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GDP growth and the composite leading index: a nonlinear causality analysis for eleven countries

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Abstract

This paper examines the ability of the composite leading index of economic activity to predict future movements in GDP growth using a nonlinear Granger causality test. Our empirical results are shown to contrast sharply with those from the conventional linear causality test.

Keywords: Composite leading index; Nonlinear Granger causality

JEL classification: C32; E32

1. Introduction

There has been a revival of interest in using the composite leading index of economic activity (CLI) to forecast future levels or growth of GDP/GNP. Emerson and Hendry (1996) observe that this seems to be partly a reaction to perceived forecasting failures by macro-econometric models and partly due to developments in leading-indicator theory. The present paper aims to offer an empirical evaluation on the prediction of GDP growth with the CLI for a large set of 11 countries. The testing method used in this paper is the Granger causality test. If the CLI Granger causes GDP, it proves to contain useful information for the prediction of GDP.

Unlike previous evaluations, however, this study employs nonlinear Granger causality tests. This is due to growing empirical evidence that suggests nonlinearities in GDP. In our context, for example, Granger et al. (1993), Hamilton and Perez-Quiros (1996), Camacho (2000), and Camacho and Perez-Quiros (2002) examined the ability of CLI in the prediction of US GDP/GNP using popular nonlinear models. If GDP/GNP were indeed a nonlinear process, the power of traditional Granger

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tests against nonlinear causal relations can be low, as demonstrated by Baek and Brock (1992), Hiemstra and Jones (1993) and Conway et al. (1997). For this reason, traditional Granger causality tests might overlook a significant nonlinear relation between the CLI and economic activity.

The nonlinear Granger causality test used here is a modified version of Baek and Brock (1992) by Hiemstra and Jones (1994). This testing procedure is based on nonparametric estimators of temporal relations within and across time series. Nonparametric modeling of time series does not require an explicit model a priori. This may be particularly useful given that the range of nonlinear models is very wide and that there has not been sufficient experience accumulated to decide which of these models is most appropriate in economics. An obvious downside is that the nonlinear causality testing adopted here provides no guidance on the sources of the nonlinear dependence. This would require specific parameterized structural models, which is beyond the scope of this paper.

2. Data and methodology

Our empirical analysis is performed on Australia, Canada, France, Germany, Italy, Japan, South Korea, New Zealand, Taiwan, the UK, and the United States. The measure of economic activity is the value of quarterly GDP seasonally adjusted, in constant prices drawn from the IMF's *International Financial Statistics*. The Center for International Business Cycle Research (CIBCR) at Columbia University produces leading indices of economic activity for these countries using a variant of the NBER methodology. Several other measures on the leading index of economic activity are available, but we focus exclusively on the data compiled by the CIBCR for the sake of comparability across countries. The series for the leading index were provided monthly and averaged to quarterly values. For each country, the sample period begins at the earliest quarter where both leading index and GDP are all available, and ends at 1999:Q4.[1] The respective starting dates are: 1948:Q1 for the US; 1959:Q3 for Australia; 1960:Q1 for Germany and the UK; 1961:Q1 for Canada, Japan and Taiwan; 1970:Q1 for France and Italy and South Korea; 1977:Q2 for New Zealand. All data are expressed in their natural logarithms.

The nonlinear Granger causality test used here is a modified version of Baek and Brock (1992) by Hiemstra and Jones (1994). This approach postulates that by removing linear predictive power, any remaining incremental predictive power of one residual series for another can be considered nonlinear predictive power. A nonparametric statistical method is then proposed employing the correlation integral (a measure of spatial dependence across time) to uncover nonlinear causal relationships between two time series.

To define nonlinear Granger causality, assume that there are two strictly stationary and weakly dependent time series $\{X_t\}$ and $\{Y_t\}$, $t = 1, 2, 3, \ldots, T$. Let the m-length lead vector X_t be designated by X_t^m, and the Lx-length and Ly-length lag vectors of X_t and Y_t be designated by X_{t-Lx}^{Lx} and Y_{t-Ly}^{Ly}, respectively. For given values of m, Lx, and Ly and for e, $\{Y_t\}$ does not strictly Granger cause $\{X_t\}$ if:

$$\begin{aligned}&\Pr(\|X_t^m - X_s^m\| < e \mid \|X_{t-Lx}^{Lx} - X_{s-Lx}^{Lx}\| < e, \quad \|Y_{t-Ly}^{Ly} - Y_{s-Ly}^{Ly}\| < e)\\ &= \Pr(\|X_t^m - X_s^m\| < e \mid \|X_{t-Lx}^{Lx} - X_{s-Lx}^{Lx}\| < e)\end{aligned} \tag{1}$$

[1] The data on the leading index are those reported in the issue of *International Economic Indicators*, 2000, Jan/Feb, Vol. 23, No. 1 (the first which contains all figures corresponding to 1999:Q4).

here $\Pr(\cdot)$ and $\|\cdot\|$ denote probability and maximum norm, respectively. In Eq. (1), 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 Lx-length lag vectors of $\{X_t\}$ and Ly-length lag vectors of $\{Y_t\}$ are within a distance e of each other. The right-hand side in Eq. (1) 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 Lx-length lag vectors of $\{X_t\}$ are within a distance e of each other.

A test based on Eq. (1) can be implemented by writing it in terms of the corresponding ratios of joint probabilities:

$$\frac{C_1(m+Lx,Ly,e)}{C_2(Lx,Ly,e)}=\frac{C_3(m+Lx,e)}{C_4(Lx,e)} \tag{2}$$

where C_1, C_2, C_3 and C_4 are the correlation-integral estimator of the joint probabilities which are discussed in detail by Hiemstra and Jones (1994). For given values of m, Lx, and $Ly \geq 1$ and $e > 0$ under the assumption that $\{X_t\}$ and $\{Y_t\}$ are strictly stationary and weakly dependent, if $\{Y_t\}$ does not strictly Granger cause $\{X_t\}$ then,

$$\sqrt{n}\left[\frac{C_1(m+Lx,Ly,e,n)}{C_2(Lx,Ly,e,n)}-\frac{C_3(m+Lx,e,n)}{C_4(Lx,e,n)}\right]\rightarrow N(0,\sigma^2(m,Lx,Ly,e)) \tag{3}$$

where $n = T + 1 - m - \max(Lx, Ly)$. See the appendix of Hiemstra and Jones (1994) for both definition and an estimator of $\sigma^2(m, Lx, Ly, e)$. This test has very good power properties against a variety of nonlinear Granger causal and noncausal relations, and its asymptotic distribution is the same if the test is applied to the estimated residuals from a VAR model (Hiemstra and Jones, 1994).

3. Empirical results

To help decide what models to fit, the two series GDP and CLI were tested for unit roots and then for cointegration. Augmented Dickey–Fuller tests suggest that both GDP and CLI are characterized by an I(1) process for all countries under study (not shown). Upon these results, we applied the Johansen procedure to test for evidence of cointegration between the two series (not shown). Both the trace and maximum eigenvalue tests find evidence of one cointegration relation for Australia and the U.S. at the 5% significance level.[2] For the other nine countries, however, Johansen tests indicated no cointegrating relationships between the series at the 5% significance level. The absence of long-run relationships in the majority of the countries may not be unusual given the fact that the CLI is designed to predict short-term movements in economic activity (around 6 months ahead). In this connection, Harvey (1993) comments that there is no strong economic reason for GNP/GDP and the index of leading indicators to be cointegrated.

Based on the results of cointegration analysis, we specify the following vector error correction (VEC) models for Australia and the US:

[2] The estimated cointegrating vectors normalized on GDP are (1.00, −0.76) and (1.00, −0.92) for Australia and the US, respectively.

$$\begin{aligned}\Delta \mathrm{GDP}_t &= \text{constant} + \sum_{i=1}^{p} \phi_i \, \Delta \mathrm{GDP}_{t-i} + \sum_{i=1}^{p} \theta_i \, \Delta \mathrm{CLI}_t + \alpha_1 \mathrm{ECT}_{t-1} + U_t \\ \Delta \mathrm{CLI}_t &= \text{constant} + \sum_{i=1}^{p} \rho_i \, \Delta \mathrm{GDP}_{t-i} + \sum_{i=1}^{p} \eta_i \, \Delta \mathrm{CLI}_t + \alpha_2 \mathrm{ECT}_{t-1} + V_t\end{aligned} \tag{4}$$

where Δ is the first difference operator and U_t and V_t are the disturbance terms. The series ECT_t is the error correction term corresponding to the largest eigenvalue of the cointegrating matrix for a given rank of one. In this case, there can exist two channels of Granger causality from the CLI to GDP: long-run and short-run causality. A test of long-run causality is conducted on the basis of the null hypothesis $\alpha_1 = 0$, which implies that GDP is weakly exogenous to the estimated long-run relationship. A test of short-run causality is conducted on the null hypothesis $\theta_i = 0$ for all i ($i = 1,2, \ldots, p$) in the usual manner. For those countries with no cointegration found, only the test of short-run causality is carried out in a standard VAR model (i.e. without error correction terms from Eq. (4)).

Table 1 reports the results of conventional Granger causality tests, which assume linearity. For Australia and the US, the null hypothesis that $\alpha_1 = 0$ is rejected strongly as the t-statistics of α_1 turned out be -5.92 and -7.01, respectively. On the other hand, the t-test statistics cannot reject the null hypothesis that $\alpha_2 = 0$ for both countries. Consequently, the long-run causality resulting from cointegration is shown to be operating in the equation for GDP, but not in the equation for the CLI. There is also strong evidence of short-run causality from the CLI to GDP for both countries. The F-statistics reject the null hypothesis of $\theta_1 = \theta_2 = \cdots = \theta_p = 0$ even at 1% significance level.

For the other countries, however, the results of short-run causality tests are mixed. Germany and Taiwan are the only countries whose CLIs are shown to Granger cause GDP growth. The F-statistics accept the null hypothesis of no causality for the remaining seven countries at standard significance levels. Taking all results together, the (linear) causality from the CLI to GDP is at work only for Australia, Germany, Taiwan and the US. We find no evidence of this causality for the rest of the countries, which may downgrade the predictive ability of the CLI. However, the results drawn from the linear causality test contrast sharply with those of the nonlinear causality test, which are reported next.

Table 1
Testing for linear Granger causality

Short-run causality test: H_0: $\theta_1 = \theta_2 = \theta_3 = \cdots = \theta_p = 0$					
Australia	Canada	France	Germany	Italy	Japan
4.16	1.88	1.34	5.28	0.79	1.05
(0.00)	(0.12)	(0.25)	(0.00)	(0.60)	(0.39)
South Korea	New Zealand	Taiwan	UK	US	
2.02	1.54	3.33	1.26	7.21	
(0.08)	(0.18)	(0.02)	(0.29)	(0.00)	
Long-run causality test: H_0: $\alpha_i = 0$, $i = 1,2$					
H_0	Australia		H_0	US	
$\alpha_1 = 0$	-5.92 (0.00)		$\alpha_1 = 0$	-7.01 (0.00)	
$\alpha_2 = 0$	-0.82 (0.41)		$\alpha_2 = 0$	-1.35 (0.18)	

Notes: figures in parentheses refer to the marginal significance levels for the test.

We test for the presence of nonlinear causal relations by applying the modified Baek and Brock test to the residuals from estimated VAR models, $\hat{U}_t$ and $\hat{V}_t$ in Eq. (4). Before conducting the tests, values for the lead length m, the lag lengths Lx and Ly, and the scale parameter e must be chosen. On the basis of the Monte Carlo results in Hiemstra and Jones (1993), for all cases, the lead length is set at $m = 1$ and $Lx = Ly$, using common lag lengths of 1–4 lags. Also, in all cases, the test is applied to the standardized series using a common scale parameter of $e = 1.5\sigma$, where $\sigma = 1$ denotes the standard deviation of the standardized time series. Table 2 sets out the results. The standardized test statistic

Table 2
Testing for nonlinear Granger causality

	H_0: The CLI does not Granger cause GDP					
$Lx = Ly$	Australia		Canada		France	
	CS	TVAL	CS	TVAL	CS	TVAL
1	0.0196	2.1638[b]	0.0307	2.0262[b]	0.0269	1.4297[a]
2	0.0254	2.3396[c]	0.0411	2.4408[c]	0.0324	1.6323[a]
3	0.0283	2.0030[b]	0.0486	2.6678[c]	0.0399	1.8285[b]
4	0.0290	1.7589[b]	0.0521	2.4231[c]	0.0478	2.0057[b]
$Lx = Ly$	Germany		Italy		Japan	
	CS	TVAL	CS	TVAL	CS	TVAL
1	0.0235	1.8227[b]	0.0095	0.5007	0.0346	2.3470[c]
2	0.0258	1.7730[b]	0.0112	0.5595	0.0405	2.4644[c]
3	0.0296	1.6589[b]	0.0190	0.7934	0.0496	2.6137[c]
4	0.0328	1.7527[b]	0.0226	0.8386	0.0547	2.6431[c]
$Lx = Ly$	South Korea		New Zealand		Taiwan	
	CS	TVAL	CS	TVAL	CS	TVAL
1	0.0301	1.5236[a]	0.0263	1.3311[a]	0.0032	0.2312
2	0.0412	1.8952[b]	0.0386	1.7486[b]	0.0079	0.5093
3	0.0638	2.6898[c]	0.0502	2.0536[b]	0.0132	0.7675
4	0.0774	3.0070[c]	0.0626	2.2386[b]	0.0186	0.9834
$Lx = Ly$	UK		US			
	CS	TVAL	CS	TVAL		
1	0.0305	2.2265[b]	0.0012	0.1421		
2	0.0376	2.5840[c]	0.0036	0.3646		
3	0.0432	2.2194[b]	0.0085	0.7070		
4	0.0486	2.0596[b]	0.0104	0.6988		

Notes: $Lx = Ly$ denotes the number of lags on the residuals series used in the test. CS and TVAL, respectively, denote the difference between the two conditional probabilities in Eq. (2) and the standardized test statistics in Eq. (3). Under the null hypothesis of nonlinear Granger noncausality, the test statistics is asymptotically distributed $N(0,1)$ and is a one-tail test.

[a] Significance at the 10% level for a one-sided test (critical value = 1.280).

[b] Significance at the 5% level for a one-sided test (critical value = 1.645).

[c] Significance at the 1% level for a one-sided test (critical value = 2.326).

from Eq. (3), denoted by TVAL, is asymptotically distributed $N(0,1)$ under the null hypothesis of nonlinear Granger noncausality from the CLI to GDP.

The findings are striking. Eight countries support nonlinear causality from the CLI to GDP. Among these, Canada, France, Japan, South Korea, New Zealand and the UK are the countries in which there was no evidence of linear causality from the CLI to GDP. Our new evidence suggests that the CLI can be helpful in predicting movements in GDP growth for these six countries, but this may not be exploited under the restriction of linearity. Table 2 also indicates that for Australia and Germany, there remains nonlinear information in the CLI, which may act to improve the prediction of GDP growth. There is no evidence of nonlinear causality from the CLI to GDP for the remaining three countries, namely, Italy, Taiwan and the US. For the cases of Taiwan and the US, no further causal relation is found beyond the linear causality.

4. Concluding remarks

This paper has set out to assess the ability of the CLI to predict future movements in GDP growth. The modified Baek and Brock test provides evidence of nonlinear causality from the CLI to GDP growth for eight countries among 11 countries under consideration. The results contrast sharply with those of the linear causality test in which only four countries were in support to the causality from the CLI to GDP growth. An important implication is that there remains nonlinear information in the CLI, which may be usefully exploited in the prediction of GDP growth.

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