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TRANSITORY CONSUMPTION AND MEASUREMENT ERRORS IN THE PERMANENT INCOME HYPOTHESIS

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Abstract

The error term in the equation defining the permanent income hypothesis is sometimes viewed in the literature as transitory consumption (generated by the agent), and is sometimes viewed as measurement error (generated by the observer). In both cases, it is usually assumed to be white noise. Sometimes it is ignored altogether, assumed to be identically zero. Using empirical evidence that combines both monthly and quarterly data, this paper shows that the error term in the permanent income equation cannot be identically zero, and that the presence of both transitory consumption and measurement errors can be consistent with the data. The evidence also confirms that the best model for this term is indeed a white noise process.

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Keywords: permanent income, transitory consumption

Transitory consumption and measurement errors in the permanent income hypothesis

1. Introduction

The standard version of the permanent income hypothesis states that consumption in every period, C_t, is a proportion, not necessarily constant, of permanent income, $Y^P{}_t$. The hypothesis is formally written as

$$C_t = \beta Y^P{}_t + u_t \ , \tag{1}$$

where u_t is a suitable "error" term, usually assumed to be a zero-mean white noise process uncorrelated with permanent income. It is fair to say that this assumption about u_t seems to be justified more for its econometric convenience than on theoretical economic grounds. Since the early empirical work on the permanent income hypothesis, in fact, economists have investigated the validity of the hypothesis by treating (1) as a regression equation of consumption against a suitably reconstructed measure of permanent income (for a review, see Deaton and Muellbauer [1980]).

The focus of both theoretical and empirical economists has always been directed exclusively to the interaction between consumption and income, and never to the origin and properties of the error term u_t. This lack of focus appears to be so common in the literature that this term receives confusingly different interpretations. Some researchers interpret u_t as transitory consumption, generated in an unspecified fashion by the representative agent (for example, Hayashi [1981], and Wickens and Molana [1984]). In this case, the related empirical work implicitly assumes the absence of measurement errors. Some others interpret u_t as measurement error, generated by the observer. In this case, the related empirical work assumes the absence of transitory consumption generated by the agent. Finally, some others assume u_t to be identically zero altogether, as the result of aggregating the consumption generated by many individual households at the economy-wide level (for example, Flavin [1981], and Muellbauer [1983]). For recent reviews, see also Deaton [1986], and Campbell and Mankiw [1987].

This lack of focus on the nature of the transitory term in (1) appears even more compelling if one subscribes to the idea that the permanent income hypothesis is in fact an incomplete theory of consumption responses to income changes. For example,

it is shown in Ermini [1989a] that the permanent income hypothesis is equivalent to the hypothesis that consumption and *disposable* income are cointegrated. An interpretation of cointegration is that two cointegrated variables may drift apart in the short-run, but "move together" in the long-run (Granger [1986]). Therefore, the equivalence between cointegration and the permanent income hypothesis means that the latter only establishes a relation between the long-run swings of consumption and income, thus totally neglecting the transitory effects on consumption of the short-run income changes.

So, the permanent income hypothesis offers no model for the transitory component u_t in (1), except for the standard white noise assumption. The purpose of this paper, then, is to establish, through the combined use of both monthly and quarterly consumption data, whether this transitory component is indeed white noise, and whether the available data can simultaneously accomodate the presence of both transitory consumption and measurement error. The investigation is based on the generating mechanism of consumption that Flavin [1981] derives from the permanent income hypothesis. In this sense, the paper can be viewed as an extension of Flavin's model in the direction of inferring a plausible model for u_t different from Flavin's assumption of it being identically zero.

The main results of this exercise are that monthly and quarterly data are consistent, under different ranges of signal-to-noise ratios, with the presence of both transitory consumption and measurement errors, as well as with the presence of only transitory consumption, or of only measurement errors. Moreover, it is found that in all three cases transitory consumption and/or measurement errors can only be white noise processes.

The paper is organized as follows. Section 2 develops the generating mechanism of consumption under the most general case of having both transitory consumption and measurement error, and suggests some testable implications for empirical work. Section 3 relates these implications to the time series properties of monthly and quarterly consumption data reported elsewhere (Ermini [1989b]). Section 4 offers some concluding remarks.

2. The generating mechanisms of consumption

Following Flavin [1981], let permanent income be the annuity R of human capital (H_t) and non-human capital (A_t), $Y^P{}_t = R(A_t+H_t)$, and let human capital be the present value of the expected flow of *labor* income over the agent's entire life span T, conditional on the information available at time t, $H_t = \sum_{k=0}^{T} E_t Y^L{}_{t+k}/R_k$, where $R_k = \prod_{j=0}^{k}(1+r_j)$, and $R = 1/\sum_{j=0}^{T} 1/R_k$. Based on these definitions, Flavin [1981] shows that the permanent income hypothesis (1) implies:

$$C_t = [1+r(1-\beta)]C_{t-1} + r\beta\phi\varepsilon'_t + u_t - (1+r)u_{t-1} \ . \tag{2}$$

To obtain this generating mechanism of consumption, Flavin assumes an infinite life span ($T=\infty$), and a constant real interest rate r, so that $R=r$. The term $\phi\varepsilon'_t$ is related to the unexpected revision, between two consecutive periods, of both human and non-human capital. Thus, by assuming that the unexpected revision of non-human capital is directly linked to the unanticipated revision of property income, $Y^K{}_t$, Flavin obtains

$$\phi\varepsilon'_t = \sum_{k=0}^{\infty} (E_{t+1}-E_t)\frac{Y^K{}_{t+k+1}+Y^L{}_{t+k+1}}{R_k} \ . \tag{3}$$

It follows that consumption innovations are related to the innovations of *total* income, and not of labor income only. Under the additional assumption of rational expectations, ε'_t is a zero-mean white noise process.

Equation (2) shows that the generating mechanism of consumption is "driven" by the innovation of total disposable income, and by the transitory component of consumption u_t. Letting $\varepsilon_t = r\phi\beta\varepsilon'_t$ for simplicity, and assuming $\beta = 1$, we get the model of consumption as generated by the representative agent:

$$C_t = C_{t-1} + \varepsilon_t + u_t - (1+r)u_{t-1} \ . \tag{4}$$

Finally, adding the measurement error e_t, we get the model of consumption as observed by the econometrician:

$$C*_t = C*_{t-1} + \varepsilon_t + u_t - (1+r)u_{t-1} + e_t - e_{t-1} \ . \tag{5}$$

The purpose of this paper is to investigate whether the combined use of both monthly and quarterly data can cast some light on the properties of the two different error terms, u_t and e_t, given that the innovations of total disposable income, ε_t, are taken to be a white noise process of variance σ^2_ε. However, as this paper uses two different series of data (monthly and quarterly), and as in principle consumption can be

generated by the agent at intervals shorter than a month (see for example Ermini [1988] for a discussion on the plausibility of this case), we must consider the effect of temporal aggregation (TA) on both models (4) and (5). In fact, we must consider two different effects: (a) the aggregation up to monthly intervals of consumption actually generated by the agent as (4) at shorter intervals; (b) the aggregation of the monthly consumption model to a quarterly interval, in order to check the consistency of the basic model with both sets of data.

Let $\bar{C}_t$ be the monthly aggregation of consumption generated by the agent, that is

$$\bar{C}_t = \sum_{j=0}^{m-1} C_{mt-j} \ ,$$

where C_{mt-j} is generated as in (4), and m is the sampling ratio, that is the ratio between a month and the interval of data generation. Assume that transitory consumption u_t is not identically zero, and that it follows a zero-mean white noise process of variance σ^2_u. Then C_t in (4) is a first-order integrated first-order moving average process, IMA(1,1), with $\mathrm{var}(\Delta C) = \sigma^2_\varepsilon + \bar{r}\sigma^2_u$ and first-order autocorrelation of ΔC given by

$$\rho(\Delta C) = -\frac{(1+r)\sigma^2_u}{\sigma^2_\varepsilon + \bar{r}\sigma^2_u} = -\frac{1+r}{ST+\bar{r}} \ , \tag{6}$$

where $\bar{r} = 1+(1+r)^2$, and $ST = \sigma^2_\varepsilon/\sigma^2_u$. ST can be interpreted as the the signal-to-noise ratio between permanent and transitory consumption. If transitory consumption in (1) is identically zero ($\sigma^2_u = 0$), then consumption is only related to the "permanent" component $\beta Y^P{}_t$, and it is generated by a mechanism whose innovation is only the innovation of total disposable income ε_t.

It is shown in Ermini [1989b] that under temporal aggregation an IMA(1,1) process remains an IMA(1,1) process for any value of the sampling ratio m, with corresponding variance and first-order autocorrelation depending on the sampling ratio. In our case, and following the derivation in the cited reference, the generating mechanism of monthly aggregated consumption is

$$\bar{C}_t = \bar{C}_{t-1} + \bar{\varepsilon}_t + h\,\bar{\varepsilon}_{t-1} \tag{7}$$

with first-order autocorrelation of $\Delta\bar{C}$

$$\rho_m(\Delta\bar{C}) = \frac{h}{1+h^2} = \frac{(m^2-1) + 2(m^2+2)\,\rho(\Delta C)}{2(2m^2+1) + 8(m^2-1)\,\rho(\Delta C)} \ . \tag{8}$$

Clearly, for $m = 1$ - corresponding to C_t generated at monthly frequency - $\rho_m = \rho$.

It is important to note at this stage that if u_t is not white noise, but follows a richer ARMA(p,q) representation, then C_t in (4) is not an IMA(1,1), but will follow in general a higher order ARIMA process. By temporally aggregating to monthly intervals, the richer ARIMA structure remains in general a higher order ARIMA structure, with the order of the autoregressive and moving average parts depending on the sampling ratio (as discussed, for example, in Weiss [1984]). Therefore, if monthly consumption is best represented - according to some specified criterion - by an IMA(1,1) representation, it excludes the possibility that u_t is different from white noise. This case is further discussed in Section 3.

The model (7) describes consumption generated by the agent. By adding a zero-mean white noise measurement error, e_t, of variance σ^2_e and uncorrelated with both ε_t or u_t, we get the model of monthly consumption as observed by the econometrician

$$\bar{C}*_t = \bar{C}*_{t-1} + \bar{\varepsilon}_t + h\,\bar{\varepsilon}_{t-1} + e_t - e_{t-1} \tag{9}$$

which is still an IMA(1,1) process, with var($\Delta\bar{C}*$) = $(1+h^2)\bar{\sigma}^2_\varepsilon + 2\sigma^2_e$, and first-order autocorrelation of the differences given by

$$\rho*_m(\Delta C*) = \frac{h\,\bar{\sigma}^2_\varepsilon - \sigma^2_e}{(1+h^2)\bar{\sigma}^2_\varepsilon + 2\sigma^2_e} = \frac{h\,SN - 1}{(1+h^2)SN + 2}\,; \tag{10}$$

$\bar{\sigma}^2_\varepsilon$ is the variance of $\bar{\varepsilon}_t$ - the innovation of monthly consumption in (7) - and $SN = \bar{\sigma}^2_\varepsilon/\sigma^2_e$ is the signal-to-noise ratio. By comparing (7) and (9) it is clear that observed monthly consumption is IMA(1,1) even if measurement errors are identically zero. For the purpose of this paper, an important implication of (9) is that if observed monthly consumption appears to be generated by a richer ARIMA process, then either transitory consumption u_t or measurement error e_t, or both, must be different from white noise.

The second TA effect mentioned above is the aggregation of the monthly process (9) to quarterly frequency. Since (9) is an IMA(1,1), it remains an IMA(1,1) at quarterly frequency as well. It can be shown that the first-order autocorrelation of the differences becomes (Ermini [1989b]):

$$\rho*_q = \frac{[4(1+h^2) + 11h]\,SN - 3}{[19(1+h^2) + 32h]\,SN + 6}\,, \tag{11}$$

where h is the MA coefficient of monthly consumption without measurement error (cfr. (7) or (9)), and SN is the signal-to-noise ratio between monthly consumption and measurement error, defined above.

Solving (10) for SN as a function of $\rho*_m$,

$$SN = \frac{1 + 2\rho*_m}{h - (1+h^2)\rho*_m}\,, \tag{12}$$

and substituting in (11),

$$\rho*_q = \frac{4 + 11\rho*_m}{19 + 32\rho*_m}\,, \tag{13}$$

we get the apparently striking result that the first-order autocorrelation associated with quarterly data is only function of the first-order autocorrelation associated with monthly data, regardless of the value of the signal-to-noise ratio.

These results can be summarized in the following propositions, which hold under the assumption that the basic generating mechanism of consumption (4) is true:

PROPOSITION 1: Under the assumption that both transitory consumption, u_t, and measurement error, e_t, are white noise, then both monthly and quarterly consumption follow IMA(1,1) processes, regardless of whether consumption is generated at monthly intervals or shorter.

PROPOSITION 2: If either transitory consumption, u_t, or measurement error, e_t, or both, are stationary processes, but not white noise, then both monthly and quarterly consumption follow higher order ARIMA(p,q) processes.

Finally, recalling Working's [1960] result that a random walk under temporal aggregation becomes an IMA(1,1) process for any value of the sampling ratio m, it is easily verified that even if transitory consumption is identically zero, and thus C_t in (4) is a random walk, the generating mechanism (7) still holds for monthly consumption, except for m = 1. So, monthly consumption will appear as IMA(1,1) with or without measurement error; consequently, quarterly consumption as well. These results can be summarized in the following:

PROPOSITION 3: Both monthly and quarterly consumption follow IMA(1,1) processes even if transitory consumption is identically zero, and measurement error is white noise; or even if transitory consumption is white noise, and measurement error is identically zero.

In the next section, it will be shown that transitory consumption and measurement error cannot be both identically zero, which is, in fact, precisely the assumption made by Flavin [1981], among others. It is important to emphasize that the results summar-

ized by the three propositions are strictly based on the property that under TA, and for any value of the sampling ratio m, a random walks process and an IMA(1,1) process are indistinguishable, as both become IMA(1,1) processes.

3. The empirical evidence

In this section, the theoretical results of the previous section are compared with the following empirical findings (Ermini [1989b]):

(i) the best univariate model to fit *monthly* consumption data is the IMA(1,1) model (t-statistics in parenthesis) [1]

$$\Delta\bar{C}*_t = -\underset{(-0.004)}{0.045} + w_t - \underset{(-4.03)}{0.221}\, w_{t-1} \tag{14}$$

The corresponding estimate of the first-order autocorrelaion is $\bar{\rho}_m$ = -0.211, with 95% confidence interval (-0.30, -0.11). The important feature to emphasize here is the negative sign of $\bar{\rho}_m$. A similar result is reported in Wheatley [1988], although not directly comparable with (14) as Wheatley uses log consumption. Note that $\bar{C}*_t$ is used here to indicate "observed" monthly consumption. If measurement errors are identically zero, then $\bar{C}*_t = \bar{C}_t$, and if the sampling ratio m is equal to 1, then $\bar{C}*_t = C*_t$ or C_t, according to whether the generation of monthly consumption by the agent is corrupted by measurement error or not.

(ii) the best univariate model to fit *quarterly* consumption data is the IMA(1,1) model

$$\Delta\bar{C}*_t = \underset{(0.02)}{0.06} + s_t + \underset{(2.67)}{0.211}\, w_{t-1}\,. \tag{15}$$

with the corresponding estimate of the first-order autocorrelation $\rho*_q$ = 0.202, (0.051, 0.326). Note the change of sign of the first-order autocorrelation from monthly to quarterly data. Similar results are also found in Christiano et al [1987].

Note, first, that through (13) the estimate of the quarterly $\rho*_q$ is consistent with the estimate of the monthly $\rho*_m$. In fact, from (13) a value $\rho*_m$ = -0.211 yields a "theoretical" value $\rho*_q$ = 0.137, with a 95% confidence interval (0.075, 0.180). Based on the estimated model (15), this theoretical value is not rejected at the 5% level, nor are the two extreme values of the 95% confidence interval.

[1] The data sets correspond to US monthly and quarterly, percapita, seasonally adjusted consumption of non-durables and services. Several different ARIMA models were unsuccessfully compared with this IMA(1,1).

One important implication of these empirical results follows from Proposition 2: as both monthly and quarterly data appear to be generated as IMA(1,1) processes, then whichever term is present in the data (transitory consumption and/or measurement error) must be white noise.

Another important implication comes from the negative sign of the first-order autocorrelation for monthly data: it excludes the possibility that both transitory consumption u_t and measurement error e_t can be identically zero. If u_t is identically zero, consumption in (4) would be generated as a random walk, which under temporal aggregation to monthly intervals would turn into an IMA(1,1) with positive first-order autocorrelation (Working [1960]). It follows that, since monthly consumption displays a negative first-order autocorrelation, measurement errors cannot be identically zero as well.

This leaves the three possibilities: (a) $u_t \equiv 0$, e_t is white noise; (b) u_t is white noise, and $e_t \equiv 0$; (c) u_t and e_t are both white noise. Consider these three cases in turn:

(a) $u_t \equiv 0$, e_t is white noise. In this case, consumption is generated by the representative agent as a random walk, at any interval of length between zero and a month (the former corresponding to continuous-time consumption decisions).Then, monthly consumption without measurement error would follow an IMA(1,1) process with first-order autocorrelation given by (Working [1960[):

$$\rho_m = \frac{m^2-1}{2(2m^2+1)}\,; \tag{16}$$

that is, with a first-order autocorrelation anywhere between zero (for m = 1) and 0.25 (for $m = \infty$). The corresponding MA coefficient h varies between 0. and 0.268, and between 3.732 and ∞. Incidentally, note that (16) can also be obtained as a special case of (8), as $\rho(\Delta C) = 0$ for consumption generated as a random walk.

Using (12), we see that with an estimated $\rho*_m$ = -0.211 for monthly data, and with h between 0. and 0.268, monthly data are consistent with the present case for a range of signal-to-noise ratios between 2.74 (for h = 0) and 1.17 (for h = 0.268). In fact, considering the 95% confidence interval for the estimated $\rho*_m$, the range of signal-to-noise ratios for h = 0 becomes (1.33, 7.09), and for h = 0.268, (0.68, 2.02). It follows that the overall range of ratios expands to (0.68, 7.09).

Regarding the possibility $h \geq 3.732$, the estimate $\rho*_m$ would entail a signal-to-noise

ratio between zero (for $h = \infty$) and 0.084 (for h = 3.732). As these values are implausibly low (for example, SN = 0.084 implies a variance of the measurement error 12 times greater than the variance of consumption innovations), the case $h \geq 3.732$ can be safely ruled out.

(b) u_t white noise; $e_t \equiv 0$. In this case, consumption is generated by the representative agent as an IMA(1,1), at any interval of length between zero and a month, and with first-order autocorrelation $\rho(\Delta C)$ as in (6). Now (8) holds for observed monthly consumption. Note, first, that with ρ = -0.5, ρ_m = -0.5 also, for all values of m. This is not surprising, as ρ = -0.5 means that consumption in (4) is generated with a unit root in the MA component, that is, is overdifferenced. This implies that C_t is stationary, and thus so remains under temporal aggregation.

From (8) it is easily verified that as m goes to infinity, the limit of ρ_m goes to 0.25, for all values of ρ (except, of course, ρ = -0.5). Since the estimates ρ_m is -0.211, negative, it follows that m cannot be infinite, that is, consumption cannot be generated in continuous time (cfr. also Ermini [1989b]). Finally, by rewriting (8) as

$$\rho = \frac{2(m^2+1)\rho_m - (m^2-1)}{2(m^2+2) - 8(m^2-1)\rho_m}, \tag{17}$$

it is clearly seen that ρ_m negative implies ρ negative as well. Thus, monthly data suggests that if consumption is generated as an IMA(1,1), then the MA coefficient must be negative.

(c) u_t and e_t are both white noise. In this case observed monthly consumption obeys (9)-(10). The range of possibilities is significantly expanded, in comparison to the previous two cases. As measurement errors are not zero, the restrictions found in case (b) no longer apply. As transitory consumption is not zero, the ranges of signal-to-noise ratios found in case (a) are greatly expanded by the possibility that h can now be negative.

To summarize, $\rho(\Delta C)$ can assume any value in [-0.5, 0.5]. Under temporal aggregation $\rho_m(\Delta C)$ increases monotonically with the sampling ratio m from any ρ in (-0.5, 0.25) to the limit of 0.25; and it decreases monotonically from any ρ in (0.25, 0.5] to the same limit 0.25. Although, as $m > 1$, the range of values for ρ_m diminishes, we must consider the whole spectrum (0.5, 0.5] for lack of any plausible hypothesis about the true value of the sampling ratio m. Consequently, we must consider the entire real

line as the set of values for h at monthly level. However, for an estimated ρ^*_m = -0.211, the signal-to-noise ratio SN in (12) is monotonically decreasing from ∞ to 0 for $h \geq -0.223$, and monotonically increasing from 0 to ∞ for $h \leq -4.52$; and remains negative for h between -4.52 and -0.223. Therefore, as SN cannot be negative, and ruling out low values of SN - say $SN \leq 0.4$ - as they would imply too large variances of the measurement errors compared to consumption innovations, the plausible range of values of the monthly MA coefficient h reduces to [-5.74, -4.52], [-0.223, 1.]. Further, h is negative for $SN > 2.74$.

Under the working hypothesis that ρ^*_m = -0.211 is the "true" value of the first-order autocorrelation of observed monthly consumption changes, the following results can be derived:

(i) for $1.17 \leq SN \leq 2.74$, ρ^*_m = -0.211 is compatible with $0 \leq h \leq 0.268$. In turn, these values of h are compatible with consumption generated, at any sampling ratio $m \geq 1$, as a random walk or as an IMA(1,1) with any first-order autocorrelation $0 \leq \rho \leq 0.25$. These values are also compatible with consumption generated as IMA(1,1) with $\rho < 0$, but only if the sampling ratio is large enough to convert the original negative MA coefficient into the positive MA coefficient of monthly data.

(ii) for $0.4 \leq SN < 1.17$, ρ^*_m = -0.211 is compatible with $0.268 < h \leq 1$. In turn, these values of h are only compatible with consumption generated, for any sampling ratio $m \geq 1$, as an IMA(1,1) with any positive first-order autocorrelation $0.25 < \rho \leq 0.5$.

(iii) for $SN > 2.74$, ρ^*_m =-0.211 is compatible with $-0.223 \leq h \leq 0$. In turn, these values of h are only compatible with consumption generated as an IMA(1,1) with any negative first-order autocorrelation $-0.50 \leq \rho \leq 0$, but at a sampling ratio not greater than $\bar{m}$, where $\bar{m}$ is the value of m such that

$$\rho = \frac{1-m^2}{2(m^2+2)}.$$

At $\bar{m}$, which depends on the initial ρ, the process is transformed into a random walk, and for $m > \bar{m}$ into a positive IMA(1,1) (cfr. also Ermini [1989b]).

These results can be easily interpreted if one considers that the presence of measurement errors decreases the first-order autocorrelation in proportion to their variance. Thus, if the original process has a positive first-order autocorrelation, a large error variance (hence a low value for SN) is needed to reduce it to the negative observed

value. On the other hand, a negative first-order autocorrelation is compatible with the observed value for low variances of the measurement errors. These effects are complicated by the fact that temporal aggregation increases the first-order autocorrelation in proportion to the sampling ratio, if initially this autocorrelation is less than 0.25, and decreases it if greater than 0.25.

Finally, further restrictions on the signal-to-noise ratios and on the values of the initial first-order autocorrelation can be obtained, if one is prepared to advance specific plausible values for the sampling ratio m. For example, Ermini [1988] argues that, under the assumption that agents react fully and immediately to any income innovation, the "true" consumption decision interval should be less than (but in the vicinity of) a month, as income in organized economies is regulalry received on average every month or less.

4. Conclusions

Using empirical evidence that combines both monthly and quarterly data, it is shown that the error term in the equation defining the permanent income hypothesis cannot be identically zero. That is, at least a transitory consumption generated by the agent or a measurement error must be present in the generating mechanism of consumption data. It is also shown that monthly and quarterly data are consistent, under different ranges of signal-to-noise ratios, with the presence of both transitory consumption and measurement errors, as well as with the presence of only transitory consumption, or of only measurement errors. Moreover, it is found that in all three cases the only acceptable representation for either transitory consumption or measurement error is a white noise process. These results are essentially based on the property that under temporal aggregation a random walk process and an IMA(1,1) process are indistinguishable, and on the empirical evidence that both monthly and quarterly consumption follow IMA(1,1) processes.

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