DEPARTMENT OF ECONOMICS
UNIVERSITY OF CYPRUS

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**Sydney Ludvigson and**
**Alexander Michaelides**

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P.O. Box 20537, 1678 Nicosia, CYPRUS Tel.: ++357-2-892101, Fax: ++357-2-750310
Web site: http://www.econ.ucy.ac.cy

# Can Buffer Stock Saving Explain the "Consumption Excesses"?*

Sydney Ludvigson

Federal Reserve Bank of New York

and

Alexander Michaelides

University of Cyprus

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**Abstract**

The buffer-stock model of precautionary saving has become a workhorse of modern-day consumer theory. Despite its growing popularity, virtually no research has set out to formally investigate whether buffer-stock behavior can replicate the well-known smoothness of aggregate consumption growth ("excess smoothness"), or its correlation with lagged labor income growth ("excess sensitivity"). We investigate an aggregate version of the standard buffer stock model and examine how its predictions vary according to whether individuals observe economy-wide variation in their income. Our results demonstrate that, when individuals observe each component of their income, aggregate buffer stock consumption growth is at least as volatile as aggregate labor income growth and insignificantly correlated with lagged labor income growth. We show that adding incomplete information about aggregate earnings goes a long way toward resolving these discrepancies, but still falls short of matching the data in magnitude. (JEL D11, D91, E21)

# 1 Introduction

One of the lasting contributions to modern day consumer theory is the idea that consumption is determined by the expected value of lifetime resources, or permanent income. This concept was first introduced by Modigliani and Brumberg (1954, 1979), and then later formalized in its modern-day version by Hall (1978) and Flavin (1981).[1] This modern-day specification is a special case of intertemporal choice theory, where felicity functions are quadratic, labor income is stochastic, there are no restrictions on borrowing, consumers have infinite horizons, and expectations are formed rationally. We refer to this model as the permanent income hypothesis (PIH).

Although the PIH has considerable intuitive appeal, a series of influential papers published after its inception revealed two notable discrepancies between the model's predictions and aggregate data. First, the model predicts that consumption growth should be more volatile than income growth if aggregate income growth has positive serial correlation (as the quarterly data suggest it does), yet aggregate consumption growth is in fact much smoother than aggregate income growth (Deaton [1987]; Campbell and Deaton [1989]; Galí [1991]). Second, the PIH predicts that consumption changes should be orthogonal to predictable, or lagged, income changes, yet the correlation between consumption growth and lagged income growth has been found to be one of the most robust features of the aggregate data (for example, Flavin, [1981]; Blinder and Deaton [1985]; Campbell and Mankiw [1989]; Attanasio and Weber [1993]). Thus aggregate consumption growth is both "excessively smooth" relative to current labor income growth, and "excessively sensitive" to lagged labor income growth. We refer to these empirical anomalies collectively as the "consumption excesses".[2,3]

In response to these and other empirical anomalies, researchers have recently sought out modifications of the PIH framework. Chief among these modifications is the so-called buffer-stock model of precautionary saving, pioneered by the work of Deaton (1991) and Carroll (1992).[4] Several authors have argued that the buffer stock paradigm provides a good description of the median consumer's behavior (for example, Deaton [1991], Carroll [1997a], Carroll and Samwick [1997], [1998]). That model modifies the PIH framework to allow for precautionary saving motives, impatience, and restrictions on borrowing. The defining feature of buffer stock behavior is the conflict between prudence (the desire to save as a precaution against bad income draws) and impatience (the desire to shift consumption forward in time). Thus, individuals are motivated to accumulate a buffer stock of assets as insurance against unanticipated income declines, but because they dislike saving and would prefer to consume sooner rather than later, few assets are held. The buffer-stock model has become a workhorse of modern day consumer theory.[5]

Can the buffer-stock model explain the smoothness of aggregate consumption and its correlation with lagged income? Several researchers have suggested that buffer stock behavior should be a good candidate for doing so (Deaton [1991], Carroll [1992], Carroll [1997a]). Yet despite the growing popularity of this model, virtually no research has set out to formally investigate whether buffer stock saving behavior can explain these well-established facts of the aggregate data.

Most work has focused on the model's implications for individual, not aggregate, consumption. Carroll (1997a) shows that the buffer-stock model can resolve several empirical puzzles found in household data, including the tracking of consumption and income over the life-cycle, and the divergence of consumption and income at higher frequencies. Gourinchas and Parker (1996) estimate the buffer-stock model using household-level data and offer plausible estimates of the model's structural parameters.

A few studies have addressed the aggregate implications of buffer stock behavior. Carroll (1992) argues that the behavior of a representative buffer-stock agent may explain some features of aggregate data that are not explained by PIH, but he does not formally address these twin consumption excesses. Deaton (1991) develops an aggregate version of the buffer stock model in which individual income is subjected to both economy-wide and idiosyncratic shocks and shows that such a model can produce some smoothing of aggregate consumption, as well as some sensitivity to lagged income. However, these results, while illuminating, are documented only for a limited set of parameter values and do not reveal how the absence (or ignorance) of contemporaneous information on economy-wide variables—emphasized in subsequent work by Pischke (1995)—influences the model's predictions.

In this paper, we address the question posed in the title by investigating two models of buffer stock behavior. Our first framework follows closely the original models of individual buffer stock behavior developed in Deaton (1991) and Carroll (1992); we refer to this framework as the *standard buffer stock model*. We then consider an alternative framework: following Pischke (1995)–who worked entirely within the context of the PIH–we investigate how the predictions of the buffer stock model vary according to whether households observe the economy-wide variation in their income. Rather than analyzing the theory's implications for individual consumer behavior, as in most of the existing literature, we assume that there are a large number of buffer stock consumers and aggregate their consumption decisions explicitly.

Our results show that the standard buffer stock model, which incorporates borrowing restrictions, impatience and precautionary motives, does not generate robust excess sensitivity and aggregate consumption growth that is smoother than aggregate income growth. These implications arise only in the alternate framework which presumes that individuals do not observe the economy-wide component of their earnings (an assumption we refer to as *incomplete information*). This incomplete information version of the model goes a long way toward resolving the consumption puzzles discussed above: it produces aggregate consumption growth that is substantially less volatile than the benchmark PIH, and generates robust excess sensitivity to expected income growth. Nevertheless, this version of the buffer-stock model still falls short of matching the data in magnitude: most notably, aggregate consumption remains insufficiently smooth relative to aggregate income. In spite of this lack of smoothness in aggregate consumption, however, we show that there may be considerable smoothing in individual consumption. An important implication of these results is that inferences about aggregate buffer stock consumption cannot be made by looking at household level, representative agent consumption functions, or vice versa.

The excess sensitivity piece of these twin consumption excesses has been empirically investigated elsewhere using alternative models of consumer behavior and by emphasizing biases created by aggregation. Attanasio and Browning (1995) argue from exploring cohort-mean data (somewhere in between aggregate and individual data) that excess sensitivity may be due to omitted variable bias. The omitted variables can, for instance, be various demographic indicators which are important in models with nonseparable preferences over consumption and leisure. Alternatively, Attanasio and Weber (1993, 1995) show that aggregation problems with Euler equations for consumption can lead to rejections of over-identifying restrictions in those equations, and thus, in principle, to excess sensitivity.

While these alternate explanations for excess sensitivity are clearly instructive, we think there are several reasons it is useful to explore alternatives. First, the literature cited above has focused primarily on explaining excess sensitivity without addressing the smoothness of consumption; yet other authors have argued that excess sensitivity and excess smoothness are intimately related (see Campbell and Deaton [1989]). Accordingly, we think it makes sense to study these phenomena jointly. Second, the results for household level cohort data using demographic variables, while suggestive, are impossible to replicate in aggregate data, and Attanasio and Weber (1993) find that excess sensitivity to expected income growth remains even after controlling for demographic variables on data averaged over the whole *British Family Expenditure Survey.* This latter finding suggests that factors other than omitted demographic variables and nonseparabilities in the utility function may play a role in generating excess sensitivity.[6] Third, the empirical studies in this literature, typically carried out using linearized Euler equations, are unable to control for the presence of a precautionary saving term (an important feature of buffer stock consumption), and other authors have argued that omitting this term may lead researchers to over estimate the share of consumption/income tracking that is attributable to labor supply and demographics (Gourinchas and Parker, 1996).[7] Finally, our approach is useful because we model aggregate consumption behavior by explicitly aggregating the consumption outcomes of individual households, thereby allowing us to directly control for the aggregation problems raised in Attanasio and Weber (1993, 1995).

The rest of this paper is organized as follows. Section 2 presents the buffer stock model of individual behavior. To conserve space, we focus our analysis here on a few benchmark specifications which we argue are most plausible; other specifications along with the properties of U.S. aggregate data are explored in more detail in Ludvigson and Michaelides [1999]. Section 3 discusses the aggregate properties of buffer stock saving behavior, comparing the implications of the complete information case with those when individuals have incomplete information about the economy-wide component of their earnings. We conclude this analysis with a short discussion of the differences between individual and aggregate consumption and how the aggregate results change if we allow unconstrained PIH consumers to comprise some fraction of the population. Finally, we briefly consider two extensions of these models in section 3.1: allowing for geometric means, and time-averaged data when the decision period of the household is shorter than the sampling interval.

## 2 Microeconomic Model of Consumption

This section presents the model of individual consumption behavior. Given that we will compare the model's implications with the properties of aggregate data, we face a preliminary choice on whether to calibrate the household decision period as a quarter or a year. Two factors favor the consideration of an annual, rather than quarterly, model of behavior. First, there are measurement problems with aggregate quarterly consumption and income data, some of which have been documented by Wilcox (1992); Ludvigson and Michaelides [1999] provide more discussion. Second, to the best of our knowledge, there exists no microeconometric study estimating a log-linear labor income growth process at quarterly frequency from which to calibrate individual income.[8]

On the other hand, other factors argue for the consideration of a quarterly specification. The presence of significant positive autocorrelation in aggregate labor income growth at quarterly frequency produces interesting differences from the results of the annual model where aggregate labor income growth is far less autocorrelated (Ludvigson and Michaelides [1999] provide documentation of the time series properties of aggregate labor income growth). Moreover, almost all of the previous macroeconomic analysis of these issues has been performed on quarterly data and then compared to the predictions of a quarterly framework. Thus we feel that some consideration of both models is warranted.

For models of both frequencies, we assume that the household decision interval matches the data sampling interval. (Later, we briefly pursue an extension in which we relax this assumption.) Time is discrete and agents have an infinite horizon. We assume there is one non-durable good and one financial asset (a riskless bond) which yields a constant after tax real return, $r$. At time $t$, the agent enters the period with assets held over from last period ($A_{it}$), and receives $Y_{it}$ units of the non-durable good from inelastically supplying one unit of labor. The agent chooses the level of non-durable good expenditures ($C_{it}$) to solve the following dynamic program:

$$MAX_{\{C_{it}\}} E_0 \sum_{t=0}^{\infty} \beta^t U(C_{it}), \tag{1}$$

subject to

$$A_{it+1} = (1+r)(A_{it} + Y_{it} - C_{it}) \tag{2}$$

$$Y_{it} = P_{it} U_{it} \tag{3}$$

$$P_{it} = G_t P_{it-1} N_{it} \tag{4}$$

$$A_{it+1} \geq 0 \tag{5}$$

$E_0$ is the expectation conditional on information available at time 0, and $\beta = \frac{1}{1+\delta}$ is the constant discount rate. Following Deaton (1991), equation (5) places an exogenous restriction on borrowing. We assume that preferences are of the constant relative risk aversion family; specifically, $U(C_t) = \frac{C_t^{1-\rho}}{1-\rho}$ when $\rho > 0$; if $\rho = 1$, $U(C_t) = \ln C_t$. Unlike the quadratic utility specification in the PIH, this specification has a positive coefficient of relative prudence, equal to $1 + \rho$, leading to a precautionary motive for saving.[9]

We define "cash-on-hand", $X_t$, as the sum of current income and assets, $Y_t + A_t$ which evolves according to

$$\begin{aligned} X_{t+1} &= A_{t+1} + Y_{t+1} \\ &= (1+r)(X_t - C_t) + Y_{t+1} \end{aligned} \tag{6}$$

Given the borrowing restriction in (5), the first order condition for optimal consumption choice can then be written[10]:

$$U'(C_t) = MAX[U'(X_t), \beta(1+r)E_t U'(C_{t+1})] \tag{7}$$

If the agent is constrained at time $t$, the maximum that can be spent on consumption is the cash on hand ($X_t$), implying that marginal utility can never be less than $U'(X_t)$.

The process for individual income given in (3) and (4) was first used in a nearly identical form by Carroll (1992) and is decomposed into a "permanent" component, $P_{it}$, and a transitory component, $U_{it}$. We assume that $\ln U_{it}$ and $\ln N_{it}$ are independent and identically distributed with mean zero and variances $\sigma_u^2$ and $\sigma_n^2$, respectively. We assume that $\ln G_t$ is common to all individuals and has an unconditional mean $\mu_g$ and constant variance $\sigma_g^2$, while the innovation to $\ln G_t$ is uncorrelated with $\ln U_{it}$ and $\ln N_{it}$. As a result, the permanent component of labor income, $\ln P_{it}$, evolves as a random walk with a stochastic drift.

Given these assumptions, the growth in individual labor income follows

$$\Delta \ln Y_{it} = \ln G_t + \ln N_{it} + \ln U_{it} - \ln U_{it-1}, \tag{8}$$

where the unconditional mean growth for individual earnings is $\mu_g$, and the unconditional variance equals $(\sigma_g^2 + \sigma_n^2 + 2\sigma_u^2)$. Because the last three terms in (8) are idiosyncratic, per capita aggregate labor income growth inherits the data generating properties of $\ln G_t$.[11]

We make the following additional assumption:

$$\beta(1+r)E_t[(G_{t+1}N_{t+1})^{-\rho}] < 1 \tag{9}$$

As Deaton-Laroque (1992) have verified, this assumption is a necessary condition for (7) to have a unique solution. If we let $\beta = \frac{1}{1+\delta}$, use the fact that $G$ and $N$ are independent, and take logs of (9), this condition can be written

$$\frac{r-\delta}{\rho} + \frac{\rho(\sigma_g^2 + \sigma_n^2)}{2} < \mu_g \tag{10}$$

where the approximation $\ln(1+x) \approx x$, for $x$ small, has been used.

Equation (10) gives the "impatience" condition common to buffer-stock models which insures that borrowing is part of the unconstrained plan. If income were constant, the condition $r < \delta$ is all that is necessary to insure that consumers want to run down consumption over time. By contrast, if income is growing over time, condition (10) can be satisfied as long as $\mu_g$ is sufficiently large even if $r = \delta$.

We begin by solving the model under a set of "baseline" parameter assumptions and then move on to ask how our results vary when these parameter values are changed. As a baseline, we set the rate of time preference, $\delta$, equal to 0.05, and the constant real interest rate, $r$, equal to 0.02, both at annual rates. Carroll (1992) estimates the variances of the idiosyncratic shocks using data from the *Panel Study of Income Dynamics*, an annual household data set, and our baseline simulations use values very close to those: 0.10 percent per year for $\sigma_u$ and 0.08 percent per year for $\sigma_n$.[12] These estimates are consistent with those from other household studies (see MaCurdy [1981] and Abowd and Card [1989]). Aggregate labor income growth, $\ln G_t$, is well described by an i.i.d. process in annual data, and a positively autocorrelated AR(1) process (with a coefficient estimate equal to 0.23) in quarterly data. We use these distributions in the simulations discussed below.[13]

Unfortunately, to our knowledge there is no microeconometric study that estimates a log-linear specification of household earnings at quarterly frequency; therefore some assumption about the quarterly process for the idiosyncratic components of income growth must be made in order to model decision periods as quarters. Our solution is to convert the household process given above for annual (four quarter) log differences into the equivalent process for quarterly log differences. Since the four-quarter log difference is just the sum of the quarterly log differences during the year, the idiosyncratic components of the quarterly process for individual income growth will consist of an innovation to a random walk, "permanent" component of income, $\ln N_{is}$, plus the first difference of white noise, transitory income, $\ln U_{is} - \ln U_{is-1}$, where $s$ denotes the time interval in terms of quarters. Because quarterly permanent shocks to income growth accumulate over a year, however, we divide the standard deviation of the idiosyncratic permanent shock estimated from annual data by two (the variance by four) to get quarterly permanent innovations, so that $\sigma_n = 0.04$ for the baseline quarterly model.[14] Note that this procedure significantly reduces the role of the permanent component relative to the transitory component in individual income shocks, an adjustment that will have important implications when there is incomplete information. We discuss this further below.

Results in Ludvigson and Michaelides [1999] on aggregate data show that the standard deviation, denoted, $\sigma_g$, is estimated to be 0.025 at an annual rate in annual data (.0115 at a quarterly rate in quarterly data). The mean of the aggregate income growth process, denoted $\mu_g$, is set equal to 0.02 at an annual rate (0.005 at a quarterly rate).

There is no known analytical solution to the problem above; thus we seek a numerical solution described in the Appendix.

## 2.1 Information Assumptions

In a recent paper, Pischke (1995) argues that economy-wide shocks account for a very small fraction of the variance in individual earnings growth. As such, households have little incentive to distinguish aggregate from idiosyncratic shocks to their income. Although Pischke does not address the impact of this form of incomplete information on buffer stock saving behavior, he shows that informational assumptions can have important effects on aggregate consumption when individual households behave according to the PIH.

We apply Pischke's insights to the buffer stock model by considering two frameworks. In the first, which we define as the standard buffer stock model, we assume that individuals observe each component of their earnings separately (*complete information*); in the second, we assume that households have no way of separating the individual and aggregate components of their earnings growth process (incomplete information), but rather can only observe how much their income changed in a given period.

We assume that the growth in income is stationary, so that the aggregate and individual components can be described by their respective stationary Wold representations,

$$\Delta \ln Y_{it} = A(L)\varepsilon_t + B(L)\ln U_{it} + C(L)\ln N_{it} \tag{11}$$

where $A(L)$, $B(L)$ and $C(L)$ are distributed lag operators and the subscript $i$ denotes a household-specific variable. For the standard buffer stock model, we assume that individuals can distinguish each of the separate Wold representations for income growth given in (11). Note that this complete information implies not only that individuals understand the source of each shock to their income, but also that they comprehend perfectly the implications of the aggregate shock for their future income growth.

Given stationarity, individual income changes also have a single Wold representation

$$\Delta \ln Y_{it} = D(L)\eta_{it}. \tag{12}$$

If individuals can observe only the log difference in their income each period and do not distinguish any of the separate components of their income given in (11), the process for individual income growth appears just like the single Wold representation in (12). We define incomplete information, following Pischke, by the assumption that individuals observe their income growth as the equivalent single Wold representation in (12).

When the aggregate component of the earnings growth process is i.i.d., individual income growth follows

$$\Delta \ln Y_{it} = \mu_g + \varepsilon_t + \ln N_{it} + \ln U_{it} - \ln U_{it-1}, \tag{13}$$

where $\ln G_t = \mu_g + \varepsilon_t$, and $A(L) = 1, B(L) = 1$, and $C(L) = 1 - L$. Given incomplete information, individual earnings growth looks just like an MA(1), a special case of (12) with $D(L) = 1 - \psi L$:

$$\Delta \ln Y_{it} = \mu_g + \eta_{it} - \psi \eta_{it-1}, \tag{14}$$

where $\psi > 0$.

We consider models of both annual and quarterly decision periods. In the annual incomplete information version of the model, aggregate income growth appears well described by an i.i.d. process, and we solve for the consumption policy rule assuming that individuals observe their income growth as the MA(1) process in (14), even though shocks to this process are actually generated by innovations to each of the separate components given in (13). The parameters of (14) are calibrated by setting $\psi = 0.44$, and $\sigma_\eta = 0.15$, in accordance with evidence from annual earnings in household data.[15] These values, along with an estimate of $\sigma_g$ taken from aggregate annual data, generate values for $\sigma_u$, and $\sigma_n$ (equal to .1 and .08 respectively) by matching variances and covariances between (13) and (14). Note that $\psi$ pins down the relative variances of the permanent and transitory components, implying values of .08 and .1 that are consistent with Carroll's (1992) estimates of obtained using annual PSID household data.

If $\ln G_t$ follows a stationary AR(1) process, labor income growth is given by

$$\Delta \ln Y_{it} = \mu_g + \phi(\Delta \ln Y_{1t-1} - \mu_g) + \varepsilon_t + \ln N_{it} + \ln U_{it} - \ln U_{it-1}, \tag{15}$$

a special case of (8) with $\ln G_t = \mu_g + \phi(\Delta \ln Y_{1t-1} - \mu_g) + \varepsilon_t$. The AR(1) component can be inverted and a single Wold process for $\Delta \ln Y_{it}$ can be written,

$$\Delta \ln Y_{it} = \mu_g(1 - \phi) + \eta_{it} + \varsigma \eta_{it-1} + \varsigma^2 \eta_{it-2} + \varsigma^3 \eta_{it-3} + ... \tag{16}$$

Given the values of $\sigma_\varepsilon^2, \sigma_n^2, \sigma_u^2$, and $\phi$, the appropriate value of $\varsigma$ can be found by matching variances and covariances between (16) and (15).

In the quarterly incomplete information model, aggregate income growth is well described by an AR(1) process, therefore we assume that individuals observe their income growth as the infinite order moving average representation in (16), even though shocks to this process are actually generated by innovations to each of the separate components given in (15). The process in (16) can be inverted and equivalently represented as a combined AR(1) process with autoregressive coefficient $\varsigma : (1 - \varsigma L)\Delta \ln Y_{it} = \eta_{it}$.[16] An important feature of the representation (16) is that individual income growth will be negatively autocorrelated ($\varsigma < 0$) if the variance of the idiosyncratic transitory shock, $\sigma_u^2$, is sufficiently large relative to the variance of aggregate income growth given by, $\sigma_\varepsilon^2/(1 - \phi^2)$.

# 3 Aggregate Consumption Properties of Buffer-Stock Saving Behavior

To study the properties of aggregate buffer stock consumption, we employ an aggregation procedure that accumulates the consumption decisions of many buffer stock consumers. The procedure takes the following steps. First, for a large number of households, we use Monte Carlo simulations to generate the idiosyncratic shocks to their income for 200 periods (roughly the size of our quarterly data set). In each period, every household also receives a common aggregate shock to their income growth governed by the process for $\ln G_t$. The number of households is determined by increasing the population until the individual income draws, once aggregated, match the appropriate aggregate income process. This procedure showed that 2000 households was sufficient; using more households did not change the results.

Second, given an initial value for normalized cash-on-hand, $x_{it}$, we use the policy functions computed from the microeconomic model of consumption behavior described above to determine the optimal value of individual consumption, $c_{it}$, for each household.[17] An aggregate time series on consumption and labor income is constructed by taking the cross-sectional average of the simulated data at each point in time. Aggregate consumption is simply the sum of many individual consumption outcomes.

To understand the simulation results for aggregate consumption that follow, it is useful to consider the optimal consumption response of an *individual* to the aggregate shock. Figures 1 and 2 show the consumption solutions under each informational assumption we consider, using our baseline parameter values.

Figure 1 shows the optimal consumption-income ratio for an individual with complete information when aggregate income growth is assumed to follow an AR(1) process. In this case, individual income growth is given by (15). The optimal consumption policy will vary with the current cash on hand-income ratio, $x_{it}$, the current aggregate income state, $\Delta \ln Y_{1t}$, and the current idiosyncratic transitory shock, $\ln U_{it}$, all of which help forecast tomorrow's cash-on-hand and income growth.

We assume $\Delta \ln Y_{1t}$ and $\ln U_{it}$ each follow a five point discrete Markov process, so that the policy functions relating the consumption-income ratio to $x_{it}$ have 25 branches, or 5 "clumps" of 5 branches, one corresponding to each combination of the five possible outcomes of $\Delta \ln Y_{1t}$ and $\ln U_{it}$. To avoid clutter, we show just10 of these functions, those corresponding to the five values of the idiosyncratic shock, and the highest and lowest states for aggregate income growth. The five clumps correspond to each value of $\ln U_{it}$, and the two branches within a clump correspond to each of the two aggregate income states.

Three points about Figure 1 are worth noting. First, the consumption functions are highly nonlinear. In every figure, below a particular level of cash-on-hand, consumption equals cash-on-hand (the policy function is a 45 degree line). Above this level, the policy functions flatten out and any increase in cash-on-hand leads to a less than one-for-one increase in consumption.

Second, because the idiosyncratic shock, $\ln U_{it}$, comprises a much larger fraction of the overall individual income variance than does the aggregate shock, the five clumps corresponding to values of $\ln U_{it}$ are much more widely spaced than are the two branches within each clump corresponding to the highest and lowest discrete values of $\Delta \ln Y_{1t}$. Thus, for any given level of cash-on-hand, the optimal consumption-income ratio is more dependent on the state of idiosyncratic income than on the current state of aggregate income.

Third, the five clumps of branches corresponding to values of $\ln U_{it}$ lie in descending order, so that the clump corresponding to the highest value of $\ln U_{it}$ is the lowest clump, and vice versa. This is because $\ln U_{it}$ shocks are transitory, and the household attempts to smooth the affects of these shocks on consumption by reducing the consumption-income ratio when income is temporarily high. By contrast, the two branches of the policy function which correspond to values of aggregate income growth lie in ascending order because this component follows a positively autocorrelated AR(1) process. Accordingly, households expect today's greater than average growth in the aggregate component of their earnings to be followed by greater than average growth tomorrow. Thus the figure demonstrates that the consumption-income ratio rises in response to higher aggregate income growth because it is expected to persist.

How do the consumption functions change with incomplete information? Figure 2 shows the optimal consumption-income ratio for an individual with incomplete information when aggregate income growth is assumed to follow the same AR(1) process that generated Figure 1. In this case, the household observes only the (log) income change, which is equivalent to observing individual income growth as governed by the process in (16). Consequently, the 10 policy functions in Figure 2 correspond to one of ten discrete states for the log change in individual income, $\Delta \ln Y_{it}$.

An important feature of the functions in Figure 2 follows from the fact that the autoregressive coefficient in the individual income process, $\varsigma$, is *negative* (equal to about -0.46 given our baseline parameter values) since the variance of the idiosyncratic, transitory shock, $\sigma_u^2$, is considerably larger than the variance of the shock to aggregate income growth which is positively autocorrelated.[18] As a result, the ten branches of the policy function in Figure 2 which correspond to values of $\Delta \ln Y_{it}$ lie in descending order, just the opposite ordering of the branches corresponding to the aggregate income state, $\Delta \ln Y_{1t}$, in the complete information case. Households believe that greater than average growth in their income today will be followed by *lower* than average growth tomorrow, regardless of the source of the shock. Unlike the household with complete information, when an aggregate shock hits the economy, households with incomplete information mistake it for transitory and unwittingly attempt to smooth its affects on their consumption by reducing the consumption-income ratio.

We now move on to present the results of time series simulations, computing the model's implications for excess smoothness and excess sensitivity. Throughout the paper we define the *smoothness ratio* as the ratio of the standard deviation of consumption growth to that of labor income growth. The *sensitivity coefficient* is defined as the ordinary least squares (*OLS)* coefficient from a regression of aggregate consumption growth on lagged aggregate labor income growth. These properties from the model can be compared with the stylized facts from U.S. aggregate data, shown in Table 1 taken from Ludvigson and Michaelides [1999]. The table gives the smoothness ratio and sensitivity coefficient for three measures of real, per capita consumption expenditure: nondurables and services less shoes and clothing ($C$), nondurables less shoes and clothing ($C^{ND}$), and services ($C^{S}$). The construction of all of these variables is detailed in Ludvigson and Michaelides [1999].[19]

Table 1 shows that consumption growth is about half as volatile as the growth in aggregate labor income in both quarterly and annual data, with a smoothness ratio equal to 0.48 in annual data and 0.47 in quarterly data. Much of the smoothness is coming from services expenditure: the smoothness ratio for this component of expenditure is .46, compared to about .68 for nondurables. Consumption growth is also positively correlated with lagged income growth in both annual and quarterly data. The sensitivity coefficients are statistically significant at better than the 5 percent level in data of both frequencies, and the point estimates are virtually identical regardless of which measure of consumption is used, equal to 0.16 and 0.17 for quarterly and annual data respectively.

To investigate how closely the aggregate buffer stock models come to matching these stylized facts, we perform 100 simulations and report the average smoothness ratio and sensitivity coefficients in Tables 2 and 3. The simulations are performed over a range of parameters that do not violate the impatience condition. Table 2 presents results from the standard, complete information framework for both the annual model (where aggregate labor income growth is assumed to be an i.i.d. process) and the quarterly model (aggregate labor income growth is assumed to be an AR(1) process); Table 3 presents the analogous results for the alternate model with incomplete information. The top panel of each table corresponds to the i.i.d. case and the bottom panel corresponds to the AR(1) case.

As Table 2 shows, over a range of parameter values, simulated aggregate consumption from the annual, standard model is as volatile as aggregate income—the smoothness ratio is roughly equal to one in each case. Consumption and income have roughly the same volatility in this model because the variation in aggregate consumption reflects those saving and dissaving decisions of individuals that do not cancel out in the aggregate, the responses of individual consumption to economy-wide shocks. Since (for the results reported in the top panel) consumers correctly perceive that shocks to the aggregate component of their income are permanent, it is undesirable for households to undertake any smoothing out of aggregate shocks. The table also shows that there is no sensitivity of aggregate consumption growth to lagged income growth—the *OLS* point estimate on lagged aggregate income growth is not statistically different from zero.

As a benchmark, these results for the standard buffer stock model can be compared with the smoothness ratios that would be implied by a representative agent version of the PIH, where the representative agent receives the aggregate income process.[20] These figures are presented in the third row of the first panel of Table 2. The benchmark numbers depend only on the real interest rate and the persistence of the aggregate income growth process and therefore do not vary over all the parameter permutations we consider for the buffer stock households. The excess sensitivity coefficient is always zero in the PIH, and when income growth is i.i.d., the smoothness ratio is unity. Thus, the complete information, annual model produces a smoothness ratio and sensitivity coefficient that virtually indistinguishable from that which would be implied by the representative agent PIH.

How do the results in the standard model differ at quarterly frequency when the process for aggregate income growth is positively autocorrelated? The second panel of Table 2 presents the smoothness and sensitivity coefficients when aggregate labor income growth follows an AR(1) process that Ludvigson and Michaelides [1999] find to characterize the U.S. data, with a coefficient on lagged income growth equal to 0.23. Positively autocorrelated aggregate income growth produces aggregate consumption that is less smooth than in the annual model. The smoothness ratios range from 1.06 to 1.09, so that consumption is always more volatile than income. Since shocks to the aggregate component of income growth are expected to persist, individuals respond to those shocks by dipping into their savings when they are not constrained and raising consumption more than one-for-one.

Again, these values can be compared with the smoothness ratios that would be implied by the representative agent PIH, where the representative agent receives the aggregate, AR(1) process for the first difference in income, given in the last row of Table 1. Unlike the annual model in which all shocks to aggregate income are permanent, the quarterly model generates noticeable differences between the predictions of the standard buffer stock model and those of the PIH. With $r = 0.03$, the PIH would generate a smoothness ratio of about 1.25. Thus, although the standard buffer stock model fails to generate consumption smoothing that is close to empirical values, it does generate consumption that is considerably smoother than a representative agent, PIH benchmark in the face of positively autocorrelated shocks to aggregate income growth. If we compare these figures to the smoothness ratio for expenditures on nondurables (less shoes and clothing) (Table 1), we find that the standard buffer stock model produces a smoothness ratio that is about halfway between that of the representative agent, PIH model and the U.S. data.

Table 2 also shows that the quarterly model under complete information does not produce a statistically significant correlation between consumption growth and lagged income growth. We conclude that the mere presence of liquidity constraints, coupled with impatience and precautionary motives is not enough to generate robust excess sensitivity or consumption that is substantially smoother than income.

How does the alternate model with incomplete information fare? Table 3 shows that the introduction of incomplete information into the standard framework causes the smoothness ratio to fall substantially. In the annual model, the smoothness ratio is 0.84 in one case, considerably lower than the benchmark PIH figure of 1.26. And, the alternate framework produces aggregate consumption which is far less volatile than the analogous case with complete information. The reason for this result is that, when a positive aggregate shock hits the economy, individuals do not raise their consumption one for one because they mistake part of the shock as idiosyncratic and therefore transitory; smoothing at the individual level gets transferred to aggregate consumption as a result of an (unwitting) smoothing of the aggregate shock.

For the quarterly model, the alternate framework displays considerably more consumption smoothing than the standard model, with smoothness ratios ranging between 0.80 and 0.92. These results are presented in the bottom panel of Table 3. In contrast to the analogous complete information model, consumption growth is always smoother than income growth. In addition, the presence of incomplete information coupled with positive serial correlation in the aggregate income process produces robust excess sensitivity. If a positive aggregate shock to income occurs, individuals mistake the shock for transitory and do not raise consumption by the amount warranted by the persistence of the shock. This misperception creates a sluggish response of consumption to aggregate income shocks: next period's consumption will be raised again when income is higher than expected. The sluggishness of consumption in turn produces a direct correlation between consumption growth and lagged income growth and explains why consumption growth may be correlated with lagged aggregate income growth even when the latter follows an i.i.d. process. This is the only version of the buffer stock model we consider that can replicate this feature of the annual data shown in Table 1.

The excess sensitivity coefficient for the quarterly model with incomplete information ranges from about 0.36 to 0.44 and is strongly significant for every parameter combination we consider. These point estimates, however, are considerably higher than those from aggregate data, the latter being equal to about 0.16.

In summary, the buffer stock model with incomplete information goes a long way toward resolving the consumption excesses: it produces aggregate consumption growth that is substantially less volatile than the benchmark PIH, and generates robust excess sensitivity to expected income growth. It still falls well short of matching the data, however. Consumption growth typically remains both too volatile and too highly correlated with lagged income growth.

Why isn't aggregate buffer stock consumption smoother? It is tempting to attribute this finding to the fact that buffer stock consumers hold few assets and face constraints on their liquidity, thereby making it difficult for them to smooth out the effects of transitory shocks to their income. This is not the case, however, because buffer stock households can achieve a great deal of smoothing with few assets.

To understand this, it is useful to compare the smoothness ratio that arises from simulating the model for a single household with that which arises from simulating the model for many households and aggregating their consumption decisions, as we do above. For the quarterly model using baseline parameter values, we find that the smoothness ratio for an individual buffer stock consumer is equal to 0.65 in the incomplete information model, and 0.40 in the standard model with complete information. These should be compared with the much higher values for aggregate consumption given in Tables 2 and 3, equal to 0.84 and 1.08, respectively. This comparison demonstrates that there may be considerable smoothing at the individual level even when there is little or no smoothing at the aggregate level. And, this smoothing occurs despite the fact that buffer stock households hold few assets. Households can smooth consumption with a relatively small buffer stocks of assets because there is substantial transitory variation in income at the individual level. By contrast, in the aggregate, consumption more closely reflects the optimal responses to economy-wide shocks which are expected to persist. An important implication of these results is that inferences about aggregate buffer stock consumption cannot be made by looking at household level consumption functions, or vice versa.

Would aggregate consumption be smoother in an economy that also included more patient households who may at times hold large amounts of assets and who do not face constraints on their ability to borrow? It is clear that the answer to this question would be 'no' if those households were PIH consumers with complete information about the income processes we have been considering. This follows because we know from the benchmark results in Table 2 that, in most cases, those households will have consumption that is significantly more volatile than that of an aggregate of buffer stock consumers with or without incomplete information. Moreover, results in Ludvigson and Michaelides [1999] show that adding some fraction of PIH consumers to the population who have the same incomplete information about their earnings process as do the buffer stock consumers typically does not improve the aggregate model's performance. Indeed, when the economy is populated entirely by PIH consumers, the smoothness ratio is farther from its empirical counterpart than for any other mix of these two types of consumers, equal to .92 for the baseline annual model, compared to 0.84 when the economy is populated entirely with buffer stock consumers. We conclude that the lack of smoothness at the aggregate level cannot be explained by an absence of unconstrained households.

It is possible that the insufficient aggregate consumption smoothness of these models could be resolved by changing the specification of the income process while maintaining the presumption of incomplete information. Results (not reported) suggest that decreasing the variance of the permanent shock relative to that of the transitory shock may lead to a lower smoothness ratio at both the individual and aggregate level in the model with incomplete information. This occurs because a decrease in the variance of the permanent component reduces the perceived persistence of the individual's income process when households cannot observe these components separately, thereby magnifying the mistakes households make when responding to persistent aggregate shocks. However, there are at least two caveats with accepting a reduction in the relative variance of the permanent component as a resolution to the smoothness puzzle. First, such a reduction is not supported by existing evidence from studies using household income data (MaCurdy [1981]; Carroll [1992]; Abowd and Card [1989]). Second, decreasing the perceived persistence of the household's income process leads not just to more smoothing at the aggregate level, but also to greater excess sensitivity, already too high in the existing model.

## 3.1 Extensions

We have explored whether the features of two variants of buffer stock saving models can account for the excess smoothness and excess sensitivity observed in aggregate data. In this section we briefly investigate two extensions of these models as possible alternative explanations for excess sensitivity.

The first extension follows Attanasio and Weber (1993) who stress the possible role of aggregation bias in generating excess sensitivity in linearized Euler equations. Since the first-order condition for optimal consumption choice is often approximated as being linear in logs, they argue that these "Euler" equations should ideally be estimated using the average of the logarithms of expenditures, rather than the logarithm of the average. While this estimation is not possible with aggregate data, Attanasio and Weber carry out this exercise using household level data and find that the over-identifying restrictions of the standard Euler equation may be rejected simply because logs are taken over arithmetic averages rather than taking geometric averages. This finding suggests that some amount of excess sensitivity may be attributable to this type of aggregation bias.

In the simulation exercises performed above, we compiled results by calculating the logarithm of the arithmetic average since this replicates the procedure used to construct actual aggregate data. Although it is impossible to control for this possible source of bias in the data, there is of course no restriction in our simulations and it is straightforward to recompute the statistics using geometric means. We did not find that this change qualitatively influenced the results. For example, using geometric means and our baseline parameter values, the quarterly model with incomplete information produces as excess sensitivity coefficient of 0.41 that is strongly statistically significant, while the smoothness ratio is 0.83. These results are almost identical to those presented in Table 3 for the same case using arithmetic means. It appears that other features of the buffer stock model dominate these aggregation affects in generating excess sensitivity.[21]

A second extension we consider is to alter the timing of households' decisions so as to create a mismatch between their decision interval and the data sampling interval. The possibility that these intervals do not coincide has been explored elsewhere as an explanation for the excess sensitivity finding in aggregate data (for example, Ermini [1989, 1993]; Christiano et. al. [1991]; Heaton [1993]). These authors point out that if the decision period of households is more frequent than the data sampling interval, measured consumption will be the time-averaged value of multiple consumption decisions, a phenomenon that may introduce spurious serial correlation in consumption growth. If the original consumption process follows a martingale (as in the PIH), the first difference of time averaged consumption will follow a first order moving average process (Working [1960]).[22] Thus, in empirical tests, this type of temporal aggregation bias could create excess sensitivity even if consumption growth is, in fact, unforecastable over the interval in which households make decisions.[23]

The results discussed previously cannot be explained by this type of temporal aggregation because we assumed above that household's decision intervals match the data sampling interval. Moreover, since there is no martingale presumption in the buffer stock model, the findings of Working are not directly applicable to the framework we consider. Nevertheless, it is possible that the standard complete information model–which displays little excess sensitivity in the results above–might match the data better if we modeled households' decision intervals so that they occurred more frequently than the sampling interval. To do so, we investigate a simple extension of our model in which we assume that households make decisions on a quarterly basis, but that the stylized consumption facts are computed from annual averages of quarterly data. For this procedure, we simulate the quarterly model, compute annual consumption and labor income as the sum of quarterly data in levels, and take log differences of these time averaged data. We then recompute our results for excess sensitivity and excess smoothness using these annual averages, which should be compared with the results from the annual model above for which data are not time-averaged. Because the difference in results this extension produces are not highly sensitive to variations in the parameter values, we only discuss the findings under our baseline parameter assumptions.

Our results show that time-aggregation of household consumption decisions does improve the standard model's predictions along the excess sensitivity dimension, increasing the excess sensitivity coefficient to .20 from about zero. However, even with this time-aggregation, the coefficient is still not statistically significant at the five percent level. Moreover, the smoothness ratio is hardly changed, remaining about .98. The results are qualitatively similar for the alternate model with incomplete information; using annual averages, the excess smoothness parameter is found to be 0.98, while the sensitivity coefficient is found to be 0.29.[24] Without time-averaging, these figures were 0.85 and 0.17, respectively. In summary, time-averaging increases the sensitivity coefficient in both models, but the point estimate is typically not statistically significant in the complete information version and the smoothness ratios are little affected.

# 4 Conclusion

One of the primary objectives of modern-day consumer theory has been to understand the degree of smoothness and predictability of aggregate consumption. Buffer-stock models with precautionary motives and borrowing restrictions have recently become popular tools for thinking about the way the typical consumer behaves. Yet existing research gives little indication of how close buffer stock saving behavior, once aggregated, might come to quantitatively matching these well known features of aggregate consumption.

Can buffer stock saving explain the "consumption excesses"? To find out, we consider two versions of buffer stock behavior. The first builds closely on the original models presented in Deaton (1991) and Carroll (1992, 1997a); the second takes into account incomplete information as emphasized by Pischke (1995). Our results show that incomplete information about the aggregate component of individual earnings may be an important factor in explaining the smoothness of aggregate consumption growth and its correlation with lagged labor income growth. Only the incomplete information version of the aggregate buffer stock model is capable of simultaneously producing some smoothing of aggregate consumption in the face of persistent aggregate income shocks (excess smoothness), and a robust correlation between consumption growth and lagged income growth (excess sensitivity).

Nevertheless, even the buffer stock model with incomplete information creates a smoothness puzzle that remains to be explained. The lowest smoothness ratio generated by the model is about 0.8, compared to about 0.5 in aggregate data. Further, the incomplete information model often produces estimates of the excess sensitivity coefficient that are too large to fall within empirical ranges, while cases which deliver estimates closer to empirical values do not deliver the most favorable degrees of consumption smoothing. Lack of smoothing at the individual level or the absence of unconstrained permanent income consumers does not appear to explain the insufficient smoothness at the aggregate level.

# A Appendix: Numerical Procedures

Define the marginal utility of money (price of consumption) $p(x_t)$ by

$$p(x_t) = U'(f(x_t)) \tag{17}$$

or equivalently

$$c_t = f(x_t) = U'^{-1}(p(x_t)) \tag{18}$$

We seek the solution to the functional equation

$$p(x) = MAX[U'(x), \zeta(x)] \tag{19}$$

where the second argument on the right hand side is defined by

$$\begin{aligned} &\beta \int_\eta \int_g \int_y (1+r)(\exp(g\eta))^{-\rho} \\ &p\{(1+r) * (\exp(-g\eta))(x - U^{'-1}(p(x))) + y\} dY(y) dG(g) dN(\eta) \end{aligned} \tag{20}$$

Ten policy functions (one for each aggregate state) are defined by:

$$\begin{aligned} p(x,i) \quad = \quad & \max[U'(x), \beta \sum_j \sum_k \sum_l \pi_{ij}\pi_k\pi_l(1+r) \\ & (G_j N_l)^{-\rho} * p\{(1+r)(G_j N_l)^{-1} \\ & *(x - U'^{-1}(p(x,i))) + U_k, j)] \end{aligned} \tag{21}$$

We assume that each shock can be well described by a ten point discrete Markov process that approximates the Normal distribution, thus $\pi_{ij}, \pi_l$, and $\pi_k$ are transition probabilities associated with $G_t$, $N_t$ and $U_t$ respectively. We discretize the state variable $x$ by dividing it into 100 equidistant grid points. Starting from an initial guess for the policy function on the right hand side, we update the function using the above functional equation until convergence, the convergence criterion being a difference of six decimal points between a guess and its update at all grid points. Whenever the need arises to evaluate a candidate policy function in between grid points, we use an interpolation scheme such as cubic splines.

An additional complexity in the AR(1) case involves the transition probabilities for the common shock. Given the autoregression's Markov structure, knowing the current state contains information about next period's state that is used to compute expectations. The transition probabilities are set identical to the transition probabilities of the true underlying autoregressive process.[25] We numerically solve for the transition probabilities $\pi_{ij}$ of moving from interval $i$ to interval $j$ set to be identical to the transition probabilities from interval to interval of the underlying normal autoregressive process for aggregate income growth. The aggregate shock is approximated using $\{\mu_g + \vartheta z_i\}_{i=1}^{i=10}$ where $\vartheta = \frac{\sigma_\varepsilon}{\sqrt{1-\phi^2}}$. From the properties of the normal distribution of the error term perturbing the aggregate shock, we have

$$\begin{aligned} \pi_{ij} &= \Pr(\vartheta z_j \geq g_t - \mu_g \geq \vartheta z_{j-1} | \vartheta z_i \geq g_t - \mu_g \geq \vartheta z_{i-1}) = \\ & \frac{1}{\vartheta\sqrt{2\pi}} \int_{\vartheta z_{i-1}}^{\vartheta z_i} \exp(\frac{-x^2}{2\vartheta^2})\{\Phi(\frac{\vartheta z_j - \phi x}{\sigma}) - \Phi(\frac{\vartheta z_{j-1} - \phi x}{\sigma})\}dx \end{aligned} \tag{22}$$

For any given $\{\sigma, \phi\}$, this integral can be calculated directly using GAUSS routines that approximate the cumulative normal ($\Phi$).

The optimal individual policy function under incomplete information is obtained by the following functional equations:

$$\begin{aligned} p(x,i) &= \max[\lambda(x), \beta \sum_j \pi_{ij} \gamma_{ij}^{\rho} \\ & * p\{[1 + \gamma_{ij}(1+r)(x - \lambda^{-1}(p(x,i))], j\}] \end{aligned} \tag{23}$$

where $\beta$ is the discount factor, $\gamma_{ij} = \exp(-Y_{it+1}/Y_{it})$ and $\pi_{ij}$ is the probability from income state $i$ given that income state $j$ has occurred.

# References


[1] Abowd, John and David Card. 1989. "On the Covariance Structure of Earnings and Hours Changes" *Econometrica* 57: 411-45.

[2] Attanasio, Orazio and Martin Browning. 1995 "Consumption Over the Life Cycle and Over the Business Cycle." *American Economic Review* 85(5): 1118-37.

[3] Attanasio, Orazio and Guglielmo Weber. 1993. "Consumption Growth, the Interest Rate and Aggregation." *Review of Economic Studies* 60: 631-49.

[4] Attanasio, Orazio and Guglielmo Weber. 1995. "Is Consumption Growth Consistent with Intertemporal Optimization? Evidence from the Consumer Expenditure Survey." *Journal of Political Economy* 103(6): 1121-57.

[5] Beaudry, Paul, and Eric van Wincoop 1996. "The Intertemporal Elasticity of Substitution: An Exploration Using a U.S. Panel of States." *Economica* 63: 251.

[6] Blinder, Alan and Angus Deaton.1985. "The Time Series Consumption Function Revisited." *Brookings Paper on Economic Activity* 465-521.

[7] Bacchetta,Philippe, and Stefan Gerlach 1997. "Consumption and Credit Constraints: International Evidence." *Journal of Monetary Economics* 40(2): 207-38.

[8] Campbell, John Y., and Deaton Angus. 1989. "Why is consumption so smooth?" *Review of Economic Studies* 56, 357-74.

[9] Campbell, John Y., and N. Gregory Mankiw, 1989."Consumption, Income and Interest Rates: Reinterpreting the Time Series Evidence', in Olivier J. Blanchard and Stanley Fischer (Eds..), NBER *Macroeconomics Annual 1989*, Cambridge, Mass, MIT Press, 185-216.

[10] Campbell, John Y., and N. Gregory Mankiw, 1990. "Permanent Income, Current Income, and Consumption." *Journal of Business and Economic Statistics* 8: 256-79.

[11] Carroll, Christopher D., 1992. "The Buffer-Stock Theory of Saving: Some Macroeconomic Evidence." *Brookings Papers on Economic Activity* no. 2: 61-156.

[12] Carroll, Christopher D., 1997a. "Buffer Stock Saving and the Life Cycle / Permanent Income Hypothesis." *Quarterly Journal of Economics* CXII no. 1: 3-55.

[13] Carroll, Christopher D., 1997b. "Death to the Loglinearized Euler Equation! (And Very Poor Health to the Second-Order Approximation)." NBER Working Paper No. 6298.

[14] Carroll, Christopher and Andrew Samwick. 1997. "The Nature of Precautionary Wealth." *Journal of Monetary Economics*, 40(1).

[15] Carroll, Christopher and Andrew Samwick. 1998. "How important is precautionary saving?" *Review of Economics and Statistics* 80(3): 410-19.

[16] Christiano, Lawrence, Eichenbaum Martin and Marshall David. 1991. "The Permanent Income Hypothesis Revisited." *Econometrica 59: 371-396.*

[17] Deaton, Angus. 1987."Life-Cycle models of consumption: Is the evidence consistent with the theory?" in Truman F Bewley (Ed..) *Advances in Econometrics*, *Fifth World Congress*, Vol. 2, Cambridge and New York. Cambridge University Press, 121-48.

[18] Deaton, Angus.1991. "Saving and Liquidity Constraints." *Econometrica* 59(5): 1221-48.

[19] Deaton, Angus. 1992. "Understanding Consumption." Clarendon Press, Oxford.

[20] Deaton, Angus, and Guy Laroque. 1992. "On the Behavior of Commodity Prices." *Review of Economic Studies* 59: 1-23.

[21] Eichenbaum, Martin S., Lars Peter Hansen and Kenneth J. Singleton, 1988. "A Time Series Analysis of Representative Agent Models of Consumption and Leisure Choice Under Uncertainty." *Quarterly Journal of Economics* February, 51-77.

[22] Ermini, Luigi. 1993. "Effects of Transitory Consumption and Temporal Aggregation on the Permanent Income Hypothesis." *Review of Economics and Statistics* 75: 736-39.

[23] Ermini, Luigi. 1989. "Some New Evidence on the Timing of Consumption Decisions and on Their Generating Process." *Review of Economics and Statistics* 71: 643:650.

[24] Flavin, Marjorie. 1981."The Adjustment of Consumption to Changing Expectations About Future Income." *Journal of Political Economy* 89: 974-1009.

[25] Friedman, Milton. 1957. *A Theory of the Consumption Function*. Princeton, NJ Princeton University Press.

[26] Fuhrer, Jeffrey. 1999. "An Optimizing Model for Monetary Policy Analysis: Can Habit Formation Help?" Manuscript, Federal Reserve Bank of Boston.

[27] Galí, Jordi. 1991. "Budget Constraints and Time Series Evidence on Consumption." *The American Economic Review* 81(5): 1238-53.

[28] Gourinchas P., and Parker J., 1996. "Consumption over the Life Cycle." MIT mimeo.

[29] Hall, Robert. 1978."Stochastic Implications of the life cycle-permanent income hypothesis: theory and evidence." *Journal of Political Economy* 96: 971-87.

[30] Heaton John. 1993. "The Interaction between Time-Nonseparable Preferences and Time Aggregation" *Econometrica* 61: 353-85.

[31] Heaton John, and Deborah Lucas. 1996. "Evaluating the Effects of Incomplete Markets on Risk Sharing and Asset Pricing." *Journal of Political Economy* 104: 443-487.

[32] Heaton John, and Deborah Lucas. 1997. "Market Frictions, Savings Behavior, and Portfolio Choice." *Macroeconomic Dynamics* 1: 76-101.

[33] Kimball, Miles S. 1990. "Precautionary saving in the small and in the large." *Econometrica* 58: 53-73.

[34] Laibson, David, Andrea Repetto, and Jeremy Tobacman. 1998. "Self Controll and Saving for Retirement." *Brookings Papers on Economic Activity* 1: 91-196.

[35] Ludvigson, Sydney and Alexander Michaelides. 1999. "Can Buffer Stock Saving Explain the Consumption Excesses?" Federal Reserve Bank of New York Working Paper.

[36] Ludvigson, Sydney and Christina H. Paxson, 1999 "Approximation Bias in Linearized Euler Equations." NBER Working Paper No.T0236.

[37] Ludvigson Sydney. Forthcoming. "Consumption and Credit: A Model of Time Varying Liquidity Constraints." *Review of Economics and Statistics.*

[38] MaCurdy, T. E. 1981. "The use of time series processes to model the error structure of earnings in longitudinal data analysis." *Journal of Econometrics.* 18: 83-114.

[39] Modigliani, Franco and Richard, Brumberg. 1954. "Utility analysis and the consumption function: an interpretation of cross-section data." in Kenneth K. Kurihara (Ed..) *Post-Keynesian Economics*, New Brunswick, NJ, Rutgers University Press 388-36.

[40] Modigliani, Franco and Richard Brumberg. 1979. "Utility analysis and the consumption function: an attempt at integration." in Andrew Abel (Ed..) *The collected papers of Franco Modigliani*, Vol. 2, Cambridge, Mass. MIT Press 128-97.

[41] Pishcke Jörn-Steffen, 1995. "Individual Income, Incomplete Information and Aggregate Consumption." *Econometrica* 63, 4: 805-40.

[42] Quah, Danny. 1990. "Permanent and transitory movements in labor income: an explanation for 'excess smoothness' in consumption." *Journal of Political Economy* 98: 449-75.

[43] Wilcox, David, 1992. "The Construction of U.S. Consumption Data: Some Facts and Their Implications for Empirical Work." *American Economic Review* 82, 4: 922-41.

# Notes

[1]Friedman (1957) was also an important contributor to this literature, suggesting that individuals take future income into consideration when making consumption decisions today. In contrast to the modern-day PIH, however, he assumed that people discounted future income at a very high rate, making it closer to a buffer stock model than the modern day version of Flavin (1981).

[2]Note that the important insight of Quah (1990), that individuals may be better able than econometricians to distinguish short-run from long-run innovations to their income, cannot resolve the excess smoothness puzzle laid out in Campbell and Deaton (1989). These authours show that –in the context of the PIH– excess sensitivity and excess smoothness are the same phenomena. In addition, Campbell (1987) demonstrates that superior information of the type emphasized by Quah will show up in households' saving behavior, and using this information allows the econometrician to control for the agent's private information when predicting income. Since excess sensitivity is well established, and controlling for saving does not eliminate it (see Campbell and Deaton 1989), the observed smoothness of consumption cannot be explained by superior information on the part of permanent income consumers. See Deaton (1992) for further discussion.

[3]Ludvigson (forthcoming) and Bacchetta and Gerlach (1997) document another kind of excess sensitivity: the correlation between consumption growth and predictable changes in consumer credit. Although we do not explore these findings here, Ludvigson finds that a buffer-stock model with time-varying liquidity constraints can replicate such a correlation.

[4]In a more recent paper, Fuhrer (1999) argues that modifying the PIH to allow for habit formation may improve its quantitative performance by imparting a motive to consumers to smooth the change in consumption.

[5]A vast literature has appeared that examines and extends the implications of the standard buffer-stock model of Deaton (1991) or Carroll (1992, 1997a). See for example, Carroll and Samwick (1997, 1998); Heaton and Lucas (1996, 1997); Hubbard, Skinner, and Zeldes (1995); Gourinchas-Parker (1996); Laibson et. al. (1998); Ludvigson (forthcoming).

[6]Consistent with this finding, several papers using aggregate data find no evidence of any important nonseparability in preferences between consumption and labor supply, and controlling for these labor supply indicators does not eliminate the excess sensitivity of consumption growth to expected income growth (see Eichenbaum, Hansen and Singleton [1988]; Campbell and Mankiw [1990]; Beaudry and van Wincoop [1996]).

[7]Similarly, Carroll (1997b) and Ludvigson and Paxson (1999) find that higher order moments of consumption growth, in addition to the second moment typically designated as 'the precautionary term,' may be important omitted variables in linearized Euler equations.

[8] Pischke (1995) estimates a linear model using the Survey of Income and Program Participation (SIPP) at quarterly frequency.

[9] The coefficient of relative prudence is defined by Kimball (1990) as $\frac{-U'''(C_t)C_t}{U''(C_t)}$. Note that borrowing restrictions may induce a form of prudence (convexity in the marginal utility of consumption) even if preferences exhibit no prudence (e.g., quadratic preferences). See Deaton (1992).

[10] This form for the Euler equation was first derived in Deaton (1991).

[11] It can be shown that $\ln(\frac{1}{N}\sum_{i=1}^{N} Y_{it}) - \ln(\frac{1}{N}\sum_{i=1}^{N} Y_{it-1}) = \ln G_t + .5\sigma_u^2$.

[12] Carroll uses $\{\sigma_n = \sigma_u = 0.1\}$. We deviate slightly from these values by using $\{\sigma_n = 0.08, \sigma_u = 0.1\}$ to be consistent with the earnings process specification in the incomplete information case discussed below. Using $\sigma_n = 0.1$ instead of $\sigma_n = 0.08$ did not change the conclusions from the simulations reported later in the paper.

[13] Ludvigson and Michaelides [1999] report several different selection criteria to evaluate the best ARMA process for aggregate labor income growth.

[14] The idiosyncratic transitory shocks, once accumulated, completely cancel each other out since the transitory component is white noise. Accordingly, we keep the standard deviation of this component the same at both quarterly and annual frequency. This procedure follows Carroll and Samwick (1997) who show that, for the income process in (8) (ignoring the aggregate component), the $d$-period variance of the log difference in income will be equal to $d\sigma_n^2 + 2\sigma_u^2$.

[15] See MaCurdy (1982), Abowd and Card (1989), and Pischke (1995), which find that $\psi$ is estimated around 0.44. The choice of .15 for $\sigma_\eta$ follows Deaton (1991). Although this value is lower than MaCurdy estimated, Deaton argues that this variance should be reduced from its estimated value which is likely inflated by substantial measurement error in recorded income. We alter this value in simulations reported below.

[16] It is straightforward to show that $\varsigma = \frac{(\phi\sigma_\varepsilon^2/(1-\phi^2)-\sigma_u^2)}{\sigma_\varepsilon^2/(1-\phi^2)+\sigma_n^2+2\sigma_u^2}$.

[17] We used several different procedures to find initial cash-on-hand-income ratio. In practice, the results are not sensitive to the initial asset-income ratio because $x_{it}$ converges to an invariant distribution after about 12 periods. This characteristic of buffer stock saving behavior has been documented elsewhere. See Deaton [1991], [1992]; and Carroll [1997].

[18] This is consistent with evidence from household income data showing that individual income growth is negatively serially correlated; see Abowd and Card (1989).

[19] Labor income is defined as wages and salaries plus other labor income minus personal contributions for social insurance minus taxes. Taxes is defined as (wages and salaries/ (wages and salaries + proprietors income with IVA and Ccadj + rental income + personal dividends + personal interest income))*personal tax and non tax payments. This measure is deflated by the PCE chain-type price deflator.

[20] The PIH is formulated in levels, rather than in log levels. It relates changes in the level of consumption to changes in the level of labor income given by: $\Delta C_t = A\left(\frac{1}{1+r}\right)\varepsilon_t$, where income has a Wold representation $\Delta Y_t = A(L)\varepsilon_t$. For the purposes of providing a rough benchmark, we assume the process for the first difference in aggregate income can be described by the process for log changes used above, so that the smoothness ratio in this case is the standard deviation of aggregate consumption changes to that of aggregate income changes.

[21] This may be partly a result of the fact that the typical household in our sample is constrained about 35 percent of the time.

[22] If the original process is IMA(1,1), then the temporally aggregated series will also be IMA(1,1) (Ermini, 1989).

[23] In practice, time-averaging has not been found to explain excess sensitivity in aggregate data. Time-averaging problems induce spurious correlations for adjacent observations of a series that has been first-differenced: there is no overlap between differences two or more periods apart. Researchers have instrumented for income growth using instruments that have been lagged at least two periods to avoid a spurious finding of excess sensitivity. Excess sensitivity typically remains in tests which use instruments lagged at least two periods (for example, Campbell and Mankiw [1989]; Deaton [1992]; Ludvigson, forthcoming).

[24] Comparing this estimate of excess sensitivity with that from the *quarterly* model with incomplete information, it may appear that the model with annual averages generates less excess sensitivity than the quarterly model without averaging. This is not the case, however, since the standard error of the excess sensitivity coefficient computed from the averaged data is more than twice as large as that computed from the non-averaged data. Thus the point estimate of the latter is well within the 95% confidence interval of the point estimate of the former.

[25] See Deaton (1991) and Deaton-Laroque (1995) for a lengthier analysis.

**Table 1**

*Stylized Facts of U.S. Aggregate Consumption and Labor Income Data*

| Annual Data | Relative Smoothness | Excess Sensitivity |
|---|---|---|
| $\Delta C_t/C_{t-1}$ | .48 | .17* |
| $\Delta C_t^{ND}/C_{t-1}^{ND}$ | .61 | .18* |
| $\Delta C_t^{S}/C_{t-1}^{S}$ | .43 | .17* |
| **Quarterly Data** | **Relative Smoothness** | **Excess Sensitivity** |
| $\Delta C_t/C_{t-1}$ | .47 | .16* |
| $\Delta C_t^{ND}/C_{t-1}^{ND}$ | .68 | .16* |
| $\Delta C_t^{S}/C_{t-1}^{S}$ | .46 | .15* |

Notes: Sample:1947:1-1997:4. *statistically significant at the 5% level. $\Delta C_t/C_{t-1}$ denotes nondurables and services consumption growth less shoes and clothing; $\Delta C_t^{ND}/C_{t-1}^{ND}$ is nondurables consumption growth less shoes and clothing, and $\Delta C_t^{S}/C_{t-1}^{S}$ is services growth. Income is real after tax per capita labor income growth (see Ludvigson and Michaelides [1999] for details on data definitions). Relative smoothness is the ratio of the standard deviation of consumption growth to the standard deviation of labor income growth. Excess sensitivity is the OLS coefficient of consumption growth on lagged labor income growth.

**Table 2**

*Complete Information, Annual and Quarterly Models*

*Relative Smoothness and Excess Sensitivity*

| $\Delta \ln Y_t =$ | $\sigma_u = .07, \sigma_n = .05$ | $\sigma_u = .07, \sigma_n = .05$ | $\sigma_u = .1, \sigma_n = .08$ | $\sigma_u = .1, \sigma_n = .08$ |
|---|---|---|---|---|
| *i.i.d.* | $r = .02$ | $r = .03$ | $r = .02$ | $r = .03$ |
| $\rho = 1$ | .994, .004 | .993, .003 | .987, 0.00 | .984, 0.00 |
| $\rho = 2$ | .989, .001 | .989, .011 | .982, 0.00 | .977, .010 |
| PIH | 1.00, .000 | 1.00, .000 | 1.00, .000 | 1.00, 0.00 |
| $\Delta \ln Y_t =$ | $\sigma_u = .07, \sigma_n = .025$ | $\sigma_u = .07, \sigma_n = .025$ | $\sigma_u = .1, \sigma_n = .04$ | $\sigma_u = .1, \sigma_n = .04$ |
| AR(1) | $r = .005$ | $r = .0075$ | $r = .005$ | $r = .0075$ |
| $\rho = 1$ | 1.06, .082 | 1.07, .083 | 1.06, .051 | 1.07, .056 |
| $\rho = 2$ | 1.09, .057 | 1.09, .049 | 1.08, .036 | 1.08, .016 |
| PIH | 1.26, .000 | 1.25, .000 | 1.26, .000 | 1.25 .000 |

Notes: $\Delta \ln Y_t$ is the aggregate income growth process; the model with i.i.d. growth is calibrated at annual frequency; the model with AR(1) growth is calibrated at quarterly frequency. The first number in each cell is the average excess smoothness ratio; the second number is the average excess sensitivity parameter. The AR parameter, $\phi$, is set equal to 0.23. The rows labeled PIH give the smoothness ratios and sensitivity parameters that would be implied by a representative agent version of the PIH, where the representative agent receives the aggregate, i.i.d. process for the first difference in income.

**Table 3**

*Incomplete Information, Annual and Quarterly Models*

*Relative Smoothness and Excess Sensitivity*

| $\Delta \ln Y_t =$ | $\sigma_u = .07, \sigma_n = .05$ | $\sigma_u = .07, \sigma_n = .05$ | $\sigma_u = .1, \sigma_n = .08$ | $\sigma_u = .1, \sigma_n = .08$ |
|---|---|---|---|---|
| *i.i.d.* | $r = .02$ | $r = .03$ | $r = .02$ | $r = .03$ |
| $\rho = 1$ | .964, .047 | .944, .090 | .921, .114*** | .894, .128** |
| $\rho = 2$ | .917, .110*** | .902, .143** | .854, .168* | .835, .184* |
| PIH | 1.00, 0.00 | 1.00, 0.00 | 1.00, 0.00 | 1.00, 0.00 |
| $\Delta \ln Y_t =$ | $\sigma_u = .07, \sigma_n = .025$ | $\sigma_u = .07, \sigma_n = .025$ | $\sigma_u = .1, \sigma_n = .04$ | $\sigma_u = .1, \sigma_n = .04$ |
| AR(1) | $r = .005$ | $r = .0075$ | $r = .005$ | $r = .0075$ |
| $\rho = 1$ | .928, .365* | .923, .401* | .904, .381* | .894, .407* |
| $\rho = 2$ | .905, .433* | .894, .437* | .837, .415* | .803, .404* |
| PIH | 1.26, .000 | 1.25, .000 | 1.26, .000 | 1.26, .000 |

Notes: See Table 2. *statistically significant at the 1% or better level; **statistically significant at the 5% level. ***statistically significant at the 10% level. The AR parameter, $\phi$, is set equal to 0.23. The rows labeled PIH give the smoothness ratios and sensitivity parameters that would be implied by a representative agent version of the PIH, where the representative agent receives the aggregate, i.i.d. process for the first difference in income.

Figure 1
Complete Information Policy Functions
AR(1) Agg Growth

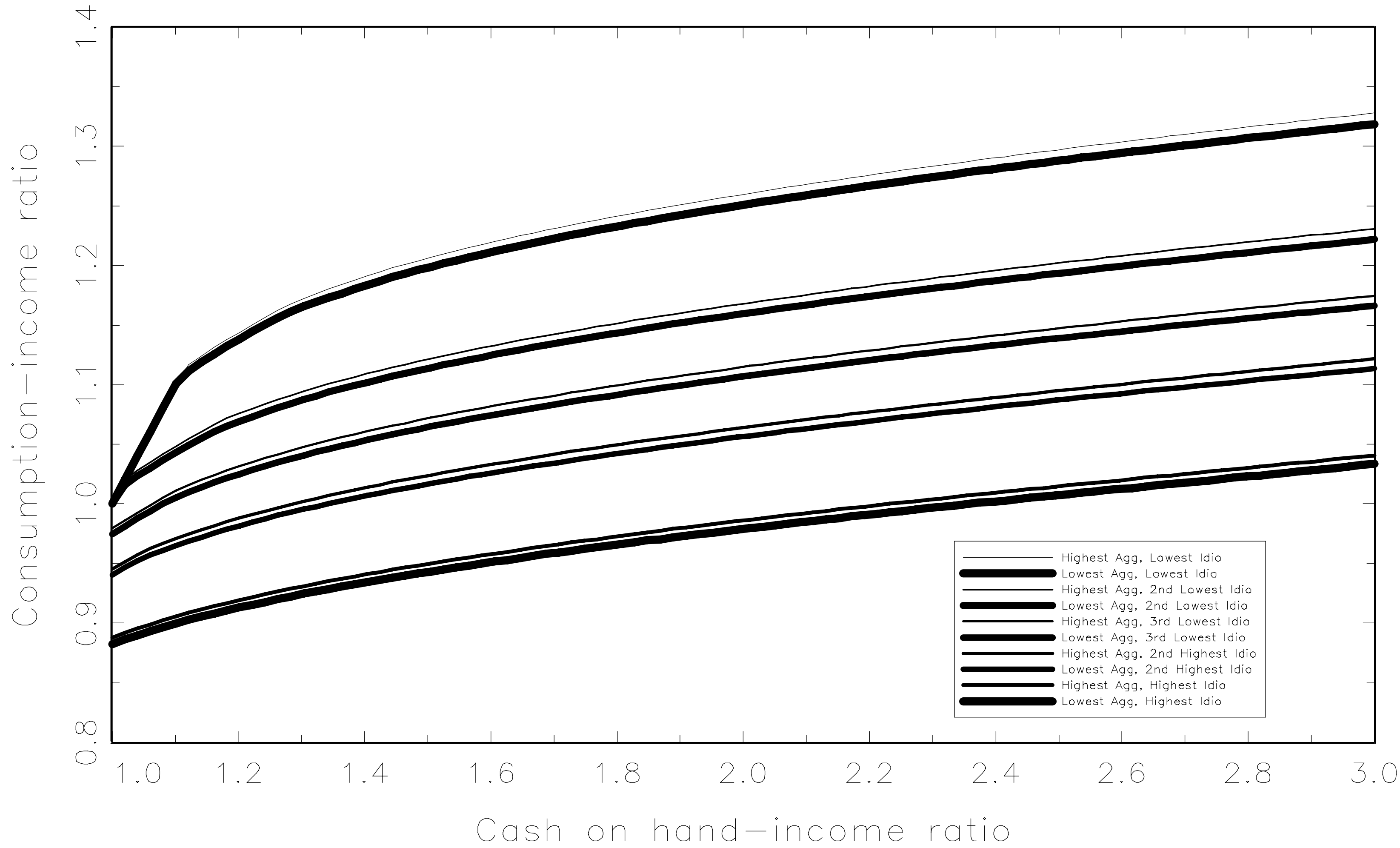
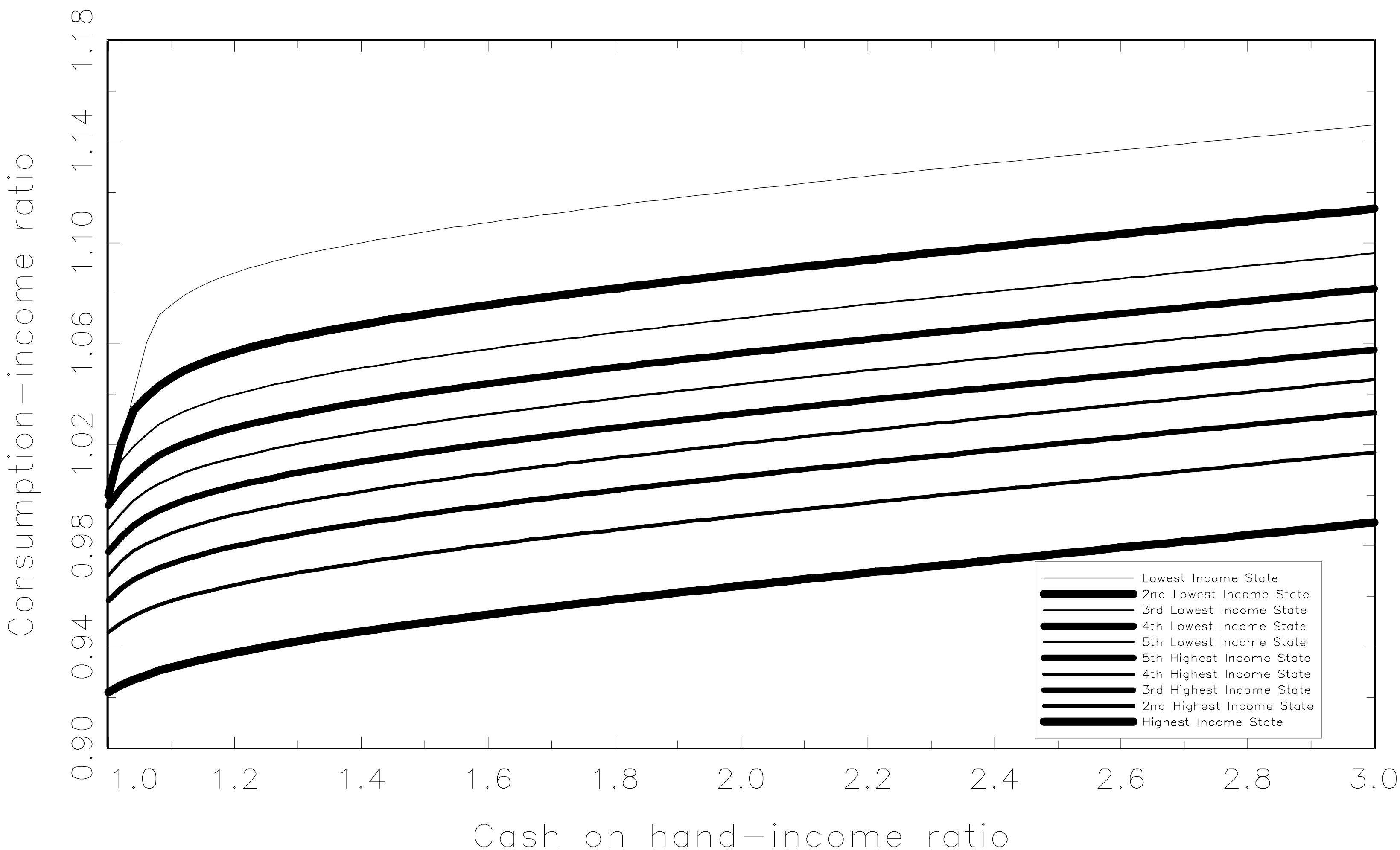


Figure 2
Incomplete Information Policy Functions
AR(1) Agg Growth



## SELECTED RECENT PUBLICATIONS


Bertaut, C. and Haliassos, M,. "Precautionary Portfolio Behavior from a Life - Cycle Perspective", *Journal of Economic Dynamics and Control,* 21, 1511-1542, 1997).

Caporale, G. and Pittis, N. "Causality and Forecasting in Incomplete Systems", *Journal of Forecasting*, 1997, 16, 6, 425-437.

Caporale, G. and Pittis, N. "Efficient estimation of cointegrated vectors and testing for causality in vector autoregressions: A survey of the theoretical literature", *Journal of Economic Surveys*, forthcoming.

Caporale, G. and Pittis, N. "Unit root testing using covariates: Some theory and evidence", *Oxford Bulletin of Economics and Statistics*, forthcoming.

Caporale, W., Hassapis, C. and Pittis, N. "Unit Roots and Long Run Causality: Investigating the Relationship between Output, Money and Interest Rates". *Economic Modeling*, 15(1), 91-112, January 1998.

Clerides, K., S. "Is Learning-by-Exporting Important? Micro-Dynamic Evidence from Colombia, Morocco, and Mexico." *Quarterly Journal of Economics* 113(3), pp. 903-947, August 1998, (with Lach and J.R. Tybout).

Cukierman, A., Kalaitzidakis, P., Summers, L. and Webb, S. "Central Bank Independence, Growth, Investment, and Real Rates", Reprinted in Sylvester Eijffinger (ed), *Independent Central Banks and Economic Performance,* Edward Elgar, 1997, 416-461.

Eicher, Th. and Kalaitzidakis, P. "The Human Capital Dimension to Foreign Direct Investment: Training, Adverse Selection and Firm Location". In Bjarne Jensen and Kar-yiu Wong (eds), *Dynamics,Economic Growth, and International Trade,* The University of Michigan Press, 1997, 337-364.

Gatsios, K., Hatzipanayotou, P. and Michael, M. S. "International Migration, the Provision of Public Good and Welfare", *Journal of Development Economics*, 60/2, 561-577, 1999.

Haliassos, M. "On Perfect Foresight Models of a Stochastic World", *Economic Journal*, 104, 477-491, 1994.

Haliassos, M. and Bertaut, C., "Why Do So Few Hold Stocks?", *The Economic Journal,* 105, 1110- 1129, 1995.

Haliassos, M. and Tobin, J. "The Macroeconomics of Government Finance", reprinted in J. Tobin, *Essays in Economics,* Vol. 4, Cambridge: MIT Press, 1996.

Hassapis, C., Pittis, N. and Prodromidis, K. "Unit Roots and Granger Causality in the EMS Interest Rates: The German Dominance Hypothesis Revisited", *Journal of International Money and Finance*, pp. 47-73, 1999.

Hassapis, C., Kalyvitis, S., and Pittis, N. "Cointegration and Joint Efficiency of International Commodity Markets", *The Quarterly Review of Economics and Finance,* Vol 39, pp. 213-231, 1999.

Hassapis, C., Pittis, N., and Prodromides, K. “EMS Interest Rates: The German Dominance Hypothesis or Else?” in *European Union at the Crossroads: A Critical Analysis of Monetary Union and Enlargement*, Aldershot, UK., Chapter 3, pp. 32-54, 1998. Edward Elgar Publishing Limited.

Hatzipanayotou, P. and Michael, M. S. "General Equilibrium Effects of Import Constraints Under Variable Labor Supply, Public Goods and Income Taxes", *Economica*, 66, 389-401, 1999.

Hatzipanayotou, P. and Michael, M. S. “Public Good Production, Nontraded Goods and Trade Restriction”, *Southern Economic Journal,* 63, 4, 1100-1107, 1997.

Hatzipanayotou, P. and Michael, M. S. "Real Exchange Rate Effects of Fiscal Expansion Under Trade Restrictions", *Canadian Journal of Economics,* 30-1, 42-56, 1997.

Kalaitzidakis, P. "On-the-job Training Under Firm-Specific Innovations and Worker Heterogeneity", *Industrial Relations,* 36, 371-390, July 1997.

Kalaitzidakis, P., Mamuneas, Th. and Stengos, Th. “European Economics: An Analysis Based on Publications in Core Journals*.” European Economic Review*,1999.

Lyssiotou, P., Pashardes, P. and Stengos, Th. “Testing the Rank of Engel Curves with Endogenous Expenditure”, *Economics Letters,* 64, 1999, 61-65.

Lyssiotou, P., Pashardes, P. and Stengos, Th. "Preference Heterogeneity and the Rank of Demand Systems", *Journal of Business and Economic Statistics*, Vol 17, No 2, April 1999, 248-252.

Lyssiotou, Panayiota, "Comparison of Alternative Tax and Transfer Treatment of Children using Adult Equivalence Scales", *Review of Income and Wealth*, Series 43, No. 1 March 1997, 105-117.

Mamuneas, T.P. (with Demetriades P.). “Intertemporal Output and Employment Effects of Public Infrastructure Capital: Evidence from 12 OECD Economies”, *Economic Journal,* forthcoming.

Mamuneas T.P. (with Kalaitzidakis P. and Stengos T.). “A Nonlinear Sensitivity Analysis of Cross-Country Growth Regressions”, *Canadian Journal of Economics,* forthcoming.

Mamouneas T.P. (with Bougheas S. and Demetriades P.).”I΄nfrastructure, Specialization and Economic Growth”, *Canadian Journal of Economics*, forthcoming.

Mamuneas, Theofanis P. “Spillovers from Publicly – Financed R&D Capital in High-Tech Industries”, *International Journal of Industrial Organization,* 17(2), 215-239, 1999.

Mamuneas, T. P. (with Nadiri, M.I.). “R&D Tax Incentives and Manufacturing-Sector R&D Expenditures”, in *Borderline Case: Interntational Tax Policy, Corporate Research and Development, and Investment*, James Poterba (ed.), National Academy Press, Washington D.C., 1997. Reprinted in *Chemtech*, 28(9), 1998.

Michaelides, A. and Ng, S. "Estimating the Rational Expectations Model of Speculative Storage: A Monte Carlo Comparison of three Simulation Estimators", *Journal of Econometrics,* forthcoming.

Pashardes, Panos. "Equivalence Scales in a Rank-3 Demand System", *Journal of Public Economics*, 58, 143-158, 1995.

Pashardes, Panos. "Bias in Estimating Equivalence Scales from Grouped Data", *Journal of Income Distribution*, Special Issue: Symposium on Equivalence Scales, 4, 253-264, 1995.

Pashardes, Panos. "Abstention and Aggregation in Consumer Demand", *Oxford Economic Papers*, 46, 502-518, 1994 (with V. Fry).

Pashardes, Panos. "Bias in Estimation of the Almost Ideal Demand System with the Stone Index
Approximation", *Economic Journal*, 103, 908-916, 1993.

Pashardes, Panos. "What Do We Learn About Consumer Demand Patterns From Micro-Data?", *American Economic Review*, 83, 570-597, 1993 (with R. Blundell and G. Weber).

Pashardes, Panos. "Non-Linearities and Equivalence Scales", *The Economic Journal*, 103, 359-368, 1993 (with R. Dickens and V. Fry).

Spanos, Aris " Revisiting Date Mining: ´hunting´ with or without a license", forthcoming *Journal of Methodology,* July 2000.

Spanos, Aris. "On Modeling Heteroscedasticity: The Student's *t* and Elliptical Linear Regression Models", *Econometric Theory*, 10, 286-315, 1994.

Spanos, Aris. "On Normality and the Linear Regression Model", *Econometric Reviews,* 14, 195-203, 1995.

Spanos, Aris. "On Theory Testing in Econometrics: Modeling with nonexperimental Data", *Journal of Econometrics,* 67, 189-226, 1995.