

# Inattentive Consumers

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This draft: January 2006

First draft: September 2003

## Abstract

This paper studies the consumption decisions of agents who face costs of acquiring, absorbing and processing information. These consumers rationally choose to only sporadically update their information and re-compute their optimal consumption plans. In between updating dates, they remain inattentive. This behavior implies that news disperses slowly throughout the population, so events have a gradual and delayed effect on aggregate consumption. The model predicts that aggregate consumption adjusts slowly to shocks, and is able to explain the excess sensitivity and excess smoothness puzzles. In addition, individual consumption is sensitive to ordinary and unexpected past news, but it is not sensitive to extraordinary or predictable events. The model further predicts that some people rationally choose to not plan, live hand-to-mouth, and save less, while other people sporadically update their plans. The longer are these plans, the more they save. Evidence using U.S. aggregate and microeconomic data generally supports these predictions.

*JEL classification codes:* E2, D9, D1, D8

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\*I am grateful to N. Gregory Mankiw, Alberto Alesina, Robert Barro, and David Laibson for their guidance and to Andrew Abel, Susanto Basu, John Campbell, Larry Christiano, Mariana Colacelli, Benjamin Friedman, Jens Hilscher, Yves Nosbusch, David Romer, John Shea, Monica Singhal, Adam Szeidl, Bryce Ward, Justin Wolfers, and seminar participants at UC Berkeley, Board of Governors, Chicago GSB, Columbia GSB, ECB, Harvard, Johns Hopkins, Kansas City Fed, Kennedy School, New York Fed, Northwestern, Pompeu Fabra, Princeton, Stanford, and Yale for useful comments. The Fundacao Ciencia e Tecnologia, Praxis XXI and the Eliot Memorial fellowship provided financial support. Contact: rreis@princeton.edu.

*“Attention as the Scarce Resource. [...] Many of the central issues of our time are questions of how we use limited information and limited computational ability to deal with enormous problems whose shape we barely understand.”*

*Herbert A. Simon (1978, page 13)*

*“Perhaps it is not surprising that many people do not report an expectation given the costs of it.”*

*Sherwin Rosen (1990, page 284)*

## 1 Introduction

Most economists would agree that a rational consumer sets the marginal utility of consuming in the present equal to the discounted marginal utility of consuming in the future times the price of present relative to future consumption. After all, this is just the basic optimality condition from consumer choice that the marginal rate of substitution between two goods must equal their relative price. If the future is uncertain though, it is expected marginal utility that is relevant, and a crucial component of a model of consumption must specify how agents form their expectations. In a pioneering contribution, Hall (1978) assumes that agents form expectations rationally in the Muth sense: they know the entire structure of the economy and have full information on all the relevant variables needed to form statistically optimal forecasts. Rational expectations leads to the prediction that consumption should be a martingale: consumption growth should not be predictable over time. Hall’s finding that post-war U.S. aggregate consumption approximately follows a random walk was an early empirical success of rational expectations modelling.

Over the past 25 years though, many papers have found problems with the Hall model. Deviations of aggregate consumption from a martingale in the data have been convincingly established, taking the form of either excess sensitivity of consumption to past known information, or excess smoothness in response to permanent income shocks.<sup>1</sup> Campbell and Mankiw (1989, 1990) illustrate these failures by showing that if the world is partially populated by rational expectations agents, then there must be as many irrational consumers who consume their current income every period, in order to match the data on aggregate consumption.

This paper revisits the modelling of expectations formation by consumers. With rational expectations, agents can costlessly absorb and process information on all the relevant characteristics of the economy, can costlessly think through this information, and can costlessly calculate optimal forecasts and actions. I assume instead that it is costly for agents to acquire, absorb, and process information in forming expectations and making decisions. In a dynamic setting, while agents with rational expectations undertake these costly activities at every instant in time, in this paper, agents rationally choose to update their information and plans infrequently: Expectations are rational,

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<sup>1</sup>Consumption is excessively sensitive (Flavin, 1981) if future consumption growth depends on lagged information. It is excessively smooth (Deaton, 1987) if it does not respond one-to-one to shocks to permanent income, and thus is smoother than permanent income.

but are only sporadically updated. Following a new event, many agents will be unaware of the news for a while, and will continue following their outdated plans, only eventually updating their expectations. Agents are inattentive and the information in the economy is sticky, gradually dissipating over time to the entire population. Consumption in turn is excessively sensitive, since when agents adjust plans and consumption, they react to all the information (present and past) since their last adjustment date. Consumption is also excessively smooth, or insufficiently sensitive to permanent income shocks, since only a fraction of agents are attentive when there is a shock to permanent income and react to it instantly.

The model in this paper has further predictions beyond people's inattentiveness, excess sensitivity, and excess smoothness. It also predicts that while aggregate consumption moves sluggishly in response to shocks, the extent of this sluggishness is endogenously determined by the size of the information costs and income volatility, which may be different in different periods. Moreover, the model predicts that consumers only respond with a delay to a news that was not easily anticipated far in advance and that did not refer to some extraordinary event that captured everyone's attention. Finally, the model predicts that about one third of the U.S. population rationally chooses to never plan, live hand-to-mouth, and save very little.

A few papers have recently explored the potential of modelling inattentiveness. Gabaix and Laibson (2001) assume that investors update their portfolio decisions infrequently, and show that this can explain the puzzling premium of equity over bond returns. Mankiw and Reis (2002, 2003) study inattentiveness on the part of price-setting firms and show that the resulting model of the Phillips curve matches well the dynamics of inflation and output that we observe in the data. Relative to these papers, this paper differs by focusing on consumption decisions and deriving predictions for individual and aggregate consumption, which are empirically tested.<sup>2</sup> Moreover, I do not assume that agents infrequently adjust their plans, but rather I derive this behavior endogenously as the optimal response to explicitly modelled costs of planning.

Sims (2003) and Moscarini (2004) develop an alternative model of rational inattention. Both use Shannon's information theory to model the costs of obtaining information and solve for the optimal choice of which pieces of information to pay attention to, and how to use these to infer the current state of the world. Their approach is very complementary to the one in this paper, since the models differ more in focus than in substance. Sims and Moscarini focus on the information problem facing agents, at the cost of simplifying the study of their real actions; this paper focuses on these real decisions, their interaction with inattentiveness, and in deriving predictions to contrast with data, at the cost of simplifying the information acquisition problem.<sup>3</sup>

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<sup>2</sup>Carrol and Sommer (in progress) also study the empirical implications of slow dissemination of information for aggregate consumption.

<sup>3</sup>A few other theoretical papers have explored consumption decisions with limited information: Goodfriend (1992) and Pischke (1995) assume that agents cannot distinguish between permanent and transitory income shocks, Ameriks et al. (2003b) model absent-minded consumers who cannot keep track of how much they have already consumed, and Mullainathan (2002), Bernheim and Thomsen (2005), and Wilson (2003) model agents who have full information on the present but recall the past imperfectly.

Recent empirical work using microeconomic data has also emphasized that most people are inattentive and that this affects their behavior. Lusardi (1999, 2002) and Ameriks, Caplin, and Leahy (2003a) find that a significant fraction of survey respondents make financial plans infrequently (if at all) and that their planning behavior has a statistically significant and sizeable effect on the amount of wealth they have accumulated. This paper contributes to this literature a theoretical model of costly and infrequent planning. Inattentiveness rationalizes these authors' findings and suggests further implications to test using observations of individual behavior.

More generally, this paper is part of a recent wave of research rethinking how to model the process by which people form their expectations. Some have assumed that people instead use simple least squares learning algorithms to form their expectations of the future (see Evans and Honkapohja, 2001, for a survey). Others have studied models in which agents's expectations are consistent with the data while not using all of the available information (Kurz, 1997), and still others model agents as choosing between different simple mechanisms to form expectations according to their past performance (Brock and Hommes, 1997). Which is the right approach to model expectations is at this point still unclear (and many of these approaches are not mutually exclusive). One virtue of the inattentiveness model is that it remains firmly rooted in classical economics, in that agents are modelled as maximizing utility subject to constraints, the novelty being that the constraints also include costly information. One can therefore use the powerful tools of constrained optimization and rational expectations with limited information that economists have for long developed, to quickly get very far in terms of predictions.

This paper is organized as follows. Section 2 informally describes the model of inattentiveness and intuitively describes its predictions. Section 3 rigorously sets up the general problem of an agent facing costs of planning, and derives the optimality conditions describing consumption and planning behavior. It aggregates individual consumption decisions over many such agents to obtain the predictions of the model for the time-series of aggregate consumption, which will later be tested in the data. Section 4 solves the inattentive agent's problem analytically for a particular specification of preferences and uncertainty. This provides further implications and intuition on the effects of costly planning on savings and optimal inattentiveness.

Section 5 tests the implications of the model with aggregate and individual data. The model is also contrasted with models of rule-of-thumb behavior, habit formation, and state-contingent adjustment. Section 6 concludes by collecting the many theoretical results and empirical estimates in the paper into a coherent description of individual and aggregate consumption in the United States, and by discussing directions for future research.

## **2 An informal description of inattentiveness and its predictions**

Consider the problem facing a person who lives forever, earns a stochastic income and consumes every period, and maximizes utility subject to a standard budget constraint. The new assumption

in this paper is that despite being fully rational and making optimal choices, this person must incur a cost whenever she acquires information and makes optimal decisions. This is the cost in money and time of obtaining information, processing and interpreting it, and deciding how to optimally act. It can be interpreted as the money spent acquiring information and paying a financial advisor to interpret the information and compute the optimal financial plan, or it could stand for the opportunity cost of taking the time to plan. While I model these costs as a monetary expense, they can be thought of as the wages foregone at times of planning, if planning takes time away from supplying labor at a market wage and leisure enters utility separately from consumption. Likewise, modelling the costs of planning as additive reductions in utility, because some people may find the process annoying or frustrating, leads to similar results to the ones discussed in this paper.

Facing these costs, a person setting a plan of action for consumption must choose not only what to consume, but also when to plan again. With regards to her consumption plan, between two periods which are in between planning dates, the person is not obtaining any new information. Therefore, the dynamics of consumption are as if the consumer was living under perfect certainty, with consumption following a pre-determined plan, irrespective of the news in the economy.<sup>4</sup> On the other hand, optimality with respect to consumption at two successive planning dates is determined by a stochastic Euler equation, just as in the Hall model. At planning dates, the consumer obtains new information and takes the random arrival of news into account in trading off current for future consumption.

Costly planning and inattentiveness affect not just the dynamics of consumption, but especially its level. The longer a person stays inattentive for, the larger is her exposure to risk, since she is not reacting to shocks as they occur. This larger risk leads in turn to higher precautionary savings in order to safeguard against a sequence of bad income shocks. Therefore, if a person faces higher planning costs, she plans less often, and saves more.

The optimal length of inattentiveness weights the costs of reacting with a delay to news against the costs incurred by planning. There are several interesting properties of optimal inattentiveness. First, a person who faces very small costs of planning can be inattentive for a long time. The reason is that being inattentive and reacting only with a delay to news is close to being optimal in the sense of implying only a small loss in welfare. The second property of optimal inattentiveness is that the lower is the risk faced by the person and the lower her aversion to this risk, the longer she will be inattentive for. The lower these are, the smaller is the effective cost of being inattentive in terms of exposure to risk, and thus the less frequently the desire to adjust plans. A third less intuitive property is that a larger interest rate lowers optimal inattentiveness. Inattentiveness leads to sub-optimal savings and the larger is the interest rate, the larger is the impact of these inefficient savings on her future assets.

So far, I have been describing the problem of a person who chooses plans for consumption. Yet, she could instead set plans for her savings. If the agent has full information or if there is no income

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<sup>4</sup>In the psychology literature, Bargh and Chartrand (1999) describe this as “the unbearable automaticity of being.”

uncertainty, then the two are indistinguishable. But if the agent is not monitoring her income every instant, she must choose to either set a plan for consumption and let savings adjust to the shocks, or to set a plan for savings and let consumption adjust. More concretely, an inattentive consumer is someone whose paycheck is deposited in her bank account, spends a planned amount, and leaves whatever remains in the bank. An inattentive saver is someone who receives her paycheck in her pocket, puts aside a planned amount in savings, and spends the rest until her pocket is empty.

One immediate implication of inattentive saver behavior is that consumption absorbs all of the income shocks. Therefore, the marginal propensity to consume out of current income is one, so the inattentive savers live hand-to-mouth. Another important feature of the behavior of an inattentive saver is that, as long as the costs of planning are not too small, it is optimal to never plan at all. To understand the intuition behind this result, consider the special case in which income shocks are serially uncorrelated. If the person does not update her information this period, next period's assets equal this period's assets plus savings and capital returns, all of which are not random. Therefore, the agent is facing exactly the same problem as in the previous period, and thus she must again choose not to update her plans. Iterating on this logic shows that the saver will either always be attentive, or never update her plans. If the cost of planning is not too small, she will choose to never plan. The inattentive saver is a rational non-planner.

Having characterized the behavior of inattentive consumers and inattentive savers, the next question is which do people choose to be. In the case where the inattentive savers rationally choose to never plan, they are unaffected by the costs of planning. The inattentive consumers on the other hand are worse off the larger are these costs. It then follows that if the costs of planning are above a certain threshold, people only choose savings plans, whereas if they are below, they will choose a consumption plan. This gives the following characterization of behavior in an inattentive economy: some agents have high costs of planning and optimally choose to live hand-to-mouth and never make plans. The other agents, who have lower planning costs, opt instead for following infrequently-updated plans on consumption.

In this inattentive economy, aggregate consumption responds gradually to a shock, with a reaction that builds up over time. The reason is that people only gradually update their plans and become aware of the news, which only slowly disseminates throughout the entire economy. If the shock affects income then in the inattentive economy one will find that aggregate consumption is excessively sensitive, since past income shocks affect current consumption growth. Moreover, since only a fraction of the agents react contemporaneously to changes in permanent income, consumption will be smoother than income. Slow dissemination of information can therefore solve both the excess sensitivity and excess smoothness puzzles.

Finally, note that the inattentiveness model refines the meaning of tests for excess sensitivity. In an inattentive economy, a consumer responds to present and past shocks only if she could not predict them when she last planned. Past predictable events do not affect present individual consumption changes. Moreover, it is reasonable to extend the baseline model to allow people to observe some

extraordinary events when they take place. The defining features of these events is that they refer to changes in variables that only move infrequently, so the cost of monitoring them is very small, and which lead to large changes in the agent's income. For instance, if the agent suddenly becomes unemployed or wins the lottery, it is reasonable to suppose that the agent becomes immediately aware of these rare significant events, and responds to them. Past extraordinary events do not affect present individual consumption changes.

Summarized and simplified, these are the main features of the theory of inattentive consumption. The next two sections formalize this description, before turning to the evidence in Section 5.

### 3 The general inattentiveness model

#### 3.1 The set-up of the problem

I model the problem of the inattentive consumer in continuous time, so that the planning dates are chosen from a continuous set.<sup>5</sup> Time is indexed by  $t$  on the positive real line while the decision periods are denoted by  $D(i)$  where  $i \in \mathbb{N}_0$  orders the decision times so that  $D(i+1) \geq D(i)$  for all  $i$  with  $D(0) \equiv 0$ . If  $d(i)$  denotes the time until the next adjustment, defined recursively as  $d(i) = D(i) - D(i-1)$ , it is clearly equivalent for the agent to choose the calendar dates of planning  $D(i)$  or the inattentiveness intervals  $d(i)$ .

The economy is populated by many infinitely-lived consumers, who each instant consume an amount of goods  $c_t$ , which yields an amount of utility given by the function  $u(c_t)$ . This function is continuous, everywhere twice differentiable, increasing and concave, and future utility is discounted at the positive rate  $\rho$ .

Each instant, the agent receives an income flow  $y(x)$ , and her assets  $a_t$  earn returns at the interest rate  $r$ . The flow budget constraint is  $da_t = (ra_t - c_t + y(x_t))dt$ , stating that at each instant, assets increase by the interest earned plus new savings,  $s_t = y(x_t) - c_t$ . Borrowing is constrained by the condition that all debts must be repaid, so the agent cannot run Ponzi schemes rolling over debt forever:  $\lim_{t \rightarrow \infty} e^{-rt}a_t \geq 0$ . Income is a function of a state vector  $x_t$ , of potentially very large dimension, which is generated by a continuous time stochastic process defined on a standard filtered probability space  $\{X, F, P\}$  where  $X$  is the set of possible states,  $F$  is the filtration  $F = \{F_t, t \geq 0\}$  where  $F_t$  is the  $\sigma$ -algebra through which information on  $x_t$  is revealed, and  $P$  is the probability measure on  $F$ . I will write  $y(x_t)$  more compactly as  $y_t$ . The notation  $E_k[\cdot]$  will be used to denote the expectation conditional on information up until time  $k$ :  $E_k[y_t] = \int y_t dP(F_k)$ . I further assume that the state vector has the Markov property, and, without loss of generality, that it is arranged in such a way that it is first-order Markov. Therefore, a sufficient statistic for the probability of any state  $y_t \in Y$  from the perspective of time  $k < t$  is the state vector at time  $k$ :  $P(y_t | F_k) = P(y_t | x_k)$ .

The consumer's choice of planning dates defines a new filtration  $\mathfrak{F} = \{\mathfrak{F}_t, t \geq 0\}$  such that

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<sup>5</sup>An earlier version of this paper solved the model also in discrete time. Details are available from the author.

$\mathfrak{S}_t = F_{D(i)}$  for  $t \in [D(i), D(i+1))$ . When the consumer writes a plan at time  $D(i-1)$ , she first makes a decision on whether to write a plan for consumption  $c_t$  or a plan for savings  $s_t$ . Each period, the agent visits a goods market and an asset market; she can choose to either follow a plan of conduct in one or in the other market. Having decided on the type of plan, the agent must then choose the content of the plan which consists of a sequence of actions until the next adjustment,  $z(i) = [z_{D(i-1)}, z_{D(i)}]$  where  $z$  equals  $c$  or  $s$ , and when to plan again  $D(i)$ . The restriction embodied in the existence of a plan is that these choices must be contingent on the information available at time  $D(i-1)$ : if  $\{z, D\} = \{z(i), D(i)\}_{i=1}^{\infty}$  these must be  $\mathfrak{S}$ -adapted processes.

Whenever she plans, the consumer incurs a fixed monetary cost given by  $K_t \equiv K(x_t)$ , which can be stochastic and time-varying. If the consumer enters period  $D(i)$  with assets given by  $a_{D(i)}^-$ , her wealth then changes discontinuously to  $a_{D(i)}^+ = a_{D(i)}^- - K_{D(i)}$ .<sup>6</sup> Formally,  $a_{D(i)}^-$  is the left-hand side time limit of assets, while  $a_{D(i)}^+$  is the right-hand side limit, and they differ by the fixed cost.

The problem of the consumer can then be compactly written as:

$$\max_{\{z, D\}} E_0 \left[ \sum_{i=0}^{\infty} \int_{D(i)}^{D(i+1)} e^{-\rho t} u(c_t) dt \right] \quad (1)$$

$$\text{s.t.} \quad : z(i) = c(i) \text{ or } s(i), \quad (2)$$

$$\{z, D\} \text{ are } \mathfrak{S}\text{-adapted}, \quad (3)$$

$$da_t = (ra_t - c_t + y_t)dt, \quad (4)$$

$$s_t = y_t - c_t, \quad (5)$$

$$a_{D(i)}^+ = a_{D(i)}^- - K_{D(i)}, \text{ for all } i \in \mathbb{N}_0, \quad (6)$$

$$\lim_{t \rightarrow \infty} e^{-rt} a_t \geq 0, \quad (7)$$

with initial conditions  $a_0, x_0$ . It is difficult to solve this problem both because it is hard to impose the measurability restriction (3) and because of the discontinuity in the level of assets at the planning dates (6). To make progress, the problem must be re-stated in a more convenient form.

Start by integrating the law of motion for assets in (4) between  $D(i)$  and  $D(i+1)$ , and replace  $a_{D(i)}^-$  by  $a_{D(i)}^+ + K_{D(i)}$  using (6). This gives:

$$a_{D(i+1)}^+ = e^{rd(i)} \left( a_{D(i)}^+ - \int_0^{d(i)} e^{-rt} c_{D(i)+t} dt + \int_0^{d(i)} e^{-rt} y_{D(i)+t} dt \right) - K_{D(i+1)},$$

thus eliminating the  $a_t^-$  variables, so that only  $a_t^+$ 's are left. Moreover, realize that there is a recursive structure between planning dates so the cumbersome time indices can be dropped by denoting  $a_{D(i)}^+$  by  $a$  and  $a_{D(i+1)}^+$  by  $a'$ , and similarly  $x_{D(i)}$  by  $x$  and  $x_{D(i+1)}$  by  $x'$ . Next, let  $V(a, x)$

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<sup>6</sup>Implicit in this setup is the assumption that while it is costly to re-write new plans, this can be done in an instant of time. I could assume instead that it takes a fixed interval of time to devise a plan. While this would require some modifications to the analysis that follows, it would not affect the main conclusions.

be the value function associated with this problem. The state vector is  $(a, x)$  since the law of motion for assets and the Markov assumption for the state vector imply that  $(a, x)$  is a sufficient statistic for the uncertainty facing the agent until the next planning date.

With these changes, the problem in (1)-(7) becomes:

$$V(a, x) = \max\{V^c(a, x), V^s(a, x)\}, \quad (8)$$

$$V^c(a, x) = \max_{c, d} \int_0^d e^{-\rho t} u(c_t) dt + e^{-\rho d} E[V(a', x')] \quad \text{and} \quad (9)$$

$$V^s(a, x) = \max_{s, d} \int_0^d e^{-\rho t} E[u(y_t - s_t)] dt + e^{-\rho d} E[V(a', x')], \quad (10)$$

$$\text{subject to } a' = e^{rd} \left( a + \int_0^d e^{-rt} \underbrace{(y_t - c_t)}_{=s_t} dt \right) - K'. \quad (11)$$

Focussing on the consumption problem, the measurability constraints are imposed by having passed the expectations operator through  $\{c, d\}$ , so that these choices are made conditional only on the information in  $(a, x)$ . The only unknown at this planning date is what assets and accumulated income will be by the next planning date. The notation  $V^c(\cdot)$  and  $V^s(\cdot)$  denotes the value from at a date choosing to form consumption or savings plans respectively. As for the initial conditions, note that since there is planning at date 0, the initial post-planning asset level is  $a_0 - K_0$ .<sup>7</sup>

The solution to the problem in (9)-(11) will be a pair of functions,  $c_t(a, x)$  or  $s_t(a, x)$  and  $d(a, x)$ , determining optimal consumption or savings from time 0 to time  $d$  and when the next planning will take place. Consumption or savings at any date between 0 and  $d$  is inattentive since it is chosen regardless of the state of the world at that date. In turn, the date of the next adjustment does not depend on the state at that date – adjustment is not state-contingent. However, adjustment is also not purely time-contingent, since the date of the next adjustment depends on the state of the world at the last adjustment. For lack of better words, I describe adjustment with inattentiveness as *recursively time-contingent*: it occurs at a pre-set date which depends recursively on the state at the past planning date. In some cases,  $d(a, x)$  might be independent of  $(a, x)$ , in which case the inattentiveness model leads to purely time-contingent adjustment.

The problem in (9)-(11) is a familiar dynamic programming problem. If the utility function is bounded, arguments similar to those in Stokey et al. (1989) prove the existence of a solution and give the necessary restrictions for uniqueness of this solution. With an unbounded-from-below utility function, the problem of the inattentive consumer has one additional technical difficulty relative to the full information problem. To illustrate it, consider the case in which income follows an arithmetic Brownian motion, which has infinite local variation. If the agent is inattentive for

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<sup>7</sup>Some related problems have been studied in engineering under the headings: sampled-data control systems, and digital control. The two closest to this paper are control problems in which the state is observed at exogenously given infrequent dates (Franklin et al., 1990), and optimally choosing how often to sample a continuous time stochastic process to maximize the information content of the messages (Miller and Runggaldier, 1997).

even an instant then with positive probability her income may fall to a very large negative number inducing her to borrow a very large amount. Satisfying the intertemporal budget constraint would then require setting consumption so low that utility would be unbounded from below, so being inattentive could never be optimal. On the other hand, being always attentive cannot be optimal since it involves an infinite expenditure of resources in planning, so the problem does not have a well-defined solution.

There are two ways to get around this problem. A reasonable solution is to simply assume that income follows a bounded stochastic process that cannot fall extremely every instant. If the reader of this paper knew that in the instant it takes to read this sentence while being inattentive to her income, her life circumstances could change so suddenly as to throw her into a life of bondage, she would never read anything at all and would go through life doing nothing but monitoring income every instant. This is not the case for most people, so it is reasonable to assume it is also not the case for the inattentive consumer. A second solution to the problem is to retain the mathematical convenience of using Wiener processes for income, while specifying preferences that do not run into the problem. For instance, assuming that the utility function is of the constant absolute risk aversion form and allowing consumption to sometimes be negative is enough to guarantee a well-defined optimization problem. This is the approach that I will follow in section 4, and it is also the approach in the engineering literature which focusses on quadratic objective functions or  $H_\infty$  control (Chen and Francis, 1995).

Finally, note that this model makes the extreme assumption that even paying attention to your own income or bank account balance is costly. In some ways, this assumption may not be so extreme as it seems: while surely people observe some things at little cost, actually understanding what this information implies for the relevant state variables, updating their forecasts, solving for their optimal choices, and agreeing within the household what is the best course of action, are likely quite costly. Even if the costs of acquiring information may be small, the costs of absorbing and processing this information may be quite substantial.

One reasonable extension of the model allows people to keep an eye open to extreme events. These events have two key features: they occur very infrequently so monitoring them costs little, and when they do occur they have a large impact on the person's income so she will want to react instantly. Section 6 of Reis (2004) models these extraordinary events explicitly as Poisson shocks to income. The only modification to the predictions of the model is that consumption now responds instantly to these extraordinary events when they take place.<sup>8</sup>

### 3.2 Characterizing the solution

Taking the derivative of (9) with respect to  $d$  and setting it equal to zero gives:

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<sup>8</sup>Section 6 of Reis (2004) considers another extension of the basic model, which allows people to enroll in fixed contribution IRA plans which save a fixed percentage of income every month. These hybrid consumption-savings plans do not affect the main results of the model.

$$E[u(c_d)] = \rho E[V(a', x')] - \frac{\partial}{\partial d} E[V(a', x')]. \quad (12)$$

This first-order condition states that the agent plans to adjust when the marginal cost of adjusting equals the marginal benefit of doing so. On the left-hand side is the flow of value from extending the interval of non-adjustment, which is the utility the agent would get if she kept to her outdated consumption plan. On the right-hand side is the value of adjusting at time  $d$ . The first term is the present flow value of having re-planned and obtained new information, while the second term is the benefit from acquiring this information at  $d$  rather than in the next instant when this value has fallen. The cost  $K$  enters the first-order condition on the right-hand side by lowering the benefits of planning through the fall in assets by  $K$  to  $a'$  at the planning date.

Consider first the case of an inattentive consumer. One can show that the first-order conditions with respect to  $c_t$  and the envelope theorem condition imply that if the consumer is inattentive between times  $t$  and  $s > t$ , consumption between these periods obeys the deterministic Euler equation:

$$u'(c_t) = e^{(r-\rho)(s-t)} u'(c_s). \quad (13)$$

If  $D(i)$  and  $D(i+1)$  are two successive planning dates, consumption between these periods obeys instead the stochastic Euler equation:<sup>9</sup>

$$u'(c_{D(i)}) = e^{(r-\rho)(D(i+1)-D(i))} E_{D(i)} [u'(c_{D(i+1)})]. \quad (14)$$

The dynamics of inattentive consumption over time are therefore simple to describe. During the intervals of inattentiveness, consumption evolves just like in the standard consumer problem with certainty. At adjustment dates, consumption evolves just like in the standard consumer problem with uncertainty. Intuitively, between adjustments the agent is not receiving new information so it is as if there is no uncertainty; at adjustments, information is revealed and optimal choices incorporate it.

If the agent instead chooses a savings plan, then the most interesting result is that consumption moves one-to-one with income since  $c_t = y_t - s_t$  and  $s_t$  does not respond to income news. The optimal path for  $s_t$  is determined by Euler equations similar to the ones above.

### 3.3 Aggregate consumption

There are many inattentive agents in the economy, individually behaving in the way described above. They have the same preferences but differ for instance in their realization of income shocks and in the costs of planning they face. They therefore differ in whether they choose consumption or savings plans, on how much they consume or save, and on how long they stay inattentive for.

First focus on the choices of inattentive consumers; at the end of this section I will consider savers

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<sup>9</sup>To be rigorous,  $c_{D(i)}$  and  $c_{D(i+1)}$  are the right-side time limits.

as well. Following the literature, I work with linearized versions of the optimality conditions.<sup>10</sup> A first-order Taylor approximation of (13) around the point where  $c_t = c_s$  and  $r = \rho$  gives:

$$c_s = c_t + \frac{1}{\alpha}(r - \rho)(s - t), \quad (15)$$

where  $\alpha = -u''(c_t)/u'(c_t)$  is the coefficient of absolute risk aversion. A similar approximation of (14) leads to:

$$c_{D(i+1)} = c_{D(i)} + \frac{1}{\alpha}(r - \rho)(D(i+1) - D(i)) + e_{D(i+1),D(i)}, \quad (16)$$

where  $e_{D(i+1),D(i)} \equiv c_{D(i+1)} - E_{D(i)}[c_{D(i+1)}]$ , the innovation to consumption between  $D(i)$  and  $D(i+1)$ , where  $D(i) \leq s \leq t \leq D(i+1)$ .

Consider then the change in consumption of any inattentive consumer between  $t$  and  $t+1$ . If she has not adjusted her plan between  $t$  and  $t+1$ , then her behavior is described by equation (15) with  $s = t+1$ . If she has adjusted, then let  $j$  denote how long ago starting in  $t+1$  did the agent last adjust, and similarly, let  $i$  denote how long starting from  $t$  one must go back to the last adjustment date for that same agent. Then, combining equation (15) and (16) establishes the relation between consumption choices at  $t$  and  $t+1$  by these agents:

$$c_{t+1} - c_t = \frac{1}{\alpha}(r - \rho) + e_{t+1-j,t-i}.$$

Summing over all of the inattentive consumers in the economy, it is then easy to see that

$$C_{t+1} - C_t = \text{constant} + u_{t+1},$$

where  $C_t$  is aggregate consumption by inattentive consumers and  $u_{t+1}$  is a sum of the  $e_{t+1-j,t-i}$  of the different people in the economy. This has the property  $E_{t-I}[u_{t+1}] = 0$ , where  $I$  is the largest amount of time during which consumers remain inattentive. We therefore get the result:

**Proposition 1** *Aggregate consumption growth by inattentive consumers between  $t$  and  $t+1$  should be unpredictable from the perspective of  $t-I$  information, where  $I$  is the largest amount of time during which consumers remain inattentive.*

With full information ( $I = 0$ ), Hall (1978) first showed that any variable dated  $t$  or before should not predict consumption growth between  $t$  and  $t+1$ . With inattentive agents, events between  $t-I$  and  $t$  predict consumption growth, since some consumers who had been inattentive, update their information and plans between  $t$  and  $t+1$  and only then react to past events.

Assuming that there is a finite number of people in the world, and that the  $e_{t+1-j,t-i}$  can be broken into independent homoskedastic increments:<sup>11</sup>

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<sup>10</sup>This is not to say that these non-linearities are not important. Attanasio and Weber (1995) argue that they can significantly affect tests of the Hall model. Examining their effect on the inattentiveness model is left for future work.

<sup>11</sup>The proof of this Proposition is lengthy and can be found in Reis (2004b). The new relevant assumption relative

**Proposition 2** *Aggregate consumption growth by inattentive consumers can be written as:*

$$C_{t+1} - C_t = \text{constant} + \Phi(0)e_{t+1} + \Phi(1)e_t + \dots + \Phi(I)e_{t-I+1}, \quad (17)$$

with  $\Phi(s) \geq \Phi(s+1) \geq 0$  for  $s = 1, 2, \dots, I$ , while  $E_{t-s}[e_{t+1-s}] = 0$  defines the innovations.

It is appropriate to call the  $e_t$ 's "news" since they are mutually uncorrelated and are unpredictable one period ahead. The  $\Phi(s)$ 's correspond approximately to the share of agents in the population that update their information between  $t$  and  $t+1$  and had last done so at or before  $t-s$ . Thus, they are non-increasing in  $s$ . The size of  $\Phi(s)$  depends on the length of inattentiveness chosen by consumers, so to make equation (17) empirically testable with a time series, one must add the assumption that the economy has converged to a stationary distribution of inattentiveness.<sup>12</sup>

Equation (17) reveals another implication of the model for aggregate consumption. With full information, consumption responds immediately to the news ( $\Phi(0) = 1$  and  $\Phi(s) = 0$  for  $s \geq 1$ ), since all agents are attentive and so react immediately. With inattentiveness though, when news arrives, consumption rises immediately by  $\Phi(0)$ . The following period, consumption rises further but now by the smaller amount  $\Phi(1)$ , and the following period it rises further by the even smaller amount  $\Phi(2)$ , and so on until  $I$  periods after. The impulse response of aggregate consumption to a shock is therefore increasing for a few periods, and concave. A related implication from equation (17) is that consumption growth depends on past news with more recent news receiving a larger weight than older news does. Combining these two results:

**Proposition 3** *Aggregate consumption by inattentive consumers exhibits:*

- a) *Slow adjustment - the impulse response of consumption to shocks is increasing and concave.*
- b) *Slow dissemination of information - consumption growth depends on current and past news and the estimates from regressing consumption growth on current and past news are non-increasing in how far in the past the news had arrived.*

While the Hall (1978) model predicts that aggregate consumption should follow a random walk, equation (17) implies that the change in aggregate consumption should follow an  $MA(I)$  process with positive coefficients. Turning to the frequency domain emphasizes the difference between the two: the normalized power spectrum of aggregate consumption changes ( $f_{\Delta C}(\omega)$ ) is horizontal in the Hall model, but has a shape determined by  $\Phi(s)$  in the inattentiveness model. Moreover, Gali (1991), following Deaton (1987), showed that  $\psi \equiv 1/\sqrt{2\pi f_{\Delta C}(0)}$  equals the excess smoothness ratio, that is the square root of the ratio between the variance of changes in consumption and

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to proposition 1 is that of homoskedasticity of shocks. It precludes, for instance, the possibility that everyone obtains an unexpected pay rise in one particular month every year. In this case, the  $\Phi(s)$  would be different for this month but they would also follow the pattern described in the proposition.

<sup>12</sup>Reis (2005) derives an interesting result regarding this distribution: if the decisions of when to adjust are mutually independent over time and across consumers, and the costs of planning are almost surely positive and such that inattentiveness is not always a constant multiple of some integer, then the stationary distribution will be exponential.

the variance of changes in permanent income.<sup>13</sup> In the Hall model, this ratio equals one, since consumption reacts immediately one-for-one to changes in permanent income, so findings of  $\psi < 1$  have been described as revealing excess smoothness of consumption. One can show that:

**Proposition 4** *In the inattentiveness model:*

a) *Changes in aggregate consumption have a normalized power spectrum given by:*

$$f_{\Delta C}(\omega) = \frac{1}{2\pi} \left\{ 1 + 2 \frac{\sum_{j=1}^I \sum_{k=0}^{I-j} \Phi(k) \Phi(k+j) \cos(\omega j)}{\sum_{k=0}^I \Phi(k)^2} \right\}. \quad (18)$$

b) *The excess smoothness ratio is:*

$$\psi = \sqrt{\frac{\sum_{i=0}^I \Phi(i)^2}{\left[\sum_{i=0}^I \Phi(i)\right]^2}}. \quad (19)$$

*If some agents are inattentive for at least one period, consumption is excessively smooth.*

Note that if there is excess smoothness, then it must be that  $\Phi(i) \neq 0$  for some  $i > 0$ , so there is excess sensitivity. Yet, excess sensitivity per se does not necessarily imply excess smoothness. Proposition 4 shows the tight relation between excess sensitivity and excess smoothness in the inattentiveness model.<sup>14</sup> Any particular pattern of excess sensitivity coefficients ( $\Phi(i)$ ) implies not just excess smoothness, but also an exact value for  $\psi$ . The model requires that the same set of parameters must fit these two related but distinct features of the data.

Finally, I turn to the behavior of inattentive savers. Following very similar steps, it is easy to show that for these agents

$$c_{t+1} - c_t = \text{constant} + y_{t+1} - y_t + e_{t+1-j,t-i}, \quad (20)$$

where, as before,  $e_{t+1-j,t-i}$  captures news on savings to inattentive savers whose most recent planning date since  $t+1$  was at  $t+1-j$  and most recent planning date since  $t$  was at  $t-i$ . Note especially that if  $j > 1$ , then  $j = i+1$  and  $e_{t+1-j,t-i} = 0$ . If, for instance, savers never plan, then all their  $e_{t+1-j,t-i}$  are zero.

Aggregating over the inattentive savers then leads to a similar expression as in (17) but now with an added term involving the change in the aggregate income of inattentive savers. Aggregating over all of the consumers in the economy then leads to:

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<sup>13</sup>Heuristically, Gali's argument goes as follows. The variance ratio of Deaton is  $\psi = \sqrt{\text{Var}(\Delta C)/\text{Var}(\Delta Y^P)}$ , where  $Y^P$  denotes permanent income. Gali notes that since the agent faces a budget constraint, changes in permanent income must lead to changes in permanent consumption, so  $\text{Var}(\Delta Y^P) = \text{Var}(\Delta C^P)$ . But  $2\pi$  times the normalized spectrum at frequency zero of consumption changes measures exactly the fraction of the variability of consumption changes driven by permanent movements:  $2\pi f_{\Delta C}(0) = \text{Var}(\Delta C^P)/\text{Var}(\Delta C)$ . That  $\psi = 1/\sqrt{2\pi f_{\Delta C}(0)}$  then follows.

<sup>14</sup>Campbell and Deaton (1989) link excess sensitivity and excess smoothness in the rational expectations model.

**Proposition 5** *Aggregate consumption growth over all agents can be written as:*

$$\hat{C}_{t+1} - \hat{C}_t = \text{constant} + \lambda(Y_{t+1} - Y_t) + \hat{\Phi}(0)e_{t+1} + \hat{\Phi}(1)e_t + \dots + \hat{\Phi}(I)e_{t-I+1}, \quad (21)$$

where  $\lambda$  is the share of aggregate income going to inattentive savers and the  $\hat{\Phi}(s)$  and  $e_{t+1-s}$  have the same properties as in Proposition 2.

This result shows that regressing consumption growth on income growth, instrumenting the latter with information lagged at least  $I$  periods will give an estimate of the share of inattentive savers in the economy. This refines the prediction in proposition 1 that consumption growth is unpredictable  $I$  periods ahead: with inattentive savers, consumption will respond to movements in income predictable as of  $I$  periods ahead, but only through the behavior of inattentive savers.

This section has spelled out the implications of inattentiveness for aggregate consumption following a path similar to the literature on consumption with rational expectations. Proposition 1 provided a counterpart to the result that, with rational expectations, consumption follows a martingale. Proposition 2 added the assumption of homoskedastic shocks to obtain the counterpart to Hall's random walk result. Proposition 3 spelled out the implications of inattentiveness for the sensitivity of consumption to news, and proposition 4 its implications for the smoothness of consumption. Finally, proposition 5 provided the counterpart to Campbell and Mankiw's characterization of consumption dynamics. All of these predictions can be tested using aggregate data.

Yet the available measurements of consumption do not give consumption at an instant in time, but rather as the sum over a time period. In other words, while the Propositions assert implications for  $C_{t+1}$ , the available observations are of  $\bar{C}_{t+1} = \int_0^1 C_{t+1-s} ds$ . Nevertheless, it can be shown that this only affects equation (17) insofar as it turns the  $MA(I)$  process into an  $MA(I+1)$  with a new set of coefficients which are still non-increasing. All the propositions are likewise affected solely by replacing  $I$  by  $I+1$ .

## 4 Functional form assumptions and further predictions

The problem of optimal consumption over time with stochastic labor income even with full information only has a closed-form solution for particular forms of the utility function. In this Section, I derive further implications of the model making assumptions on the utility function, the income process and the costs of planning, that lead to a closed-form solution while being roughly consistent with the data.

I assume that the utility function is of the constant absolute risk aversion (CARA) form:

$$u(c) = -e^{-\alpha c}/\alpha,$$

where  $\alpha > 0$  is the coefficient of absolute risk aversion. It is well-known that this is one of the few utility functions for which the full information problem has an analytical solution. Also for

tractability, I assume that the costs of planning are fixed at a constant  $K$ .<sup>15</sup>

Following Friedman (1957), I assume that income is the sum of two independent components. The first component is permanent income, denoted by  $y_t^P$ , which is assumed to follow a driftless Brownian motion with variance  $\sigma_P^2$  and Wiener increments  $dz_t^P$ . This corresponds for instance to changes in employment status or to changes in experience, training or education. The second component is transitory income,  $y_t^T$ , which is assumed to follow an Ornstein-Uhlenbeck process (a continuous time AR(1)), with mean reversion speed  $\phi$  and independent Wiener impulses  $\sigma_T dz_t^T$ . Shocks to transitory income affect income only temporarily, and the larger is  $\phi$  the more short-lived their effects are. For instance, these could stand for overtime payment, illness, or winning a prize.

If permanent income is observed at discrete points in time, it generates observations matching a discrete-time random-walk, while transitory income observed in discrete time is an AR(1). Income changes therefore follow an ARMA(1,1) process. MaCurdy's (1982) seminal study of annual earnings in the United States finds that this specification describes the data well.<sup>16</sup> If  $\phi$  is large, income changes will be close to the MA(1) process originally proposed by Muth (1960).

#### 4.1 Optimal consumption and inattentiveness

First, I solve the problem of an inattentive consumer. Defining the consumer's wealth,  $w_t$ , as the sum of her assets,  $a_t$ , and the present value of her expected income,  $y_t^P/r + y_t^T/(r + \phi)$ , the law of motion for wealth is:

$$dw_t = (rw_t - c_t)dt + \frac{\sigma_P}{r} dz_t^P + \frac{\sigma_T}{r + \phi} dz_t^T. \quad (22)$$

Whereas generally the agent must keep track of  $a_t$  and  $y_t$  separately in order to assess how her constraints will evolve, (22) shows that in this case  $w_t$  is a sufficient statistic. I can then write the value function as  $V(w_t)$ , reducing the dimension of the state space. The agent solves the problem:

$$V(w) = \max_{c,d} \int_0^d e^{-\rho t} \left( -\frac{e^{-\alpha c_t}}{\alpha} \right) dt + e^{-\rho d} E [V(w')], \quad (23)$$

$$\text{subject to } w' = e^{rd} \left[ w - \int_0^d e^{-rt} c_t dt + \int_0^d e^{-rt} \left( \frac{\sigma_P}{r} dz_t^P + \frac{\sigma_T}{r + \phi} dz_t^T \right) \right] - K. \quad (24)$$

Denoting the variance of wealth shocks by  $\sigma^2 \equiv \sigma_P^2/r^2 + \sigma_T^2/(r + \phi)^2$ , the Appendix proves:

**Proposition 6** *In the CARA-utility, ARMA-income, inattentive consumer problem, the optimal*

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<sup>15</sup> As is well-known, a caveat of the CARA model is that it lacks absolute wealth effects. These would lead, given a fixed  $K$ , to richer people planning more often. If the cost of planning is interpreted as a cost of time though, it is reasonable to expect that planning involves a higher opportunity cost for the wealthy, in which case they may plan more or less, depending on the precise assumptions made about  $K$ .

<sup>16</sup> MaCurdy (1982) finds that an MA(2) fits the data equally well, and his findings have been confirmed by Abowd and Card (1989), Pischke (1995), and Meghir and Pistaferri (2004).

inattentiveness intervals are given by:

$$d^* = \frac{1}{r} \ln \left( 1 + \sqrt{\frac{4K}{\alpha\sigma^2}} \right). \quad (25)$$

Optimal consumption between adjustments, for  $D(i) < t < D(i+1)$ , is:

$$c_t^* = rw_{D(i)} + \frac{(r-\rho)(t-D(i))}{\alpha} - \frac{(r-\rho)}{\alpha r} - \frac{rK}{e^{rd^*}-1} - \frac{\alpha r\sigma^2}{4}(e^{rd^*}+1) \quad (26)$$

$$= rw_{D(i)} + \frac{(r-\rho)(t-D(i))}{\alpha} - \frac{(r-\rho)}{\alpha r} - \frac{r\alpha\sigma^2}{2} - r\sqrt{\alpha\sigma^2 K}, \quad (27)$$

If  $c_t^A$  denotes the consumption decisions of an agent that has  $K=0$  and so is always attentive, then the consumption of an inattentive agent at a planning date equals:

$$c_{D(i)}^* = c_{D(i)}^A - \frac{rK}{e^{rd^*}-1} - \frac{\alpha r\sigma^2}{4}(e^{rd^*}-1). \quad (28)$$

**Corollary 1** *At time 0, in the CARA-utility, ARMA-income problem, inattentive agents consume less than attentive ones. The larger are the costs of planning, the longer they are inattentive for, and the more they save.*

The lower consumption is due to two reasons, captured by the two terms in (28). The first reason is that costly planning lowers the agent's wealth, since she must pay an amount  $K$  every  $d^*$  periods, and lower permanent income reduces optimal consumption. The present value of this periodic expense is given by the second term in the right-hand side of (28). The second reason for lower consumption is that the inattentive agent is more vulnerable to risk, since she only periodically adjusts her behavior to take account of the income shocks that are arriving every instant. Savings after expenditure on consumption and planning is therefore higher for precautionary reasons captured in the third term in (28), which increases in the length of inattention. Larger costs of planning lead to longer periods of inattentiveness thus strengthening the precautionary motive and raising savings.<sup>17</sup>

Inspecting the optimal inattentiveness in (25) establishes:

**Corollary 2** *In the CARA-utility, ARMA-income case, inattentiveness by a consumer ( $d^*$ ):*

1. Falls with the volatility of the income shocks ( $\sigma^2$ );
2. Falls with the coefficient of absolute risk aversion ( $\alpha$ );
3. Falls with the real interest rate ( $r$ );

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<sup>17</sup>The inattentiveness model suggests a curious explanation for the decline in the U.S. personal savings rate in the last two decades. If advances in information technology have lowered the costs of obtaining and processing information, then agents should optimally respond by saving less.

4. *Increases with the costs of planning ( $K$ );*
5. *Is first-order long with only second-order costs of planning.*

In a world that is quickly changing in which income is volatile, it is very costly to not pay attention to news so people avoid being inattentive for long. Similarly, if people are very averse to risk, they will want to lower the risk they face by updating information more often and responding to shocks faster. This does not imply that higher volatility is beneficial by inducing greater attentiveness. Quite on the contrary, a higher  $\sigma^2$  unambiguously lowers welfare, since it increases uncertainty which the risk-averse agent dislikes, and moreover it forces her to spend more resources updating plans more frequently. If policy can stabilize the economy, it will raise welfare by allowing people to be inattentive and direct their resources towards productive uses, rather than towards planning consumption.

Between planning dates the inattentive consumer (dis)saves all the unexpected changes in income, whereas the full-information consumer (dis)saves only a fraction of the new income. The larger is the interest rate, the larger is the repercussion that this inefficient (dis)saving will have on her future wealth. Facing a high interest rate, the agent will want to adjust more often to avoid past mistakes and to keep her assets under control.

The final interesting property of inattentiveness is that even very small costs of planning can lead to considerable inattentiveness.<sup>18</sup> The intuition for this result is similar to that in Mankiw (1985), Akerlof and Yellen (1985) and Cochrane (1989). Inattentiveness leads to consumption differing from its full information optimum. However, since the choices of the inattentive consumer are close to this optimum, this deviation only has a second-order effect on utility. Therefore, even a second-order cost of planning will induce the agent to tolerate the second-order costs of being inattentive for a first-order period of time.<sup>19</sup>

Table 1 illustrates how large  $d^*$  can be using different parameter estimates. In the first column, are the estimates by Pischke (1995), who measures  $y_t^P$  as aggregate income and  $y_t^T$  as idiosyncratic income. His estimates of aggregate income variability, and of the serial correlation and standard deviation of income changes imply that  $\sigma_P = \$45$ ,  $\phi = 0.487$ , and  $\sigma_T = \$1,962$ . I set the quarterly interest rate at 1.5%, approximately its historical value in the United States, and  $\alpha = 2/6926$ , where \$6,926 is mean income in the Pischke sample, so the coefficient of relative risk aversion is about 2. Equation (25) implies that if the costs of updating plans are just \$30, the agent stays inattentive for over 2 years. Very small costs of planing can lead to considerable inattentiveness.

Column 2 repeats the calculation with  $r = 0.5\%$ , which may be more appropriate since this is a riskless rate, while columns 3-5 follow Bound et al. (1994) by lowering the variance of income by 1/3, while changing  $\sigma_P$  by factors of 0.5, 1.5, and 2. Across these different parameter specifications,

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<sup>18</sup>Further deviations from rationality may magnify this inertia. For instance, if agents have hyperbolic discount functions, costly planning can lead to procrastination (Akerlof, 1991).

<sup>19</sup>Note that the formula in equation (25) is scale-invariant, since  $K$  is in income units,  $\sigma^2$  is in squared units of income, and  $\alpha$  equals scale-free relative risk aversion divided by consumption.

costs of planing between \$10 and \$50 still lead to 2 years of inattentiveness. Column 6 uses instead the estimates in Gourinchas and Parker (2002). In this case, a \$30 cost of planning leads to slightly lower inattentiveness at 2.5 quarters, and it takes now a cost of about \$80 to induce one year of inattentiveness. These calculations are solely meant to illustrate how large inattentiveness can be. They suggest that small costs can generate substantial inattentiveness.<sup>20</sup>

## 4.2 Optimal savings and inattentiveness

An inattentive saver sets plans for savings  $s_t$ , subject to the constraint that this choice is conditional on the information at the last planning date. The Appendix solves for the optimal choices of this agent, proving the following:

**Proposition 7** *The CARA-utility, ARMA-income, inattentive saver lives hand-to-mouth following a plan for savings. Her choice of inattentiveness  $\hat{d} = +\infty$  if:*

$$K \geq \frac{\alpha\phi\sigma_T^2}{4(r+2\phi)(r+\phi)^2}.$$

Otherwise,  $\hat{d}$  is finite and is the unique solution of the equation:

$$re^{2\phi\hat{d}} \left( 1 - \frac{4(r+2\phi)(r+\phi)^2K}{\alpha\phi\sigma_T^2} \right) = r + 2\phi(1 - e^{-r\hat{d}}).$$

The intuition for the  $\hat{d} = +\infty$  result comes from realizing that while consumption reacts optimally (one-to-one) to permanent income shocks, it also responds one-to-one to transitory income shocks when the optimal reaction would be to consume only a fraction  $r/(r+\phi)$  of these shocks. As the costs of planning and optimal inattentiveness rise, less remains of a transitory shock by the time the agent responds to it. The incentive to update her plans therefore falls as inattentiveness rises, and a small increase in the costs of planning leads to a large increase in inattentiveness. After a certain level, optimal inattentiveness becomes convex in the costs of planning, and shoots to infinity. A person that chooses  $\hat{d} = +\infty$  is a rational non-planer in the sense that she writes a plan once at time 0 and follows it forever. For the parameter estimates in Pischke (1995), she chooses to do so once the costs of planning exceed \$543.

Rational non-planners not only live hand-to-mouth, but also, as the Appendix shows:

**Corollary 3** *At time 0, in the CARA-utility, ARMA-income problem, rational non-planners save less than the consumption planners.*

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<sup>20</sup>As discussed at the end of Section 3.1, tractability required allowing consumption to be negative. How often does this happen? Using the Pischke (1995) parameters and assuming that  $\rho = r$ ,  $K = \$30$ , and  $c_0$  equals 90% of median income (since the savings rate in the national accounts is about 10%) to infer a value for  $w_0$ , the probability that  $c_d$  is negative is essentially zero: it would take 8 successive quarters of negative wealth shocks equal to more than 10 times their standard deviation for  $c_d$  to be negative.

### 4.3 The choice between consumption and savings plans

The Appendix solves for the inattentive agent's optimal choice of which type of plan:

**Proposition 8** *If  $(\phi - r)/(\phi + r) > \sigma_P^2/\sigma_T^2$ , the CARA-utility, ARMA-income, inattentive agent prefers a consumption plan if her costs of planning are below a threshold  $\hat{K}$ , and a savings plan otherwise. When the agent shifts from a consumption to savings plans, her inattentiveness rises discontinuously, and possibly to infinity.*

The condition in Proposition 8 likely holds for plausible parameter values. Most studies of individual income find that transitory shocks are the dominant source of income variation, so the condition is close to assuming that  $\phi > r$ . With an annual interest rate of 6%, this requires that transitory income shocks have a half life of no more than 11.5 years. From the other perspective, if  $\phi = 0.487$  as estimated by Pischke (1995), the annual interest rate must be lower than 601%.

Proposition 8 shows that the model predicts that there are two distinct groups in the population. On the one hand, are those who make financial plans for consumption, updating them sporadically. On the other hand, are those who are inattentive for longer, live hand-to-mouth and save less. This second group may be composed only of people who rationally choose to never plan:

**Corollary 4** *As long as:*

$$\frac{\phi^3 - r^2(r + 2\phi)}{(r + 2\phi)(r + \phi)^2} > \sigma_P^2/\sigma_T^2,$$

*then agents who choose to be inattentive savers also choose to be rational non-planners.*

For the parameter estimates of  $\sigma_P^2/\sigma_T^2$  and  $\phi$  found by Pischke (1995), the condition in the corollary holds as long as the annual interest rate is below 232%. It is reasonable to expect that all inattentive savers are rational non-planners.

A convenient way to assess how likely it is to find rational non-planners in the economy is to use the following result, proven in the Appendix:

**Proposition 9** *If the conditions in Proposition 8 and Corollary 4 apply, then consumption plans are strictly preferred to rational non-planning if:*

$$\frac{\sigma_P^2}{\sigma_T^2}(e^{rd^*} - 1) + \left(\frac{r}{r + \phi}\right)^2 e^{rd^*} - \frac{r}{r + 2\phi} < 0. \quad (29)$$

While this condition involves an endogenous variable ( $d^*$ ), it only requires knowledge of  $\sigma_P^2/\sigma_T^2$  and  $\phi$  from the earnings data, and no information on the degree of risk aversion. Using the benchmark estimates in Pischke (1995) for  $\sigma_P^2/\sigma_T^2$  and  $\phi$ , then if the agent would choose to be inattentive for 8 quarters under a consumption plan, she prefers this plan to being a rational non-planner as long as the quarterly real interest rate is below 12.5%. From a different perspective, if the quarterly

interest rate is 1.5%, then only if the consumption-planning agent stays inattentive for more than 41 years would she prefer to become a rational non-planner. Some agents may face such high costs of planning and interest rates that they live hand-to-mouth, but these calculations suggest that the majority of the population follows consumption plans.

## 5 Evidence of inattentiveness

### 5.1 Slow adjustment to shocks, excess sensitivity, and excess smoothness in the aggregate data

The previous two sections stated a series of predictions of the inattentiveness model for the behavior of aggregate consumption. I test these using U.S. quarterly time series from 1953:1 to 2002:4 for aggregate consumption ( $C_t$ ) measured as real consumption of non-durables and services per capita, and aggregate income ( $Y_t$ ) measured as real disposable personal income per capita. I will also use data on real asset returns ( $r_t$ ) using the value-weighted S&P500. All series are deflated using the price deflator for consumption of non-durables and services. I measure consumption in logs, since the series is closer to log-linear than linear. (The predictions in Section 3 could be re-stated in terms of log consumption by log-linearizing rather than linearizing the Euler equations.)<sup>21</sup>

Proposition 3 stated that the impulse response of consumption to shocks should be increasing and concave. A simple analysis of the adjustment of aggregate consumption to shocks comes from estimating a structural vector autoregression (VAR) on consumption and income growth. I set the lag length on the VAR at 5, as suggested by the use of the Schwartz's Bayesian information criterion and by examining the significance of the last lag included in the VAR. Following Blanchard and Quah (1989), I identify the impulse response to permanent shocks to consumption.

Figure 1 displays the impulse response of log consumption to a permanent shock together with a 90% point-wise confidence interval generated by a bootstrap. Aggregate consumption adjusts with a delay to the shock, as the inattentiveness model predicts would be the case due to slow dissemination of information. Moreover, while consumption is sluggish, it is only moderately so: most of the adjustment is completed within one year of the shock. This is consistent with an inattentiveness model in which agents update their information approximately once a year. The concave shape predicted by the model is also visible in Figure 1.

A sharper test of the slow adjustment of consumption to news comes from examining its response to news on a particularly important variable: income. Given a statistical model for income, surprises ( $y_t$ ) can be constructed as one-step ahead forecast errors. By construction, these have mean zero and are uncorrelated, so they satisfy the properties that define the innovations  $e_t$  in Proposition 2. Regressing consumption growth on several lags of  $y_t$  leads to a test of the model's predictions in

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<sup>21</sup>I tried using different consumption series, which exclude services and some components of non-durables that are arguably durable, and using other measures of returns, on different assets and using alternative adjustments for taxes. The results were robust.

equation (17).

The first possible model for income growth I consider is an AR(5). The results from regressing consumption growth on income news are in Panel A of Table 2. Panel B adds 5 lags of the log consumption income ratio to predict income. As did Campbell (1987), I find that these new regressors have significant predictive power for income growth: the p-value of an F-test on their significance is below 0.1% and the adjusted  $R^2$  of the first stage regression rises by a factor of 3. Panel C further adds 5 lags of the real interest rate as predictors of future income growth, though these variables help very little in forecasting income growth.

The estimates are very similar across the three panels. As predicted by the inattentiveness model, lagged income surprises affect future consumption growth, with coefficients that are approximately unchanged across the different panels. The F-statistic reported in the Table tests the null hypothesis of the Hall (1978) model that lagged income surprises do not affect current consumption growth. This hypothesis is always strongly rejected at significance levels above 0.1%. Moreover, income surprises explain much of the variability of consumption growth; the adjusted  $R^2$  of the regression is between 0.23 and 0.33. Estimating a regression by least squares subject to the model's restriction that the coefficients on income surprises  $s$  periods ago are declining in  $s$  produces the restricted estimates presented in the Table. These restricted estimates are quite close to the unrestricted estimates supporting the validity of the model's restrictions. The null hypothesis of the model can be formally tested using Wolak's (1989) Wald test. In Table 2,  $W_{IN}$  displays the value of the test statistic and the p-value of the test of the inattentiveness null. The model cannot be rejected at statistical significance level below 37%.<sup>22</sup>

Figure 2 displays graphically these results. Since the estimates are so similar across panels, I display only the results in Panel B. The top panel of the Figure plots  $\hat{\Phi}(j)/\sum_{i=0}^{I+1}\hat{\Phi}(i)$  for  $j$  from 0 to  $I+1$ , together with 95% confidence intervals. The inattentiveness model predicts a declining sequence of non-negative points, and this is consistent with the plot. In the bottom panel, I plot instead the cumulative dissemination of the news. It shows the increasing and concave shape that the model predicts, similar to that estimated earlier in Figure 1.

Proposition 4 makes sharp predictions on the shape of the power spectrum of aggregate consumption changes. Figure 3 plots estimates of the spectrum, constructed using a sample spectral density weighted over a 5-lag Bartlett window. Figure 3 also displays the spectrum for aggregate consumption growth predicted by the inattentiveness model using the weights  $\hat{\Phi}(i)$  estimated in panel B of Table 2. The predicted spectrum matches the empirical spectrum well, despite somewhat more pronounced swings, and the fit is especially good using the theory-restricted estimates.

Table 3 displays different estimates of the excess smoothness ratio  $\psi$ . They lie between 0.52 and 0.7, and the full information rational expectations null hypothesis that they equal one is always

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<sup>22</sup>Mishkin (1983) noted that the two-step econometric procedure that I used will not produce efficient estimates. I have estimated the system of two equations simultaneously using the iterative procedure suggested by Mishkin (1983). The results were very similar to those in Table 2, so the inferences are robust to this econometric issue.

rejected. The inattentiveness model using the weights estimated in Table 2 predicts an excess smoothness ratio between 0.47 and 0.66, well within what we observe in the data (or slightly below). The inattentiveness model is therefore able to simultaneously generate the extent of excess sensitivity and excess smoothness that we observe in the data.

## 5.2 The share of inattentive savers and inattentiveness versus Campbell-Mankiw

Proposition 5 stated that regressing consumption growth on income growth, instrumenting with variables lagged  $I + 1$  periods will give an estimate of the share of income attributed to inattentive savers. Table 4 presents these estimates, computed using as instruments for the change in income variables dated at least 9 quarters before. The estimates in Section 5.1 suggested that within one year most agents have updated their plans, so letting  $I$  be 2 years is a conservative choice. Since the model predicts that the residuals of this regression should be serially correlated, I compute the Hayashi and Sims (1984) nearly-efficient estimates, rather than the conventional (but inefficient) two-stage least squares estimates.

The estimated coefficients on income growth,  $\lambda$ , are quite low, between 0.05 and 0.15, and the null hypothesis that  $\lambda = 0$  can never be rejected at conventional significance levels. This confirms the prediction in Section 4.3 that the share of aggregate consumption attributable to hand-to-mouth behavior should be small, with the bulk of aggregate consumption dynamics accounted for by inattentive consumers.

The instruments used in these regressions are weak though, as reflected by the low F-statistics: income growth is difficult to forecast 9 quarters in advance. With weak instruments, the IV estimates are biased towards the OLS estimates, so I report these in Panel B. Since the OLS estimates are higher than the IV estimates, the estimates of  $\lambda$  in Panel A are, if anything, too large. An alternative estimator is the limited information maximum likelihood (LIML) estimator, and the third column shows that these estimates are slightly lower than those in Panel A. Columns 4 to 6 of Panel B present three different tests proposed in the literature on weak instruments to powerfully test the hypothesis that  $\lambda = 0$ : none of them rejects this hypothesis. While these tests likely suffer from lack of power, note that both the IV and the LIML estimates are consistent (and the tests of the over-identifying restrictions implied by instrument validity are never rejected), and they consistently estimate  $\lambda$  to be small.

Equation (21) also describes aggregate consumption dynamics in the model proposed by Campbell and Mankiw (1989, 1990), in which a fraction  $1 - \lambda$  of consumption is accounted for by rational expectations agents, while the remaining  $\lambda$  fraction is accounted for by irrational, myopic, hand-to-mouth people. The difference is that in their model,  $\Phi(i) = 0$  for  $i \geq 1$ . Using variables lagged two quarters as instruments for income growth, Campbell and Mankiw (1989, 1990) found that hand-to-mouth agents account for 40 – 50% of aggregate consumption. According to their model though, it is equally valid to use instruments lagged nine quarters. However, Table 4 shows that doing so produces estimates of  $\lambda$  that are insignificant and much lower, between 5% and 15%,

supporting instead the inattentiveness model.

It would be desirable to test the Campbell-Mankiw model against the inattentiveness model, having both stated as null hypotheses in order to ensure that lack of power does not bias the results in favour of the model that is stated as a null hypothesis. Note that  $Y_{t+1} - Y_t$  can be written instead as  $(E_t - E_{t-1})(Y_{t+1} - Y_t) + (E_{t-1} - E_{t-2})(Y_{t+1} - Y_t) + \dots + E_{t-T}(Y_{t+1} - Y_t) + (Y_{t+1} - E_t Y_{t+1})$ . Equation (21) can therefore instead be written in the form:

$$C_{t+1} - C_t = \beta_0 + \sum_{s=1}^T \beta_s (E_{t-s+1} - E_{t-s})(Y_{t+1} - Y_t) + \lambda E_{t-T}(Y_{t+1} - Y_t) + u_{t+1}, \quad (30)$$

In terms of this regression equation, the null hypothesis describing the Campbell-Mankiw model is<sup>23</sup>

$$H_0^{CM} : \beta_2 = \dots = \beta_T = \lambda.$$

Since  $(E_{t-s+1} - E_{t-s})(Y_{t+1} - Y_t)$  has a zero expectation as of  $t - s$ , it fits into the definition of the news  $e_{t-s+1}$ , so the prediction of the inattentiveness model is that

$$H_0^{ING} : \beta_1 \geq \beta_2 \geq \dots \geq \beta_T \geq 0,$$

as long as  $T \geq I + 1$ , and the estimate of  $\lambda$  gives the share of inattentive savers. If there are only inattentive consumers this leads to the stronger null hypothesis:

$$H_0^{ING} : \beta_1 \geq \beta_2 \geq \dots \geq \beta_T \geq 0, \lambda = 0.$$

Finally, the Hall (1978) model predicts that

$$H_0^{RE} : \beta_2 = \dots = \beta_T = \lambda = 0,$$

so that no lagged variables predict future consumption growth. Intuitively, the difference between the Campbell-Mankiw and the inattentiveness models is that in the former, consumption depends on lagged income news solely through hand-to-mouth consumption, so how far away in the past the news was revealed does not affect its impact. With inattentiveness instead the longer the news has been known for, the more likely it is that agents have since updated their plans and so the smaller their current impact.

I generated the regressors in (30) using the forecasts of income growth from a VAR with 5 lags on the change in log income, the log consumption-income ratio, and the real interest rate. Table 5 presents the point estimates of equation (30). They are somewhat discouraging for all four models since they do not seem to have the pattern described in either  $H_0^{CM}$  or  $H_0^{ING}$ , and several of them

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<sup>23</sup>There is no restriction on  $\beta_1$  because of time aggregation, and I do not impose the restriction  $\lambda \geq 0$ , which may bias the results in favor of the Campbell-Mankiw model.

are individually large and statistically significant contrary to  $H_0^{RE}$ . Panel B of Table 5 formally tests the models using Wald tests for  $H_0^{CM}$ ,  $H_0^{RE}$ ,  $H_0^{IN}$ , and  $H_0^{ING}$ . Consistent with the other results in this paper, the full information rational expectations model is decisively rejected even at a 0.01% significance level. The Campbell-Mankiw model is also rejected at the 5% significance level (but not at the 1% level), which is not surprising given the low estimate of  $\lambda$ . The null hypothesis of the general inattentiveness model on the other hand has a p-value of 12.8%, so it is not statistically rejected at conventional significance levels. Moreover, note that it is estimated that only 3.4% of consumption is done by inattentive savers, so hand-to-mouth behavior is economically and statistically insignificant. Consequently, the model with inattentive consumers alone is not statistically rejected at the 5% significance level.

These results suggest that the hand-to-mouth behavior detected in aggregate consumption data may be attributable to inattentiveness rather than to the model proposed by Campbell and Mankiw (1990). Moreover, as predicted by the theory, rational non-planning seems to have a small impact on aggregate consumption.

### 5.3 Inattentiveness versus habits

A popular alternative theory of consumption has stressed that consumers may develop habits over consumption, in which case they have a preference for sluggish consumption adjustments (e.g., Fuhrer, 2000). In the simplest case (see Deaton, 1992, pp. 31-33) this model implies that consumption growth will be an AR(1) process, with the AR coefficient equal to the preference parameter determining the habit. Since an AR(1) is also an MA( $\infty$ ) with declining coefficients a model with a representative consumer with a habit generates aggregate consumption observations close to the MA( $I + 1$ ) with declining coefficients predicted by the inattentiveness model. One can see the inattentiveness model as providing a “micro-foundation” for a representative consumer with a habit.<sup>24</sup>

Using other information aside from the stochastic process describing consumption, the models can be distinguished in several ways. For instance, since in the habit model sluggishness of consumption is a result of preferences, then this sluggishness should be constant across different periods in time. In the inattentiveness model on the other hand, slow adjustment is a result of inattentiveness, and this is optimally chosen by agents in response to, among other things, the volatility of income. If the volatility of disposable income fell, the model predicts that agents would respond by staying inattentive for longer, so that consumption should adjust more sluggishly to shocks. Kim and Nelson (1999) and McConnell and Perez-Quiros (2000) identify a large fall in the volatility of U.S. GDP after around 1984. Figure 4 repeats the calculations behind Figures 1 and

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<sup>24</sup>With more flexible specifications of habits, the match between the two models may be even closer. Chetty and Szeidl (2005) show that, under some circumstances, a model with time-contingent consumption adjustment exactly mimics the aggregate consumption dynamics that would be chosen by a representative agent with a specific habit formation process.

2, but now splitting the sample between before 1982 and after 1985. The model predicts that the latter period should show a more sluggish response to shocks, and this is what we observe.

Likewise, the representative consumer habit model predicts that consumption should respond sluggishly to any event. The inattentiveness model on the other hand predicts that consumption moves sluggishly with respect to events towards which people are inattentive. People become aware of extraordinary events though (as discussed at the end of section 3.1), and react to them instantly. One notable such event is the end of hyper- and high-inflations, which usually occurs suddenly with the implementation of drastic and well-publicized stabilization programs. Fischer et al. (2002) examine 45 such episodes in 25 countries since 1960. They find that these noticeable disinflation programs have a large effect on real variables, and especially that aggregate consumption responds immediately, consistently with the inattentiveness model but not with the habit model.

Another approach to distinguishing inattentiveness from habits is to look at individual data. Inattentiveness implies that individual consumption adjusts infrequently, so that all the sluggishness in aggregate consumption comes from aggregation, whereas habit formation predicts that individual consumption is serially correlated. Dynan (2002) uses data from the PSID to find that individual consumption growth is close to serially uncorrelated. Therefore, when she estimates the optimality conditions imposed by the habit model she finds no evidence for habits. Her findings are consistent with inattentiveness.

#### **5.4 Inattentiveness versus state-contingent adjustment and the micro evidence on inattention, slow dissemination of information, and planning**

Caballero (1995) proposes a model of non-durables consumption in which it is costless to obtain, acquire, and process information, but it is costly to implement the optimal consumption plan. Consumers are always attentive, but only decide to adjust consumption at sporadic dates contingent on the current state of the economy. Consumption adjustment is now state-contingent.

Since both models imply a disconnect between available information and observed actions, given data on these two alone, it will generally be difficult to distinguish the two models. One way to contrast the models is over the empirical realism of their assumptions. I have argued that it is costly to collect and process information and to compute an optimal solution. With state contingent adjustment though, every instant the agent *is* observing the full state of the economy, *is* processing this information to realize what is her wealth, and *is* performing costly computations to determine whether it should adjust consumption. State-contingent behavior is as complicated as following the full information rational expectations optimal plan, so it cannot be justified as describing “near-rational” behavior. Rather, behind this model there must be some actual physical cost of adjusting consumption. It is difficult to find evidence for this cost in the consumption of non-durables.

There is an alternative way to compare state-contingent adjustment with inattentiveness though. It consists of looking at an intermediate step in the disconnect between publicly available infor-

mation and observed actions: the information that agents have. According to the inattentiveness model, agent's private information, expectations and future plans are only sporadically updated, whereas in the state-contingent model private and public information coincide at all instants.

There is much evidence that people are inattentive, but one is particularly relevant to the model in this paper. In 1992, President George H. Bush announced a reduction in the standard rates of withholding for income taxes, which lowered employees' tax withholding by about \$29 per month. Using a survey of 501 people, 1-2 months after the announcement, Shapiro and Slemrod (1995) find that about half of the respondents were not aware of any change in withholding, and as many as 2/3 did not know whether withholding rates had increased or fallen.

The inattentiveness model further predicts that news disseminates slowly throughout the population. Carroll (2003) and Mankiw, Reis, and Wolfers (2003) use survey data on inflation expectations to test this prediction. Carroll (2003) finds that the expectations of the public lag those of professional forecasters and that when newspapers mention inflation more often, the public updates its expectations faster, consistent with an optimal choice of inattentiveness. Mankiw, Reis, and Wolfers (2003) find that a model with exogenous staggered updating of information matches the time-series of disagreement about expected inflation in the data well, and can explain the particularly large increase in disagreement that occurred in the early 1980s during the Volcker disinflation.

A separate piece of evidence supporting the inattentiveness model comes from recent empirical work on planning behavior. The inattentiveness model predicts that a fraction of the population choose to never make plans and save less than those who do. Lusardi (1999, 2002) finds that in the sample of people over 50 years old in the Health and Retirement Study (HRS), approximately one third have hardly thought about retirement. She finds that those who have not planned are more likely to be less educated, self-report lower cognitive abilities, be single, and do not have older siblings to use as a source of information. Using these proxies of the costs of planning as instruments, she finds that planning strongly predicts accumulated wealth. Ameriks, Caplin and Leahy (2003a) perform a similar exercise in a sample of TIAA-CREF members, asking people whether they write financial plans, and using as measures of the costs of planning whether they are confident with their mathematical skills, and whether they usually plan their vacations. They find that approximately 25% of households report not having a financial plan, and that those who do not plan have significantly lower savings and accumulated wealth.

In addition, in their survey, Ameriks, Caplin, and Leahy (2003a) also asked those with plans, for how long they have had their plan in place. The inattentiveness model predicts that planners who update less frequently will save more. Ameriks, Caplin, and Leahy (2003a) support this prediction as they find that people who have had plans in place for longer accumulate significantly more wealth. In related work, Alessie, Kapteyn, and Lusardi (1999) use the Dutch CentER data-panel, and find that the longer is people's reported planning horizon, the larger are their savings, though the effect is not statistically significant.

Finally, Hurst (2003) uses data from the Panel Study of Income Dynamics (PSID) to find that

people that reach retirement with low wealth, also have a larger drop in consumption at retirement (consistent with inadequate planning for retirement), and earlier in life had consumption growth responding to predictable changes in income. Moreover, he finds that this behavior cannot be accounted for by liquidity constraints, precautionary savings, or habit formation, but can be explained by hand-to-mouth behavior. The identification of a group in the population that simultaneously does not plan, saves less, and lives hand-to-mouth, supports the model in this paper.

This evidence that, when asked, people report being unaware of important current economic events; that individual expectations are consistent with slow dissemination of information; that reported planning behavior is a determinant of accumulated wealth; and that there is a group in the population that does not plan, saves little, and lives hand-to-mouth, all support the inattentiveness model, but would not be predicted by a state-contingent adjustment model.

## **5.5 Inattentiveness and excess sensitivity at the micro level**

There have been many tests of excess sensitivity using individual consumption data but the results so far are inconclusive: some studies find it, while others do not, and it is unclear what explains the different results. The inattentiveness model suggests an explanation. The model predicts that people are inattentive to ordinary unpredictable events and thus react with a delay to these shocks, only at their next planning date. If the event is easily predictable though, the agents will have reacted to it when they set their plans in the past. Likewise, if the event is extraordinary in the sense of capturing people's attention, the model also predicts an instantaneous reaction.

Two key papers that have found evidence that small past news on after-tax income affects consumption some time after are Parker (1999) and Souleles (1999). Parker (1999) looks at the patterns of Social Security tax withholding, while Souleles (1999) looks at income tax refunds. In both cases, the news were to ordinary components of income and were not especially noticeable and they were also unpredictable. Parker and Souleles findings that consumption is sensitive to these past news supports the inattentiveness model.

In turn, Browning and Collado (2001) and Souleles (2000) look at the response of consumption to large and easily predictable changes in income, and find that consumption does not react to these past news. Browning and Collado (2001) examine the reaction of Spanish households to well-known income fluctuations driven by the timing of bonus payments, while Souleles (2000) examines the impact of the easily predicted college tuition payments on parent's consumption. Hsieh (2003) studies the reaction of Alaskans to the extraordinary payments made to them by the Alaska's Permanent Fund associated with oil royalties. These payments were very large (on average \$1,964 in 2000), infrequent, and amply discussed in the media. Hsieh (2003) finds that consumption does not respond to this past extraordinary news, supporting the inattentiveness model.

The inattentiveness model can therefore reconcile the apparently contradictory findings in the literature that has tested for excess sensitivity to past events.

## 5.6 Possible new tests of inattentiveness

The inattentiveness model makes a series of sharp predictions on the behavior of individual consumption. The discussion so far shows that these predictions are consistent with a wide set of known facts about individual behavior.

The model also generates many novel predictions that can be tested using micro data. For instance, the model predicts that the longer it takes from the announcement of an income shock to its realization, then the smaller should be a cross-sectional estimate of the response of consumption to the shock when it is realized. An alternative test of the model would be to use information that at some point in time (e.g., at tax-filing dates) some agents are more likely to be paying attention to their income than others (e.g., those that fill their tax forms on their own vs. those that use a tax-preparer), and see whether those that are inattentive are more likely to respond to the available information with a delay (e.g., change consumption when the income tax refund check arrives). Yet a third alternative could examine whether shocks that are common to all individuals raise the dispersion of consumption over households, as some react to it and others do not. These, and other tests, are beyond the scope of this already long paper, but hopefully can be undertaken in future work.

## 6 Conclusion

In his Nobel lecture, James Tobin (1982, page 189) wrote:

*“Some decisions by economic agents are reconsidered daily or hourly, while others are reviewed at intervals of a year or longer except when extraordinary events compel revisions. It would be desirable in principle to allow for differences among variables in frequencies of change and even to make these frequencies endogenous. But at present, models of such realism seem beyond the power of our analytical tools.”*

In this paper, I developed some of the tools that Tobin called for and examined the implications of modelling behavior in this way for the dynamics of aggregate consumption. I assumed (and justified) the existence of decision costs inducing agents to only sporadically update their decisions and characterized the decisions of these agents on how much to consume and how often to plan. This individual behavior implies that information should be sticky in the aggregate economy, only gradually dissipating throughout the population, so that aggregate consumption adjusts slowly to the arrival of news. I found that this prediction is confirmed in U.S. data and that the model also generates dynamics for aggregate consumption which have the “excess sensitivity” and “excess smoothness” with respect to income that had been previously identified in the data. For individual consumption, the model predicted that consumption changes should be sensitive to small and unpredictable past shocks, but should not be sensitive to past large or predictable changes. This dichotomy reconciles the disparate findings of the many microeconomic studies which have studied

the excess sensitivity of consumption to shocks. The model further predicted that information and expectations are only sporadically updated, which has also been shown to be the case using inflation expectations surveys. Finally, the model predicted that a group of people do not plan and save less than those who plan, and that among planners, those who plan for longer, save more. Again, this has been confirmed in the data.

Beyond passing tests in the data, the set of theoretical results and empirical estimates in this paper offer a plausible description of consumption behavior. There are two types of agents in the United States. About one third of people face high costs of planning (e.g., because of lack of education) and so rationally choose to never plan, living hand-to-mouth and consuming their income less a predetermined amount every period. These people save less and accumulate less wealth. Because they are poorer, they account for only a small fraction of aggregate consumption, around 5%. The bulk of aggregate consumption is accounted for instead by the other two thirds of people who form plans for consumption regularly. Because they only sporadically update their plans, these people react to small unexpected income shocks only gradually over time. Aggregate consumption therefore reacts sluggishly to shocks, but not too sluggishly since people do update their plans within a year or so.

Because the model in this paper is a model of how dynamic decisions are made and expectations are formed, in principle it is widely applicable to different economic problems. Decisions on how much to invest in stocks or bonds, how often to change prices or revise contracts are some to which the inattentiveness approach can be applied. While it is difficult to know for sure how successful these applications will be, there is enough promise to justify paying some attention to inattention.

## Appendix

### Proof of Proposition 6

The Euler equation in (13) with CARA utility implies:

$$c_t^* = \frac{(r - \rho)t}{\alpha} + c_0^*. \quad (31)$$

Using this to substitute out  $c_t$  in the budget constraint (24), a little algebra shows that wealth at the next planning period is:

$$w' = e^{rd^*} \left[ w - \frac{(r - \rho)(1 - e^{-rd^*} - rd^*e^{-rd^*})}{\alpha r^2} + \int_0^{d^*} e^{-rt} \left( \frac{\sigma_P}{r} dz_t^P + \frac{\sigma_T}{r + \phi} dz_t^T \right) \right] - K - \frac{e^{rd^*} - 1}{r} c_0^*$$

Since  $w'$  is a linear combination of normally distributed variables, it is normally distributed with:

$$E[w'] = e^{rd^*} \left[ w - \frac{(r - \rho)(1 - e^{-rd^*} - rd^*e^{-rd^*})}{\alpha r^2} \right] - K - \frac{e^{rd^*} - 1}{r} c_0^*, \quad (32)$$

$$Var[w'] = \frac{\sigma^2}{2r} (e^{2rd^*} - 1), \quad (33)$$

Next, I make the (educated) guess that the value function is exponential:  $V(w) = -A \exp(-Bw)$ , where  $A$  and  $B$  are coefficients to be determined. The envelope theorem condition implies that:

$$-Bw = (r - \rho)d^* + \ln \left( E \left[ e^{-Bw'} \right] \right). \quad (34)$$

Since  $w'$  is normally distributed, from the properties of the log-normal distribution,  $\ln [E[\exp(-Bw')]]$  equals  $-BE[w'] + B^2 Var[w']/2$ . Using this result and (32)-(33) in (34), gives the solution for  $c_0^*$ :

$$c_0^* = rw - \frac{rK}{e^{rd^*} - 1} - \frac{B\sigma^2}{4} (e^{rd^*} + 1) - \frac{(r - \rho)}{e^{rd^*} - 1} \left[ \frac{rd^*}{B} + \frac{e^{rd^*} - 1 - rd^*}{\alpha r^2} \right]. \quad (35)$$

The marginal utility of consumption equals the marginal value of assets:

$$e^{-\alpha c_0^*} = AB e^{-Bw}. \quad (36)$$

If the guess of the value function is valid, (36) must hold for all possible realizations of  $w$ . Matching coefficients shows that  $B = \alpha r$ . Going back to (35) with this result gives:

$$c_0^* = rw - \frac{rK}{e^{rd^*} - 1} - \frac{\alpha r \sigma^2}{4} (e^{rd^*} + 1) - \frac{r - \rho}{\alpha r}. \quad (37)$$

The last optimality condition is the first-order condition with respect to  $d$ , which is just:

$\partial V(w)/\partial d = 0$ . Given the guess for the value function,

$$V(w) = \max_d \left\{ -\frac{e^{-\alpha c_0^*}}{\alpha r} \right\},$$

the first-order condition is just  $\partial c_0^*/\partial d = 0$ , which I can evaluate using (37) to obtain:

$$(e^{rd^*} - 1)^2 = \frac{4K}{\alpha\sigma^2}. \quad (38)$$

Solving this equation gives (25). Using the solution for  $d^*$  in (37) gives the solution for  $c_0^*$  in (27).  $\square$

### Proof of Proposition 7

The problem facing the agent can be written as:

$$W(w) = \max_{d, \{s_t\}} E \left[ \int_0^d e^{-\rho t} u(y_t - s_t) dt + e^{-\rho d} W(w') \right] \quad (39)$$

$$\text{s.t. } da_t = (ra_t + s_t) dt \quad (40)$$

Integrating (40) between two decision dates, using the fact that  $w' = w_d - K$ , that  $y_t = y_t^P + y_t^T$ , and the definition  $w_t = a_t + y_t^P/r + y_t^T/(r + \phi)$ , leads to:

$$w' = e^{rd} \left( w + \int_0^d e^{-rt} s_t dt \right) - K + \frac{y^{P'} - e^{rd} y^P}{r} + \frac{y^{T'} - e^{rd} y^T}{r + \phi}.$$

Since permanent income follows a Brownian motion,  $y^{P'}$  is normally distributed with mean  $y^P$  and variance  $\sigma_P^2 d$ . Likewise, since  $dy_t^T = -\phi y_t^T dt + \sigma_T dz_t^T$ , then transitory income is normally distributed with mean  $y^T \exp(-\phi d)$  and variance  $\sigma_T^2 (1 - \exp(-2\phi d))/2\phi$ . Therefore,  $w'$  is normally distributed with:

$$E_0 [w'] = e^{rd} \left( w + \int_0^d e^{-rt} s_t dt \right) - K + \frac{1 - e^{rd}}{r} y^P + \frac{e^{-\phi d} - e^{rd}}{r + \phi} y^T, \quad (41)$$

$$\text{Var}_0 [w'] = \frac{\sigma_P^2}{r^2} d + \frac{\sigma_T^2 (1 - e^{-2\phi d})}{2\phi (r + \phi)^2} \quad (42)$$

The first-order conditions determining the optimal choices of  $s_t$  are:

$$E_0 [u'(y_t - s_t)] = e^{(r-\rho)(d-t)} E_0 [W_w(w')], \quad \text{for } t \in [0, d]. \quad (43)$$

Combining this equation for time  $t$  and for time 0:

$$\begin{aligned} u'(y_0 - s_0) &= e^{(r-\rho)t} E_0 [u'(y_t - s_t)] \Leftrightarrow \\ -\alpha y_0 + \alpha s_0 &= (r - \rho)t + \alpha s_t + \ln (E_0 [e^{-\alpha y_t}]). \end{aligned}$$

Using the normality of  $y_t$ , it takes a few steps to obtain:

$$s_t = s_0 - (1 - e^{-\phi t})y_0^T - \frac{\alpha}{2} \left( \sigma_P^2 t + \frac{\sigma_T^2(1 - e^{-2\phi t})}{2\phi} \right) - \frac{(r - \rho)t}{\alpha}. \quad (44)$$

The envelope theorem condition is:

$$W_w(w) = e^{(r-\rho)d} E [W_w(w')]. \quad (45)$$

Again, I guess that the value function is exponential:  $W(w) = -Ae^{-\alpha r w}$ , where  $A$  is a coefficient to be determined. Taking logs of (45), and using the properties of the log-normal distribution together with (41)-(42) gives leads to:

$$\begin{aligned} w(e^{rd} - 1) &= \frac{(r - \rho)d}{\alpha r} - e^{rd} \int_0^d e^{-rt} s_t dt + K + \frac{e^{rd} - 1}{r} y^P + \frac{e^{rd} - e^{-\phi d}}{r + \phi} y^T \\ &\quad + \frac{\alpha \sigma_P^2}{2r} d + \frac{\alpha r \sigma_T^2 (1 - e^{-2\phi d})}{4\phi(r + \phi)^2}. \end{aligned}$$

Using the solution for  $s_t$  in (44) to substitute out savings in this equation gives, after rearranging,:

$$s_0 = -r w + y + \frac{r - \rho}{\alpha r} + \frac{\alpha \sigma_P^2}{2r} + \frac{\alpha \sigma_T^2}{2(r + 2\phi)} + \frac{rK}{e^{rd} - 1} - \frac{\alpha r \phi \sigma_T^2 (1 - e^{-2\phi d})}{4(r + 2\phi)(r + \phi)^2 (e^{rd} - 1)} \quad (46)$$

Combining the envelope theorem (45) with (43) gives the condition:

$$u'(y_0 - s_0) = W_w(w).$$

Using the form of the utility function, the guess for the value function, and the expression for  $s_0$  in (46), this I can solve this equation  $A$  to obtain:

$$A = \frac{1}{\alpha r} \exp \left\{ \frac{r - \rho}{r} + \frac{\alpha^2 \sigma_P^2}{2r} + \frac{\alpha^2 \sigma_T^2}{2(r + 2\phi)} + \frac{\alpha r K}{e^{rd} - 1} - \frac{\alpha^2 r \phi \sigma_T^2 (1 - e^{-2\phi d})}{4(r + 2\phi)(r + \phi)^2 (e^{rd} - 1)} \right\}. \quad (47)$$

Given (47) and the guess for the value function, to maximize  $W(w)$  with respect to  $d$  is equivalent to minimizing  $A$  with respect to  $d$ , which in turn is equivalent to minimizing:

$$\hat{A}(K, d) \equiv \frac{K}{e^{rd} - 1} - \frac{\alpha \phi \sigma_T^2 (1 - e^{-2\phi d})}{4(r + 2\phi)(r + \phi)^2 (e^{rd} - 1)}. \quad (48)$$

The first-order necessary condition for an interior minimum is:

$$\frac{e^{(r-2\phi)d}}{\Xi (e^{rd} - 1)^2} \underbrace{\left[ r e^{2\phi d} (1 - K \Xi) + 2\phi e^{-rd} - 2\phi - r \right]}_{\equiv B(d)} = 0, \quad (49)$$

$$\text{where : } \Xi \equiv \frac{4(r + 2\phi)(r + \phi)^2}{\alpha\phi\sigma_T^2}. \quad (50)$$

If  $K\Xi > 1$ ,  $B(d)$  is always negative, which implies that  $\hat{A}$  falls monotonically with  $d$ , and so the optimal  $\hat{d}$  is  $+\infty$ . Otherwise,  $\hat{d}$  is the zero of  $B(d)$ . Straightforward evaluation and differentiation of  $B(d)$  shows that with strictly positive costs of planning:  $B(0) < 0$ ,  $B_d(0) < 0$ ,  $B_{dd}(\cdot) > 0$ , and  $\lim_{d \rightarrow +\infty} B(d) = +\infty$ . Thus, there is a unique solution to  $B(d) = 0$ , where  $B(d)$  cuts the horizontal axis from below, and therefore there is a unique optimal  $\hat{d}$ .  $\square$

### Proof of Proposition 8

The agent prefers a consumption plan if the value from doing so  $V(w)$  is larger than the value from following a savings plan  $W(w)$ . It is easy to see that  $V(w) = -\exp(-\alpha c_0^*)/\alpha r$ , while  $W(w)$  is in (47). The condition  $V(w) > W(w)$  then becomes:

$$H(K) \equiv \frac{rK}{e^{r\hat{d}} - 1} - \frac{\alpha r \phi \sigma_T^2 (1 - e^{-2\phi\hat{d}})}{4(r + 2\phi)(r + \phi)^2 (e^{r\hat{d}} - 1)} - r\sqrt{\alpha\sigma^2 K} + \frac{\alpha\sigma_T^2 \phi^2}{2(r + 2\phi)(r + \phi)^2} > 0.$$

If  $K = 0$ , then  $\hat{d} = 0$  and using L'Hopital's rule it follows that  $H(0) = 0$ : under full information rational expectations, consumption and savings plans are equivalent. Moreover, when  $K > 1/\Xi$  and so  $\hat{d} = +\infty$ , then the first two terms in the definition of  $H(K)$  are zero, so clearly  $H(K)$  is declining in  $K$  tending towards minus infinity. More generally, using the envelope theorem:

$$H_K(\cdot) = \frac{r}{e^{r\hat{d}} - 1} - r\sqrt{\frac{\alpha\sigma^2}{4K}} = \frac{r}{e^{r\hat{d}} - 1} - \frac{r}{e^{rd^*} - 1},$$

where the second equality follows from (38). Then,  $\text{sign}\{H_K(\cdot)\} = \text{sign}\{d^* - \hat{d}\}$ , so I must compare optimal inattentiveness with consumption and savings plans.

Evaluating the function  $B(d)$  defined in (49), whose zero is the optimal inattentiveness with savings, at the optimal inattentiveness with consumption  $d^*$ , replacing for  $K$ , gives:

$$F(d^*) \equiv r e^{2\phi d^*} \left( 1 - \frac{\Xi \alpha \sigma^2 (e^{rd^*} - 1)^2}{4} \right) + 2\phi e^{-rd^*} - 2\phi - r.$$

Since I know that if  $B(d)$  is negative it is to the left of its zero, and when it is positive it is to the right of its zero, then when  $F(d^*)$  is positive it follows that  $d^* > \hat{d}$ . Conversely when  $F(d^*)$  is negative, then  $d^* < \hat{d}$ , and at  $\hat{d}$ ,  $F(\hat{d}) = 0$ .

Straightforward evaluation and differentiation of  $F(\cdot)$  shows that:  $F(0) = 0$ ,  $F_d(0) = 0$ , and  $F_{dd}(0) = 2r\phi(2\phi + r) - r^3\Xi\alpha\sigma^2/2$ . Using the definition of  $\Xi$  in (50) shows that if the assumption in Proposition 8 holds, then  $F_{dd}(0) > 0$ . Thus, close to 0,  $F(\cdot)$  is positive and so  $d^* > \hat{d}$ .

Next, I will show that aside from the trivial intersection at 0,  $d^* = \hat{d}$  only once. Note that the

derivative of  $F(\cdot)$  at a point of intersection is:

$$\begin{aligned}
F_d(\hat{d}) &= 2\phi r e^{2\phi\hat{d}} \left( 1 - \frac{\Xi\alpha\sigma^2 (e^{r\hat{d}} - 1)^2}{4} \right) - \frac{r^2 e^{(2\phi+r)\hat{d}} \Xi\alpha\sigma^2 (e^{r\hat{d}} - 1)}{2} - 2\phi r e^{-r\hat{d}} \\
&= 2\phi (2\phi + r - 2\phi e^{-r\hat{d}}) - \frac{r^2 e^{(2\phi+r)\hat{d}} \alpha\sigma^2 \Xi (e^{r\hat{d}} - 1)}{2} - 2\phi r e^{-r\hat{d}} \\
&= 2\phi (r + 2\phi) (1 - e^{-r\hat{d}}) \left( 1 - \frac{r^2 \alpha\sigma^2 \Xi e^{2(\phi+r)\hat{d}}}{4\phi(r + 2\phi)} \right),
\end{aligned}$$

where the second line follows from replacing the first term using the condition  $F(\hat{d}) = 0$ , and the third line follows from rearranging. Then, it is clear that if  $\hat{d}$  is small enough,  $F_d(\hat{d})$  is positive, but once  $\hat{d}$  rises above a certain threshold, it becomes negative forever. Now, since for small  $K$ ,  $F(d^*)$  is positive, this continuous function must intersect the horizontal axis first at a point where  $F_d(\hat{d}) < 0$ . Towards a contradiction, say that it intersects the horizontal axis again at some higher  $d$ . By continuity of the  $F(d)$  function, it must cut the axis from below. Yet, we know that at any zero of the  $F(d)$  function the slope must be negative, which leads to a contradiction. Therefore,  $d^* = \hat{d}$  only once at some value of  $K$ , and if the costs of planning exceed this value then  $\hat{d} > d^*$ .

Returning back to the initial aim of studying  $H(\cdot)$  I conclude that starting from 0 when  $K = 0$ , the function increases up to a certain  $K$  (when  $d^* = \hat{d}$ ). Then it declines monotonically towards minus infinity, intersecting the horizontal axis at a unique point  $\hat{K}$ . Therefore, if  $K \in (0, \hat{K})$ , then  $H(K) > 0$ , so consumption plans are preferred. If  $K > \hat{K}$ , savings plans are preferred.

Finally, note that at  $\hat{K}$  where  $H(\hat{K}) = 0$ , we know that  $H_K(\hat{K}) < 0$ , and so that  $\hat{d} > d^*$ ; therefore when  $K$  passes  $\hat{K}$  and the agent shifts from consumption to savings plans, her inattentiveness takes a discontinuous jump from  $d^*$  to  $\hat{d}$ .  $\square$

#### Proof of Corollary 4

If  $K > 1/\Xi$ , then  $\hat{d} = +\infty$ . Also, consumption plans are preferred as long as  $H(K) > 0$ , which if  $\hat{d} = +\infty$  becomes:

$$K < \bar{K} \equiv \frac{\alpha\sigma_T^4\phi^4}{4(r+2\phi)^2(r+\phi)^2 \left( (r+\phi)^2\sigma_P^2 + r^2\sigma_T^2 \right)}.$$

Moreover, if  $K > \hat{K}$ , then savings plans are preferred. Combining these three facts, it follows that if  $\bar{K} > 1/\Xi$ , then  $\hat{K} = \bar{K}$ . Using the definitions of  $\bar{K}$  and  $\Xi$ , the condition  $\bar{K} > 1/\Xi$  becomes the condition in Corollary 4.  $\square$

#### Proof of Proposition 9

Using the solutions for  $V(w)$  and  $W(w)$  with  $\hat{d} = +\infty$ ,  $V(w) > W(w)$  becomes

$$c_0^* > rw - \frac{r - \rho}{\alpha r} - \frac{\alpha \sigma_P^2}{2r} - \frac{\alpha \sigma_T^2}{2(r + 2\phi)}. \quad (51)$$

Using the solution for  $c_0^*$  in (26) gives, after cancelling terms:

$$\frac{4K}{e^{rd^*} - 1} + \alpha \left( \frac{\sigma_P^2}{r^2} + \frac{\sigma_T^2}{(r + \phi)^2} \right) (e^{rd^*} + 1) < 2\alpha \left( \frac{\sigma_P^2}{r^2} + \frac{\sigma_T^2}{r(r + 2\phi)} \right).$$

Using (38) to replace for  $K$  and rearranging gives the condition in (29).  $\square$

### Proof of Corollary 3

Using the fact that  $\hat{c}_0 = y_0 - \hat{s}_0$  and (46) with  $\hat{d} = +\infty$ , shows that:

$$\hat{c}_0 = rw_0 - \frac{r - \rho}{\alpha r} - \frac{\alpha}{2} \left( \frac{\sigma_P^2}{r} + \frac{\sigma_T^2}{r + 2\phi} \right).$$

Then, for  $\hat{s}_0 < s_0^*$ , it must be that  $\hat{c}_0 > c_0^*$ , which using the expressions above is equivalent to condition (51) holding, which is true for the agent who chooses to be an inattentive saver.  $\square$

## References

- Abowd, John, and David Card (1989) "On the Covariance Structure of Earnings and Hours Changes," *Econometrica*, 57, pp. 411-445.
- Akerlof, George A. (1991) "Procrastination and Obedience," *American Economic Review Papers and Proceedings*, 81 (2), pp. 1-19.
- Akerlof, George A., and Janet L. Yellen (1985) "A Near Rational Model of the Business Cycle with Wage and Price Inertia," *Quarterly Journal of Economics*, 100, pp. 823-838.
- Alessie, Rob, Arie Kapteyn, and Annamaria Lusardi (1999) "Saving after Retirement: Evidence from Three Different Surveys," *Labour Economics*, 6 (2), pp. 277-310.
- Ameriks, John, Andrew Caplin and John Leahy (2003a) "Wealth Accumulation and the Propensity to Plan," *Quarterly Journal of Economics*, 118 (3), pp. 1007-1047.
- Ameriks, John, Andrew Caplin and John Leahy (2003b) "The Absent-Minded Consumer," unpublished, New York University.
- Andrews, Donald W. K., and Christopher J. Monahan (1992) "An Improved Heteroskedasticity and Autocorrelation Consistent Covariance Matrix Estimator," *Econometrica*, 60 (4), pp. 953-966.
- Attanasio, Orazio P. and Guglielmo Weber (1995) "Is Consumption Growth Consistent with Intertemporal Optimization? Evidence from the Consumer Expenditure Survey," *Journal of Political Economy*, 103 (6), pp. 1121-1157.
- Bargh, John, and Tania Chartrand (1999) "The Unbearable Automaticity of Being," *American Psychologist*, 54, pp. 462-479.
- Bernheim, B. Douglas and Raphael Thomadsen (2005) "Memory and Anticipations," *Economic Journal*, vol. 115, pp. 271-304.
- Billingsley, Patrick (1995) *Probability and Measure*, 3rd edition, New York, Wiley & Sons.
- Blanchard, Olivier J. and Danny Quah (1989) "The Dynamic Effects of Aggregate Demand and Aggregate Supply Disturbances," *American Economic Review*, 79, pp. 655-673.
- Bound, John, Charles Brown, Greg J. Duncan and Willard L. Rodgers (1994) "Evidence on the Validity of Cross-sectional and Longitudinal Labor Market Data," *Journal of Labor Economics*, vol. 12, pp. 345-368.
- Brock, William and Cars Hommes (1997) "A Rational Route to Randomness," *Econometrica*, vol. 65 (5), pp 1059-1095.
- Browning, Martin and M. Dolores Collado (2001) "The Response of Expenditures to Anticipated Income Changes: Panel Data Estimates," *American Economic Review*, 91 (3) pp. 681-692.
- Caballero, Ricardo J. (1995) "Near-Rationality, Heterogeneity, and Aggregate Consumption" *Journal of Money, Credit and Banking*, 27 (1), pp. 29-48.
- Campbell, John Y. (1987) "Does Savings Anticipate Declining Labor Income? An Alternative Test of the Permanent Income Hypothesis," *Econometrica*, 55, pp. 1249-1273.
- Campbell, John Y. and Angus Deaton (1989) "Why is Consumption So Smooth?" *Review of Economic Studies*, 56, pp. 357-374.

Campbell, John Y. and N. Gregory Mankiw (1989) "Consumption, Income and Interest Rates: Reinterpreting the Time Series Evidence," *NBER Macroeconomics Annual*, 4, pp. 185-216.

Campbell, John Y. and N. Gregory Mankiw (1990) "Permanent Income, Current Income and Consumption," *Journal of Business and Economic Statistics*, 8 (3), pp. 265-279.

Carroll, Christopher D. (2003) "Macroeconomic Expectations of Households and Professional Forecasters," *Quarterly Journal of Economics*, 118 (1), pp. 269-298.

Carroll, Christopher D., and Martin Sommer (in progress) "Epidemiological Expectations and Consumption Dynamics," Johns Hopkins University, unpublished.

Chen, Tongwen, and Bruce Francis (1995) *Optimal Sampled-Data Control Systems*, Springer-Verlag, London.

Chetty, Raj, and Adam Szeidl (2005) "Consumption Commitments: Neoclassical Foundations for Habit Formation," UC Berkeley, unpublished.

Cochrane, John H. (1989) "The Sensitivity of Tests of the Intertemporal Allocation of Consumption to Near-Rational Alternatives," *American Economic Review*, 79, pp. 319-337.

Deaton, Angus (1987) "Life-Cycle Models of Consumption: Is the Evidence Consistent with the Theory?" in *Advances in Econometrics, Fifth World Congress*, vol. 2, ed. Truman Bewley, Cambridge, Cambridge University Press.

Deaton, Angus (1992) *Understanding Consumption*, Oxford, Oxford University Press.

Dynan, Karen (2000) "Habit Formation in Consumer Preferences: Evidence from Panel Data," *American Economic Review*, 90, pp. 391-406.

Evans, George and Seppo Honkapohja (2001) *Learning and Expectations*, Princeton, Princeton University Press.

Fischer, Stanley, Ratna Sahay, and Carlos A. Vegh (2002) "Modern Hyper- and High Inflation," *Journal of Economic Literature*, 150 (3), pp. 837-880.

Flavin, Marjorie A. (1981) "The Adjustment of Consumption to Changing Expectations about Future Income," *Journal of Political Economy*, 89, pp. 974-1009.

Franklin, Gene F., J. David Powell, Michael L. Workman (1990) *Digital Control of Dynamic Systems: second edition*, Addison-Wesley, Massachusetts,

Friedman, Milton (1957) *A Theory of the Consumption Function*, Princeton University Press.

Fuhrer, Jeffrey (2000) "Habit Formation in Consumption and Its Implications for Monetary Policy," *American Economic Review*, vol. 90 (3), pp. 367-390.

Gabaix, Xavier and David Laibson (2002) "The 6D Bias and the Equity Premium Puzzle," *NBER Macroeconomics Annual 2001*, pp. 257-311.

Gali, Jordi (1991) "Budget Constraints and Time Series Evidence on Consumption," *American Economic Review*, 81, pp. 1238-1253.

Goodfriend, Marvin (1992) "Information-Aggregation Bias," *American Economic Review*, 82, pp. 508-519.

Gourinchas, Pierre-Olivier, and Jonathan Parker (2002) "Consumption Over the Life-Cycle,"

*Econometrica*, vol. 70 (1), pp. 47-89.

Hall, Robert E. (1978) "Stochastic Implications of the Life Cycle-Permanent Income Hypothesis: Theory and Evidence," *Journal of Political Economy*, 86, pp. 971-987.

Hayashi, Fumio and Christopher A. Sims (1983) "Nearly Efficient Estimation of Time Series Models with Predetermined, but not Exogenous, Instruments," *Econometrica*, 51 (3), pp. 783-798.

Hsieh, Chang-Tai (2003) "Do Consumers React to Anticipated Income Shocks? Evidence from the Alaska Permanent Fund," *American Economic Review*, 93 (1), pp. 397-405.

Hurst, Erik (2003) "Grasshoppers, Ants and Pre-Retirement Wealth: A Test of Permanent Income Consumers," NBER working paper 10098.

Kim, Chang-Jin and Charles R. Nelson (1999) "Has the U.S. Economy Become More Stable? A Bayesian Approach Based on a Markov-Switching Model of the Business Cycle," *Review of Economics and Statistics*, 81 (4), 608-616.

Kurz, Mordecai (1997) *Endogenous Economic Fluctuations: Studies in the Theory of Rational Belief*, Springer series in Economic Theory, No. 6, Springer-Verlag.

Lusardi, Annamaria (1999) "Information, Expectations, and Savings," in *Behavioral Dimensions of Retirement Economics*, ed. Henry Aaron, Brookings Institution Press/Russell Sage Foundation, New York, pp. 81-115.

Lusardi, Annamaria (2002) "Explaining Why So Many Households Do Not Save," Dartmouth College, unpublished.

MaCurdy, Thomas E. (1982) "The Use of Time Series Processes to Model the Error Structure of Earnings in a Longitudinal Data Analysis," *Journal of Econometrics*, 18, pp. 83-114.

Mankiw, N. Gregory (1985) "Small Menu Costs and Large Business Cycles: A Macroeconomic Model of Monopoly," *Quarterly Journal of Economics*, 100, pp. 529-537.

Mankiw, N. Gregory and Ricardo Reis (2002), "Sticky Information versus Sticky Prices: A Proposal to Replace the New Keynesian Phillips Curve," *Quarterly Journal of Economics*, 117 (4).

Mankiw, N. Gregory and Ricardo Reis (2003) "Sticky Information: A Model of Monetary Nonneutrality and Structural Slumps," in *Knowledge, Information, and Expectations in Modern Macroeconomics: In Honor of Edmund S. Phelps*, eds. Phillipe Aghion, Romain Frydman, Joseph Stiglitz and Michael Woodford, Princeton, Princeton University Press.

Mankiw, N. Gregory, Ricardo Reis and Justin Wolfers (2004) "Disagreement in Inflation Expectations," *NBER Macroeconomics Annual 2003*, vol. 18, pp. 209-147.

McConnell, Margaret and Gabriel Perez Quiros (2000) "Output Fluctuations in the United States: What has Changed Since the Early 1980s?" *American Economic Review*, 90, pp. 1464-76.

Meghir, Costas, and Luigi Pistaferri (2004) "Income Variance Dynamics and Heterogeneity," *Econometrica*, vol. 72 (1), pp. 1-32.

Miller, Boris M. and Wolfgang J. Runggaldier (1997) "Optimization of Observations: a Stochastic Control Approach," *SIAM Journal of Control and Optimization*, 35 (3), pp. 1030-1052.

Mishkin, Frederick (1983) *A Rational Expectations Approach to Macroeconometrics: Testing*

*Policy Ineffectiveness and Efficient-Markets Models*, Chicago, University of Chicago Press.

Moreira, Marcelo J. (2003) "A Conditional Likelihood Ratio Test for Structural Models," *Econometrica*, 71 (4), pp. 1027-1048.

Moscarini, Giuseppe (2004) "Limited Information Capacity as a Source of Inertia," *Journal of Economic Dynamics and Control*, vol. 28 (10), pp. 2003-2035.

Mullainathan, Sendhil (2002) "A Memory-Based Model of Bounded Rationality", *Quarterly Journal of Economics*, 117 (3), pp. 735-774.

Muth, John (1960) "Optimal Properties of Exponentially Weighted Forecasts," *Journal of the American Statistical Association*, 55, pp. 290-306.

Newey, Whitney and Kenneth West (1987) "A Simple Positive Semi-Definite, Heteroskedasticity and Autocorrelation Consistent Covariance Matrix," *Econometrica*, 55, pp. 703-708.

Parker, Jonathan (1999) "The Reaction of Household Consumption to Predictable Changes in Social Security Taxes," *American Economic Review*, 89 (4), pp. 959-973.

Pischke, Jorn-Steffen (1995) "Individual Income, Incomplete Information, and Aggregate Consumption," *Econometrica*, 63 (4), pp. 805-840.

Reis, Ricardo (2004) "Inattentive Consumers," NBER working paper 10883.

Reis, Ricardo (2005) "Inattentive Producers," *Review of Economic Studies*, forthcoming.

Rosen, Sherwin (1990) "Comment," in *Issues in the Economics of Aging*, David Wise, ed., Chicago, The University of Chicago Press.

Rozanov, Yu A. (1967) *Stationary Random Processes*, San Francisco, Holden Day.

Shapiro, Matthew D. , and Joel Slemrod (1995) "Consumer Response to the Timing of Income: Evidence from a Change in Tax Withholding," *American Economic Review*, 85 (1), pp. 274-283.

Simon, Herbert A. (1978) "Rationality as Process and as Product of Thought," *American Economic Review Papers and Proceedings*, 68 (2), pp. 1-16.

Sims, Christopher A. (2003) "Implications of Rational Inattention," *Journal of Monetary Economics*, 50 (3), pp. 665-690.

Souleles, Nicholas S. (1999) "The Response of Household Consumption to Income Tax Refunds," *American Economic Review*, 89 (4), pp. 947-958.

Souleles, Nicholas S. (2000) "College Tuition and Household Savings and Consumption," *Journal of Public Economics*, 77 (2), pp. 185-207.

Stokey, Nancy L., Robert E. Lucas Jr., with Edward C. Prescott (1989) *Recursive Methods in Economic Dynamics*, Cambridge, Harvard University Press.

Tobin, James (1982) "Money and Finance in the Macroeconomic Process," *Journal of Money, Credit and Banking*, May, 14 (2), pp. 171-204.

Wilson, Andrea (2003) "Bounded Memory and Biases in Information Processing," unpublished, Princeton University.

Wolak, Frank A. (1989) "Testing Inequality Constraints in Linear Econometric Models," *Journal of Econometrics*, 41 pp. 205-235.