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A DISCRETE-TIME CONSUMPTION-CAP MODEL UNDER DURABILITY OF GOODS, HABIT FORMATION AND TEMPORAL AGGREGATION

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Abstract

This paper addresses the empirical failure of the basic consumption-capital asset pricing (CCAP) model, by relaxing three of its assumptions simultaneously: separability of the utility function; non-durability of goods; no temporal aggregation effects. The paper finds that durability seems to prevail over habit formation, both with and without temporal aggregation effects, though with the available data it is arguably quite difficult to distinguish between the two phenomena. The paper also argues that monthly data reject the continuous-time version of the model.

Keywords: consumption, durability, habit formation, temporal aggregation
JEL Classification: no. D91, G12

A Discrete-Time Consumption-CAP Model under Durability of Goods, Habit Formation and Temporal Aggregation

1. Introduction

This paper addresses the empirical failure of the basic consumption-capital asset pricing (CCAP) model in explaining the stochastic properties of monthly consumption data, by relaxing three of its assumptions simultaneously: separability of the utility function; non-durability of goods; no temporal aggregation effects (that is, the effects on the model structure of the possibility that consumers take decisions at intervals shorter than the interval of data observation). Previous work in this area is found in Phlips [1983], who allows only the possibility of either durability or habit formation, and no temporal aggregation (his model is tested with consumption data disaggregated over several commodity groups); in Ferson and Constantinides [1991] and in Brown, Constantinides and Ferson [1993], who restrict the model of durability and habit formation to one past lag only, neglect temporal aggregation effects, and test the model using the Generalized Method of Moments; in Heaton [1993], who examines the simultaneous relaxation of all three assumptions, but in a continuous-time framework. As the continuous-time modelling of agents behavior is argued to be inappropriate, the purpose of this paper is to examine the simultaneous relaxation of these three assumptions in a discrete-time framework.

The paper finds that the continuous-time model is rejected by monthly data; that the "rich" parametrization of durability and habit formation assumed by Heaton is rejected in favor of the more parsimonious parametrization of Phlips, both with and without consideration of temporal aggregation effects; that Ferson and Constantinides's conclusion that habit formation prevails over durability is reversed. The overall conclusion of the paper is that the possibility of distinguishing with the available data between geometrically decaying durability and geometrically decaying habit formation appears quite difficult; this suggests that either the durability model or the habit formation model should be substantially revised.

The paper is organized as follows. Section 2 describes the basic CCAP model; section 3 discusses various directions taken in the literature to improve the basic model; section 4 presents the discrete-time CCAP model with durability and habit formation; section 5 compares this model with previous work; section 6 derives the stochastic process of consumption implied by the CCAP model with durability and habit formation; section 7 presents the empirical results; section 8 discusses the effect of temporal aggregation; finally, section 9 provides some concluding remarks.

2. The Basic Model

Consider the standard "basic" consumption-capital asset pricing model or CCAP (Lucas [1978], Breeden [1979], Grossman and Shiller [1982]): at time t the representative consumer chooses an optimal consumption stream $\{C_{t+\tau}\}$ and an optimal portfolio $\{\alpha_{t+\tau}\}$ for $\tau \geq 0$ by maximizing the expected value of discounted future utilities of consumption, subject to the standard budget contraint. In symbols:

$$\max_{\{\alpha_{t+\tau},\, C_{t+\tau}\}} E_t \left[\sum_{\tau=0}^{\infty} \beta^{\tau} U(C_{t+\tau}) \right], \tag{1}$$

subject to

$$W_{t+1} = (W_t + Y_t - C_t)\, R_{t+1}^{T} \alpha_t , \tag{2}$$

where C is consumption expenditures, Y is labor income, W is wealth, R is a K-vector of total returns on assets (i.e. the rate of return plus one), α is a K-vector of asset shares (summing up to one), β is the rate of time preference, $U(.)$ is period-t utility of consumption, with positive and decreasing marginal utility. Notice that in (1) the Von Neumann-Morgenstern utility of consumption streams, $V(C_t, C_{t+1}, \ldots)$, is additive separable.

The first-order conditon (FOC), or Euler's condition, for the optimal consumption stream and the optimal portfolio is:

$$U'(C_t) = \beta E_t \left[U'(C_{t+1})\, R_{t+1} \right], \tag{3}$$

where U' is the marginal utility of consumption. This FOC - which holds for every asset - has a very simple intuitive interpretation: for a consumption decision to be optimal, an infinitesimal perturbation should leave the representative agent indifferent. Thus, the reduction of utility this period due to a dC_t reduction of consumption expenditures, $-U'(C_t)\,dC_t$, must be equal to the present value (at discount rate β) of the increase of utility next period due to the increase of consumption, $(R_{t+1}\,dC_t)$, derived from investing the saving dC_t in the asset with return R_{t+1}.

This FOC has two important implications. One is derived from applying (3) to the safe asset, obtaining an explicit representation of the stochastic process that generates consumption under the hypothesis that the model is true. This process will be called MGP for "Model Generating Process" [1]. The second implication is derived from applying (3) simultaneously to two assets (one of which could be the safe asset), obtaining the consumption-CAP relation that explains equity premia.

Regarding the MGP of consumption, for the safe asset with time-invariant return R_s (subscript s for safe), (3) becomes:

$$E_t\,U'(C_{t+1}) = (\beta R_s)^{-1}\,U'(C_t)\,. \qquad (4)$$

This is the same martingale relation for marginal utility of consumption derived by Hall [1978] in solving the representative agent's problem of choosing consumption streams only. Notice that in the absence of a wealth effect (i.e. the absence of W in the argument of the utility), decisions about consumption are completely separated from decisions about portfolio composition. In fact, (4) can also be derived from a problem similar to (1)-(2), where the representative agent allocates all the wealth in the safe asset only. Through simplifying assumptions (for instance, $R_s = \beta$) and first-order approximations of the marginal utility, the expectation equation (4) yields

1. Two additional definitions are useful: the DGP, or "Data Generating Process", which is the true unknown stochastic process that generates the actual data; the OGP, or "Observation Generating Process", which is the stochastic process that would generate the observed values of the variable of interest under the hypothesis that the model is true. The OGP may be different from the MGP due to temporal aggregation, seasonal adjustment procedures, measurement errors, differences of economic meaning for the variable of interest between theory and actual measured data. Most empirical work in macroeconomics usually assumes that the OGP coincides with the MGP.

the random walk model of consumption. This model is rejected with monthly, quarterly and annual data (among others, Flavin [1981], Hayashi [1982, 1985], Mankiw [1982], Ermini [1989, 1994]).

Regarding the CCAP equity premium relation, the FOC (3) implies for any two risky assets with returns R and R^* the following orthogonality condition:

$$E_t \left[U'(C_{t+1})\,(R_{t+1} - R^*_{t+1}) \right] = 0\,, \tag{5}$$

which can be directly tested with the Generalized Method of Moments (GMM) of Hansen [1982] (see also section 4). An identical relation holds in unconditional expectations, from which the CCAP relation is derived (Breeden [1979], Grossman and Shiller [1982]), of the form:

$$E(R) - R_s = A\,E(\frac{\Delta C}{C}\,R) \tag{6}$$

for all risky assets. A is the Arrow-Pratt measure of relative risk aversion. In some versions of the CCAP relation, the cross-correlation of consumption growth with asset returns is replaced with their variance, and the consumption growth is replaced with its level.

The CCAP relation (6) has a similarly simple intuitive interpretation. To hedge, a risk-averse representative agent clearly prefers an asset whose return is negatively correlated with consumption growth. Therefore, for the agent to choose an asset whose return is positively correlated with consumption growth, a higher premium must be returned; moreover, the greater the aversion to risk the higher the premium.

Although the CCAP model has a very attractive theoretical feature, as it explains equity premia with the co-movement of asset returns with consumption, it is systematically rejected by the evidence: not only is the martingale proposition for marginal utility rejected (in the usual version of the random walk model of consumption, as noted above), but the CCAP equity premium relation is also rejected. Among others, Mehra and Prescott (1985) point out that using long historical data on asset returns, equity premia and consumption growth, the implied coefficient of relative risk aversion A is estimated from (6) at around 150-200, too high to be considered plausible (see also Grossman, Melino and Shiller [1987] and

Ermini [1991]; see also the work of Mankiw and Zeldes [1990] with cross-sectional data and liquidity contrained agents). Using the GMM technology, Hansen and Singleton [1982] reject the orthogonality condition (5). Finally, Mankiw and Shapiro [1986] reject the CCAP equity premium relation against the classical CAP equity premium relation of financial economics that explains equity premia with co-movements of asset returns with the market return.

Incidentally, to appreciate the implication of the CCAP model failure, consider that this model is crucial to bridge macroeconomics with financial economics (the body of theories that explain asset prices on the basis of the behavior of financial markets only); this bridge is necessary if one wants to explain asset prices with macroeconomic fundamentals.

3. Directions of Improvement

The rejection of the basic version of the CCAP raises the obvious question of what can be wrong. To answer this question, economists have proceeded along three main directions of research. One direction claims that assets are not priced efficiently, and thus even if (6) may be theoretically correct, it does not describe the actual process of asset pricing. This school of thought has received considerable support from recent evidence against the martingale model for asset prices and against the conjecture of unpredictability of asset returns (see Fama and French [1988], Nelson and Kim [1990], Granger [1992], among others).

A second direction of research identifies the main cause of failure of the CCAP model in the representative agent assumption. The CCAP equity premium relation has been shown to hold in aggregation over agents under quite general conditions (for instance, Grossman and Shiller [1982]); however, it requires the fundamental assumption that all agents trade assets at all periods. It is the implausibility of this assumption that supports the search for a non-representative agent model of asset pricing. On the general issue of representative agent models, see Stoker [1993].

The third direction of research preserves the market efficiency of asset prices and the representative agent model, and identifies the cause of failure of the CCAP model in one or more of the many assumptions implicitly or explicitly imbedded into the basic model (1)-(2). A list of some of the assumptions whose relaxation has been examined in the literature includes: (i) complete markets and tradable assets (see, among others, Sheinkman [1989], Lucas [1991], Telmer [1991] for the implications of incomplete markets); (ii) no transactions costs (Aiyagari and Gertler [1991], He and Modest [1991], Luttmer [1991], Cochrane and Hansen [1992]); (iii) no liquidity constraints (Sheinkman and Weiss [1986], Zeldes [1989], He and Modest [1991). Other aspects of the empirical work on the CCAP model that have not been satisfactorily investigated concern the effects of seasonal adjustment procedures, and other data distortions.

This paper will address the failure of the basic CCAP model along the latter direction, relaxing the following three assumptions of the basic model simultaneously: *separability of the utility*, *non-durability of goods* and *no temporal aggregation effects*. Previous work in this same area is found in Phlips [1983], who relaxes separability by introducing habit formation, but allows only for either durability or habit formation (no temporal aggregation effects are considered); in Ferson and Constantinides [1991] and Brown, Constantinides and Ferson [1993], who distinguish between separability and non-durability in a discrete time framework, but disregard temporal aggregation[2]; and in Heaton [1983], who examines the simultaneous relaxation of all three assumptions, but in a continuous-time framework. This paper argues that continuous-time modelling of agents behavior is inappropriate; the purpose of this paper is thus to examine the simultaneous relaxation of these three assumptions in a discrete-time framework. Before discussing the contribution of this paper, consider each of the three assumptions in turn.

Regarding separability of the utility function, two important implications of this assumption on consumer behavior have been questioned in the literature (for a review see, among others, Deaton and Muellbauer [1980],

2. As the model of Brown, Constantinides and Ferson is the same as Ferson and Consantinides' [1991], replicated for a number of European countries, here reference will be made only to the latter work.

Phlips [1983]). The first implication is the independence of the marginal rate of intertemporal substitution on past consumption (equivalently, the implication is that the system of consumer preferences is cardinal rather than ordinal). The shorter is the true but unknown consumer decision interval, the more implausible is this implication; in fact, it may become untenable under the conjecture of continuous-time decisions. The second implication is that the Arrow-Pratt measure of relative risk aversion is identical to the (negative of the) elasticity of marginal substitution. This prevents the possibility of disentangling the attitude toward risk from the attitude toward intertemporal substitution. To overcome these two issues, non-separable utilities have been proposed in the literature; see particularly Epstein and Zin's [1989] recursive utility model, and Constantinides' [1990] habit formation model, which generalizes models already appeared in the literature (for example, Houthakker and Taylor [1970], Phlips [1972, 1983] for an application to consumption demand analysis). The habit formation model is the form of non-separability of the utility function also considered in Heaton [1993] and in this paper.

Regarding non-durability of goods, consider that the empirical failure of the basic CCAP model (which assumes that consumer goods depreciate entirely within the decision period) with US data is usually the result of tests conducted with the National Income and Product Account (NIPA) category of "non-durables". It is known, however, that this category includes expenditures for goods that last for up to *three* years. Thus, at quarterly decision intervals or less these expenditures ought to exhibit some degree of durability (see Ermini [1992] for estimates of durability rates). It is quite plausible then to consider durability as a possibile cause of the model's failure.

Finally, regarding temporal aggregation - i.e. the possibility that agents take decisions at intervals shorter than the interval of data observation - notice that the assumption of no temporal aggregation effects is equivalent to the assumption that the decision interval is identical to the interval of data observation. Apart from the arbitrariness of this commonly adopted assumption, it is interesting to note the contradiction implicit in those empirical works which assume no temporal aggregation effects and test the same model simultaneously with monthly, quarterly and annual data, thus implicitly assuming the representative agent making decisions simultaneously at monthly, quarterly and annual frequency.

One consequence of temporal aggregation is that the MGP - the process generating the variable of interest at the decision interval - is different from the OGP - the process that ought to be observed by the econometrician at the interval of observation if the hypothized model is true. For linear processes of the ARIMA type, the transformation of MGP into OGP caused by temporal aggregation is well known (see, for example, Working [1960], Tiao [1975], Weiss [1984], Ermini [1989]).

Under temporal aggregation, the continuous-time modelling of consumer decisions is as arbitrary as assuming no temporal aggregation effects at all. To explain, let m be the ratio of the observation interval over the decision interval. Then, the case of no temporal aggregation effects imposes the restriction $m = 1$, while a continuous-time model of consumption, when observed at monthly or quarterly or annual intervals, imposes the restriction $m = \infty$, which is as arbitrary as $m = 1$. Heaton's [1993] CCAP model with durability of goods and habit formation is a continuous-time model, and thus imposes the restriction $m = \infty$. This paper, instead, examines a discrete-time version of the same model, which allows m to vary between 1 and infinity. Note, however, that the purpose of this paper is not to evaluate the true value of m, but simply to evaluate the consequence on testing the MGP of consumption under the conjecture of m between 1 and ∞. Finally, in section 8 it will be argued that monthly evidence rejects Heaton's hypothesis of $m = \infty$.

4. The Habit-Formation Model with Durable Goods

Durability of goods entails that the representative consumer consumes a flow of services out of the current stock of purchased goods. As goods depreciate, the current flow of services provided by past expenditures can be expressed as

$$C_t^F = \sum_{j=0}^{\infty} \delta_j \, C_{t-j} \, , \tag{7}$$

where C is consumption expenditures, C^F is the amount of service provided by all past expenditures, and δ_j is the fraction (between zero and one) of goods purchased at time $t - j$ that still survives at time t.

Habit formation entails that period-t utility of consumption depends on the deviation of the current flow of services, C_t^F, from the current "bliss" level. The model suggests that this bliss value - called, perhaps inappropriately, subsistence level by Constantinides [1990] - is the accumulation of past consumption patterns which are formed into a habit of consumption. For example, if the representative consumer is used to a certain house size, moving into a smaller house may induce disutility. With the same notation of problem (1)-(2), the enlarged model now is:

$$\max_{\{\alpha_{t+\tau},\, C_{t+\tau}\}} = E_t \left[\sum_{\tau=0}^{\infty} \beta^{\tau}\, U\left(C_{t+\tau}^F - h \sum_{s=1}^{\infty} a_s\, C_{t+\tau-s}^F\right) \right], \tag{8}$$

subject to the durability law (7) and the budget constraint (2). The term $\sum_{s=1}^{\infty} a_s\, C_{t+\tau-s}^F$ measures the consumption habit formed at time $t + \tau$ as a consequence of previous levels of service flow; h is a non-negative parameter that calibrates the relative importance of period-$(t + \tau)$ flow of services with period-$(t + \tau)$ bliss value determined by habit.

For notational convenience, (8) can be rewritten as

$$\max_{\{\alpha_{t+\tau},\, C_{t+\tau}\}} = E_t \left[\sum_{\tau=0}^{\infty} \beta^{\tau}\, U(\overline{C}_{t+\tau}) \right], \tag{9}$$

with $\overline{C}$ expressed directly in terms of expenditures as

$$\overline{C}_t = C_t^F - h \sum_{s=0}^{\infty} a_s\, C_{t-s}^F \equiv \sum_{j=0}^{\infty} b_j\, C_{t-j}\,, \tag{10}$$

where b_j ($b_0 = 1$) are coefficients whose expressions in terms of δ_j, h and a_j are readily derivable from the definitions. With some algebra, the FOC of the model with durability and habit formation becomes

$$U'(\overline{C}_t) = E_t \left[\sum_{\tau=1}^{\infty} \beta^{\tau}\, U'(\overline{C}_{t+\tau})\, (b_{\tau-1} R_{t+1} - b_{\tau}) \right]. \tag{11}$$

This Euler's condition has a simple intuitive explanation, similar to the Euler's condition of the basic model. An infinitesimal reduction dC_t expenditures this period reduces current utility in the amount $U'(\overline{C}_t)\, dC_t$, and the utility in every future period in the amount $U'(\overline{C}_{t+\tau})\, b_\tau\, dC_t$, due to the decumulation $b_\tau\, dC_t$ of service flow and habit formation in the future. The investment of the saved income in the risky asset with return R_{t+1} correspondingly increases future utility by $U'(\overline{C}_{t+\tau})\, b_{\tau\text{-}1}\, R_{t+1}\, dC_t$. For optimality, the present value of the expected utility loss must equal the expected value of the utility gain. Note that for $b_\tau = 0$, $\tau \geq 1$, FOC (11) reduces to FOC (3) of the basic CCAP model.

5. Comparison with Previous Work

Regarding Ferson and Constantinides' [1991] model,

(i) they assume $b_\tau = 0$ for all $\tau \geq 2$, thus reducing the habit-service consumption flow, $\overline{C}_t$, to $C_t + b\, C_{t\text{-}1}$ only. They do not justify this assumption, but note that it makes their chosen estimation method (the Generalized Method of Moments, GMM, of Hansen [1982]) practical. They also note that previous literature has used the same assumption when using GMM (for example, Eichenbaum and Hansen [1990]).

(ii) as a consequence of this assumption, they cannot make any direct inference on the "inner" parameters of durability and separability, δ, a and h. At the most, they can only provide qualitative statement of the type: a positive b indicates that durability dominates habit formation; *vice versa* with a negative b.

(iii) they test the validity of the Euler's condition by testing the implied orthogonality condition. The GMM test of this condition has quite attractive properties, and has produced important results and insights; however, it presents some disadvantages that limit its usefulness to the investigation of only a limited number of empirical questions. First, the GMM test is only a test against nature: the orthogonality condition is either rejected or not rejected, but it cannot be tested against an alternative model; it thus does not provide any useful insight as to which direction the researcher should pursue to improve the model. Secondly, it is unsuitable to treat temporal aggregation effects directly and explicitly (which is probably why these are not considered by Ferson and Constantinides). Thirdly and most importantly, even if the non-rejection of the orthogonality condition is an important result *per se*, it does not provide any useful insight on the stochastic properties of the consumption model generating process, nor any insight on the extent of risk premia and their relation with consumption growth. In other words, the GMM test does not provide any usable characterization of the optimal solution of the consumer choice problem - characterization that for the case of the basic model is precisely given by the martingale proposition (4) and by the risk premium proposition (6).

Regarding Phlips [1983], he assumes $C_t^F = C_t$ in (10) and lets h be unrestricted: if h is negative durability prevails over habit formation; *vice versa* if h is positive. This parametrization of the durability/habit formation process is taken from Houthakker and Taylor [1970], and captures the idea that under durability past expenditures accumulate positively in the argument of the utility function, and thus the higher the accumulation the smaller the current expenditure; the opposite happens under habit formation. Phlips does not consider temporal aggregation effects.

Finally, Heaton [1993] assumes geometric processes for both durability and habit formation in a continuous-time framework, thus restricting the analysis of temporal aggregation effects to the case $m = \infty$. This paper, as described next, assumes the same geometric processes as Heaton's for durability and habit formation, but models consumer decisions in discrete time as in Ferson and Constantinides.

6. The Model Generating Process of Consumption

Under the assumption of geometric processes for durability and habit formation - i.e. $\delta_j = \delta^j$, and $a_j = a^j$, with some algebra one gets

$$b_j = \frac{\delta^j (\delta - a - ha) + ha^{j+1}}{\delta - a}; \qquad (12)$$

notice that no durability of goods ($\delta = 0$) implies $b_j = a^j$, and no habit formation (either $h = 0$ or $a = 0$) implies $b_j = \delta^j$. The FOC (11) becomes

$$U'(\overline{C}_t) = \frac{\delta - a - ha}{\delta(\delta - a)} \sum_{\tau=1}^{\infty} (\beta\delta)^{\tau} E_t\left[U'(\overline{C}_{t+\tau})(R_{t+1} - \delta)\right] + \frac{h}{\delta - a} \sum_{\tau=1}^{\infty} (\beta a)^{\tau} E_t\left[U'(\overline{C}_{t+\tau})(R_{t+1} - a)\right]. \qquad (13)$$

The derivation of the consumption model generating process from this FOC applied to the safe asset is the object of this paper. The derivation of the equity premium relation from the same FOC applied to a pair of assets will be the object of future work. In relation to the safe asset with time invariant return R_s, the FOC (13) becomes

$$U'(\overline{C}_t) = \frac{(\delta - a - ha)(R_s - \delta)}{\delta(\delta - a)} \sum_{\tau=1}^{\infty} (\beta\delta)^{\tau} E_t U'(\overline{C}_{t+\tau}) + \frac{h(R_s - a)}{\delta(\delta - a)} \sum_{\tau=1}^{\infty} (\beta a)^{\tau} E_t U'(\overline{C}_{t+\tau}) . \tag{14}$$

This expectations-difference equation has solution

$$E_t U'(\overline{C}_{t+\tau}) = (\beta R_s)^{-\tau} U'(\overline{C}_t) , \tag{15}$$

which is identical to the martingale proposition (4) of the basic model, but with expenditures C_t replaced by the habit-service flow $\overline{C}_t$. This relation thus generalizes Hall's model and the model of geometric durability of Mankiw [1982] (see also Hayashi [1985]). Under identical assumptions/simplifications to Hall's, one gets the random walk model of habit-service flow $\overline{C}_t$

$$\Delta\overline{C}_t = \varepsilon_t , \tag{16}$$

with $E_t\varepsilon_{t+\tau} = 0$ for all $\tau > 0$. Recalling the definition of $\overline{C}_t$, and the assumption of geometric processes for durability and habit formation, (16) can be expressed in terms of expenditures C_t as (possible drift not reported)

$$(1 - (1+h)aB)\, \Delta C_t = (1 - aB)(1 - \delta B)\, \varepsilon_t , \tag{17}$$

which shows that the MGP for changes of consumption expenditures is represented by an ARMA(1,2).

7. The Empirical Results

Provided that the parameters of an ARMA model can be estimated with sufficient precision, so can in principle the three "inner" parameters of the model, δ, a and h. This would permit to distinguish the relative strength of two phenomena of durability and habit formation precisely: in case of habit formation only ($\delta = 0$), the process becomes an ARMA(1,1); in case of durability only (either $h = 0$ or $a = 0$), the process becomes an ARMA(0,1); with no durability and no habit formation, the process becomes a random walk or ARMA(0,0).

However, given the parametrization of durability and habit formation chosen by Heaton [1993] and replicated here in (10), durability can be distinguished from habit formation only under the restriction of non-negative *h*. But *h* can be negative, in which case (10) can be given Phlips' interpretation of a positive accumulation of past expenditures as a sign of durability prevailing over habit formation. Heaton's rich parametrization would thus be reduced to the simpler parametrization of Phlips, and the ARMA(1,2) would be reduced to an ARMA(1,1) with negative *h*, and with the moving average coefficient identifiying the positive rate of accumulation *a* of past expenditures (durability). Thus, to the above list of possible empirical models, we must add the possibility of an ARMA(1,1) with negative *h*.

To capture these various possibilities, the following estimation strategy was chosen: (i) we start with estimating an ARMA(2,2) as the general model nesting all the possible cases listed above[3]; (ii) the unrestricted ARMA(1,2) is then tested against this ARMA(2,2) (if rejected, the whole model is rejected); (iii) if not rejected, the possibility of a common factor in the ARMA(1,2) is tested: if the common factor is rejected, the unrestricted ARMA(1,1) is tested against the ARMA(1,2); if the common factor is not rejected, the unrestricted ARMA(0,0) is tested against the ARMA(0,1) obtained by eliminating the common factor.

Using U.S. *per-capita* seasonally adjusted monthly consumption data of non-durables and services from the National Income and Product Account (from 1968-7 to 1988-6)[4], the ARMA(1,2) is not rejected against the

3. In principle, we should first estimate the ARMA(p, q) that satisfies the criterion of *data congruence* (parameter stability, homoskedasticity of residuals, etc.; see Hendry [1994] for a discussion), and then move from this congruent model toward the nested parametrizations of interest.

4. Source: Citibank database 1990. The consumption series is the sum, in Citibank notation, of *GMCN* 82 + *GMCS* 82. To obtain the *per-capita* value, this sum is multiplied by *GMYDP* 8 and divided by GMYDP82.

unrestricted ARMA(2,2), with a statistic $F(1,220) = 1.22$ (with P-value of [.2714]). The presence of a common factor in the unrestricted ARMA(1,2) is rejected with a statistic $\chi^2(1) = 17.5$ against a 5% critical value of 3.85; the ARMA(1,1) is not rejected against the ARMA(1,2), with $F(1,221) = 3.03$ [0.083]; finally, the ARMA(0,1) is rejected against this ARMA(1,1). The estimated ARMA(1,1) model is

$$(1 + 0.21\,B)\,\Delta C_t = 13.35 + \varepsilon_t - 0.068\,\varepsilon_{t-1}\,, \qquad (18)$$

from which $a = 0.068$ and $h = -4.18$. From the above discussion, we can conclude that monthly U.S. consumption seems to corroborate Phlips' simpler parametrization, indicating that durability prevails over habit-formation (negative h); this conclusion is also reached qualitatively by Heaton (he finds that adding habit formation to geometric durability improves the likelihood function only marginally), though his estimates of δ, h and a are quite different. Ferson and Constantinides, instead, interpret their GMM result as indicating that habit formation prevails over durability.

8. The Effect of Temporal Aggregation

The above conclusion is based on the absence of temporal aggregation effects (sampling ratio $m = 1$). To introduce these effects, consider that, as m increases, the stable autoregressive parameter ω in $(1 - \omega L)$ decreases at the rate ω^m (Weiss [1984]), while the second-order moving average parameter decreases even more rapidly (in practice goes to zero already with $m = 3$ (Tiao [1972])). Therefore, a value of $m \approx 3$-5 would suffice to reduce an ARMA(1,2) to the observed ARMA(1,1), and thus to corroborate the richer parametrization (17). However, as in (18) the estimated ω^m is negative (= -0.21), so is necessarily the original ω. It follows that the original h is also negative, thus supporting again the conjecture that durability prevails over habit formation even under temporal aggregation.

Regarding Heaton's conjecture of $m = \infty$ (continuous modelling of agents' behavior), recall the important result by Tiao [1972] (see also Working [1960] and Weiss [1984]) whereby under $m = \infty$ (in practice, m = 10 suffices) any ARIMA(p, d, q) tends to the limiting process IMA(d, d) with a *positive* first-order autocorrelation of 0.25. Thus, if consumption is generated as the ARIMA(1,1,2) of (17) at very short intervals (in the limit, in continuous time), monthly consumption would appear as generated by an IMA(1,1). But this model is rejected by two pieces of evidence: (i) as seen above, the IMA(1,1) for consumption is rejected against the ARIMA(1,1,1); (ii) if one disagrees on the confidence about this test, and considers the IMA(1,1) as equally valid, the first-order autocorrelation is *negative* (Ermini [1989] and [1991]). Therefore, we must rule out $m > 10$, and thus Heaton's conjecture.

9. Conclusions

This paper test the consumption-CAP model under geometric durability and habit formation in discrete time, and compares the results with previous work in this area: Phlips [1983], who allows only the possibility of either durability or habit formation (his model is tested with consumption data disaggregated over several commodity groups); Ferson and Constantinides [1991], who restrict the model of durability and habit formation to one past lag only and neglect temporal aggregation effects; Heaton [1993], who considers simultaneously durability, habit formation and temporal aggregation effects, but in a continuous-time framework. The paper finds that the continuous-time model is rejected by monthly data; that the rich parametrization of Heaton is rejected in favor of the more parsimonious parametrization of Phlips, both with and without consideration of temporal aggregation effects; that Ferson and Constantinides' result is reversed, as durability seems to prevail over habit formation, and not *vice versa*. The overall conclusion of the paper is that with monthly data the possibility of distinguishing between geometrically decaying durability and geometrically decaying habit formation appears quite difficult. This suggests that either the durability model or the habit-formation model should be substantially revised.

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