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Has China's Economy Become More Stable and Inertial? Nonlinear Investigations Based on Structural Break and Duration Dependent Regime Switching Models*

Angang Hu

School of Public Policy and Management, Tsinghua University, Beijing 100084 P. R. China
E-mail: anganghu@tsinghua.edu.cn

Jie Lu

School of Public Policy and Management, Tsinghua University, Beijing 100084 P. R. China
E-mail: lujie@tsinghua.edu.cn

and

Zhengyan Xiao

The Center for Applied Statistics, Renmin University of China, Beijing 100872 P. R. China
E-mail: zhengyanxiao@gmail.com

In this study we use both the structural break model and duration dependent transition model to study the characteristics of China's GDP growth from 1953 to 2009. The empirical results show that China's economic growth had become more stable since the economic reform in the end of the 1970s, and had transformed from a "low growth rate, high volatility" state to a "high growth rate, low volatility" state. In contrast to other transitional countries, China's structural break did not happen immediately, but rather it experienced a long transition period (1977-1992) which shows that China's economic development has a strong "growth inertia".

Key Words: Structural break; Duration dependent transition; Growth inertia.
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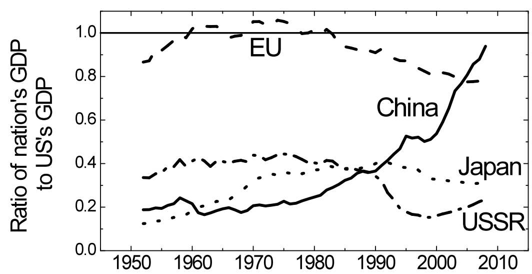
1. INTRODUCTION

China has enjoyed the fastest economic growth in the world for the last three decades. Its gross domestic product (calculated in Purchasing Power Parity), surpassed that of the Soviet Union in 1988, Japan in 1992, and Western Europe (12 countries) in 2005; also, the gap between China and the United States in GDP narrowed from 5.3 times in 1952 to 1.06 times in 2008, as shown in Figure 1. However, there are still many doubts about China's future development. In the two financial crises happened in 1997 and 2008, some emerging countries and developed countries were deeply affected, some of them even experienced growth decline. But China still maintained a high GDP growth rate above 8%, which was beyond many people's expectation. In the book The Coming Collapse of China, Chang (2001) made the statement which represented most western scholars' point of view in that time: "there is a weak China, one that is in long-term decline and even on the verge of collapse. The symptoms of decay are to be seen everywhere, like the shock of China's World Trade Organization (WTO) obligations, the government's lack of fiscal resources, the straitjacket of Communist Party ideology, and the Party's lack of ideological authority". After the global financial crisis in 2008, Bloombergy News said "China may face an economic slowdown in the middle of 2010 because the nation's growth model is unsustainable".[1] At the same time, The New York Times warned that China's hyper-stimulated economy was headed for a crash.[2] However, the results that emerged later were completely different from those predictions. China's economy achieved a high growth rate of 9.1% in 2009, and 10.3% in 2010.

FIG. 1. Gap between China's GDP and US's GDP (1953-2009) [3]



[1]Bloomberg News, 2009, Oct. 24th
[2]New York Times, 2010, Jan. 7th.
[3]Maddison, 2009, million 1990 International Geary-Khamis dollars

So in this study we will answer two questions: whether China's economic growth has become more stable and whether it will keep its high growth rate in the future. First we analyze the GDP output stabilization by using the Markov switching model embedded with a structural break. Then, to confirm the result of "volatility reduction" and study the sustainability in each growth regime, we use the duration-dependent regime-switching model, which is not a Markov process. So besides of the growth characteristics such as potential growth rate and volatility in each economic growth regime, we can also explore the properties of the economic transitions, to see whether the transition is completed immediately and whether the transition will be easier when China's economy stays within one growth regime for longer. Furthermore, we will investigate the current challenges China's economy is facing and how to accelerate the second transition to achieve sustainable growth in the future.

2. MODEL DESCRIPTION

A few different powerful methods can be used to study the characteristics of GDP growth and fluctuations. One of them is the regime switching model, introduced by Hamilton in 1989. Hamilton (1989) investigated the business cycle in the US as the outcome of a Markov process that switches between two discrete states, with one of the states representing expansions and the other representing contractions. Then, Hensan (1992) developed a theory of testing under non-standard conditions for the Markov switching model. McConnell and Quiros (2000) found no evidence of increased stability in the nondurables, services or structures sectors of the economy, and no other G7 country experienced a contemporaneous reduction in output volatility. Girardin (2005) used the regime-switching techniques to examine the similarities of the GDP growth-cycle features of ten East Asian countries. Marmer (2008) presented tests for the null hypothesis of no regime switching in Hamilton's regime switching model. Sugita (2008) introduced a Bayesian approach to a Markov switching cointegration model that allows the cointegration relationships to be switched on and off depending on the regime.

In Hamilton's model, the output growth switches between two different regimes with a Markov process. The two regimes can be indexed by the discrete-valued variable S_t (equals to 0 or 1). Within each state, a time series denoted y_t generated by the stochastic process can be described as:

$$\begin{aligned} \Phi(L)(y_t - \mu_{S_t}) &= e_t, e_t \sim i.i.d.N(0, \sigma_i^2), \quad 0 < t \leq T \\ \mu_{S_t} &= \mu_0(1 - S_t) + \mu_1 S_t \\ \sigma_t &= \sigma_0(1 - S_t) + \sigma_1 S_t \end{aligned} \tag{1}$$

Here we select the best lag length by using the AIC method. The transitions between the two different regimes follow the probabilities:

$$\begin{aligned} Pr[S_t = 0|S_{t-1} = 0] &= p, \quad Pr[S_t = 1|S_{t-1} = 0] = 1 - p \quad (0 < p < 1) \\ Pr[S_t = 1|S_{t-1} = 1] &= q, \quad Pr[S_t = 0|S_{t-1} = 1] = 1 - q \quad (0 < q < 1) \end{aligned} \tag{2}$$

2.1. Markov-Switching Model with a Structural Break

In 1999, Kim and Nelson proposed a modified model to estimate the date of a structural break in the output growth process to investigate whether there had been a structural break in postwar U.S. and real GDP growth towards stabilization. Mills (2003) also studied the structural break and got the results that stabilization had typically been achieved at the expense of a reduction in growth rates. The modified structural break model is based on the Markov switching process, but with a structural break in the hyperparameters. The parameters, including shift parameters (μ) and variance (σ^2), are different before and after the unknown break point τ ($1 < \tau < T$). The two regimes divided by the structural break point are indexed by using D_t (equals to 0 or 1):

$$\begin{aligned} \mu_{S_t} &= [\mu_0(1 - S_t) + \mu_1 S_t](1 - D_t) + [\mu_0^*(1 - S_t) + \mu_1^* S_t]D_t \\ \sigma_t &= \sigma_0(1 - D_t) + \sigma_1 D_t \end{aligned} \tag{3}$$

The probability of the happening for the structural break was given by:

$$\begin{aligned} Pr[D_t = 0|D_{t-1} = 0] &= d, \quad Pr[D_t = 1|D_{t-1} = 0] = 1 - d, \quad 0 < d < 1 \\ Pr[D_t = 0|D_{t-1} = 1] &= 0, \quad Pr[D_t = 1|D_{t-1} = 1] = 1 \end{aligned} \tag{4}$$

In this paper, we consider various null and alternative hypotheses, resulting in the following two models:

Model I(a): A model with structural break only in the variance ($\mu_0^* = \mu_0, \mu_1^* = \mu_1, \sigma_0 \neq \sigma_1$)

Model I(b): A model with structural break in both shift parameters and the variance ($\mu_0^* \neq \mu_0, \mu_1^* \neq \mu_1, \sigma_0 \neq \sigma_1$)

2.2. Duration Dependent Regime Switching Model

The classical regime switching model is based on the Markov chain, which means that the transition probability is only determined by the current state, not related with any previous states. To modify this assumption, some researchers proposed the duration dependence switching model, which relaxed this constraint of the Markov switching model in favor of time-varying transition probabilities. In 1990 Diebold and Rudebusch concluded that expansions exhibited less duration dependence, while contractions exhibited more duration dependence. Durland and McCurdy (1994) extended Hamilton's nonlinear Markovian filter to allow state transitions to be duration dependent. Iiboshi (2007) applied the regime-switching model with duration dependence that makes use of the Weibull model to analyze the business cycle in Japan. In 2007, Layton and Smith developed a state-dependent multinomial Logit modeling framework incorporating both duration and movements in two leading indexes.

The duration dependent model can be expressed as follows:

$$ModelII: \quad y_t = \mu_{S_t} + \sum_{i=1}^{L} \phi_{j,S_{t-i}}(y_{t-i} - \mu_{S_{t-i}}) + u_t, \quad u_t \sim NID(0, \sigma_{S_t}^2) \tag{5}$$

$$\mu_{S_t} = \mu_0(1 - S_t) + \mu_1 S_t, \quad \sigma_{S_t} = \sigma_0(1 - S_t) + \sigma_1 S_t \text{ and } S_t = 0 \text{ or } 1$$

The transition matrix can be written as

$$\begin{pmatrix} P(S_t = 0) \\ P(S_t = 1) \end{pmatrix} = \begin{pmatrix} p_{00} & p_{10} \\ p_{01} & p_{11} \end{pmatrix} \begin{pmatrix} P(S_{t-1} = 0) \\ P(S_{t-1} = 1) \end{pmatrix}$$

$$\begin{aligned} Pr[S_t = 0|S_{t-1} = 0] &= p_{00} = \exp[(a_0 d_t)^{b_0} - (a_0(d_t + 1))^{b_0}] \quad (6) \\ Pr[S_t = 1|S_{t-1} = 0] &= p_{01} = 1 - \exp[(a_0 d_t^{b_0} - (a_0(d_t + 1))^{b_0}] \\ Pr[S_t = 0|S_{t-1} = 1] &= p_{10} = 1 - \exp[(a_1 d_t)^{b_1} - (a_1(d_t + 1))^{b_1}] \\ Pr[S_t = 1|S_{t-1} = 1] &= p_{11} = \exp[(a_1 d_t)^{b_1} - (a_1(d_t + 1))^{b_1}] \end{aligned}$$

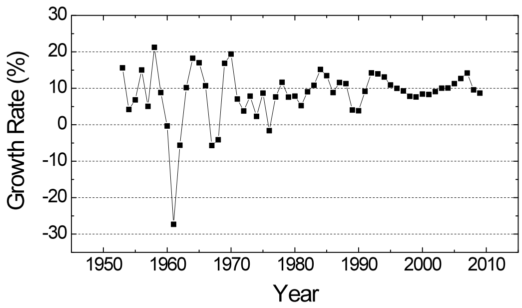
where a_0, b_0, a_1, b_1 are the transition parameters in the two regimes and d_t is the duration length in period t.

3. DATA AND EMPIRICAL RESULTS

3.1. Data

The data we use is China's annual GDP growth rate covering the sample period of 1953-2009,[4] as shown in Figure 2.[5] Before we start the Gibbs sampling, first the ADF method is used to check its stationarity. The T-statistic value is -5.78 which means the GDP series from 1953 to 2009 is stationary under the significance 1%. Then by using the AIC method, we choose the best lag length to be $L = 1$.

FIG. 2. China's annual GDP growth rate (%, 1953-2009)



3.2. Estimation procedures for the structural break models and empirical results

Hamilton (1989) estimated the parameters of the classical Markov-switching model by using the MLE method, which is very convenient in the classical case. However, if the model were embedded with structural break or the transition probabilities were no longer constant, direct computation of the unknown variates would not be straightforward. In 1993, Albert and Chib used Gibbs sampling to examine autoregressive time series models that were subject to regime switching. The Gibbs sampler is an estimation method that makes use of the tendency of a conditional distribution of a parameter to converge to its marginal distribution upon iterated computation. The posterior marginal distributions of the parameters are derived from their posterior conditional distributions. For this case, the joint posterior

[4]Though New China was founded in 1949, the period from 1949 to 1952 was a special recovering period after the civil war, so our data samples start from 1953.

[5]The data are from National Bureau of Statistics of China, updated in May, 2010. The GDP growth rate during 2005-2008 have been updated to 11.3%, 12.7%, 14.2%, 9.6% (the old ones are 10.4%, 11.6%, 13.0%, 9.0%)

density for the structural break model can be expressed as follows:

$$g(S_1,\ldots,S_T,D_1,\ldots,D_T,\phi,\mu_0,\mu_1,\mu_0^*,\mu_1^*,\sigma_0,\sigma_1,p,q,d|Y_1,\ldots,Y_T) \quad (7)$$

Direct Bayesian inference about the unknown variates

$$\theta = \{p,q,\mu_0,\mu_1,\mu_0^*,\mu_1^*,\sigma_0,\sigma_1,\phi,d\}$$

based on their posterior distribution is not suitable here, since it entails the computation of the complicated likelihood. Therefore Albert and Chib proposed treating the states $\{S_t\}$ and $\{D_t\}$ as additional unknown parameters and then analyzing them jointly with $\theta = \{\phi,\mu_0,\mu_1,\mu_0^*,\mu_1^*,\sigma_0,\sigma_1,p,q,d\}$ using Monte Carlo methods. Then the steps for the generation of the above parameters can be shown as follows:[6]

1). Generation of S_t conditional on $S_{\neq t}, D_1,\ldots,D_T,\theta$[7]

As shown by Albert and Chib, the posterior distribution of S_t can be written as

$$\begin{aligned} g(S_t|Y_T,S_{\neq t},D_1,\ldots,D_T,\theta) \;\propto\; & g(S_t|S_{t-1})g(S_{t+1}|S_t)g(y_t|S_t,S_{t-1},D_1,\ldots,\theta) \\ & \times g(y_{t+1}|S_{t+1},S_t,D_1,\ldots,D_T,\theta) \qquad (8) \end{aligned}$$

The values of the first two items on the right side can achieved from the transition matrix of S_T, and the last two items can be calculated as a normal distribution density:

$$\begin{aligned} & g(y_i|S_i,S_{i-1},D_1,\ldots,D_T,\theta) \qquad (9) \\ = & \frac{1}{\sqrt{2\pi\sigma^2_{D_t}}}\exp\left\{-\frac{1}{2\sigma^2_{D_t}}[y_t-\mu_{S_t,D_t}-\phi(y_{t-1}-\mu_{S_{t-1},D_{t-1}})]^2\right\} \end{aligned}$$

Then, the value of S_t can be generated by using a uniform distribution

$$Pr[S_t=j|Y_T,S_{\neq t},D_1,\ldots,D_T,\theta] = \frac{g(S_t=j|Y_T,S_{\neq t},D_1,\ldots,D_T,\theta)}{\sum_{j=0}^{1} g(S_t=j|Y_T,S_{\neq t},D_1,\ldots,D_T,\theta)}.^{8} \qquad (10)$$

[6] The solution procedures for structural break model and duration dependent model are same in generations of $S_t,p,q,\mu_0,\mu_1,\sigma_0,\sigma_1,\phi$. The only difference is the generation process of the duration dependence parameters a_0,a_1,b_0,b_1. So the steps to generate those "common parameters" can also be used in the Gibbs sampling of duration dependence model.

[7] $S_{\neq t} = \{S_1,S_2,\ldots,S_{t-1},S_{t+1},\ldots,S_T\}$

[8] A number is generated randomly between 0 and 1. If it is less than this probability, then we set $s_t = 1$, otherwise 0.

2) Generation of D_t conditional of $D_{\neq t}, S_1, \ldots, S_T, \theta$[9]

The method to generate D_t is similar as the method for S_t; the only difference is to use the transition matrix for D_T $g(D_t|D_{t-1})$. So the value of D_t can also be generated by using a uniform distribution:

$$Pr[D_t = j|Y_T, D_{\neq t}, S_1, \ldots, S_T, \theta] = \frac{g(D_t = j|Y_T, D_{\neq t}, S_1, \ldots, S_T, \theta)}{\sum_{j=0}^{1} g(D_t = j|Y_T, D_{\neq t}, S_1, \ldots, S_T, \theta)} \tag{11}$$

3) Generation of Generating ϕ conditional on $D_1, \ldots, D_T, S_1, \ldots, S_T, \theta_{(-\phi)}$:

The posterior distribution of ϕ is

$$\begin{aligned} & g(\phi|S_1, \ldots, S_T, D_1, \ldots, D_T, \theta_{(-\phi)} \\ \propto & \prod_{t=2}^{T} \frac{1}{\sigma_{D_t}} \exp\left[-\frac{(y_t - \mu_{S_t,D_t} - \phi(y_{t-1} - \mu_{S_{t-1},D_{t-1}}))^2}{2\sigma_{D_t}^2}\right]. \end{aligned} \tag{12}$$

If we set $A_t = \frac{y_t - \mu_t}{y_{t-1} - \mu_{t-1}}$, $B_t = \frac{\sigma_t}{y_{t-1} - \mu_{t-1}}$, then ϕ can be generated by a normal distribution

$$g(\phi|S_{1,\ldots,S_T,D_1,\ldots,D_T,\theta_{(-\phi)}}) \sim N\left(\frac{\sum_{t=2}^{T} \frac{A_t}{B_t^2}}{\sum_{t=2}^{T} \frac{1}{B_t^2}}, \frac{1}{\sqrt{\sum_{t=2}^{T} \frac{1}{B_t^2}}}\right). \tag{13}$$

4) Generation of $\mu_0, \mu_1, \mu_0^*, \mu_1^*$ conditional on $D_1, \ldots, D_T, S_1, \ldots, S_T, \theta_{(-\phi)}$:[10]

The value μ_0 can be drawn from the posterior distribution

$$g(\mu_0|S_1, \ldots, S_T, D_1, \ldots, D_T, \theta_{(-\mu_0)}),$$

which follows a normal distribution

$$g(\mu_0|S_1, \ldots, S_T, D_1, \ldots, D_T, \theta_{(-\mu_0)}) \sim N\left(\frac{\sum_t F_t}{\sum_t E_t}, \frac{1}{\sqrt{\sum_t E_t}}\right), \tag{14}$$

$$\text{where } \begin{cases} E_t = \frac{1}{\sigma_{D_0}^2}, F_t = \frac{y_t}{\sigma_{D_0}^2}, \text{ if } S_0 = 0 \\ E_t = \frac{(1-\phi)^2}{\sigma_{D_{t+1}}^2}, F_t = \frac{(1-\phi)(y_t - \phi y_{t-1})}{\sigma_{D_{t+1}}^2}, \text{ if } S_t = 0, S_{t+1} = 0 \\ E_t = \frac{\phi^2}{\sigma_{D_{t+1}}^2}, F_t = \frac{\phi(\mu_1 - y_t + \phi y_{t-1})}{\sigma_{D_{t+1}}^2}, \text{ if } S_t = 0, S_{t+1} = 1 \\ E_t = \frac{1}{\sigma_{D_{t+1}}^2}, F_t = \frac{y_t - \phi(y_{t-1} - \mu_1)}{\sigma_{D_{t+1}}^2}, \text{ if } S_t = 1, S_{t+1} = 0 \end{cases} \tag{15}$$

[9] $D_{\neq t} = \{D_1, D_2, \ldots, D_{t-1}, D_{t+1}, D_T\}$

[10] Because the way to generate μ_0 is same as μ_1, μ_0^*, μ_1^*, so here we just show how to generate μ_0. For Model I(a), we just need to set $\mu_0 = \mu_0^*$ and $\mu_1 = \mu_1^*$.

where the values of E_t and F_t are calculated following the different transition types, as shown in the Appendix. Correspondingly, we can generate μ_1 in the same way. After we draw both μ_0 and μ_1 in one iteration, we need to check if the two values satisfy the constraints $\mu_0 <= \mu_1$. If the constraints were not satisfied, we discard the draws and re-generate them again.

5) Generation of σ_0, σ_1 conditional on $D_1, \ldots, D_T, S_1, \ldots, S_T, \theta_{(-\sigma)}$:[11]

First we need to count the times for $D_t = 0$ and suppose the value is u. Then we can write the posterior distribution of the variance σ_0^2 as

$$\begin{aligned} & g(\sigma_0^2|S_1, \ldots, S_T, D_1, \ldots, D_T, \theta_{(-\sigma_0)}) \\ \propto & \left(\frac{1}{\sigma_0^2}\right)^{\frac{u}{2}} \prod_{t(D_t=0)} \exp\left(-\frac{[y_t - \mu_{S_t,0} - \phi(y_{t-1} - \mu_{S_{t-1},D_t})]^2}{2\sigma_0^2}\right). \end{aligned} \tag{16}$$

Assuming $G = \sum_{t(S_t=0)} \frac{[y_t - \mu_0 - \phi(y_{t-1} - \mu_{S_{t-1}})]^2}{2}$, the value of σ_0 can be drawn from the Gamma distribution:

$$g\left(\frac{1}{\sigma_0^2}|S_1, \ldots, S_T, D_1, \ldots, D_T, \theta_{(-\sigma_0)}\right) \sim Gamma\left(\frac{u}{2} + 1, \frac{1}{G}\right). \tag{17}$$

6) Generation of p, q conditional on $D_1, \ldots, D_T, S_1, \ldots, S_T, \theta_{(-p,-q)}$:

The posterior distribution of p, q is:

$$\begin{aligned} & g(p, q|S_1, \ldots, S_T, D_1, \ldots, D_T, \theta_{(-p,-q)}) \\ \propto & \ p^{(u_{00}+1)-1}(1-p)^{(u_{01}+1)-1} q^{(u_{11}+1)-1}(1-q)^{(u_{10}+1)-1}, \end{aligned} \tag{18}$$

where $u_{00}, u_{01}, u_{11}, u_{10}$ are the counts of the transitions for $S_t(0 => 0, 0 => 1, 1 => 1, 1 => 0)$ observed in the whole series. Then the posterior distributions of the transition probabilities are given by the two independent beta distributions:

$$\begin{aligned} g(p|S_1, \ldots, S_T, D_1, \ldots, D_T, \theta_{(-p)}) & \sim beta(u_{00} + 1, u_{01} + 1) \\ g(q|S_1, \ldots, S_T, D_1, \ldots, D_T, \theta_{(-q)}) & \sim beta(u_{11} + 1, u_{10} + 1) \end{aligned} \tag{19}$$

7) Generation of d conditional on $D_1, \ldots, D_T, S1, \ldots, S_T, \theta_{(-d)}$:

The posterior distribution of d is:

$$g(d|S_1, \ldots, S_T, D_1, \ldots, D_T, \theta_{(-d)}) \propto d^{(v_{00}+1)-1}(1-d)^{(v_{01}+1)-1}, \tag{20}$$

where v_{00}, v_{01} are the counts of the transitions for $D_t(0 => 0, 0 => 1)$ observed in the whole series. Then the posterior distributions of the transition

[11]Because the way to generate σ_0 is same as σ_1, so here we just show how to generate σ_0.

probabilities are given by the two independent beta distributions:

$$g(d|S_1, \dots, S_T, D_1, \dots, D_T, \theta_{(-d)}) \sim beta(v_{00}+1, v_{01}+1) \qquad (21)$$

After repeating the above process of Gibbs sampling 10,000 times and discarding the initial 2000 simulations in order to mitigate the effects of the initial conditions, we can get the statistical results for each parameter, as shown in Table 1-2. From Figure 3 we can see that the structural break was happening in 1976 and that in both Model I(a) and Model I(b) the variance σ^2 decreased after the structural break.

TABLE 1.

Model I(a) with structural break in variance

	Value	SD	MD	Lower 5%	Lower 10%	Upper 5%
ϕ	0.445	0.128	0.444	0.240	0.285	0.655
μ_0	6.711	4.921	8.360	−0.607	2.056	10.493
μ_1	11.006	2.070	10.669	9.036	9.374	13.473
μ_0^*	—	—	—	—	—	—
μ_1^*	—	—	—	—	—	—
σ_0	9.957	1.567	9.785	7.695	8.132	12.716
σ_1	2.304	0.420	2.275	1.674	1.795	3.023
p	0.568	0.270	0.601	0.096	0.164	0.957
q	0.667	0.278	0.756	0.120	0.224	0.980
d	0.922	0.052	0.933	0.823	0.853	0.985

Notes: 1. SD and MD refer to standard deviation and median, respectively.
2. Lower 5%, Lower 10% and Upper 5% refer to 5, 10 and 95 percentiles

3.3. Estimation procedures for the duration dependent model and empirical results

As mentioned above, the generation procedures of Gibbs sampling in the duration dependent model are similar to the method used in the structural break model, while in this case we just need to show how to draw the parameters for transition probabilities a_0, a_1, b_0, b_1. Because the distributions of these four parameters are not in standard cases, here we use the AR-MH algorithm proposed by Chib (1995) and Tiemey (2000). First we choose the proposal density function $g(x)$, an arbitrary positive constant c, and an appropriated initial value x_0. Then we repeat the following sequences:

1) Draw x from the proposal density function $g(x)$ and using x to calculate the acceptance rate

$$p = \min\left[\frac{f(x)}{cg(x)}, 1\right] \qquad (22)$$

TABLE 2.

Model I(b) with structural break in shift parameter and variance

	Value	SD	MD	Lower 5%	Lower 10%	Upper 5%
ϕ	0.465	0.146	0.462	0.233	0.283	0.713
μ_0	−2.978	10.303	−0.109	−22.629	−17.604	9.598
μ_1	9.880	4.776	9.289	3.200	4.597	18.752
μ_0^*	6.695	3.190	7.562	1.247	2.496	10.611
μ_1^*	10.576	1.220	10.469	8.866	9.246	12.817
σ_0	9.342	1.922	9.165	6.583	7.092	12.787
σ_1	2.389	0.473	2.319	1.745	1.860	3.254
p	0.497	0.257	0.501	0.078	0.142	0.914
q	0.781	0.221	0.868	0.255	0.414	0.978
d	0.919	0.056	0.931	0.813	0.846	0.985

Notes: 1. SD and MD refer to standard deviation and median, respectively. 2. Lowe 5%, Lower 10% and Upper 5% refer to 5, 10 and 95 percentiles

2) Accept the value of x with acceptance rate p, and reject it at rate $1-p$. If it is accepted, then set $x^{(proposal)} = x$ and go to the next step; otherwise, return to the previous step.

3) Calculate the acceptance rate q as follows:

a. If $f(x_{n-1}) < cg(x_{n-1})$, then set $q = 1$

b. If $f(x_{n-1}) \geq cg(x_{n-1})$ and $f(x^{(proposal)}) < cg(x^{(proposal)})$, then calculate $q = \frac{cg(x_{n-1})}{f(x_{n-1})}$

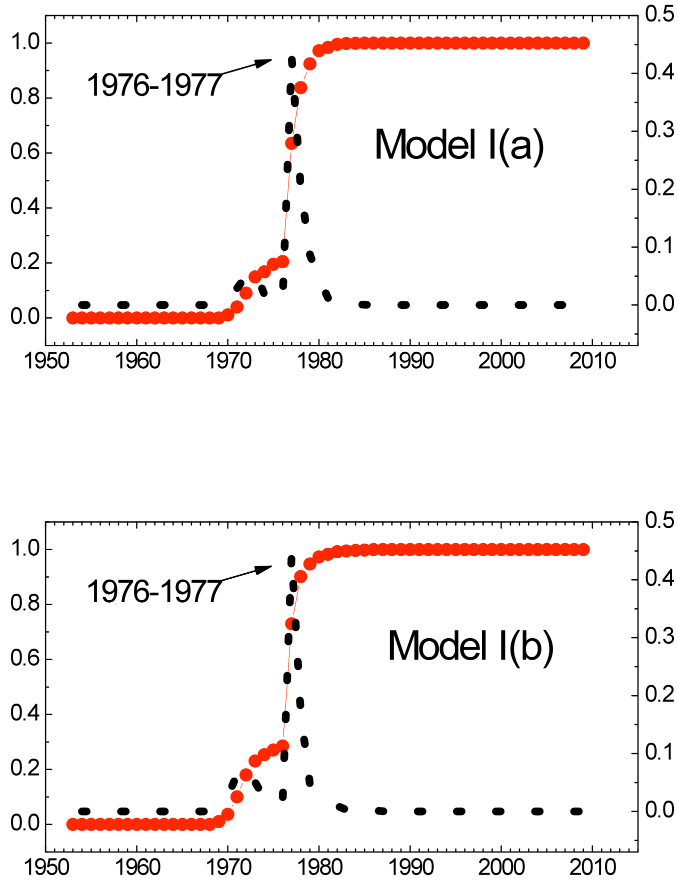
c. If $f(x_{n-1}) \geq cg(x_{n-1})$ and $f(x^{(proposal)}) \geq cg(x^{(proposal)})$, then calculate

$$q = \min\left[\frac{f(x^{(proposal)})g(x_{n-1})}{f(x_{n-1})g(x_{n-1}x^{(proposal)})}, 1\right] \tag{23}$$

4) Accept $x^{(proposal)}$ with acceptance rate q, and reject it at rate $1-q$. If it is accepted, then set $x_n = x^{(proposal)}$. Otherwise, set $x_n = x_{n-1}$.

Figure 4 provides histograms of the estimated posterior densities of the parameters. The statistical results for each parameter are as shown in Table 3; Figure 5 shows the probabilities at second regime ($S_t = 1$) for China's economic growth in each year. It is obvious that China's economic growth had already experienced one transformation from regime "0" to regime "1". And there existed three periods, each with a different type of growth: a low growth rate period (1953-1976), a transition period (or "quasi high growth period", 1977-1992) and a high growth rate period (1993-2009). The increased potential growth rate (from 5.77% to 9.76%) and reduced

FIG. 3. Probability for structural break ($D_t = 1$) and the first order difference of the probabilities (dash line)



volatility (from 8.85 to 1.39) means that China's economy became more stable as it entered into the "high growth rate period".

Another interesting result is that China shows a reversed duration dependence of the transition probability compared with some western countries. The studies by Durland and McCurdy in 1994 and by Iiboshi in 2007 indicated that the business cycles in both the U.S. and Japan exhibited positive duration dependence transition in both booms and recessions, which means that the longer the economy stays in one specific regime, the more likely

FIG. 4. Sampling of parameters of the duration dependent regime switching model (left figures show the sample paths and right figures show the histograms of the estimated posterior densities)

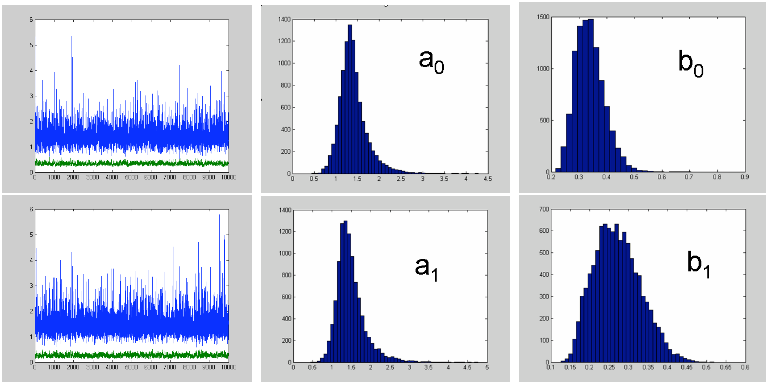


TABLE 3.

Empirical results of duration dependent model

	Value	SD	MD	Lower 5%	Lower 10%	Upper 5%
ϕ	0.505	0.120	0.500	0.310	0.356	0.710
μ_0	5.769	2.182	5.941	1.865	2.772	9.095
μ_1	9.758	0.779	9.731	8.538	8.823	11.117
σ_0	8.853	1.345	8.644	7.045	7.371	11.384
σ_1	1.390	0.561	1.223	0.722	0.825	2.506
a_0	1.418	0.355	1.362	0.966	1.058	2.077
b_0	0.328	0.056	0.323	0.249	0.259	0.428
a_1	1.532	0.456	1.430	1.000	1.091	2.388
b_1	0.303	0.073	0.301	0.197	0.212	0.431

Notes: 1. SD and MD refer to standard deviation and median, respectively.
2. Lowe 5%, Lower 10% and Upper 5% refer to 5, 10 and 95 percentiles

it is that it will jump to the other state. But in China, as shown in Figure 6, the transition probability has negative dependence on the duration length. Also, the transition probability in the initial year of one state period is not 0. So the initial jump (or transition) to the other state has some probability of "jumping back." But as the duration at one specific regime gets longer, it becomes more stable. That is the reason why there exists a long "transition period" between the "low growth rate period" and "high growth rate period."

FIG. 5. Probabilities at high growth rate regime ($S_t = 1$) in duration dependent model

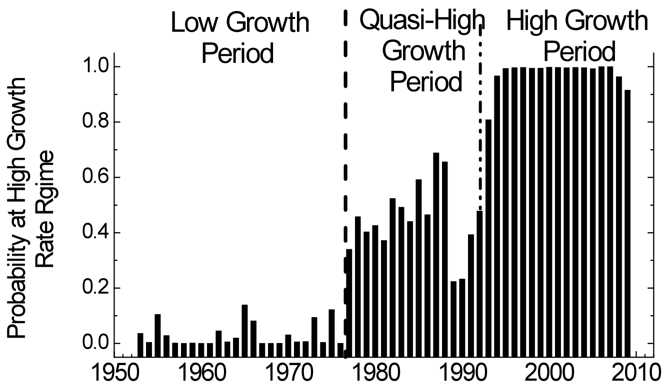
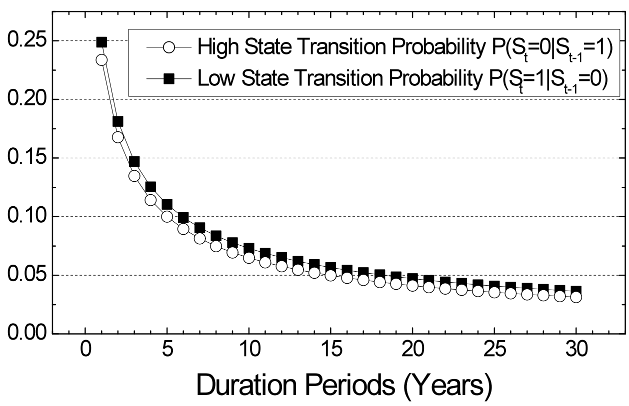


FIG. 6. Transition probabilities with respect to the duration length

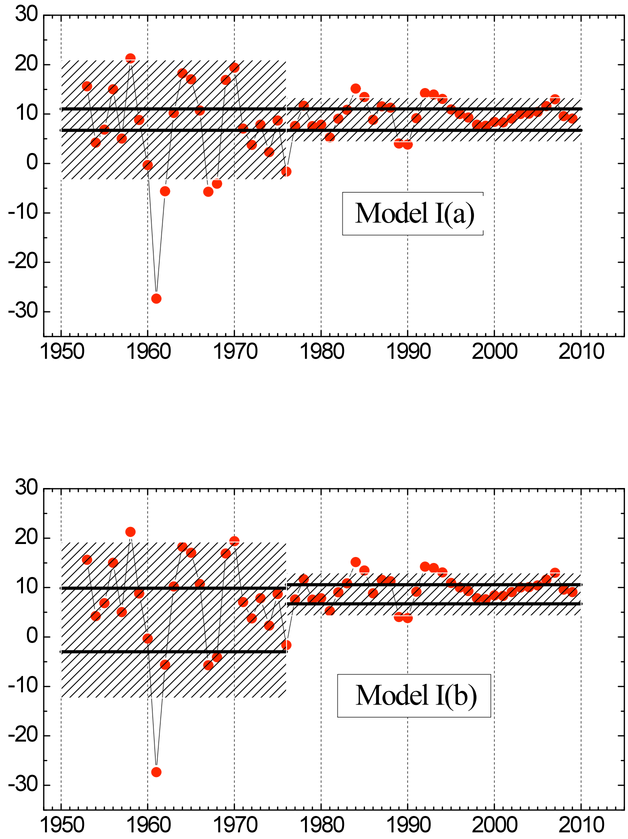


4. ANALYSIS AND DISCUSSIONS ON THE CHARACTERISTICS OF CHINA'S ECONOMIC GROWTH

4.1. China's economic growth had experienced a structural break in 1976 towards a "high growth rate, low volatility" state.

From the empirical results in both Model I(a) and I(b) we can see that there had been a structural break in China's economic growth toward more stabilization: a narrowing gap between the mean growth rates during recessions and booms (Model I.a) and the tendency of decline in the volatility (Model I.a, Model I.b), as shown in Figure 7. The structural break happened around 1976-1977; based on this point, we can divide the whole period into two parts: 1953-1976 and 1977-2009.

FIG. 7. Volatility reduced after the structural break (The solid lines represent the mean growth rates in each regimes and the shaded areas represent the variances)



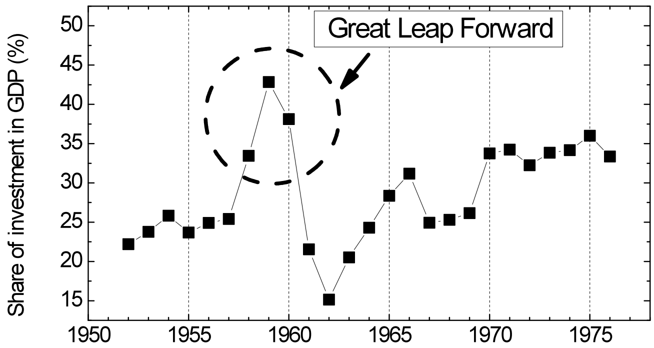
The first period was from 1953 to 1976, with the characteristics of the low GDP growth rate and high volatility. China's economic growth was experiencing "big ups and big downs" then. The average economic growth rate in this period was 5.9% and the fluctuations coefficient reached to

166%.[12] Compared with other large economies in the same time, China's economic fluctuation was the most significant. From 1953 to 1976, the Soviet Union's lowest and highest economic growth rates were −2% and 12.9%, and U.S.'s were −1% and 7.4%, while in China they were −27% and 21%, respectively. The largest amplitude of the economic fluctuation of China was 3.2 times that of the Soviet Union, and 5.7 times that of the U.S. In this period, China mainly adopted the centralized planned economic system which was very successful in terms of centralized social resources for the "big push industrialization" (Naughton, 2006). The driving force for the economic growth was mainly from the national investment and political mobilization. In 1953, China launched its first Five-Year Plan, in which most industrial projects were supported by the Soviet Union. When China imported the Soviet Union's high technology and the modern industry system, China also copied its central planning economic system. By the end of the first Five-Year Plan period (1957), China had finished its primitive accumulation for industrialization. In the same time, China also completed the transformation of the private ownership to the state and started to operate as a real "socialist" economy (Naughton, 2006). The big triumph of the first Five-Year Plan had made Chinese leaders more radical in terms of economic development, resulting in blind investment and development. In Figure 2 we can see that the GDP growth rate was most volatile in the end of the 1950s and the early 1960s, which was the "Great Leap Forward" (GLF) period. The GLF was the most serious economic crisis in China during past 60 years. Over-investment in the secondary industry, especially the heavy industry, made the economic structure seriously unbalanced. In 1959, the amount of China's capital formation increased by 122% compared to the amount in 1957. But the consumption only increased by 0.6%. The share of the investment in China GDP had increased from 25% in 1957 to 43% in 1959, while the share of consumption had shrunk from 74% to 57%, as shown in Figure 8. After some recovery and readjustment in the next few years, China entered into the Cultural Revolution in 1966. Though China's economy was seriously affected by political mobilization in the first 3-4 years, the GDP growth rate held at a relatively stable level around 5%. By the end of the Cultural Revolution in 1976, China had constructed a relatively complete and independent national industrial system which made a solid foundation for the "high growth" that was to take place after the 1980s.

As the Cultural Revolution ended in 1976, Chinese leaders reconsidered the direction of the economic development and tried to implement economic reforms started in 1978. The economic reform included not only the transi-

[12] The fluctuation coefficient was defined as $\frac{1}{R}\sqrt{\frac{\sum_{i=1}^{n}(y_i-R)^2}{n}}$, where R is the average growth rate.

FIG. 8. Share of national investment in China's GDP (1952-2009)



tion of the economic system from a planned economy to a market economy, but also the transformation of the development strategy from heavy industrialization to a more balanced industrial system. By the 1980s, China had adopted a market economy and diversified ownerships. Having virtually discarded all the institutions of the centralized planned economy, China entered into the real "high growth rate period", which was from 1993 until the present. During this period, China's economy maintained the high and stable economic growth rate even facing the international shocks by the two financial crises in 1997 and 2008. The average economic growth rate increased to 10.3%, and growth volatility fell to 20.3%. Entering into the 21st century, China strengthened its opening-up policy and adapted its economic system to the trend of globalization, marked by its entry to WTO. Compared with other main economies in the world, China achieved the highest economic growth rate and lowest fluctuation, as shown in Table 4.

4.2. China's economy had shown a strong "growth inertia" which resulted in a long period of transition

Though China's economy had successfully transitioned from a "low growth rate" state to a "high growth rate" state after the economic reform 1978, the transformation was not achieved in a short time, but rather it took place over a long "transition period" from the end of the 1970s to the early 1990s, as shown by Model II and Figure 5. Figure 9 presents the expected

TABLE 4.
Comparison of China's economic growth and fluctuations with other countries (1993-2009)

	Average Growth Rate (%)	Fluctuation Coefficient (%)		Average Growth Rate (%)	Fluctuation Coefficient (%)
South Africa	3.4	40.6	Indonesia	4.4	114.8
Argentina	3.6	169.3	Saudi Arabia	2.7	88.9
Brazil	3.3	56.7	Euro-Union	2.0	57.0
Mexico	2.9	107.6	France	1.9	62.5
Canada	3.1	45.2	Germany	1.5	77.9
USA	3.0	39.4	Italy	1.3	96.7
China	10.3	20.3	Russia	2.3	299.7
Japan	1.2	119.6	Turkey	4.4	109.6
Korea	4.9	80.6	Britain	2.8	29.8
India	6.8	28.8	Australia	3.7	20.5

Data source: World Development Indicator, 2009

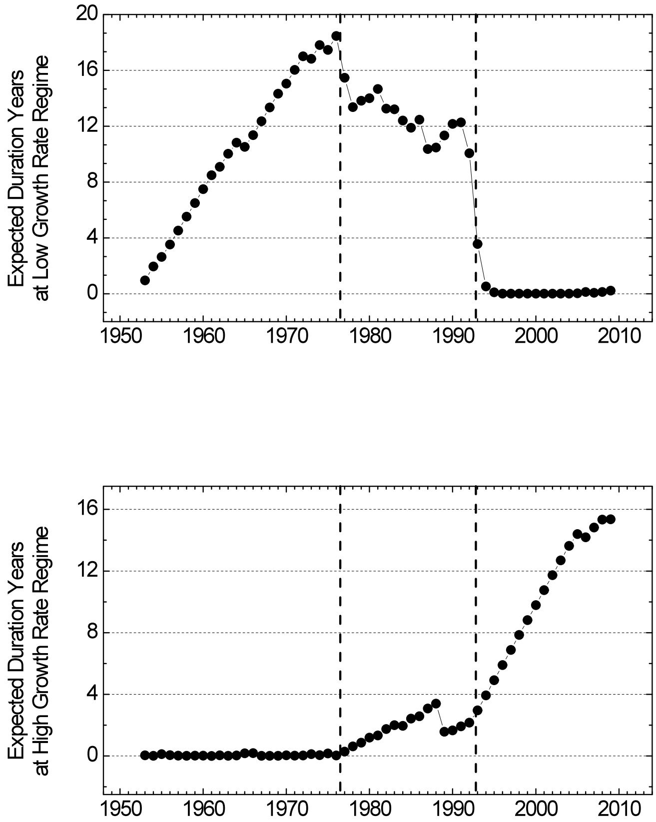
duration of the two regimes based on

$$E[D_t|Y_t] = \sum_{d=1}^{\infty} P(D_t = d|Y_T) \times d \qquad (24)$$

from which we notice that on average China had experienced the "real" low growth rate regime for 18 years and the "real" high growth period for 15 years, between which occurred the "quasi" high growth period, or the transition period, for 16 years. The long transition period was very unique for China and it had shown that its economy was holding a strong "growth inertia," which means that it is very difficult for China to transform its economic system and economic development pattern. So what factors resulted in China's growth inertia and what are the advantages and disadvantages for such inertia? Since 1978, China's economic reform has followed a "gradualist reform" track, or an incremental reform (Qian, 2000). Its reform was not like the models in Eastern Europe or Soviet Union, in which the transition from a command planned economy to a modern market economy took place very quickly, known as "radical reforms." When China started its economic reform, Chinese leaders didn't simply take the categories of command economy and market economy or blindly copied the western economic system. The strong political will to maintain both social stability and economic growth caused the economic system to be transformed step by step.

The economic reform was initially launched in rural areas by implementing the institution of contracting land to households. The new agricultural

FIG. 9. Expected duration of "low growth rate" regime and "high growth rate" regime



economic system was based on the contracting of individual pieces of land to farm households. Such policy reduced the role of the collectives and, in a way, "returned" the land back to the farmers to arouse their enthusiasm for agricultural investment and production. After the big success of the institution of contracting land to households in most of rural areas in China, agricultural production began to surge (Naughton, 2006) and provided the basic material conditions for the next step of reform, as shown in Table 5.

Then China started the reforms of the price system and enterprise ownership. The price reform followed a so-called "dual-track" mechanism in

TABLE 5.
Agricultural production before and after the economic reform (million tons, 1970-1984)

	Food	Oil	Sugar
1970	240.0	3.8	15.6
1975	284.5	4.5	19.1
1978	304.8	5.2	23.8
1980	320.6	7.7	29.1
1982	354.5	11.8	43.6
1984	407.3	11.9	47.8

Data source: National Bureau of Statistics of China

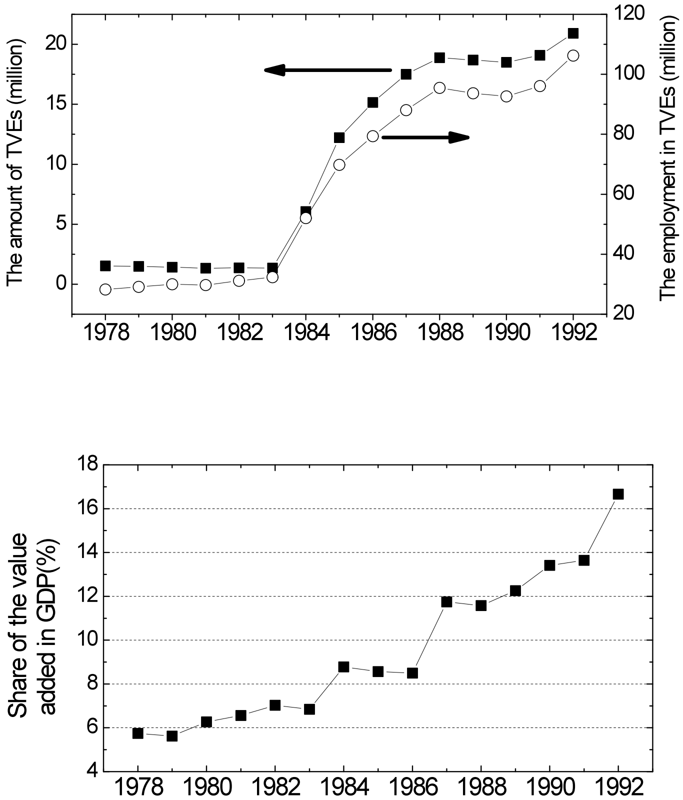
which price was freed up at the margin while the planned prices, maintained for planned quantities, froze for some time (Qian, 2000). The dual-track price system was one of the most distinguished features for China's gradualist reform. To ensure social and economic stability and maintain the government authority, China did not dismantle the planned system immediately, but rather set two pricing systems, one for the state-set planned price and one for free-trading market price. Thus the state-owned factories could sell their extra products at a higher price after completing the planned mission. By around 1992, more than 90 percent of price was determined by market forces rather. The positive aspects for the dual track system include: the promotion of price reform at the same time as maintaining economic stability and providing the market conditions for the development of non-state owned enterprises (SOE). However, it also had some disadvantages, like increasing production cost, interfering with macroeconomic planning and making the small-scale firms grow too quickly.

During the transition period, to maintain the production stability and keep the public ownership for the key industries, China did not privatize any SOE in the 1980s. Instead, the development of the township and village enterprises (TVE) played the most important roles in the transition from a command economy to a market economy. The amount of TVEs grew from 1.5 million to 20.9 million from 1978 to 1992, with an annual growth rate of 20.6%; the TVE employment expanded from 28 million in 1978 to 106 million in 1992, a 9.9% annual growth rate. The value added of TVE accounted from only 6% of GDP in 1978, but rapidly ramped up to 16.7% in 1992, as shown in Figure 10.[13] The ownership for TVE was in multiple forms. Some were run by the government, and most of them were private. So people working for TVEs had much more enthusiasm and the rural industries became much more profitable than the SOEs. By the

[13]Data source: China labor statistical year book, 2009

early 1990s, the success of TVEs had made the central government more confident to implement deeper reform on the ownership of whole industries.

FIG. 10. Amount and employment of TVEs and share of the value added of TVEs in GDP



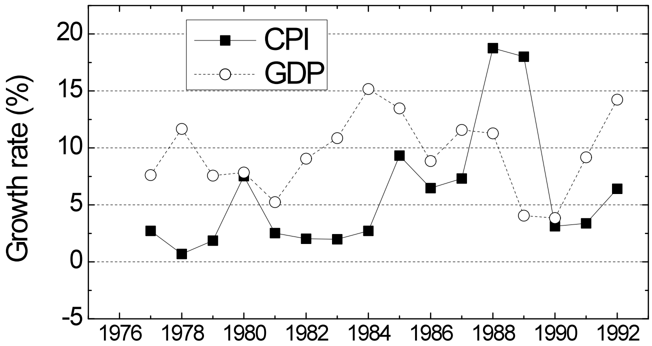
Though the gradualist reform was considered to be driven by the leaders' political will, there did exist some other reasons for China to keep such development and growth inertial. First, China's socialist planned economy was different from the Soviet Union's central planned economy. The key difference lays in the division of power between the central and local governments. The top leader — Mao — did not appreciate the over-centralized planning system of the Soviet Union. He believed that it was far better to have the initiative come from both the central and the local authorities than from one source alone, and that China should not follow the example of the Soviet Union in concentrating everything in the hands of the central authorities, shackling the local authorities and depriving their right of independent decision makings (Mao, 1956). So with Mao's support, China continuously transferred power to local governments during 1953-1976. By the end of the Cultural Revolution, local governments had gained considerable division of power authorized by thecentral government. So when the economic reform started in 1978, it was impossible for China's central government to launch the same rapid and radical reform as the Soviet Union. It had to follow the principle described as "pilot first, spread later; rural areas first, urban areas later."

The gradualist reform prevented China's economy from suffering the same crisis as the Soviet Union and some other Eastern European countries did. However, the economic growth was still accompanied by some serious fluctuations. In this period, China's average GDP growth rate was 9.4%, with a fluctuation coefficient of 36.1%. In Figure 11 we can see that, during 1977-1992, the GDP growth rate showed three peaks, which were in 1978, 1984, and 1988 respectively, and that the CPI (consumer price index) also had three peaks, which were in 1980, 1985 and 1988. The most serious inflation happened in 1988, with CPI increased by 18.7%. The boom in economic growth came as an investment rush due to the government's relaxation of investment and credit control, which resulted in expansion of credits and money supply followed by inflation; after the implementation of a retrenchment program to control inflation, the economic growth rate subsequently dropped; to stimulate economic growth, the government would then relax the control of investment and credit again (Lin, 2002). The fluctuations of the economy in this period could be partially explained by casual mistakes in macroeconomic policies, but the main reason should be identified as the unexpected difficulties of the transformation from a centralized planned economy to a market economy. Also, the instability in economy was the main source of the social conflicts at the end of the 1980s. In spite of those negative aspects, China has been proved to be the most successful one among all the transitional countries, transitioning from planned economy to market economy, while maintaining both high economic growth and social stability.

4.3. The second transition and the sustainability of China's economic growth in the future

Since 1992, China has kept an annual economic growth rate in average above 10%. But China's rapid economic growth has also brought unprecedented challenges in two aspects: high energy consumption and high CO_2 emissions. China has become a "super nation" on energy consumption, ranking second in the world (after the United States). Rapid growth of

FIG. 11. Comparison of the growth rates of China's GDP and CPI during the transient period (1977-1992)



the demand for fossil fuels, especially coal, has led to high rates of greenhouse gas and sulfur dioxide emissions, exacerbating the harmful effect on the environment and accelerating climate change. China's CO_2 emissions increased from 2.24 billion tons in 1990 to 60.7 billion tons in 2007. The proportion of China's emission to the world's total amount doubled from 10.7% in 1990 to 21.1% in 2007. This shows that it took 17 years (1990-2007) for China to jump to the world's largest emission country. If China keeps pursuing high GDP growth records, high energy consumption and CO_2 emission accordingly, it will doubtlessly be disaster for China and for the whole world. So how to keep the sustainable growth and how to transform the pattern of its economic growth will be two key issues for China in the next 10 to 20 years. Behind the beautiful GDP growth rate are the huge investment in infrastructure and high consumption of resources, which have promoted high-emission industries like cement and steel, and caused severe damage to the environment, resulting in "black" economic growth.

As mentioned above, China's economy has a strong "growth inertia." On the one hand, such inertia could stabilize China's economy during the transition period, but on the other hand, it is very difficult to change its current "black" growth track. Though China's economy suffered considerable shocks from the global financial crisis, it still achieved high GDP growth rates of 9.6% and 9.1% in 2008 and 2009, respectively. In the 9th Five Year Plan period (1996-2000), the central government proposed "transformations" for the mode of economic growth. However, after 10 years, China is still on the "black" development road with "high energy consumption, high emission". To truly transform the economic growth mode, first of all we should lower the GDP growth rate to a moderate level. In China, the environmental cost expands dramatically when the GDP growth rate is higher than 9%. During the period of 1996-2000, China's annual growth rate was only 8.63% and the GDP elasticity of some factors, like energy consumption and CO2 emissions, was much lower than in the next period, 2001-2008, during which the growth rate was 10.3%. Therefore in the future, China should focus on the quality, but not quantity, of economic output. It means that China should lower the ratio of the secondary industry in its national output, and develop those industries which have low energy intensity and low carbon intensity.

TABLE 6.

Growth elasticity of energy related factors under different GDP growth rates

GDP growth rate (%)	8.6 (1996-2000)	10.3 (2001-2008)
Growth elasticity of energy consumption	0.13	0.94
Growth elasticity of electricity production	0.71	1.21
Growth elasticity of coal consumption	−0.1	0.96
Growth elasticity of CO_2 emissions	−0.02	0.9

Data source: National Bureau of Statistics of China

Note: The growth elasticity of each factor is calculated following by $\frac{\text{Grpwth rate of each factor}}{\text{Growth rate of GDP}}$

5. CONCLUSION

By applying the structural break and duration-dependent regime switching models to China's GDP growth rate during 1953-2009, we found that China's economic growth had become more stable since 1977. Unlike other transitional countries, China's economic growth exhibited a strong "growth inertia" from planned economy to market economy during the transition period of 1977-1992. Such growth inertia made China follow a gradualist reform track and achieve the economic system transition concurrently with high economic growth. Right now China is facing the second economic transformation which is the transition from "black development" to "green development". However, its growth inertia blocks the transformation of China's economic growth mode from "high growth, high emission" to "moderate growth, low emission". To break the black development inertia and make economic growth more sustainable, China should withdraw the "worship of GDP" as soon as possible.

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