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Cointegration analysis with structural changes between consumption and economic growth in China

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Abstract: In order to investigate the existence of a stable long-run equilibrium relationship between economic growth and consumption in China, the relationship between the gross domestic product (GDP) and consumption in China was investigated by the cointegration analysis method. Using the Engle-Granger (EG) test and considering the possibility of structural changes, the impact of external economic shocks on the long-run equilibrium relationship between economic growth and consumption in China was analyzed. Analysis results show that without considering structural changes, the EG test cannot detect cointegration in the series subjected to structural changes; in considering structural changes, cointegration is successfully detected by specifying the dummy variable. In addition, the error correction models were constructed in different periods. This study verifies the existence of a long-run equilibrium relationship between economic growth and consumption in China, and this relationship has significantly changed in 1989 and 1997, respectively.

Key words: cointegration with structural changes; economic growth; dummy variable; consumption; error correction model

Consumption is important to stimulate economic growth. According to microeconomic theory, the increase in consumption will promote the increase of aggregated demand, which contributes greatly to economic growth. However, the increase in consumption will decrease capital accumulation, which is important for economic growth. Therefore, a stable long-run equilibrium relationship can be conceived to exist between consumption and economic growth. Cointegration is one of the powerful tools of characterizing this relationship. Cointegration characterizes the long-run relationship between variables. It can be imagined that the longer the period in a real economic environment, the higher the possibility that the economic system will be affected by some external events; therefore, the higher the possibility that the data structural changes. Naturally, it can be conceived that the changes in data structure will change the original cointegration relationship if it exists.

Because of economic reformation, economic situations around the world change frequently, such as the financial crises in southeast Asian countries, the Peso crisis of Mexico, and the economic transformation in China. All these events influence the data generating process and cause changes in data structure. If data structure really changes, the results of cointegration analysis ignoring the change are questionable. In this paper, structural change is considered in the cointegration analysis of economic growth and consumption, and the method of the Engle-Granger (EG) test is used.

The relationship between consumption and economic growth has been extensively studied. Han[1] found that the stable dynamic equilibrium relationship between income and consumption cannot be justified for the period of 1980 to 1995 due to the sharp change of economic regime and environment. Zhu et al.[2] found the cointegration relationship between Chinese national income and consumption in the period of 1952 to 1993 and built an error correction model. Yang et al.[3] examined the cointegration between China national income and gross consumption in the period of 1952 to 1993 and found that the cointegration relationship between Chinese national income and the aggregate consumption had changed. However, the possibility of data generating process change has not been adequately considered so far. Gregory and Hansen[4] show that structural breaks have important influences on cointegration analysis, for example, the cointegration testing power deterioration. Thereby, it fails to reject the null hypothesis; i. e., it erroneously concludes no cointegration. In addition, the sample data used in the literature so far are only up to the 1990s; therefore, the changes in economic growth and consumption in the recent ten years cannot be reflected. Furthermore, a dramatic change in the economic environment since 1978 undermines the value of using the data before 1978 to characterize the relationship between consumption and

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economic growth from 1978.

On the cointegration with structural changes, Yang et al. provided a definition and classification[3]. Gregory and Hansen[4] studied the cointegration with drifting using a method of cointegration based on residuals. Brooks et al. [5] examined the cointegration with structural changes using EuroSterling rates and found that it was unconvincing if the structural change was not considered. Yang et al. [6] investigated cointegration between a number of emerging stock markets and the USA stock market using recursive cointegration analysis and concluded that significant crisis events could change the degree of cointegration and need to be considered in the study of long-run relationships among economic variables.

Based on the analyses of the literature, the relationships between consumption and economic growth subject to structural changes need further study. In this paper, we use the data from 1978 to 2003 to study the relationships between consumption and economic growth with structural changes.

1 Cointegration Analysis without Structural Change

The cointegration relationship between two economic variables using the EG method is tested in this section. First, we define the two time series variables and perform the sample normality test. Secondly, we examine the stationarity of the two series. Finally, we perform the cointegration analysis.

1.1 Variable definition and normality test

Let X_t denote the consumption level presented by general consumption data and Y_t indicate the economic growth presented by GDP data. Considering natural log transformation will not change the relationship between variables, we apply natural log transformation on both series, and let variables X_t^L and Y_t^L represent the transformed time series variables. The data for this study come from *China Statistical Yearbook* (2004) covering the period from 1978 to 2003.

Jarque-Bera statistics for X_t^L and Y_t^L are 2.224 2 and 2.328 4, respectively, with corresponding companion probabilities 0.328 9 and 0.312 2. It demonstrates that the series of residuals follow normal distribution.

1.2 Stationary analysis

Empirical tests for cointegration can only proceed if the time series involved is $I(1)$. In this paper, the augmented Dickey-Fuller (ADF) is conducted to test this property on raw series and differenced series at lag 1. The results are shown in Tab. 1.

Tab. 1 Results of stationarity test

Variables	ADF-statistics	Test form(C, T, K)	10% critical value
Y_t^L	−0.930 3	(C, T, 1)	−2.634 8
X_t^L	−0.877 3	(C, T, 1)	−2.634 8
ΔY_t^L	−2.673 4 *	(C, N, 1)	−2.638 1
ΔX_t^L	−2.461 6	(C, N, 1)	−2.638 1

Notes: C, T and K represent the intercept, the tread and the lag order chosen by AIC, respectively; N means that the tread is not included in the test form; Δ denotes first order difference; * represents the significant level at 10%.

There is striking evidence of the non-stationarity of time series. The ADF test statistics of differenced Y_t^L at lag 1 is smaller than 10% critical value, demonstrating that differenced Y_t^L series is stationary at 10% level. The ADF test statistics of differenced X_t^L at lag 1 is very close to 10% critical value. Generally, rejecting null hypothesis is regarded as strong evidence of stationarity. Correspondingly, failure to reject null hypothesis implied non-stationary. However, the power of the ADF tests falls sharply in the presence of a structural change, resulting in the results of the ADF test being shown to be non-stationary while it is. Thus, whether or not to reject the null hypothesis cannot be regarded as decisive evidence on series stationarity[5, 7, 8]. Allowing for the incompetence of the ADF test in a small sample, it is safe to conclude that differenced X_t^L series is stationary at low critical levels. In summary, the two series satisfy the requirement of cointegration analysis.

1.3 Cointegration analysis

We first make an ordinary least square (OLS) regression on the two variables to produce the residual series $\hat{u}_t$. Then we test the residual series with results shown in Tab. 2.

Tab. 2 Results of stationarity test of residual series $\hat{u}_t$

ADF-statistics	10% critical level	5% critical level	Test form
−2.393 4	−2.634 8	−2.990 7	(N, N, 1)

Test results demonstrate that the residual series is non-stationary. Therefore, we conclude that the cointegration of the two series does not exist.

The above analysis demonstrates that there is no cointegration between economic growth and consumption by using the EG method without considering structural changes. However, the results should be interpreted with caution. As discussed previously, conventional cointegration tests assume that the long-run equilibrium relationship between the economic variables in question is stable over the entire sample period. This assumption may not hold if there are significant changes in the economic environment over the sample period, leading to the cointegration analysis subject to structural changes.

2 Cointegration Analysis with Structural Change

2.1 Dummy variable definition

Change points allowing for significant events are typically used to model structural changes. However, due to the lag of the real economic system, it is not possible to precisely gain a prior knowledge on change points. Therefore, change points have to be estimated. In this paper, we define a dummy variable such that

$$D_{t,\tau} = \begin{cases} 0 & \text{if } t \leqslant [n\tau] \\ 1 & \text{if } t > [n\tau] \end{cases}$$

where the unknown parameter $\tau \in (0, 1)$ denotes the timing of change points, and $[n\tau]$ denotes the absolute integer part with $n = 26$ (the number of observations). Usually, τ is within the range of $(0.15, 0.85)$. When τ are 0.15, 0.30, 0.45, 0.60 and 0.75, $[n\tau]$ are 3, 7, 11, 15, 19, respectively. Using the value of $[n\tau]$, we can estimate the point of structural changes.

2.2 Change point estimation

The model for estimating structural changes is specified as

$$Y_t^{\mathrm{L}} = \alpha + \mu D_{t,\tau} + \beta X_t^{\mathrm{L}} + \varepsilon_t \quad (1)$$

where α denotes the intercept before a break occurs, and μ denotes the change at the change point. According to Eq. (1), we make an OLS estimation for different dummy variables. The results are shown in Tab. 3.

Tab. 3 Results of estimating the change point

Observation number	Dummy variable	
	t-statistics	Probability
3	−1.892 9	0.071 0 *
7	1.839 5	0.078 8 *
11	2.230 0	0.035 8 **
15	0.635 0	0.531 7
19	−2.686 7	0.013 2 **

Notes: * Significant at 10% level; ** Significant at 5% level.

From Tab. 3, the probabilities of dummy variable coefficients for observation 11 and 19 demonstrate the significance at 5% level. And, we conclude that structural changes occur in 1989 and 1997.

2.3 Cointegration analysis

Using the structural change point set in 1989 and 1997, we make an OLS estimation and produce the residual series $\hat{v}_t$. Afterwards, we make an ADF test with the results shown in Tab. 4.

Tab. 4 Result of stationarity test of residual series $\hat{v}_t$

Observation number (year)	ADF-statistics	PP-statistics
11(1989)	−3.0234 *	−3.1686 *
19(1997)	−3.1242 *	−4.0501 **
Test form	(*N*, *N*, 1)	(*N*, *N*, 2)

Notes: * Significant at 5% level; ** Significant at 1% level.

Test results demonstrate that the two residual series are stationary. Therefore, we believe that the cointegration relationship between consumption and economic growth exists and the cointegration relationship took a level shift change in 1989 and 1997.

The cointegration and error correct models are rebuilt in the period of 1989 to 1997 and 1997 to 2003, respectively, such that

$$Y_t^{\mathrm{L}} = 0.277\,5 + 0.052\,5D_{t,11} + 1.018\,2X_t^{\mathrm{L}} \quad (2)$$

$$\varepsilon_t^{\mathrm{ecm}} = Y_t^{\mathrm{L}} - 0.277\,5 - 0.052\,5D_{t,11} - 1.018\,2X_t^{\mathrm{L}}$$

$$\Delta Y_t^{\mathrm{L}} = -0.019\,8 + 1.163\,2\Delta X_t^{\mathrm{L}} - 0.541\,1\varepsilon_{t-1}^{\mathrm{ecm}} \quad (3)$$

$$t = (-2.026\,1)\ (17.451\,3)\ (-3.687\,5)$$

$$p = (0.055\,0)\ (0.000\,0)\ (0.001\,3)$$

$$\text{F-stat} = 174.141\,1,\ \text{Prob(F-stat)} = 0.000\,0$$

$$R^2_{-\mathrm{adj}} = 0.935\,2$$

$$Y_t^{\mathrm{L}} = -0.013\,8 - 0.051\,0D_{t,19} + 1.053\,4X_t^{\mathrm{L}} \quad (4)$$

$$\varepsilon_t^{\mathrm{ecm}} = Y_t^{\mathrm{L}} + 0.013\,8 + 0.051\,0D_{t,19} - 1.053\,4X_t^{\mathrm{L}}$$

$$\Delta Y_t^{\mathrm{L}} = -0.013\,7 + 1.118\,0\Delta X_t^{\mathrm{L}} - 0.561\,3\varepsilon_{t-1}^{\mathrm{ecm}} \quad (5)$$

$$t = (-1.644\,0)\ (19.871\,9)\ (-4.340\,0)$$

$$p = (0.114\,4)\ (0.000\,0)\ (0.000\,3)$$

$$\text{F-stat} = 201.384\,2,\ \text{Prob(F-stat)} = 0.000\,0$$

$$R^2_{-\mathrm{adj}} = 0.943\,5$$

The long-run cointegration relationship in 1989 to 1997 and 1997 to 2003 are (2) and (4), respectively. The error correct model is (3) and (5), respectively. Formulae (3) and (5) illustrate that the short-run change in consumption will lead to a change in the economic growth in the same direction. The result is in line with the theory of microeconomics. Coefficient of ε reflects the power of adjusting violation of long-run equilibrium. The estimation of coefficient illustrates that about 56% and 54% current violation of long-run equilibrium will be adjusted in the two models, respectively. Statistically significant estimates of the error-correction term coefficient strengthen the evidence in favor of cointegration. The result demonstrates that the model, which has been built, can satisfactorily explain the relationship of variables.

2.4 Empirical results analysis

The results of cointegration analysis with structural changes finds the cointegration relationship between the economic growth and the consumption, and also the changes in cointegration relationship. This result is consistent with the situation of economic development and consumption in China. At the beginning of the economic transformation in China, the residential income improved quickly. As a result, consumption increased quickly and stimulated the growth of the consumption industry. This trend reaches its climax in the later 1980s. At the same time, residential wealth was gradually increasing, and the consumption

propensity changed greatly. The estimated change point in 1989 corresponds to the change in the cointegration relationship in 1989.

A same correspondence can be observed between the change point estimation and the economic change in 1997. With the deepening of economic transformation, the original social welfare for city residents has gradually changed since 1997. For example, housing, medical care, and education began to be marketed, all of which affect the economic growth dramatically, and change the consumption propensity.

In summary, the proposed model explains ideally the real relationship between economic growth and consumption subject to economic changes.

3 Conclusions

Structural changes are often encountered in modeling the economic system subject to economic environment changes. In particular, during the era of switching from a planned economy to a market economy, precise and timely reflection of economic system changes is the basis of successful analysis of the relationship between economic variables. In this paper, considering the possibility of structural changes and using dummy variables and the cointegration method, we make the cointegration analysis with structural breaks for economic growth and consumption. The results of this study demonstrate that:

1) Cointegration is not observed by using the EG method without considering structural changes;

2) When considering structural changes, the EG method can detect the cointegration relationship;

3) The cointegration relationship between consumption and economic growth changed in 1989 and 1997. In addition, the error correct model is built in the periods of 1989 to 1997 and 1997 to 2003.

In conclusion, significant statistical evidence exists to indicate the change in the cointegration relationship between consumption and economic growth based on current samples.

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中国经济增长与消费的变结构协整分析

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摘要:为了研究中国经济增长与消费之间是否具有长期稳定均衡关系,用协整分析方法检验了中国国内生产总值(GDP)与消费水平之间的关系. 采用恩格尔-葛兰杰(EG)检验并考虑数据结构变化的可能,研究了外部经济环境冲击对中国经济增长与消费之间长期均衡关系的影响. 分析结果表明:如不考虑样本数据的结构变化,对于变结构时间序列数据,EG 方法没有检验到协整关系;如考虑结构变化,通过设定虚拟变量,协整关系被成功测出. 并且建立了不同时期的误差修正模型. 研究表明我国经济增长与消费之间已形成长期稳定均衡关系,该关系分别于 1989 年和 1997 年产生显著变化.

关键词:变结构协整;经济增长;虚拟变量;消费;误差修正模型

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