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Zhuo Qiao

Michael McAleer

Wing Keung Wong
Hong Kong Baptist University, awong@hkbu.edu.hk

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Linear and nonlinear causality between changes in consumption and consumer attitudes*

Zhuo Qiao

Faculty of Business Administration, University of Macau, Macau

Michael McAleer

School of Economics and Commerce, University of Western Australia, Australia

Wing-Keung Wong*

Department of Economics, Hong Kong Baptist University, Hong Kong

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*Corresponding author. Wing-Keung Wong, Department of Economics, Hong Kong Baptist University, Kowloon Tong, Hong Kong. Tel.: (852)-3411-7542, Fax: (852)-3411-5580, Email: awong@hkbu.edu.hk.

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Abstract

Adopting both linear and nonlinear Granger causality tests, we find consumer attitude indices of the University of Michigan's surveys are very useful in predicting consumption movements of the United States.

Keywords: Consumer sentiment; Consumer expectations; Consumption growth; Nonlinear Granger causality; Prediction

JEL classifications: C32; E32

1. Introduction

Predicting future consumer expenditures can be critical for successful business performance (see, for example, Kotler (1994)). Lilien and Kotler (1983), Georgoff and Murdick (1986), and Kotler (1994) have suggested that consumer attitude indices, such as the widely used Index of Consumer Sentiment (ICS) and Index of Consumer Expectations (ICE) of the University of Michigan, could be invaluable tools in anticipating future consumption. However, Makridakis and Wheelwright (1989) question the usefulness of these indices for forecasting.

An empirical investigation of a Granger causal relation between consumer attitudes and consumption is helpful in determining whether consumer attitudes are useful for predicting consumption. If consumer attitudes Granger cause consumption, they can be shown to contain useful information for predicting consumption, and they should be included as forecasting variables in various consumption forecasting models.

Accordingly, the conventional linear Granger causality test has been adopted frequently in the literature to determine such issues empirically. Using ICS and ICE data, Throop (1992) finds that consumer attitudes Granger cause expenditure on durables but do not Granger cause expenditure on nondurables and services. Huth et al. (1994) find that these indices Granger cause total retail sales and retail sales of automobiles, durables, nondurables and house sales. Using the index data from the University of Michigan and the Conference Board, Eppright et al. (1998) find consumer sentiment and expectation indices Granger cause retail sales of automobiles and total retail sales of durables and services. More recently, using consumer confidence index data for Germany, France, the Netherlands and Belgium, and ICS data for the United States, respectively, Gelper and Croux (2007) and Gelper et al. (2007) find that consumer attitudes do not Granger cause retail sales in these four countries and similarly for total consumption and consumption of durables, nondurables and services in the United States.

Though many researchers have adopted the linear Granger causality test to investigate the usefulness of consumer attitudes in predicting consumption in different countries, their analyses have neglected the possible nonlinear relation between these variables. This is because the linear Granger causality test has low power to detect nonlinear causal relations among variables (see, for example, Baek and Brock (1992) and Hiemstra and Jones (1994)). Thus, the power of consumer attitudes to predict consumption may be overlooked by relying solely on the linear Granger causality test.

In order to circumvent the limitations of the linear Granger causality test, this paper adopts the nonlinear Granger causality test, as developed by Hiemstra and Jones (1994) (hereafter, HJ) to examine the nonlinear Granger causal relation from the consumer attitude indices, ICS and ICE, to consumption expenditures in the United States. This test has high power to detect a nonlinear Granger causal relation, which could be overlooked by its linear counterpart, between the economic variables. Because of this advantage, it has been widely used in the literature (see, for example, Hiemstra and Jones (1994), Abhyankar (1998), Silvapulle and Moosa (1999), Ciner (2002), and Huh (2002)).

The empirical results show that, in sharp contrast to results from the linear Granger causality test, in which causal relations from ICS and ICE to the consumption of nondurable goods can be overlooked, the nonlinear Granger causality test shows that they have predictive power for the consumption of nondurable goods. Overall, our empirical results indicate that consumer attitudes can be very useful in predicting the United States consumption.

2. Data and Methodology

2.1. Data

Real monthly consumption data in the United States are collected by the United States Bureau of Economic Analysis, an agency of the United States Department of Commerce. The data measure the goods and services purchased by persons resident in the United States. Four consumption series are analyzed, namely, total real personal consumption (RC) and its three components, real consumption of durables (RD), nondurables (RND), and services (RS). These monthly time series data are quantity indices and are seasonally adjusted at annual rates by the data provider.

The United States index of consumer sentiment (ICS) and index of consumer expectations (ICE), which are computed by the Survey Research Center at the University of Michigan, are derived from answers to five questions asked of United States consumers.[1] All data in this paper are for the period January 1985 to December 2005, resulting in 252 observations. Figures 1 and 2 plot the consumption variables and consumer attitude indices, respectively. It is clear that the two consumption series move closely with each other, but they do not display a deterministic trend.

2.2. Methodology

This section presents the methodology adopted to investigate the nonlinear causal relation between consumer attitudes and consumption. The first sub-section briefly introduces the linear Granger causality test, and the second sub-section presents the nonlinear Granger causality test.

2.2.1. Linear Granger Causality

In order to test for a linear causal relation between consumer attitudes and consumption, we proceed in the following manner. First, we apply a unit root test to examine the stationarity property of all six data series. If any variable is $I(1)$, it is necessary to use first differences to ensure that all variables in the bivariate VAR system are stationary. We then adopt the following VAR model to test for Granger causality:

$$y_{1t} = c_1 + \sum_{i=1}^{m} \phi_i y_{1t-i} + \sum_{i=1}^{m} \theta_i y_{2t-i} + \varepsilon_{1t} \tag{1a}$$

$$y_{2t} = c_2 + \sum_{i=1}^{m} \rho_i y_{1t-i} + \sum_{i=1}^{m} \eta_i y_{2t-i} + \varepsilon_{2t} \tag{1b}$$

[1] ICS and ICE are constructed by the Survey Research Center at the University of Michigan. Every month the center asks approximately 500 respondents to answer five questions. The questions are concerned with the current and expected personal financial situation and current and expected overall economic conditions. The center constructs ICS based on the survey results of these five questions and constructs ICE based on the survey results of a three-question subset (those three questions are forward-looking questions) as a weighted average of the relative scores (percentage of favorable answers minus percentage of negative answers, plus 100). For further details, please see the website of the Survey Research Center at the University of Michigan.

where y_{1t} and y_{2t} denote one consumption variable and one consumer attitude variable, which are both stationary, $\varepsilon_t = (\varepsilon_{1t}, \varepsilon_{2t})'$ is the vector of error terms, and m is the optimal lag length, obtained by using Akaike's (1969) information criterion (AIC). The null hypothesis that the consumer attitude variable does not Granger cause consumption is equivalent to testing θ_i = 0 for all $i = 1, 2, ..., m$ in equation (1a).

2.2.2. Nonlinear Granger Causality

The nonlinear Granger causality test developed by Baek and Brock (1992) was modified by Hiemstra and Jones (1994). This approach postulates that, by removing the linear predictive power in the VAR model given above, any remaining incremental predictive power of one residual series on another can be considered to be nonlinear predictive power. A nonparametric statistical method is then proposed, using the correlation integral, which is a measure of spatial dependence across time, to uncover any nonlinear causal relation between two time series.

Consider two strictly stationary and weakly dependent time series, $\{X_t\}$ and $\{Y_t\}$, for $t = 1, 2, ...$ Let X_t^m be the m-length lead vector of X_t, and let $X_{t-L_x}^{L_x}$ and $Y_{t-L_y}^{L_y}$ be the L_x-length and L_y-length lag vectors of X_t and Y_t, respectively. For given values of *m*, L_x, and L_y, and for any *e*, $\{Y_t\}$ does not strictly Granger cause $\{X_t\}$ if:

$$\begin{aligned} &\Pr(\left\|X_t^m - X_s^m\right\| < e \mid \left\|X_{t-L_x}^{L_x} - X_{s-L_x}^{L_x}\right\| < e, \left\|Y_{t-L_y}^{L_y} - Y_{s-L_y}^{L_y}\right\| < e) \\ &= \Pr(\left\|X_t^m - X_s^m\right\| < e \mid \left\|X_{t-L_x}^{L_x} - X_{s-L_x}^{L_x}\right\| < e) \end{aligned} \qquad (2)$$

where $\Pr(\cdot)$ and $\|\cdot\|$ denote probability and the maximum norm, respectively.

In equation (2) above, the left-hand side is the conditional probability that two arbitrary *m*-length lead vectors of $\{X_t\}$ are within a distance *e* of each other, given that the corresponding L_x-length and L_y-length lag vectors of $\{X_t\}$ and $\{Y_t\}$, respectively, are within a distance *e* of each other. The right-hand side is the conditional probability that two arbitrary *m*-length lead vectors of $\{X_t\}$ are within a distance *e* of each other, given that the corresponding L_x-length lag vectors of X_t are within a distance *e* of each other.

The strict Granger noncausality condition in equation (2) can be implemented by expressing it in terms of the corresponding ratios of joint probabilities, as follows:

$$\frac{C_1(m+L_x, L_y, e)}{C_2(L_x, L_y, e)} = \frac{C_3(m+L_x, e)}{C_4(L_x, e)}, \tag{3}$$

where C_1, C_2, C_3 and C_4 are the correlation-integral estimators of the joint probabilities (for further details, see Hiemstra and Jones (1994)). For given values of *m*, L_x and $L_y \geq 1$ and $e > 0$, under the assumptions that $\{X_t\}$ and $\{Y_t\}$ are strictly stationary and weakly dependent, if $\{Y_t\}$ does not strictly Granger cause $\{X_t\}$, then:

$$\sqrt{n}\left(\frac{C_1(m+L_x, L_y, e, n)}{C_2(L_x, L_y, e, n)} - \frac{C_3(m+L_x, e, \cdots n)}{C_4(L_x, e, n)}\right) \xrightarrow{a} N(0, \sigma^2(m, L_x, L_y, e)), \tag{4}$$

where both $n = T + 1 - m - \max(L_x, L_y)$ and $\sigma^2(m, L_x, L_y, e)$ can be estimated (see the Appendix in Hiemstra and Jones (1994)).

A significant positive value of the test statistic implies that lagged values of $\{Y_t\}$ are able to predict $\{X_t\}$, whereas a significant negative value suggests that lagged values of $\{Y_t\}$ confuse the prediction of $\{X_t\}$. This test has very good power properties against a variety of nonlinear Granger causal and noncausal relations, and its asymptotic distribution is the same as if the test is applied to the estimated residuals from a VAR model (see Hiemstra and Jones (1994)).

3. Empirical Results

In order to examine the stationary property of the six variables, Phillips-Perron（PP） unit root tests[2] are conducted and reported in Table 1. It is found that both ICS and ICE are stationary, whereas four consumption variables are $I(1)$. Based on these results, first differences of the four consumption series are adopted to obtain the corresponding stationary series.[3] Then the VAR model is adopted to test for linear Granger causality from consumer attitudes to consumption,[4] and the results are displayed in Table 2. As can be seen from the table, both ICS and ICE Granger cause real total consumption (RC), real consumption of durables (RD) and services (RS), but the two consumer indices do not Granger cause real consumption of nondurable goods (RND).

Before testing for nonlinear Granger causality in the residuals from the linear VAR, the Ljung–Box Q-test is conducted on the residuals from the VAR models to determine

[2] Refer to Phillips and Perron (1988) for further discussion of the PP test.
[3] The PP test and Granger causality test are conducted with the econometric package EViews. Please refer to its manual for more information on these two tests.
[4] Studying the linear and nonlinear Granger causal relations from consumption to consumer attitudes is not the purpose of this paper. However, the results are available upon request.

whether any linear dependency remains in the residuals.[5] The null hypothesis of the Q-test is the absence of serial correlation in the residuals. The results of this diagnostic test, as reported in Table 2, show that the VAR models successfully account for linear dependency, as indicated by insignificant values of the Q-test.[6]

Considering the low power of the conventional linear Granger causality test in detecting nonlinear causal relations, we apply its nonlinear counterpart, the HJ test, to the residuals from the above VAR model. To implement the HJ test, we must select values for the lead length, *m*, the lag lengths, L_x and L_y, and the scale parameter, *e*. Following Hiemstra and Jones (1994), we set the lead length *m* = 1, and $L_x = L_y$, in all cases. Moreover, common lag lengths of 1–6 lags, and a common scale parameter of $e = 1.5\sigma$, are used, where σ = 1 denotes the standard deviation of the standardized series.

The results of the nonlinear Granger causality test are reported in Table 3. In general, we find strong evidence of the existence of a nonlinear causal relation from consumer attitude indices to consumption. To be more specific, a nonlinear Granger causal relation is found from ICS to the change in RC and RD, and from ICE to the change in RC. Of particular interest is the result that both ICS and ICE Granger cause RND, which contrasts sharply with the results based on the linear Granger causality test reported in Table 2. Our empirical test results indicate that consumer attitudes can be very useful in predicting movements in consumption and should be included as forecasting variables in consumption forecasting models, especially nonlinear forecasting models.[7]

[5] We are grateful to the referee for raising this issue.

[6] The optimal lag numbers based on AIC for the eight VAR models are 2, 3, 2, 2; 2, 3, 2 and 1, respectively. Although not reported in Table 2, the Ljung–Box test statistics for the residuals of equation (1b) are also insignificant. To save space, we do not report the complete set of estimation results for the VAR here, but it is available upon request.

[7] We note the difference in constructing the ICS and ICE indices, but consistent with the findings of Bram and Ludvigson (1998), our results show that there is not much difference in their ability to predict consumption

4. Conclusion

Conventional linear Granger causality tests have been widely adopted in the literature to examine whether consumer attitudes are useful in predicting consumption. However, previous studies have neglected the possible nonlinear relation from consumer attitudes to consumption. This paper adopted both linear and nonlinear Granger causality tests to examine the ability of the consumer attitude indices of the University of Michigan's surveys to predict consumption movements in the United States. The empirical results show that there is a nonlinear causal relation from consumer attitude indices to consumption. We find that the linear Granger causality test overlooks the causal relation from consumer attitudes to consumption of nondurables, which can be detected by the nonlinear Granger causality test. Overall, our results show that consumer attitudes can be very useful in predicting movements in consumption in the United States.

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Table 1
Unit root tests

Variable	Phillips-Perron（PP）tests		
	Bandwidth	**Adj. t-statistics**	**p-value**
RC	6.69	-0.625	0.976
RDG	5.36	-1.392	0.861
RNDG	6.99	0.083	0.997
RS	5.39	-1.157	0.915
ΔRC	1.93	-24.166	0.000
ΔRDG	2.49	-24.688	0.000
ΔRNDG	1.95	-24.935	0.000
ΔRS	1.01	-21.647	0.000
ICS	0.91	-3.255	0.018
ICE	1.09	-3.592	0.007

Notes: The null hypothesis of the PP test is that the variable has a unit root. The PP tests of the consumption variables are with intercept and time trend. The PP tests of the consumer attitude indices are with intercept and without time trend. The calculation of bandwidth is based on the automatic bandwidth selection method of Andrews using a Bartlett kernel. The corresponding critical values at the 5% level for the consumption variables and consumer attitude indices are -3.427 and -2.873, respectively.

Table 2
Tests for linear Granger causality

Test Statistics	Null hypothesis: ICS does not Granger cause consumption growth			
	ICS→ΔRC	**ICS→ΔRD**	**ICS→ΔRND**	**ICS→ΔRS**
F-statistics	8.665 [a]	2.885 [b]	2.430	14.285 [a]
LB(6)	1.368	1.087	0.924	1.460
LB(12)	13.736	7.884	4.204	7.941
Test Statistics	Null hypothesis: ICE does not Granger cause consumption growth			
	ICE→ΔRC	**ICE→ΔRD**	**ICE→ΔRND**	**ICE→ΔRS**
F-statistics	10.854 [a]	3.600 [b]	2.635	19.144 [a]
LB(6)	1.114	1.176	1.042	2.958
LB(12)	12.055	7.463	4.252	11.661

Notes: The table reports the results for testing linear Granger causality from consumer attitudes to consumption. LB (6) and LB(12) are the Ljung-Box statistic based on the residual series of the dependent variable in equation (1a) up to the 6th lag and 12th lag. However, the results of this test are robust to other lag length specifications. *a* and *b* denote significance at the 1% and 5% levels, respectively.

Table 3

Tests for nonlinear Granger causality

	Null hypothesis: ICS does not Granger cause consumption growth			
Lx=Ly	**ICS→ΔRC**	**ICS→ΔRD**	**ICS→ΔRND**	**ICS→ΔRS**
1	-0.213 (0.416)	0.873 (0.191)	0.527 (0.299)	-0.593 (0.277)
2	0.677 (0.249)	0.123 (0.451)	2.123 (0.017) [b]	0.640 (0.261)
3	1.789 (0.037) [b]	1.883 (0.030) [b]	2.706 (0.003) [a]	1.063 (0.144)
4	2.315 (0.010) [a]	2.403 (0.008) [a]	3.101 (0.001) [a]	1.032 (0.151)
5	2.178 (0.015) [b]	1.868 (0.031) [b]	3.065 (0.001) [a]	0.720 (0.236)
6	1.569 (0.058)	1.014 (0.155)	2.191 (0.014) [b]	0.157 (0.437)
	Null hypothesis: ICE does not Granger cause consumption growth			
Lx=Ly	**ICE→ΔRC**	**ICE→ΔRD**	**ICE→ΔRND**	**ICE→ΔRS**
1	-0.474 (0.318)	0.813 (0.208)	0.534 (0.297)	0.845 (0.199)
2	0.887 (0.188)	-0.174 (0.431)	1.606 (0.054)	1.128 (0.130)
3	2.177 (0.015) [b]	1.191 (0.117)	1.968 (0.025) [b]	0.940 (0.174)
4	1.925 (0.027) [b]	1.602 (0.055)	2.484 (0.006) [a]	1.478 (0.070)
5	1.204 (0.114)	1.046 (0.148)	2.637 (0.004) [a]	0.864 (0.194)
6	1.035 (0.150)	0.606 (0.272)	1.573 (0.058)	0.325 (0.373)

Notes: This table reports the results for testing nonlinear Granger causality from consumer attitudes to consumption. Each cell contains two numbers: numbers without parentheses are the standardized Hiemstra and Jones test statistic, as in equation (4), and numbers in parentheses are the corresponding p-values. Under the null hypothesis of nonlinear Granger noncausality, the test statistic is asymptotically distributed as N (0, 1) and is a one-tailed test. A significant positive test statistic implies that lagged values of $\{Y_t\}$ nonlinear Granger cause $\{X_t\}$. *a* and *b* denote significance at the 1% and 5% levels, respectively.

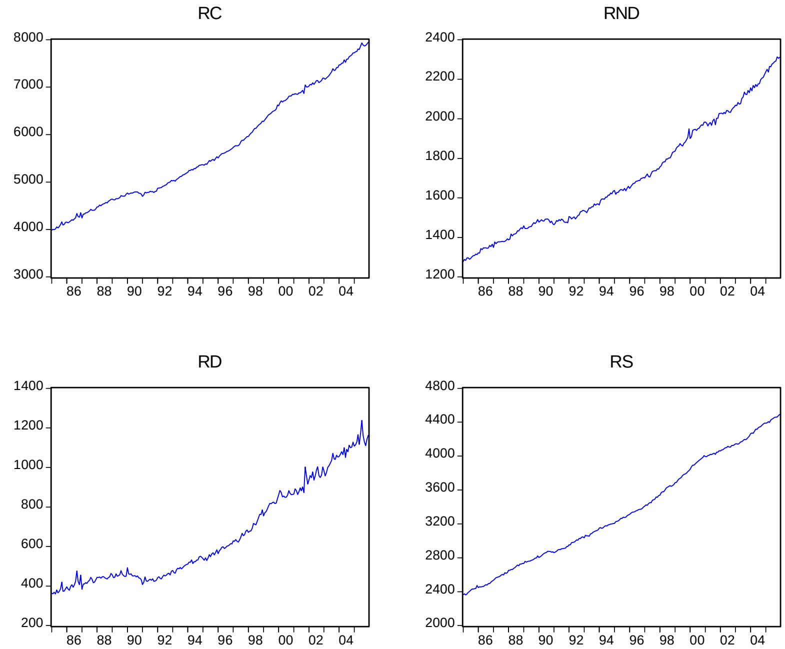
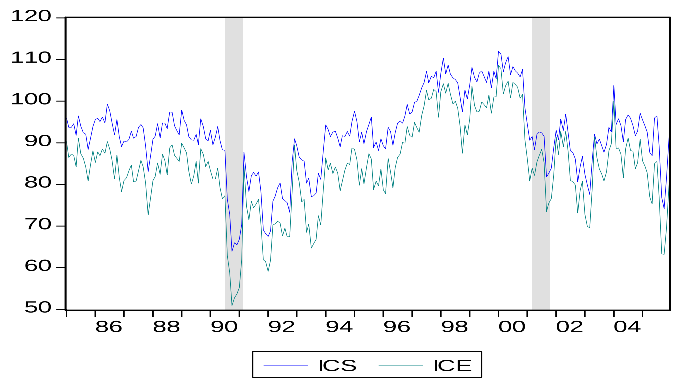


Fig. 1. Plot of Four Real Consumption Variables: Total Real Personal Consumption (RC), Real Consumption of Durables (RD), Nondurables (RND), and Services (RS)



Note: Shaded areas denote recessions as designated by the National Bureau of Economic Research (NBER).

Fig. 2. Plot of Index of Consumer Sentiment (ICS) and Index of Consumer Expectations (ICE)