Business Cycle Asymmetry in China: Evidence from Friedman's Plucking Model

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Abstract: Friedman's plucking model of business fluctuations suggests that output cannot exceed an upper limit, or ceiling level, but it is occasionally plucked downward, with depth and steepness, due to recessions. This paper investigates China's business fluctuations using the quarterly real GDP data over the period 1978-2009. Our results provide some support for the plucking model. We find that there exists the ceiling effect of real output, and the negative asymmetric shocks affect the transitory component significantly, which therefore captures the plucking downward behavior during the recession from the idea of Friedman. In addition, it is also suggested by the results that the basic asymmetric UC model is not appropriate for directly modeling China's real output since the business cycle is inaccurately measured, but it works quite well when considering a structural break at 1992:Q2.

Key Words: business cycle; plucking model; asymmetry; regime switching; structural break

1. Introduction

Asymmetry in economic expansions and recessions is one of the natural features of business cycle in modern macroeconomics. In the earlier days, Mitchell (1927) and Keynes (1936) noted that recessions are shorter than expansions, and also more sudden and violent. Delong and Summers (1986), Sichel (1993), Ramsey and Rothman (1996), etc. further reported that recessions are deeper and steeper. They attributed recessions to occasionally transitory shocks, while expansions to permanent shocks.

In accordance with Keynes' observations, Friedman (1964, 1993) also found the business cycle asymmetry: The size of a recession greatly influences the size of the succeeding expansion, with major expansions tending to follow major recessions, but not vice versa. This led him to introduce the plucking model of business fluctuations. In his model, there is another empirical regularity that real output shows an important ceiling effect; growth rates are on average below the ceiling rate, but tend back to it. If the ceiling level of output can be estimated, we can not only determine the size of the recession, but also the gap between real growth rate and trend growth rate. Both the regularities and their theoretical discussions have important implications for business cycle analysis.

The business cycle asymmetry has been put into great concern in both economic theory and empirical research, on which extensive literatures have been studying, e.g. Neftcy (1984), Hamilton (1989), Diebold, Rudebusch and Sichel (1993). Friedman (1993) used a correlation method to analyze the U.S. real GNP, and found the evidence of the ceiling effect as well as the unidirectional relationship between the size of the recession and the subsequent expansion. Goodwin and Sweeney (1993) applied Friedman's correlation method and a frontier production approach to a set of eight industrial countries. They found that although there is weak support for the hypothesis of steepness, there is substantial support for the proposal that the output ceiling plays a major role in business cycle fluctuations in Canada, France, Germany, Switzerland, and the United States. Razzak (2001) applied a nonparametric test to a set of six industrial countries and found that Japan and Australia real GDP series show significant depth, while for New Zealand, there is only significant steepness in real GDP. Kim, Morley and Piger (2005) extended the Hamilton's regime-switching model with a ''bounce-back'' term, which links the length of each recession with the strength of the following recovery. They found a strong ''bounce-back'' effect for the United States and Australia.

However, Friedman's and Goodwin and Sweeney's evidence on the plucking model is limited, in that it is not based on a formal econometric model which can capture the asymmetric business cycle. Kim and Nelson (1999, hereafter KN99) first proposed a formal econometric method describing Friedman's plucking model, which is able to estimate the size of negative shocks and test the plucking hypothesis against the symmetric trend-plus-cycle alternative. They used the Markov regime-switching state space model to estimate the trend and cyclical components for the United States and found that recessions are periodic due to relatively large negative shocks. Later on, Mills and Wang (2002), De Simone and Clarke (2007) applied KN99's methodology to G7 countries and 12 industrial countries, and their results, to some extent, again supported the fact that the plucking model is an effective method to analyze the business cycle asymmetry. Recently, Sinclair (2009) further proposed an asymmetric UC-UR model, which is the generalization of Morley, Nelson and Zivot's (2003) correlated unobserved components model, allowing for asymmetry.

In recent years, Chinese scholars have done a lot of beneficial studies on the asymmetric business cycle in China. Liu and Fan (2001), and Xu, Zhu and Liu (2005) applied the Hodrick-Prescott filter and time series methods for trend decomposition to study asymmetries and correlations of China's business cycle, by testing and analyzing steepness and depth of cyclical component. Chen and Liu (2007) examined the asymmetry and persistence of China's business cycle by utilizing a MSMV(3)-AR(2) model, and the results showed the asymmetry and different persistence in three regimes from 1979:Q1 to 2004:Q4. In addition, Liu (2003), Liu and Wang (2003), Liu and Zheng (2008) separately identified the business cycle phases between recessions and expansions in China, using different nonlinear methods.

In this paper, we will investigate the trend and cyclical components of China's real output, further analyze the phases of business cycle and test the possible asymmetry. Under the fact of business fluctuations since reform and opening up, we take an empirical study on real output (GDP) using the quarterly data from 1978 to 2009. We will take two important concerns: the first is to construct an appropriate method to describe the features of China's business fluctuations, such as the possible structural change since the 1990s, so as to achieve the applicability of Friedman's plucking model effectively; the second is to identify the phases and asymmetries of China's business cycle, and judge the depth and length of the recession.

Apart from the introduction, the remainder of the paper is organized as follows. Section 2 is a brief review of China's business fluctuations. Section 3 is about the basic econometric model and its estimation. Section 4 presents the empirical results using China's quarterly real GDP data from 1978 to 2009, to describe the ceiling effect of output, to test the business cycle asymmetry, and to analyze the depth and length of the recession. The last section draws some conclusions.

2. Brief review of China's business fluctuations

It has been widely accepted that China's business fluctuations have gone through ten complete cycles since 1953, with five cycles before reform and opening-up, four cycles afterwards, and the last two years are in the downward phases of the fifth cycle. Figure 1 reports the time path of China's real GDP and economic growth rate since 1952. From the figure, it can be easily seen that business fluctuation in China is obvious, and its periodicity is also quite pronounced.

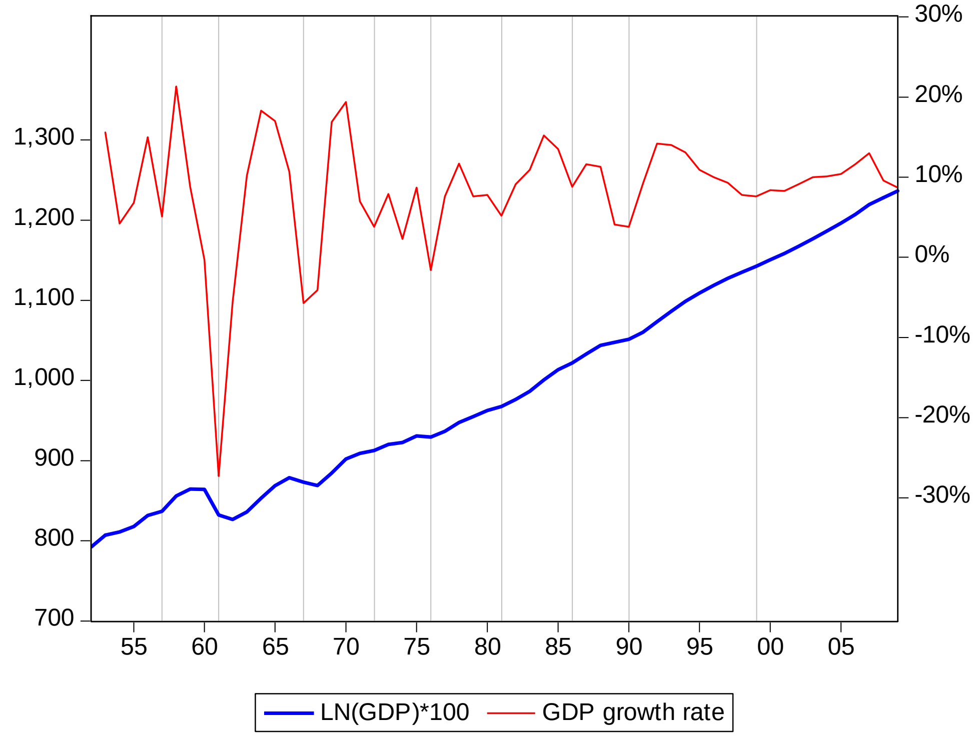

Figure 1. The log of real GDP and real GDP growth rate (1952 –2009, annual data)

Note: the solid bold line represents the log of real GDP×100, the solid thin line represents real GDP growth rate, and the vertical line represents the location of troughs for the first 9 business cycles; the 10th trough of the business cycle should be in 2009. The base year for the GDP price index is year 2000. The data are obtained from the CEI database at the China Economic Information Network.

From 1953 to the end of "the Great Cultural Revolution" in 1976, the highest peaks of economic growth rates for the five cycles appear respectively in 1956 (15%), 1958 (21.3%), 1964 (18.3%), 1970 (19.4%) and 1975 (8.7%), and the lowest troughs of economic growth rates are in 1957 (5.1%), 1961 (-27.3%), 1967 (-5.7%), 1972 (3.8%) and 1976 (-1.6%) respectively. All gaps between peaks and troughs are more than 10 percentage points except for the first cycle, the gap of which is 9.9%, and there were three violent ups and downs.

Since 1978, the highest peaks of economic growth rates appear respectively, in 1978 (11.7%), 1984 (15.2%), 1987 (11.6%), 1992 (14.2%) and 2007 (13%); the lowest troughs of economic growth rates respectively in 1981 (5.2%), 1986 (8.8%), 1990 (3.8%), 1999 (7.6%) and 2009 (the trough of this cycle, its annual GDP growth rate is 8.7%. Based on the results of quarterly data, this paper will show that the last cycle has been completed and the economic recovery began in the second quarter of 2009). All gaps between peaks and troughs are less than 8 percentage points.

Comparably speaking, after the reform and opening up, China's business cycles have changed from a path with violent fluctuations and big peak-trough gaps, to a path with gentle ups and downs and small peak-trough gaps, showing a "high growth –low fluctuation" type trend (Liu, etc. 2005).

In addition, after 1990, China's economy also shows a new feature, that is, the long "soft landing" period (1993-1999) and the long "soft expansion" period (2000-2007). During the time, the cyclical fluctuations are obviously weakened and the stabilities are markedly enhanced. In the following, we will detect this evident change, and it will be regarded as a breakthrough in our analysis.

3. Model specification

The empirical model used in this paper is mainly based on KN99's method; however, it will be appropriately adjusted in our empirical analysis. The main advantage of KN99's method is that it allows the output to be decomposed into a trend component and a cyclical component, both of which can be introduced a Markov discrete variable, so that it can capture the downward plucking behavior and the asymmetric cycle, along with the ceiling output.[1]

Consider the following asymmetric unobserved components (UC) model of business fluctuations and assume that the log of real GDP (y_t) is decomposed into two unobserved components:

$$y_t = n_t + c_t , \qquad (1)$$

where n_t is the trend component and c_t is the cyclical component.

In terms of Kim and Nelson (1999a), the cyclical component is assumed to be an AR(2) process. To capture the regime switching or asymmetric deviation of real GDP from the trend, however, we assume that the shock to the transitory component is a mixture of a symmetric shock (u_t) and an asymmetric, discrete shock (πS_t). The asymmetric shocks can capture the plucking behavior and it is consistent with the specification in Markov discrete mixture-of-normal-distributions suggested by KN99's method. Therefore, the cyclical component is given by

$$c_t = \phi_1 c_{t-1} + \phi_2 c_{t-2} + \pi S_t + u_t , \qquad u_t \sim N(0, \sigma_u^2(S_t)) , \qquad (2)$$

where πS_t is an asymmetric, discrete shock, depending upon the unobserved variable S_t , and u_t is the

[1] What reflects the business cycle feature is the cyclical component. If the cyclical component has an asymmetric innovation, then the business cycle would have asymmetric feature.

standard symmetric shock, which is also assumed to be state-dependent, i.e., $\sigma_u^2(S_t) = \sigma_{u0}^2(1-S_t) + \sigma_{u1}^2 S_t$. The discrete variable, S_t , depending on whether the economy is in normal times ($S_t = 0$) or in recession times ($S_t = 1$), is assumed to evolve according to the following first-order Markov-switching process as introduced in Hamilton (1989):

$$\Pr(S_t = 1 | S_{t-1} = 1) = q , \quad \Pr(S_t = 0 | S_{t-1} = 1) = 1 - q \tag{3}$$

$$\Pr(S_t = 0 | S_{t-1} = 0) = p , \quad \Pr(S_t = 1 | S_{t-1} = 0) = 1 - p . \tag{4}$$

To identify the states of business fluctuations, we restrict the discrete, asymmetric shock parameter (π) to be negative, i.e. $\pi < 0$. During the recession times ($S_t = 1$), the economy is hit by a transitory shock with negative expected value, and the cyclical component (c_t) is plucked downward. During normal times ($S_t = 0$), the economy is in expansion or recovery, and the cyclical component is entirely determined by a symmetric AR(2) process, where the closer the sum of the autoregressive coefficients $\phi_1 + \phi_2$ to zero, the quicker of the economic recovery must be.

To determine the stochastic trend component (the trend ceiling component), the potential output, or "the ceiling maximum feasible output," may be approximated by a random walk with all sorts of disturbances, including the technological disturbances stressed in the real business cycle literature, as suggested by Friedman (1993).[2] Therefore, the trend component is written as:

$$n_t = \mu + n_{t-1} + v_t , \qquad v_t \sim N(0, \sigma_v^2(S_t)) , \tag{5}$$

It is noteworthy that when the asymmetric parameter π is 0 (or $\pi = 0$), the model (1)-(3) would be reduced to the unobserved components (UC-UR) specification of Morley et al. (2003).[3] When the correlation parameter, $\rho = 0$, the model (1)-(3) would be reduced to KN99's specification. Moreover, when both $\pi = 0$ and $\rho = 0$, the model becomes the traditional unobservable component (UC-0) model. Therefore, the asymmetry and the correlation in this basic model can be tested through some suitable tests.

The empirical model presented above can be rewritten as a Markov-switching state space model, so we can adopt the approximate filter proposed by Kim (1994) and the approximate maximum likelihood estimation method to estimate the unobserved state vectors and the model parameters. For details of Kim's approximate MLE method, readers are referred to Kim and Nelson (1999b).

4. Empirical results

We select China's quarterly real GDP data from 1978:Q1 to 2009:Q4，with128 observations in total.

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[2] Kim and Nelson (1999a) allowed for a drift with a random walk process in the asymmetric UC model, which is consistence with the specification of Clark (1987). This paper also tries to set the drift as a random walk process, but the result is unsatisfactory. In addition, Sinclair (2009) also showed if allowing for correlation between drift and other disturbances, then the correlation coefficient may not be recognized, so she also recommended constant for the drift.

[3] Morley, Nelson and Zivot (2003) suggested that the UC-UR model with correlated innovations can be equivalently expressed to an ARIMA model, and the trend-cycle decomposition based on UC-UR model is also equivalent to the Beveridge-Nelson (BN) decomposition based on ARIMA model.

The data after 1994 are obtained from the CEI database at the China Economic Information Network, which is published by the National Bureau of Statistics. Since the official data were not published until 1994, we decompose China's annual real GDP data from 1978 to 1993 into quarterly data following the same way as Chen and Liu (2007) (for more details see Abeysinghe and Gulasekaran, 2004). Then, the series of real GDP are seasonally adjusted with the Tramo/Seats method. At last, the real output series are considered as 100 times the natural log of real GDP, that is, $y_t = 100 \times \log GDP_t$, $t = 1, 2, \ldots, T$.

In this section, our empirical analysis will be carried out in the following steps. Firstly, test the correlation between permanent and transitory shocks using the UC-UR model. If there exists, the correlation in asymmetric UC model should also be taken into account; but not vice versa. Secondly, estimate the basic asymmetric UC model. Here, the real output is decomposed into trend and cyclical components, so that we can test the asymmetry and determine whether the results are consistent with China's actual economy. Finally, consider an asymmetric UC model that allows for a structural break in model parameters. To account for that, it is mainly based on the fact that some changes have happened in China's business fluctuations since the 1990s, especially due to the "soft landing" and "soft expansion".

4.1. Testing for the correlation

Table 1 reports parameter estimates and standard errors (in parenthesis) for two linear UC models, where Model 1 represents the traditional UC-0 model with uncorrelated innovations, and Model 2 is the UC-UR model with correlated innovations. Here, we give special attention to a test for the correlation coefficient ρ , which can also be considered as an over-identification test of the UC-UR model, where the null hypothesis is $\rho = 0$, i.e., there is no correlation between the innovations, and the alternative hypothesis is $\rho \neq 0$, indicating the existence of the correlation.

Table 1. Parameter estimates for linear UC models

Parameters		Model 1	Model 2
AR(1) coefficient	ϕ_1	1.8897** (0.0475)	1.8915** (0.0477)
AR(2) coefficient	ϕ_2	-0.9218** (0.0467)	-0.9234** (0.0470)
Standard deviation of the permanent innovation	σ_v	0.5949** (0.0508)	0.4973** (0.2454)
Standard deviation of the transitory innovation	σ_u	0.2457** (0.0678)	0.2105** (0.1026)
Correlation between the innovations	ρ_{uv}	0	1.0000 (3.0879)
Drift term	μ	2.3745** (0.0577)	2.3738** (0.0495)
Log Likelihood		-138.461	-138.099

Note: Standard errors based on the negative inverse Hessian are given in parentheses. "**" denotes the rejection of the null hypothesis at 5% level of significance.

According to the log-likelihood values estimated from Model 1 and Model 2, a likelihood ratio statistic for testing $\rho = 0$ is 0.724, with its corresponding p-value being 0.3948. It is obviously shown that the null cannot be rejected, indicating that the UC-0 model is preferable. Next, although the value of correlation coefficient in the UC-UR model is very close to 1, the p-value of a Wald-type t test statistic shows that the correlation coefficient is not significant. Therefore, both the above tests for the significance of correlation coefficient suggest that we cannot reject the null of zero correlation between permanent and transitory innovations.

Since the correlation between the innovations was not found in the linear UC model, we can specify this coefficient with a constraint $\rho = 0$ in the asymmetric UC model below, which is similar to the model specification in KN99's paper, so as to avoid the problem of parameter over-identification.

4.2. Estimation results of the basic asymmetric UC model

Parameter estimates and standard errors for asymmetric UC models are reported in Table 2. Here, in Model 3, both permanent and transitory innovations are state-dependent on the discrete variable ($S_t = 0$ or 1), while in Model 4, the variances of the two innovations are assumed to be constants. In addition, the latter has the same specification as Sinclair (2009), but the former is similar to Kim and Nelson (1999a).

In the table, the results of log-likelihood values show that Model 3 performs better and reflects more information than Model 4. The reason is that the marginal log-likelihood value of Model 3 has increased by 7.02, relative to that of Model 4. On the other hand, the asymmetric UC model is more suitable for modeling China's real output series than the linear UC model (Model 1). It can be seen that the log-likelihood values of two asymmetric UC models (Model 3 and Model 4) are greatly improved, and the likelihood-ratio statistics are 34.14 and 20.10 with the corresponding p-value (bootstrapping-p value based on 1000 simulations) 0.003 and 0.012, respectively.[4] The above results show that the null of the linear UC model can be significantly rejected.

According to parameter estimates, the results indicate the existence of asymmetry in the cyclical component. It is reported in the table that the asymmetric shock parameters for Model 3 and Model 4 are both significantly less than 0; moreover, the larger the asymmetric parameter, the stronger the negative shock in the recession must be. As the standard error (σ_u) of the transitory innovation is almost 0, we can say that the cyclical component is only dependent on this asymmetric discrete shock. Compared with the linear UC model, the sum of autoregressive coefficients (i.e., $\phi_1 + \phi_2$) in the UC model is markedly reduced, indicating that the negative shock decays very fast, relatively short-lived. If there is no further negative shocks at the end of recession, economic recovery will come into being due to the coupling of positive shocks and negative shocks;[5] once all influences of the negative shocks disappear, the economy would return to the ceiling of output. In addition, the transition probabilities for measuring the probability of self-maintenance in expansions or recessions show that the self-maintenance of expansions is very strong with expected duration of $1/(1-p) = 36.5$ quarters; but it is very weak for recessions with expected duration of about 8 quarters. However, this result could be not accurate, because it is not consistent with the feature of China's business fluctuations after 1992.

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[4] Since the test statistic is non-standard for testing asymmetry in the regime-switching model, a parameter bootstrap test is implemented. In more details for bootstrap methods, readers are referred to MacKinnon (2006).

[5] Some papers also regard this stage as economic recovery of business cycle, such as Kim and Nelson (1999a), Kim, Morley and Piger (2005).

Table 2. Parameter estimates for linear asymmetric UC models

Parameters		Model 3	Model 4
AR(1) coefficient	ϕ_1	0.6861 (0.1316) **	0.6698 (0.1373) **
AR(2) coefficient	ϕ_2	0.1638 (0.1242)	0.1455 (0.1265)
Standard deviation of the permanent innovation	σ_{v0}	0.4724 (0.0323) **	0.5576 (0.0363) **
	σ_{v1}	0.8993 (0.1475) **	
Standard deviation of the transitory innovation	σ_{u0}	0.0000 (0.0974)	0.0000 (0.1433)
	σ_{u1}	0.0000 (0.5692)	
Drift term	μ	2.3056 (0.0522) **	2.3499 (0.0570) **
Asymmetric parameter	π	-2.3140 (0.2299) **	-2.3865 (0.2588) **
$\Pr[S_t = 0 \mid S_{t-1} = 0]$	p	0.9725 (0.0158) **	0.9713 (0.0165) **
$\Pr[S_t = 1 \mid S_{t-1} = 1]$	q	0.8785 (0.0655) **	0.8717 (0.0653) **
Log Likelihood		-121.394	-128.414

Note: Standard errors based on the negative inverse Hessian are given in parentheses. "**" denotes the rejection of the null hypothesis at 5% level of significance.

Next, to investigate the fitness of the asymmetric UC model, as well as the interpretability for China's business fluctuations, we use parameter results in Table 2 to estimate these unobserved variables in Model 3. Figure 3 depicts the trend component ($n_{t|t}$) which is the ceiling of output in Friedman's plucking model, and the filtered recession probabilities ($\Pr(S_t = 1 \mid Y_t)$), where Y_t represents all available information at time t. It is certain that the trend of output is well consistent with the ceiling level, describing two important plucking periods: 1980:Q4 to 1987:Q1, and 1989:Q1 to 1995:Q1. From the recession probabilities, moreover, we capture two recession periods (1980:Q4 to 1983:Q3, and 1989:Q1 to 1992:Q1, respectively) and one date of the recession (1986:Q1).

However, the results plotted by Figure 3 are not consistent with the facts of China's economy. Although the figure can well describe actual business cycles before 1992, it can hardly explain the periods after 1992, for example, the "soft landing" and "soft expansion" periods since 1993. Moreover, it also could not capture the apparent recession during the last two years due to the recent worldwide financial crisis. In view of that, it can be concluded that the basic asymmetric UC model is not appropriate to describe China's business fluctuations accurately. Therefore in the following, we introduce an asymmetric UC model with a structural break after 1990s, so as to better test and verify the applicability of Friedman's plucking model for China's business fluctuations.

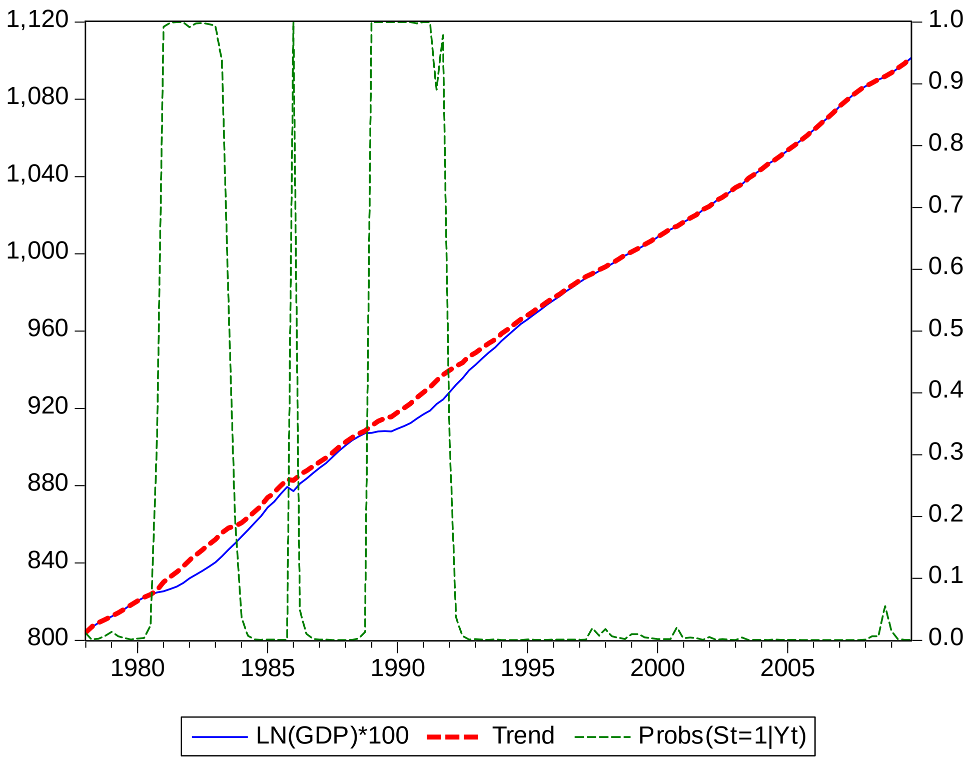

Figure 2. Trend component and recession probabilities

4.3. Structural break detection and estimation of the asymmetric UC model

One drawback of KN99's method is that the asymmetric shock parameter that measures the plucking downward behavior is assumed to be a constant. We notice that it sometimes cannot well capture the changing amplitude of recession, especially when considering the entire historical period of business fluctuations, but there could be a certain structural break ascribed to technical innovation, institutional reforms, etc. Put differently, we cannot use the same method to describe the structural change in business fluctuations. Therefore, the basic asymmetric UC models (Model 3 and Model 4) are then generalized to the models (Model 5 and Model 6 respectively) with possible structural breaks in parameters. For examples, if the asymmetric shock parameter π is changed, it implies that the degree of business cycle asymmetry has changed, and the recession pattern may change accordingly; if the drift term μ is changed, it implies that the trend slope of real output has changed; if the autoregressive parameters ϕ_1 and ϕ_2 are changed, then the persistence of the recession changes; if the standard deviations of the permanent and transitory innovations, σ_v and σ_u, are changed, then the shock strength may change. In addition, it is assumed that transition probabilities (p and q) are same before and after the breakpoint, since we have only two episodes of recessions after 1990s, which may cause the estimates to be imprecise.

Now, we consider a case that there is a structural break in the asymmetric UC model (Model 3) since 1978. Assume that each date is possibly a breakpoint from the period of 1991:Q1 to 2004:Q4, then we need to estimate 60 asymmetric UC models with different breakpoints. From estimated results, the date 1992:2 can be selected as a breakpoint, since the model reaches its maximum log-likelihood value (-98.851). Compared to Model 3, as the log-likelihood value is greatly increased, it implies that the asymmetric UC model with a structural break performs better than the basic asymmetric UC model.

There could be some economic explanations for this breakpoint 1992:Q2. From 1978 to 1991, the period from the reform and opening up to the establishment of market economy, China's economic activities followed the planned economic system. At that time, macro-regulation was not always cooperated with market regulation, so the amplitude of business fluctuations was very large. After 1992, however, with the evolution of market economic system, the basic role of market in allocating resources is improving, and the government's knowledge of economic rules has been greatly enhanced. Therefore, to some extent, the size of business fluctuations is reduced since 1992.

Table 3. Parameter estimates for asymmetry UC models with the breakpoint at 1992:Q2

Parameters		Model 5	Model 6
AR(1) coefficient before 1992	ϕ_1	0.9014 (0.0983) **	0.8885 (0.0956) **
AR(1) coefficient after 1992	ϕ_1	1.6081 (0.1037) **	1.6119 (0.1058) **
AR(2) coefficient before 1992	ϕ_2	-0.0602 (0.0884)	-0.0553 (0.0893)
AR(2) coefficient after1992	ϕ_2	-0.6501 (0.0924) **	-0.6536 (0.0943) **
Standard deviation of the permanent innovation before 1992	σ_{v0}	0.0000 (0.1644)	0.0000 (0.1559)
	σ_{v1}	0.0000 (0.4142)	
Standard deviation of the permanent innovation after 1992	σ_{v0}	0.2459 (0.0327) **	0.2918 (0.0264) **
	σ_{v1}	0.3256 (0.0389) **	
Standard deviation of the transitory innovation before 1992	σ_{u0}	0.6352 (0.0903) **	0.6679 (0.0660) **
	σ_{u1}	0.7155 (0.1309) **	
Standard deviation of the transitory innovation after 1992	σ_{u0}	0.0000 (0.0880)	0.0000 (0.1192)
	σ_{u1}	0.0000 (0.2239)	
Drift term before 1992	μ	-2.1945 (0.2971) **	-2.2566 (0.2629) **
Drift term after 1992	μ	-0.3281 (0.0891) **	-0.3236 (0.0926) **
Asymmetric parameter before 1992	π	2.4291 (0.0292) **	2.4260 (0.0275) **
Asymmetric parameter after 1992	π	2.3383 (0.0410) **	2.3436 (0.0400) **
$\Pr[S_t = 0 \mid S_{t-1} = 0]$	p	0.9197 (0.0358) **	0.9189 (0.0360) **
$\Pr[S_t = 1 \mid S_{t-1} = 1]$	q	0.9054 (0.0389) **	0.9029 (0.0399) **
Log Likelihood		-98.851	-100.146

Note: Standard errors based on the negative inverse Hessian are given in parentheses. "**" denotes the rejection of the null hypothesis at 5% level of significance.

Table 3 reports parameter estimates and standard errors for asymmetric UC models with the breakpoint at 1992:Q2, where in Model 5 the standard deviations of the permanent and transitory innovations are dependent on both the discrete state variable S_t and the breakpoint, while in Model 6 they are only dependent on the breakpoint. Overall, the standard deviations of the innovations in Model 5 are over-identified, and other parameter estimates are close to each other for Model 5 and Model 6. Firstly, the asymmetric parameter (π) is significantly less than 0 before and after 1992, but the absolute value before 1992 is 7 times larger than that after 1992, indicating that the amplitude of negative innovations or quarterly contractions is largely decreased. Secondly, the drift term μ is around 2.4, implying that the trend slope of real output is almost same, and China's annual trend growth rate is about 9.6. Thirdly, for the sum of autoregressive parameters ($\phi_1 + \phi_2$), the persistence after 1992 is obviously stronger than that before 1992, implying lower decay of the negative shock after the structural break, in accordance with the fact of the "soft landing" period. Fourthly, compared to the basic asymmetric UC model the transition probabilities change obviously, since the asymmetric UC model with a structural break can capture the actual business cycle after 1992. Here, the expected duration of expansions goes down to 12 quarters; and the expected duration of recessions increases to 10 quarters. In addition, the amplitude of permanent and transitory shocks is different before and after 1992. The real output, before 1992, is mainly affected by transitory shocks and asymmetric discrete shocks, but not the permanent shocks; while afterwards, it is mainly affected by asymmetric discrete shocks and permanent shocks, but not transitory shocks.

4.4. Trend, cycle and business cycle asymmetry

Based on the above results, we proceed to re-examine the business cycle behavior over the sample period, and evaluate the applicability of Friedman's plucking model. We use parameter estimates given in Table 3 to estimate the unobserved variables in Model 6, including the output trend ($n_{t|t}$), the cyclical component ($c_{t|t}$), and the recession probabilities ($\Pr(S_t = 1 | Y_t)$). According to Figure 3 and 4, we can obtain the following important results:

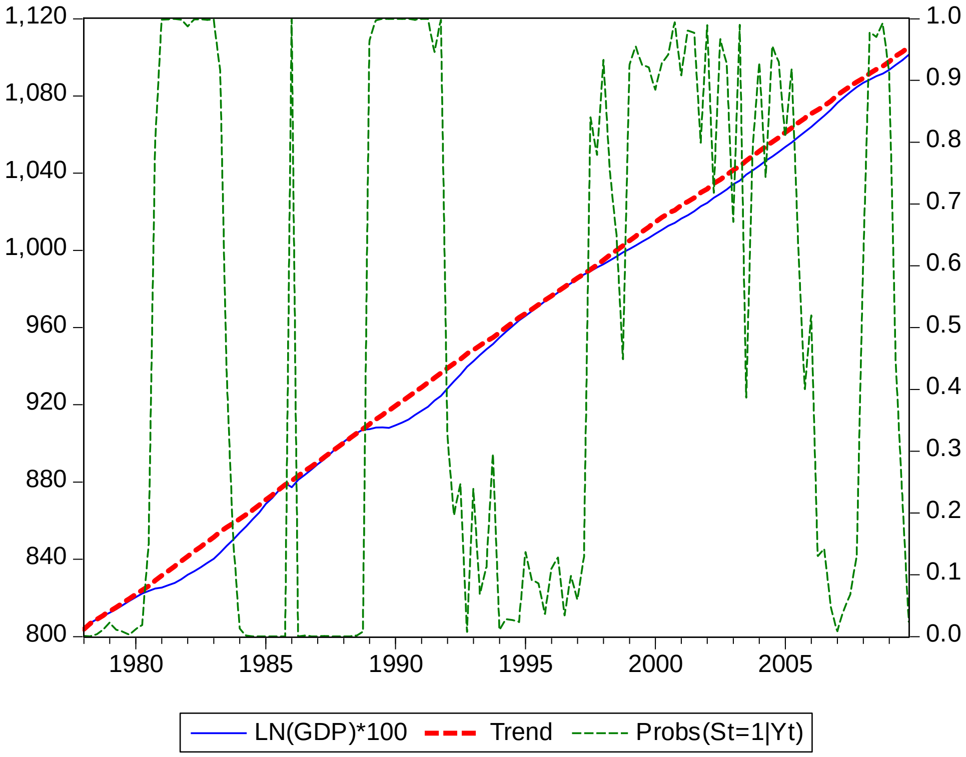

Figure 3. Trend component and recession probabilities

Firstly, recession probabilities well describe the phases of China's business cycle. We notice that if the probability is greater than 0.5, the economy is in recession. As is shown in Figure 4, we have captured five business cycles during 1978-2009, where the recession periods are respectively: 1980:Q4 to 1983:Q2 (the first recession), 1986:Q1 (the second recession), 1989:Q1 to 1991:Q4 (the third recession), 1997:Q3 to

2006:Q1 (the forth recession) and the 2008:Q1 to 2009:Q1 (the fifth recession, which is mainly affected by the worldwide financial crisis in 2008. The contractions in 2008:Q1 and 2008:Q2 are mainly caused by “Snow Disaster” and “Wenchuan Earthquake”). It is shown that the marked downward situation has been basically reversed to the overall recovery since 2009:Q2, where the GDP growth rate arrived at 10.7% when 2009:Q4. Therefore, the identified business cycles are highly consistent with China’s economy, almost the same as the results reported by Zhang, etc. (2005) based on annual data.

Secondly, output trend well explains the ceiling effect, and describes the plucking behavior. Figure 4 depicts that business fluctuations have experienced three big plucking processes and two small ones. The former three processes include 1980:Q4 to 1985:Q2, 1989:Q1 to 1994:Q4, 1997:Q3 to 2007:Q1, while the latter two ones refer to 1985:Q1 to 1985:Q4, 2008:Q2 to present (in progress). It is known that in each process, the economy still needs some time to return to the “normal” trend or the ceiling of output after going through a recession period.

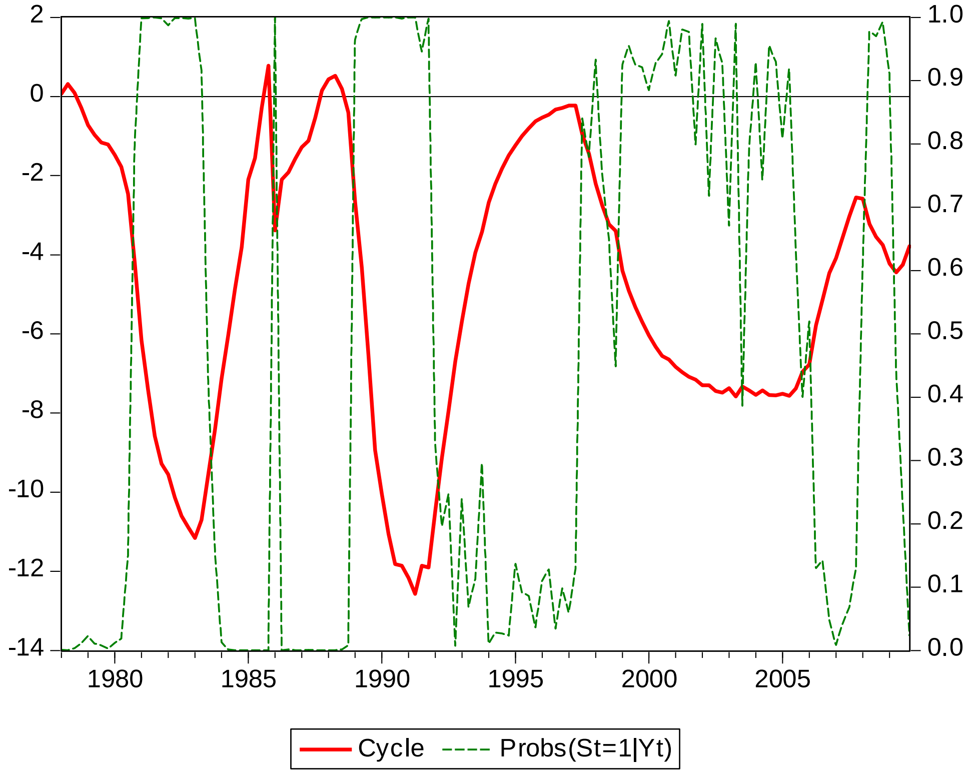

Figure 4. Cyclical component and recession probabilities

Thirdly, and perhaps most importantly, the cyclical component of real output effectively reveals the depth and length of the recession during different periods, where the depth refers to the cumulative value of negative asymmetric shocks, and the length refers to the duration of recession. As the duration of negative asymmetric shocks are longer, the recession becomes deeper. Figure 4 depicts the deviation of real output from the ceiling output in each cycle. It should be noted that the greater the deviation, the deeper the recession must be. We can see that the depth and length of the five recessions since the reform and opening up are largely different: the first and third are deeper, and it takes less time to go down to the bottom, meaning that the negative shocks are very large; the recession depth of the fourth cycle is less than that of the first and third ones, but the duration increases significantly, in accordance with the fact of the "soft landing" and "soft expansion" periods after 1993; the last recession is mainly caused by the worldwide financial crisis, and it is different from all previous recessions since real output are largely deviated from the ceiling at the beginning of this recession (2007:Q4).

5. Discussions and conclusions

Although Kim and Nelson's (1999a) methodology can be used to test the business cycle asymmetry under Friedman's plucking model of business fluctuations, whether it is applicable for China remains unknown. In this paper, under the fact since reform and opening up, we conduct an empirical study on China's quarterly real GDP data over the period 1978-2009. The results show some evidence supporting Friedman's plucking model. We find that there exists the ceiling effect of real output and the negative asymmetric shocks significantly affect the transitory component, which therefore captures the plucking downward behavior during the recession from the idea of Friedman.

It is also shown that the basic asymmetric unobservable component (UC) model in KN99 is not suitable for modeling China's real output, but the asymmetric UC model with a structure break in 1992:Q2 can accurately describe business fluctuations. We can find that the basic asymmetric UC model cannot explain the "soft landing" and "soft expansion" periods since 1990s, and it also cannot capture a recession in 2008 due to the worldwide financial crisis. However, these unreasonable results do not consequentially mean a failure to support Friedman's plucking model, but we should examine whether there exists a structural break in business fluctuations. When a structural break at 1992:Q2 is taken into account, we can not only accurately measure the five business cycles since reform and opening up, but also capture the significant change in the length and depth of the recession.

According to the above results, there exist some differences in business fluctuations between China and the countries like the United States. It can be briefly summarized in the following three outlines. The first is the amplitude of negative asymmetric shocks. One similar study provided by Mills and Wang (2002) shows that the asymmetric shock parameters for G7 countries were -0.99 (USA)[6], -0.39 (UK), -1.45 (Canada), -0.81 (France), -1.03 (Italy), -1.28 (Germany) and -0.30 (Japan), respectively. While for China, the amplitude of negative shocks is relatively large before 1992, almost larger than all the G7 countries, but after 1992, it has been greatly reduced to a low level, which is very close to the United Kingdom and Japan. The second is the depth and length of a recession. The results reported by Kim and Nelson (1999a) and Sinclair (2009) show that the maximum depth of the U.S. recessions is between -4 and -6, but the length is quite short. While for China, the depths of the first, second and third recessions are relatively deeper, and the length is relatively longer, especially during the "soft landing" period. The last is the duration of business cycle. It is mainly reflected in the difference of self-maintenance probability or expected duration between the phases of business cycle. As is pointed out by Hamilton (1989), the expected duration of

[6] In other literature, the results of the asymmetric shock parameter for U.S. real GDP are a little different from Mills and Wang (2002), but all less than -1. For example, the estimated results given by Kim and Nelson (1999a), Sinclair (2009) and De Simone and Clarke (2007) are -1.11, -1.74, and -1.26 respectively.

recessions in U.S. is very short, while that of the expansion is so long. However for China, both recession and expansion are quite long, due to the macro-control policy under the socialism market economic system.

Finally, the results in this paper reveal the fact that China's economy begins to rise again since 2009:Q2, and then the recession and the adverse effect due to the worldwide financial crisis are gradually and continually being eliminated. It is certain that the expansionary investment policy and the moderately relaxed monetary policy at the end of 2008 and during 2009 have achieved some success, and China's economy is gradually getting out of the shadow of the recession. However, it is essential for China's government to take further positive and effective measures to avoid the sharp ups and downs, keep a moderate economic growth rate, and thus maintain a sustainable development of the economy.

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