing by 4.

All consumption expenditures are deflated by their corresponding CPIs (please see table E.II, table E.III, and table E.IV). Income categories are deflated by monthly CPI for all urban consumers and all items. All the deflators are not seasonally adjusted and they are based on 1982-1984.

Disposable Income = Income before Tax - Income Taxes - Pension and Social Security Deductions.

Table E.VI: Average Demographic Characteristics - Sample

	Age of Head	Male Head	White Head	Married	High School Above	Family Size
mean	41.14	0.65	0.84	0.59	0.85	2.87

Note: Averages are weighted using average CU replicate weights. Average CU weight is derived by summing the weight of each CU (FINLWT21) across four quarters and then dividing by 4.

Table E.VII: Underlying Frequencies of CEX Expenditure Categories

	Nondurable Goods			**Memorable Goods**	
Number	Categories	Frequency	Number	Categories	Frequency
1	Food At Home	Quarterly	1	Food Away from Home Excl. on Trips	Quarterly
2	Food at School	Monthly	2	Food for Catered Affairs	Monthly
3	Meals Received as Pay	Quarterly	3	Food on Trips/Vacations	Monthly
4	Tobacco Products	Quarterly	4	Alcohol Out Excl. on Trips/Vacations	Quarterly
5	Alcohol Home	Quarterly	5	Alcohol on Trips	Monthly
6	Personal Care Services	Quarterly	6	Lodging on Trips/Vacations	Monthly
7	Maintenance, Insurance etc - Owned Housing	Monthly	7	Entertainment Fees and Admissions on Trips/Vacations	Monthly
8	Tenant-Occupied Nonfarm Dwelling – Rent	Monthly	8	Other Entertainment Services and Rental on Trips	Monthly
9	Rental Equivalence of Owned Home	Annually	9	Vehicle Maintenance, Rental etc on Trips/Vacations	Monthly
10	Rent Received as Pay	Quarterly	10	Gasoline and Oil on Trips/Vacations	Monthly
11	Lodging at School	Monthly	11	Public Transportation on Trips/Vacations Excl. Airline	Monthly
12	Electricity	Monthly	12	Airline Fares	Monthly
13	Gas	Monthly	13	Photographic Services and Rental	Monthly
14	Water and other sanitary services	Monthly	14	Religious and Welfare Activities	Monthly
15	Fuel Oil and Coal	Monthly	15	Clothing and Shoes	Monthly
16	Telephone Service	Monthly	16	Jewelry and Watches	Monthly
17	Domestic Service	Monthly			
18	Other Household Operation	Monthly			
19	Vehicle Registration	Monthly		**Durable Goods**	
20	Vehicle Maintenance, Rental etc	Monthly	Number	Categories	Informative Frequency
21	Gasoline and Oil	Monthly	1	Durable Household Furnishing and Equipment	Monthly
22	Auto Insurance	Monthly	2	New and Used Motor Vehicles (Net Outlay)	Monthly
23	Local Public Transportation	Monthly	3	Tires, Tubes, Accessories, and Other parts	Monthly
24	Reading	Monthly	4	Recreation and Sports Equipment	Monthly
25	Entertainment Fees and Admissions	Monthly			
26	Other Entertainment Services and Rental	Monthly			
27	Clothing Services, including watch and jewlry repair	Monthly			
28	Business Services	Monthly			
29	Lotteries and Pari-mutuel Losses	Monthly			
30	Life and other Personal Insurance	Monthly			
31	Prescription Drugs (Net Outlay)	Monthly			
32	Medical Supplies (Net Outlay)	Monthly			
33	Medical Services (Net Outlay)	Monthly			
34	Health Insurance	Monthly			
35	College Tuition and Fees	Monthly			
36	Nursery, Elementary, and Other School Tuition and Fees	Monthly			
37	Educational books and supplies	Monthly			

Table E.VIII: Consumption Expenditure Statistics (Quarterly Frequency)

	Ave Share	Ave Vol	Inactive Ratio	Freq Spikes	Size Spikes
Full Sample					
Outlays	1.0000	0.3211	0.0000	0.0688	1.9248
ND	0.7463	0.1946	0.0000	0.0188	1.2408
Memorables	0.1447	0.6202	0.0048	0.1735	0.2682
Durables	0.1090	1.1838	0.0389	0.2508	0.4482
Cash at Hand $\leq$ 20 pct					
Outlays	1.0000	0.2788	0.0000	0.0503	1.8774
ND	0.8406	0.2072	0.0000	0.0229	1.3993
Memorables	0.0959	0.7723	0.0170	0.2010	0.1853
Durables	0.0634	1.2037	0.1199	0.2367	0.2891
Cash at Hand $\geq$ 80 pct					
Outlays	1.0000	0.3566	0.0000	0.0866	1.8957
ND	0.6671	0.2062	0.0000	0.0227	1.1106
Memorables	0.1913	0.5523	0.0012	0.1567	0.3671
Durables	0.1415	1.1499	0.0063	0.2555	0.5433

Note: Cash at hand is the sum of total amount in checking and savings and disposable income. The percentiles of cash at hand are calculated for each reference year. We say that an expenditure is a spike if the expenditure exceeds the household-level average. Average inactivity records the fraction of households who did not incur any expenditure during the entire reference period. The average frequency of consumption spikes is the average number of consumption expenditure spikes divided by 4 quarters. The relative size of consumption spikes is the consumption expenditure spikes normalized by household-level average outlays during the reference period.

Table E.IX: Consumption Volatility Measure: Detailed Consumption Categories (Monthly Frequency)

Variable Names	Ave Share	Inactive Ratio	Ave Vol
Rent Received as Pay	0.0015	0.9791	0.0302
Lotteries and Pari-mutuel Losses	0.0002	0.9595	0.0705
Lodging at School	0.0008	0.9698	0.0774
Rental Equivalence of Owned Home	0.0208	0.3850	0.0886
Meals Received as Pay	0.0018	0.9263	0.1064
Tenant-Occupied Nonfarm Dwelling – Rent	0.1033	0.5955	0.1267
Food for Catered Affairs	0.0008	0.9381	0.2041
Nursery, Elementary, and Other School Tuition and Fees	0.0023	0.9041	0.2370
Food At Home	0.1801	0.0003	0.2674
Tobacco Products	0.0126	0.5326	0.2787
Local Public Transportation	0.0041	0.7480	0.2943
Health Insurance	0.0198	0.3856	0.3376
Food at School	0.0037	0.7139	0.3376
Gasoline and Oil	0.0739	0.0625	0.3489
Electricity	0.0505	0.0498	0.4207
College Tuition and Fees	0.0040	0.8449	0.4261
Telephone Service	0.0419	0.0134	0.4279
Other Entertainment Services and Rental on Trips	0.0007	0.8587	0.4369
Fuel Oil and Coal	0.0048	0.8020	0.4557
Gas	0.0215	0.3810	0.4805
Alcohol Out Excl. on Trips/Vacations	0.0052	0.4939	0.5248
Alcohol Home	0.0092	0.3831	0.5344
Personal Care Services	0.0123	0.0892	0.5515
Food Away from Home Excl. on Trips	0.0421	0.0498	0.5835
Reading	0.0075	0.1118	0.6633
Water and other sanitary services	0.0162	0.3085	0.6887
Public Transportation on Trips/Vacations Excl. Airline	0.0013	0.7592	0.7407
Photographic Services and Rental	0.0025	0.3292	0.7935
Domestic Service	0.0176	0.4267	0.8625

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... table E.IX continued

Variable Names	Ave Share	Inactive Ratio	Ave Vol
Entertainment Fees and Admissions	0.0114	0.2063	0.9013
Clothing Services, including watch and jewlry repair	0.0057	0.2238	0.9476
Airline Fares	0.0046	0.6869	0.9557
New and Used Motor Vehicles (Net Outlay)	0.0193	0.7033	0.9888
Other Entertainment Services and Rental	0.0268	0.0607	0.9989
Life and other Personal Insurance	0.0156	0.4046	1.0173
Educational books and supplies	0.0019	0.6342	1.0340
Religious and Welfare Activities	0.0069	0.4147	1.0397
Medical Supplies (Net Outlay)	0.0018	0.6613	1.1400
Vehicle Maintenance, Rental etc on Trips/Vacations	0.0008	0.6122	1.1536
Alcohol on Trips	0.0008	0.5858	1.1766
Maintenance, Insurance etc - Owned Housing	0.0182	0.4059	1.2791
Business Services	0.0132	0.1489	1.3998
Lodging on Trips/Vacations	0.0050	0.4904	1.4687
Clothing and Shoes	0.0510	0.0193	1.4897
Entertainment Fees and Admissions on Trips/Vacations	0.0033	0.4742	1.5222
Other Household Operation	0.0055	0.2997	1.5343
Jewelry and Watches	0.0040	0.4563	1.5958
Gasoline and Oil on Trips/Vacations	0.0052	0.3323	1.6267
Auto Insurance	0.0210	0.2014	1.6668
Recreation and Sports Equipment	0.0161	0.1743	1.7737
Vehicle Maintenance, Rental etc	0.0226	0.1161	1.7936
Food on Trips/Vacations	0.0077	0.2848	1.7999
Tires, Tubes, Accessories, and Other parts	0.0083	0.3611	1.8129
Medical Services (Net Outlay)	0.0146	0.1833	1.9942
Prescription Drugs (Net Outlay)	0.0068	0.2869	2.0296
Durable Household Furnishing and Equipment	0.0350	0.1006	2.0424
Vehicle Registration	0.0039	0.2343	2.2238

Table E.X: Consumption Volatility Measure: Detailed Consumption Categories (Quarterly Frequency)

Variable Names	Ave Share	Inactive Ratio	Ave Vol
Rent Received as Pay	0.0014	0.9791	0.0334
Lodging at School	0.0009	0.9698	0.0474
Lotteries and Pari-mutuel Losses	0.0002	0.9595	0.0554
Rental Equivalence of Owned Home	0.0188	0.3850	0.0978
Meals Received as Pay	0.0017	0.9263	0.1177
Food for Catered Affairs	0.0011	0.9381	0.1193
Tenant-Occupied Nonfarm Dwelling – Rent	0.0982	0.5955	0.1244
Nursery, Elementary, and Other School Tuition and Fees	0.0024	0.9041	0.1444
College Tuition and Fees	0.0049	0.8449	0.2410
Other Entertainment Services and Rental on Trips	0.0008	0.8587	0.2539
Fuel Oil and Coal	0.0048	0.8020	0.2764
Food At Home	0.1673	0.0003	0.2956
Electricity	0.0470	0.0498	0.3016
Tobacco Products	0.0117	0.5326	0.3079
Telephone Service	0.0390	0.0134	0.3175
Local Public Transportation	0.0039	0.7480	0.3234
Water and other sanitary services	0.0154	0.3085	0.3278
Food at School	0.0037	0.7139	0.3407
Life and other Personal Insurance	0.0157	0.4046	0.3708
Health Insurance	0.0183	0.3856	0.3730
Gas	0.0203	0.3810	0.3830
Gasoline and Oil	0.0679	0.0625	0.3833
Medical Supplies (Net Outlay)	0.0019	0.6613	0.4151
Public Transportation on Trips/Vacations Excl. Airline	0.0017	0.7592	0.4438
Airline Fares	0.0057	0.6869	0.5465
New and Used Motor Vehicles (Net Outlay)	0.0402	0.7033	0.5686
Alcohol Out Excl. on Trips/Vacations	0.0048	0.4939	0.5802
Alcohol Home	0.0084	0.3831	0.5908
Educational books and supplies	0.0020	0.6342	0.5955

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... table E.X continued

Variable Names	Ave Share	Inactive Ratio	Ave Vol
Personal Care Services	0.0113	0.0892	0.6088
Food Away from Home Excl. on Trips	0.0385	0.0498	0.6450
Vehicle Maintenance, Rental etc on Trips/Vacations	0.0009	0.6122	0.6658
Domestic Service	0.0168	0.4267	0.6769
Alcohol on Trips	0.0009	0.5858	0.6776
Other Entertainment Services and Rental	0.0257	0.0607	0.6797
Maintenance, Insurance etc - Owned Housing	0.0198	0.4059	0.6829
Auto Insurance	0.0213	0.2014	0.7205
Reading	0.0069	0.1118	0.7325
Clothing and Shoes	0.0532	0.0193	0.7977
Clothing Services, including watch and jewlry repair	0.0053	0.2238	0.8139
Lodging on Trips/Vacations	0.0059	0.4904	0.8413
Photographic Services and Rental	0.0023	0.3292	0.8469
Entertainment Fees and Admissions	0.0106	0.2063	0.8778
Entertainment Fees and Admissions on Trips/Vacations	0.0039	0.4742	0.8905
Jewelry and Watches	0.0045	0.4563	0.9139
Gasoline and Oil on Trips/Vacations	0.0055	0.3323	0.9417
Other Household Operation	0.0055	0.2997	0.9431
Medical Services (Net Outlay)	0.0201	0.1833	1.0135
Prescription Drugs (Net Outlay)	0.0065	0.2869	1.0211
Food on Trips/Vacations	0.0086	0.2848	1.0329
Tires, Tubes, Accessories, and Other parts	0.0090	0.3611	1.0350
Vehicle Maintenance, Rental etc	0.0235	0.1161	1.0691
Religious and Welfare Activities	0.0065	0.4147	1.1035
Recreation and Sports Equipment	0.0184	0.1743	1.1305
Durable Household Furnishing and Equipment	0.0413	0.1006	1.1723
Business Services	0.0132	0.1489	1.1838
Vehicle Registration	0.0039	0.2343	1.2653

Table E.XI: Welfare Cost of Consumption Fluctuations without Distinguishing between Nondurables and Memorables

	1	2	3	4	5	6	7	8	9	10
in (ND+Memorables) (%)	3.95	7.90	11.85	15.80	19.74	23.69	27.64	31.59	35.54	39.49
in Outlays (%)	3.64	7.28	10.91	14.55	18.19	21.83	25.47	29.11	32.74	36.38

Table E.XII: Welfare Cost of Nondurables Consumption Fluctuations

	1	2	3	4	5	6	7	8	9	10
in ND (%)	3.19	6.38	9.57	12.76	15.95	19.14	22.33	25.52	28.71	31.90
in (ND+Memorables) (%)	2.69	5.38	8.08	10.77	13.46	16.15	18.85	21.54	24.23	26.92
in Outlays (%)	2.49	4.97	7.46	9.94	12.43	14.92	17.40	19.89	22.37	24.86

Table E.XIII: Welfare Cost of Nondurables Plus Consumption Fluctuations

	1	2	3	4	5	6	7	8	9	10
in ND Plus (%)	3.62	7.24	10.86	14.49	18.11	21.73	25.35	28.97	32.59	36.21
in (ND Plus+MGminus) (%)	3.28	6.56	9.83	13.11	16.39	19.67	22.94	26.22	29.50	32.78
in Outlays (%)	3.02	6.04	9.07	12.09	15.11	18.13	21.15	24.17	27.20	30.22

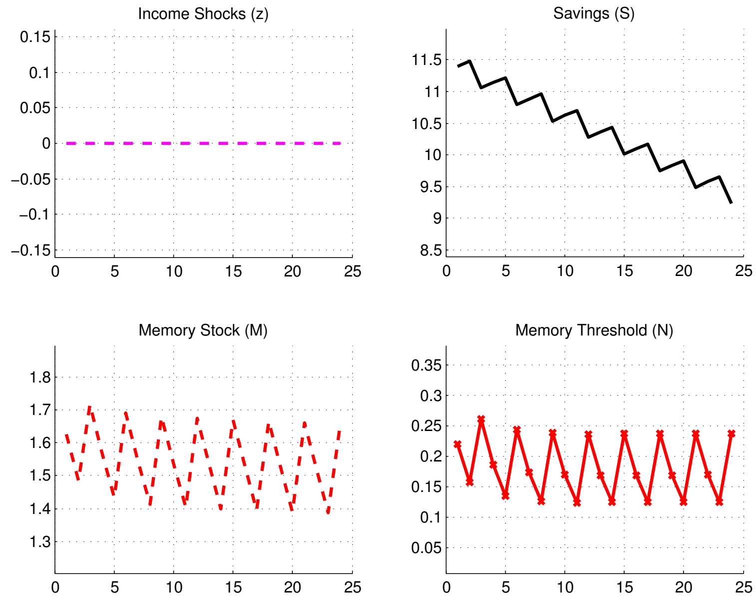


Figure 7: Changes in State Variables (Scenario I: Zero Shock)
$S_1 = \bar{S}, M_1 = \bar{M}, N_1 = \bar{N}$

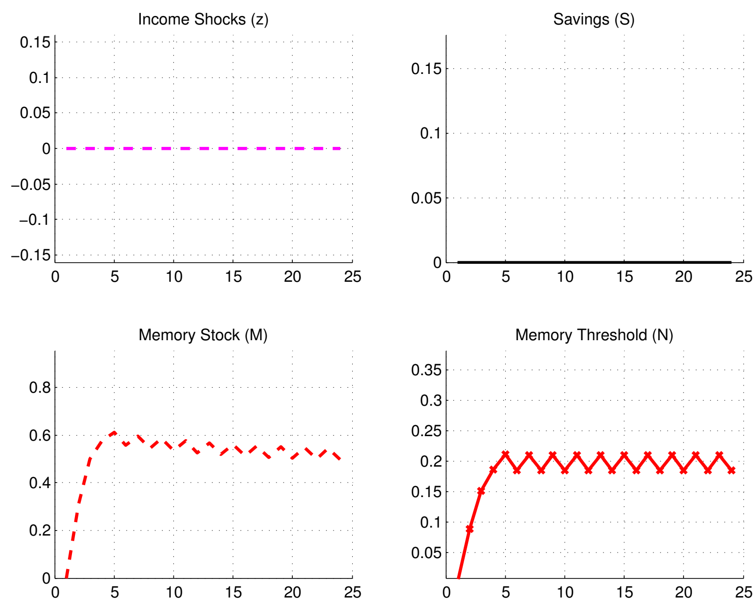


Figure 8: Changes in State Variables (Scenario I: Zero Shock)
$S_1 = 0, M_1 = 0, N_1 = 0$

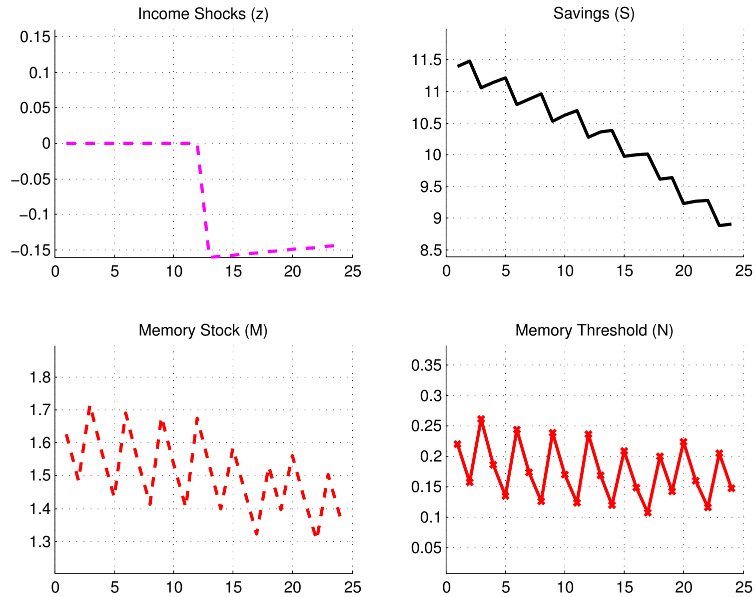


Figure 9: Changes in State Variables (Scenario II: Negative Shock)
$S_1 = \bar{S}, M_1 = \bar{M}, N_1 = \bar{N}$

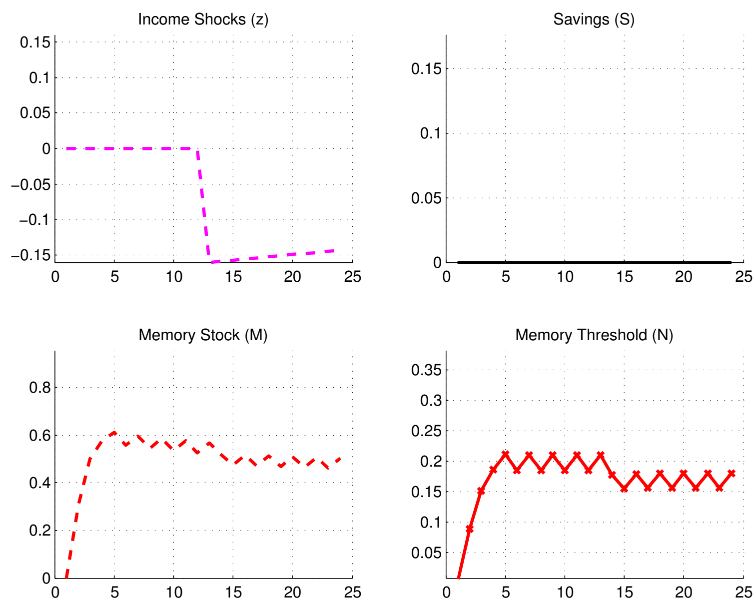


Figure 10: Changes in State Variables (Scenario II: Negative Shock)
$S_1 = 0, M_1 = 0, N_1 = 0$

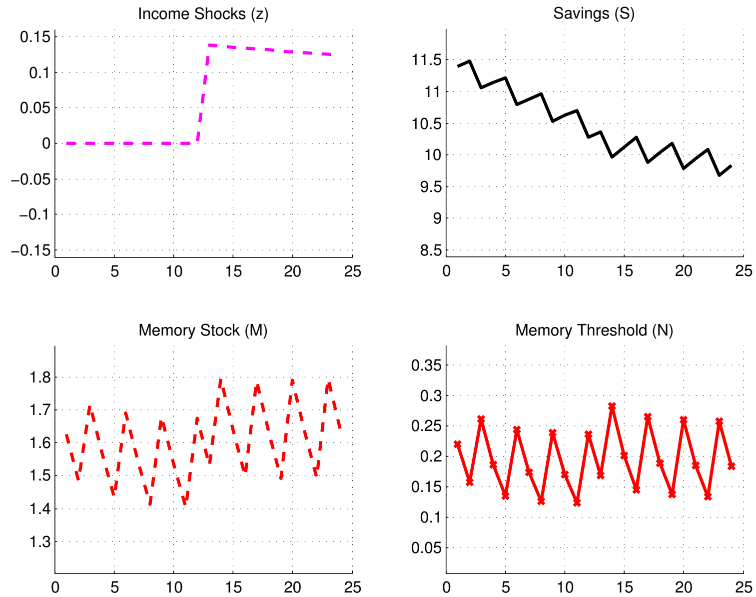


Figure 11: Changes in State Variables (Scenario III: Positive Shock)
$S_1 = \bar{S}, M_1 = \bar{M}, N_1 = \bar{N}$

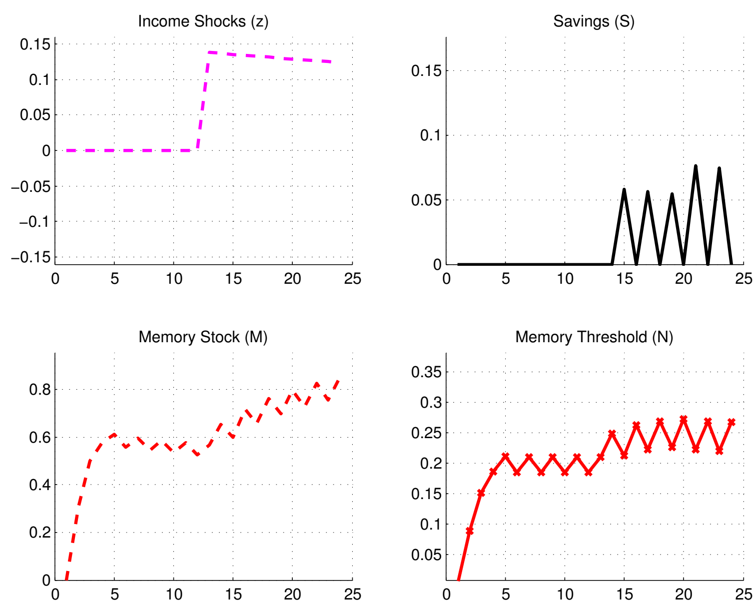
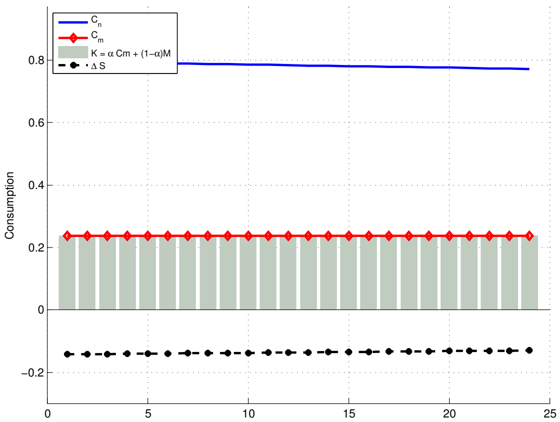
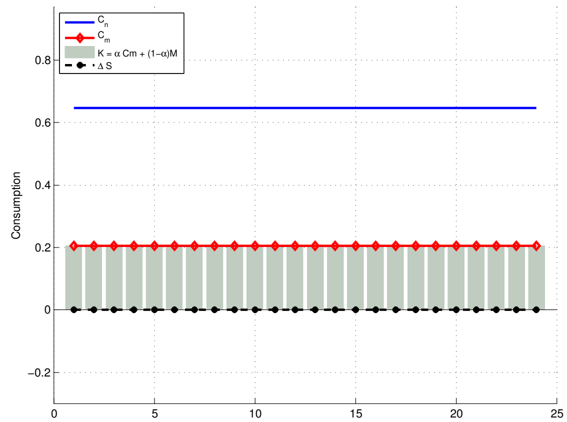


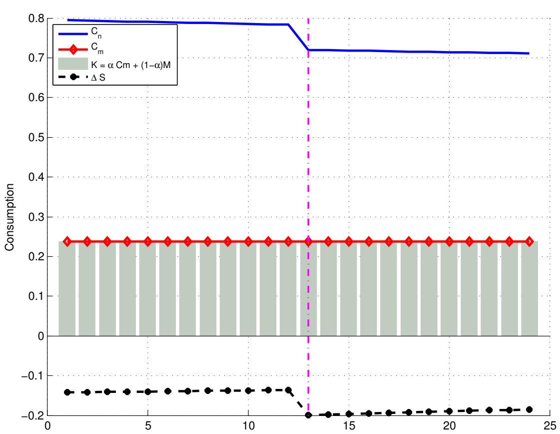
Figure 12: Changes in State Variables (Scenario III: Positive Shock)
$S_1 = 0, M_1 = 0, N_1 = 0$



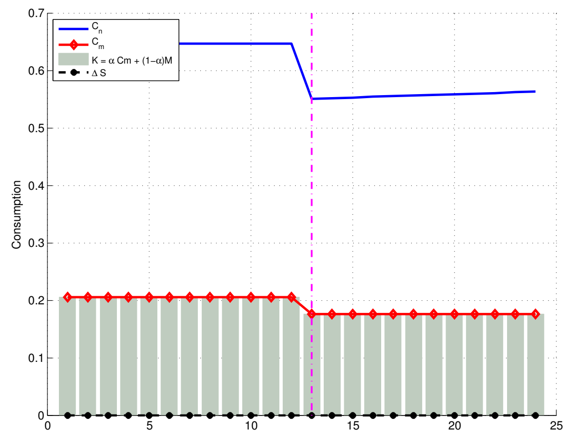
(a) Scenario I (Zero Shock): $S_1 = \bar{S}, M_1 = \bar{M}, N_1 = \bar{N}$



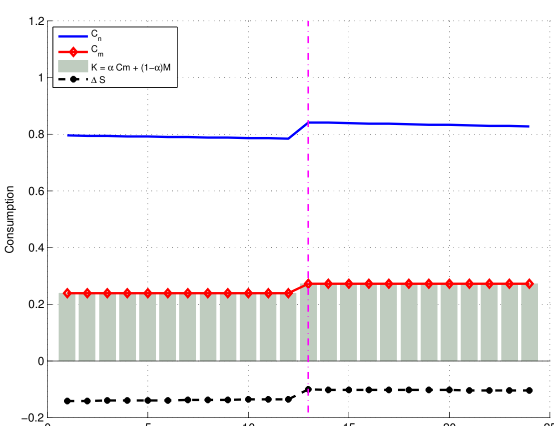
(b) Scenario I (Zero Shock): $S_1 = 0, M_1 = 0, N_1 = 0$



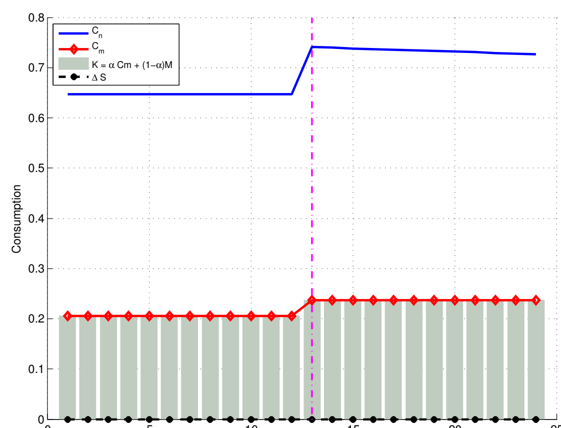
(c) Scenario II (Neg. Shock): $S_1 = \bar{S}, M_1 = \bar{M}, N_1 = \bar{N}$



(d) Scenario II (Neg. Shock): $S_1 = 0, M_1 = 0, N_1 = 0$



(e) Scenario III (Pos. Shock): $S_1 = \bar{S}, M_1 = \bar{M}, N_1 = \bar{N}$



(f) Scenario III (Pos. Shock): $S_1 = 0, M_1 = 0, N_1 = 0$

Figure 13: Changes in Consumption and Savings ($\alpha = 1$)

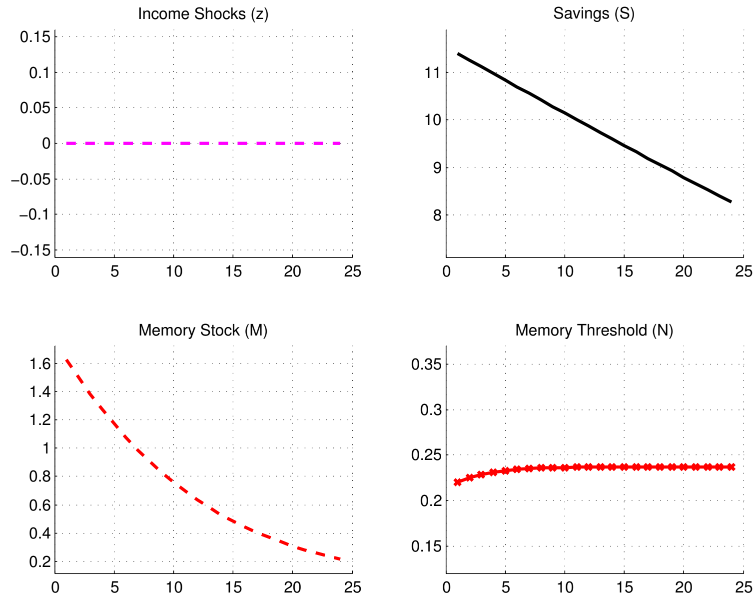


Figure 14: Changes in State Variables, $\alpha = 1$ (Scenario I: Zero Shock)
$S_1 = \bar{S}, M_1 = \bar{M}, N_1 = \bar{N}$

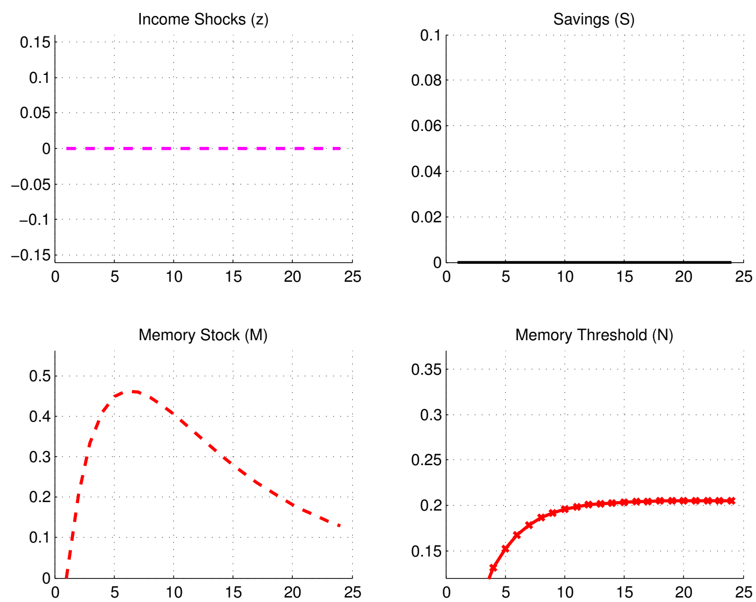


Figure 15: Changes in State Variables, $\alpha = 1$ (Scenario I: Zero Shock)
$S_1 = 0, M_1 = 0, N_1 = 0$

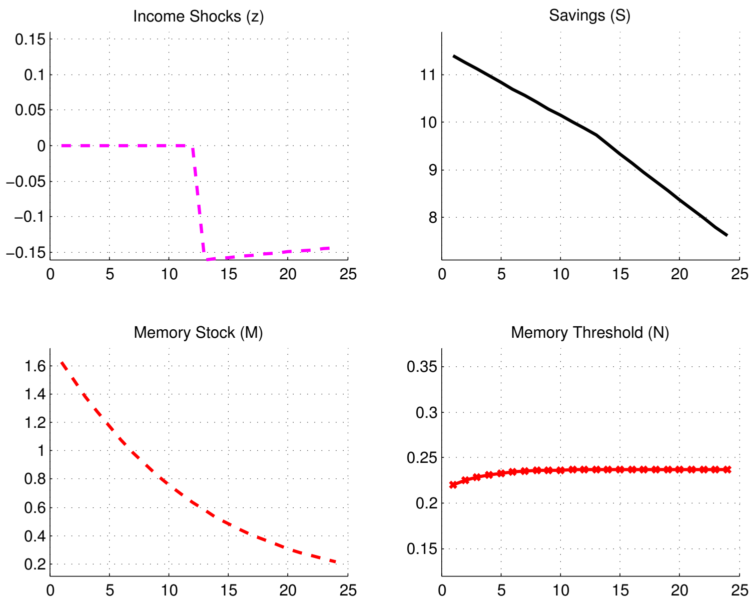


Figure 16: Changes in State Variables, $\alpha = 1$ (Scenario II: Negative Shock)
$S_1 = \bar{S}, M_1 = \bar{M}, N_1 = \bar{N}$

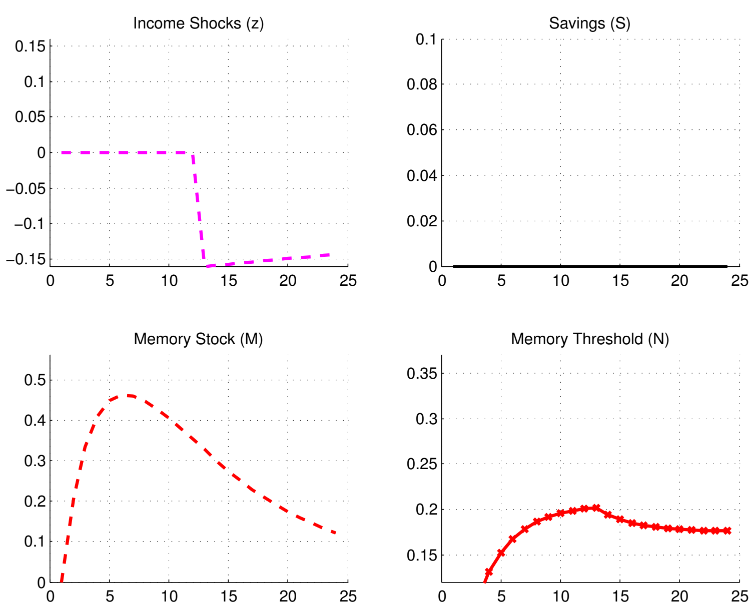


Figure 17: Changes in State Variables, $\alpha = 1$ (Scenario II: Negative Shock)
$S_1 = 0, M_1 = 0, N_1 = 0$

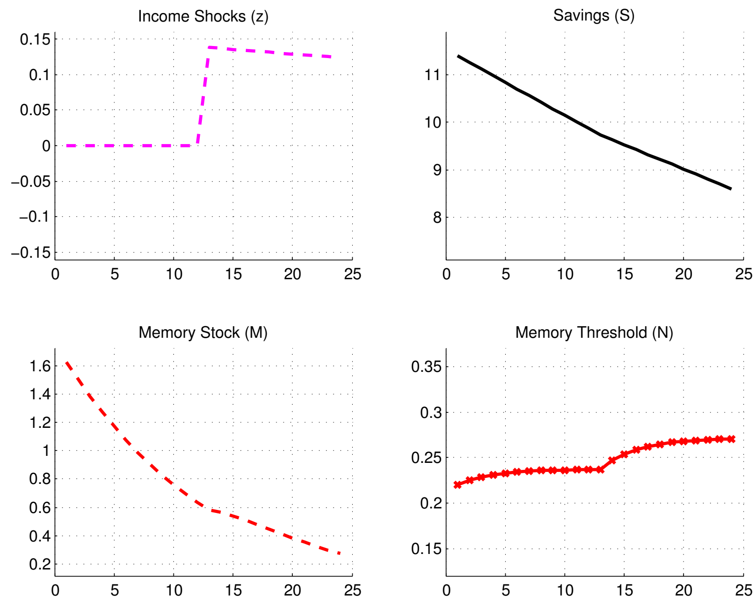


Figure 18: Changes in State Variables, $\alpha = 1$ (Scenario III: Positive Shock)
$S_1 = \bar{S}, M_1 = \bar{M}, N_1 = \bar{N}$

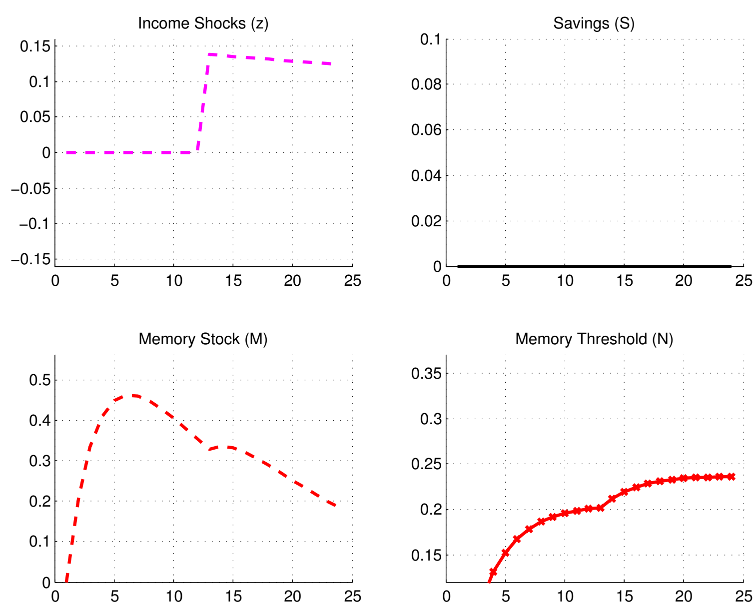


Figure 19: Changes in State Variables, $\alpha = 1$ (Scenario III: Positive Shock)
$S_1 = 0, M_1 = 0, N_1 = 0$

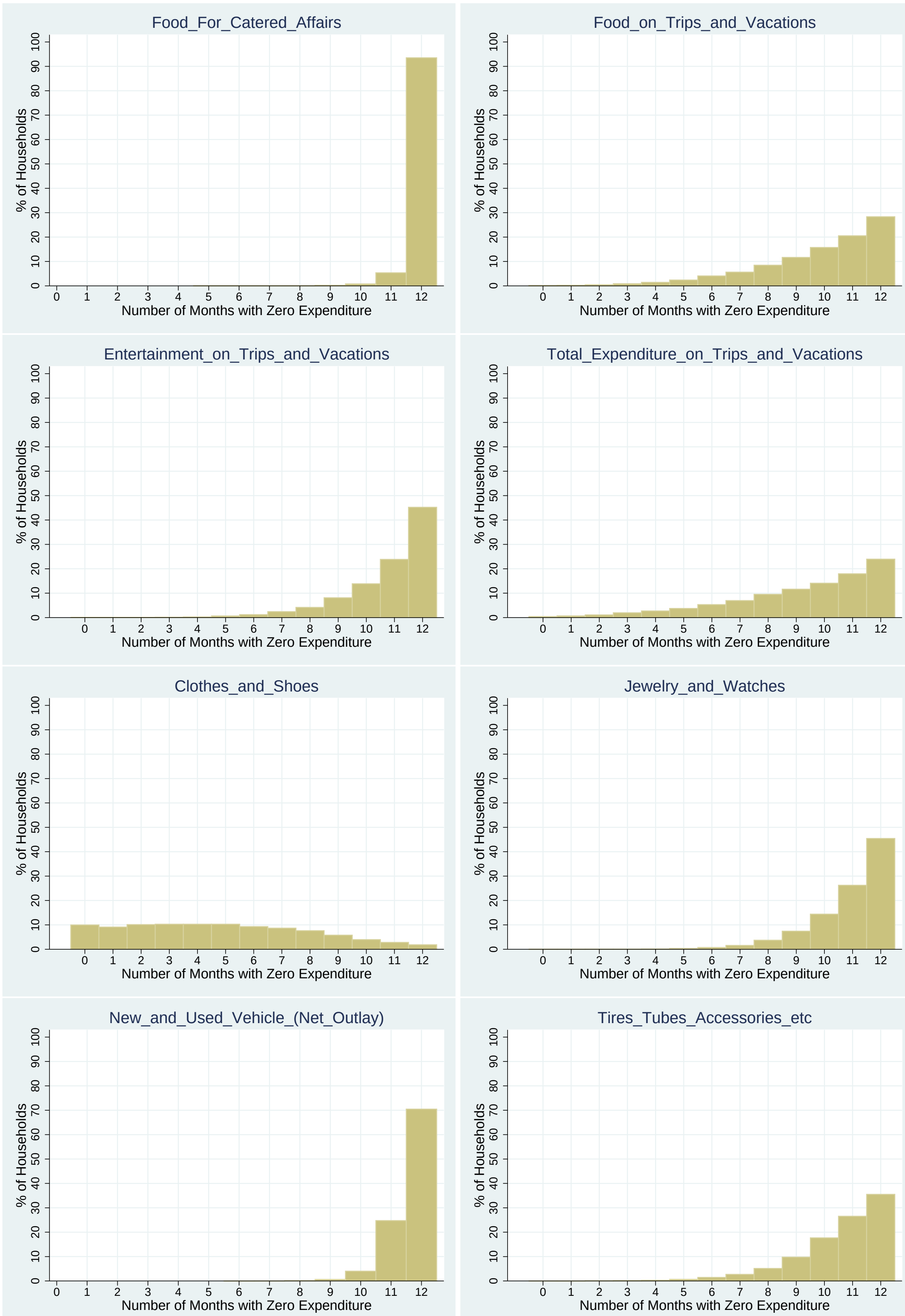


Figure 20: Number of Inactive Months

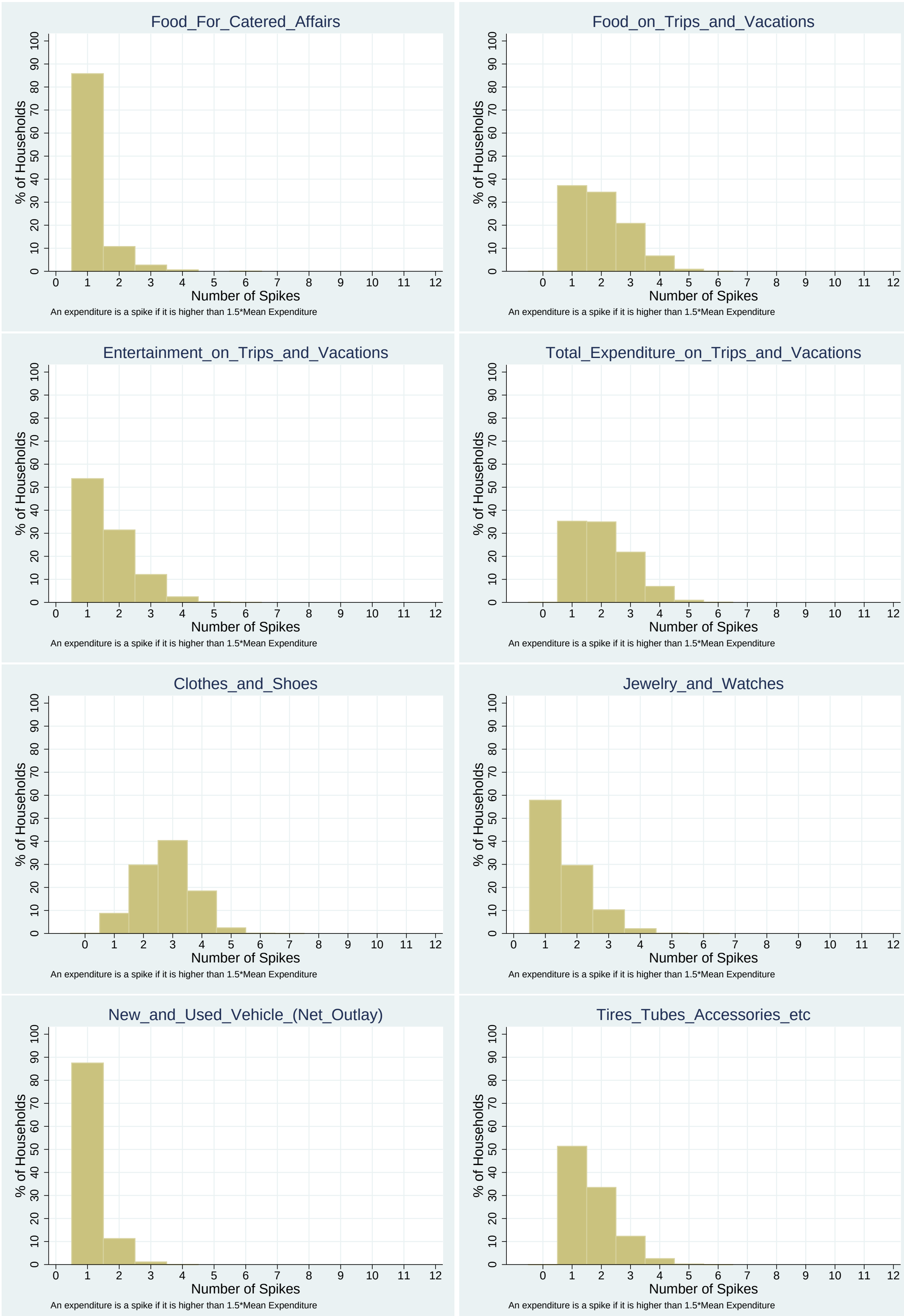


Figure 21: Number of Expenditure Spikes ($\kappa = 1.5$)

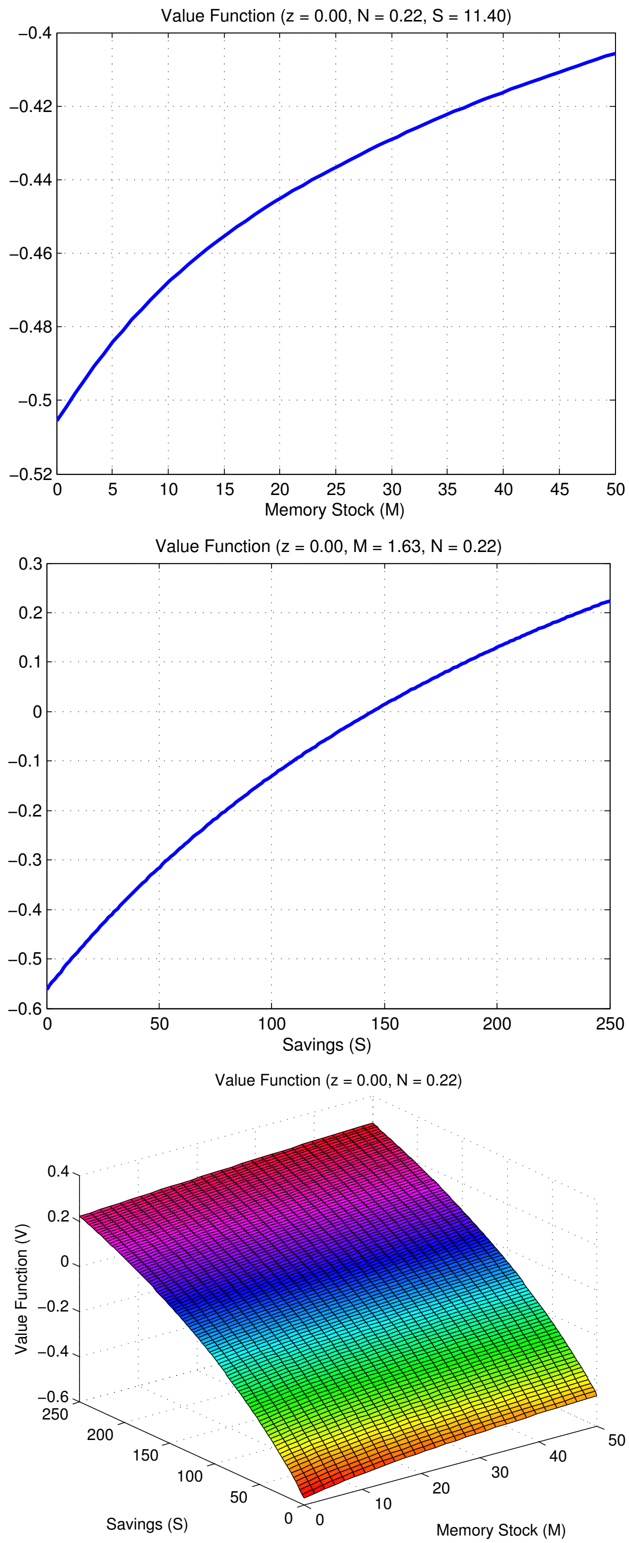


Figure 22: Value Function