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The intermittent institutional innovation and China's economic fluctuations: a calibrated model and a dynamic analysis

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Abstract

Purpose – China's economic transition is essentially the process of China's institutional changes. During the changes, the appearance of institutional innovation is not regular; instead, it is intermittent and random. The purpose of this paper is to show that the fitful appearance of institutional innovation is the root of China's economic growth and fluctuations.

Design/methodology/approach – This paper constructs a real business cycle (RBC) model introducing the institutional factor expressed in the quantitative form under the dynamic stochastic general equilibrium (DSGE) framework by measuring China's institutional changes quantitatively.

Findings – By comparing the characteristics of the actual economic data with those of the simulated economic data, we find that this RBC model can explain 94.44%, 66.07%, 23.46%, 21.03% and 15.45% of the cyclical fluctuations in output, investment, labor, consumption and capital, respectively.

Originality/value – The impulse response analysis finds that the institutional shocks have a relatively long duration, lasting about 30 years, and decline slowly over time, while technological shocks decline relatively fast, lasting approximately ten years.

Keywords Intermittent institutional innovation, Economic fluctuations, Real business cycle

Paper type Research paper

1. Introduction

Since the reform and opening-up, China has maintained a rapid economic growth rate for over 30 years, with an average annual GDP growth rate of 9.94% from 1978 to 2011, making China one of the fastest growing economies. Accompanying the high economic growth in China was the stylized fact of significant economic fluctuations – China's GDP growth rate was 15.18% in 1984 but dropped to 3.84% in 1990, with an extreme difference of 11.34% and a standard deviation of 2.73%. During this period, China experienced hyperinflation reflected by runaway price increases and deflation with negative price growth. The average inflation rate measured by the consumer price index (CPI) was 5.68%. In 1994, the inflation rate was up to

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24.13%, while just five years later, in 1999, China saw a deflation with a 1.41% drop in the price level, causing an extreme inflation rate as high as 25.54% and a standard deviation of 6.33%. These data show that high rate economic growth with significant fluctuations is a distinctive feature of China's economic performance since its reform and opening-up. So, what is the main driver behind the fluctuations of China's economy?

We have observed that while China's economy presents fluctuating high speed growth, the economic system and institutional arrangements are also changing continuously, with waves of institutional innovations emerging. A series of economic institutions, including institutions for modern enterprises, property rights, distribution, market price and opening-up to the outside world, have been gradually established and improved in China. The root of economic fluctuations also includes the factor of institutional shocks.

The school of institutional economics highly values the role of institutions in economic growth. On the one hand, institutions can act as the providers of specific services with monetary facilitation properties that can reduce transaction costs (Schultz, 1994; North, 1994; Ostrom *et al.*, 1992). On the other hand, factors such as capital accumulation and technological progress are more part of the economic growth than the cause of economic growth. The institutional factor is the key to economic growth – technological improvement and capital accumulation can continue only if institutions provide effective incentives (North, 1968, 1991, 2008). Moreover, when the external conditions on which institutions depend change, members of society would modify the institutional arrangements according to new situations for aligning their preferences with the new institutional arrangements and reaping the benefits caused by institutional changes (Bromley, 1996). The macroeconomic institutional arrangements formulated by the government have a significant impact on economic growth, and institutional arrangements fitting the country's development status can drive economic growth (Guseh, 1997).

Some Chinese scholars have studied the relationship between economic growth and institutional innovation in China. Lin (1989) elaborated on the analytical approaches for induced and imposed institutional changes from the perspectives of economic and political studies. Wang (1992) included culture in the context of China's institutional changes and considered the implication of culture for China's institutional reform. Zhang (1992) elaborated on the causes and drivers of institutional changes based on the equilibrium and nonequilibrium of institutions. Yang (1998), Fan (1993), Zhang (2002), Zhou (2000) etc. studied the path of Chinese style institutional changes.

The available domestic and foreign literature has conducted relatively sufficient research on the institutional innovation that leads to economic growth and the specific means of institutional changes. One of the observations in this paper is that institutional innovations do not appear uniformly but intermittently and that the appearance of a certain institutional innovation is a random event. And economic fluctuations are, to a large extent, to be explained by the intermittent emergence of institutional innovation. Hence, institutional changes can be included as a variable in the real business cycle (RBC) model to measure the mechanisms and effects of institutional changes on economic growth and fluctuations.

The papers by Kydland and Prescott (1982) and Long and Plosser (1983) pioneered the theory of RBC. Lucas (1982), Svensson (1985), and Cooley and Hansen (1989) introduced currency into the utility function or monetary constraints into the RBC model to analyze monetary policies and their effects. Gong and Semmler (2003) studied the RBC model in an unbalanced labor market. Bu and Jin (2002) introduced monetary factors into the exogenous labor force model to build a model of China's monetary and economic cycle and analyzed the relationship between economic growth and monetary indicators in China from 1980 to 2001. Huang (2005) considered government spending as an exogenous stochastic shock variable and studied the impact of government spending shocks on the economic cycle.

Based on the quantitative analysis of China's institutional change, this paper incorporates institutional variables into the RBC model to study the influence of institutional innovation on economic growth and fluctuations and further explores the law of China's economic fluctuations. The following sections are structured as follows: In Section 2, we analyze theories and Chinese historical facts and propose that the intermittent institutional innovation is the root cause of China's economic fluctuations during the transition period; in Section 3, we build an RBC model that contains institutional variables; Section 4 includes quantitative measurement of institutional changes and calibration of model parameters; in Section 5 we put forward the empirical results; Section 6 is the conclusion.

2. Intermittent emergence of institutional innovation: the root cause of economic fluctuations in the transition period

According to the general equilibrium theory, an institution can reach equilibrium in a certain period. Institutional equilibrium is a state where none of the actors finds it profitable to devote resources to re-establishing concordances given the preset bargaining power of the actors and the series of agreed contract negotiations that constitute the totality of economic exchange (North, 1994). Once the institutional equilibrium is reached, it does not mean that this state can be maintained forever. Since an institution is composed of various institutional arrangements, when a change to a certain institutional arrangement alters the equilibrium of the arrangement, it is a condition that breaks the equilibrium of the whole institution, thus leading to an imbalance in the institution. The trigger for institutional changes is the changes in relative price and preference. The institutional equilibrium will be broken only if changes in relative prices make the expected benefits of people's commitment to changing the system outweighing the costs, which leads to institutional changes (North, 1994).

Thereby, institutional changes may change the steady-state growth path of an economic system and thus change the actual growth path of the economic system. Under the given institutional arrangements, any economic system has an equilibrium economic growth path. During the development of an economy, if there is no change in institutions, the steady-state equilibrium growth path of the economy will remain unchanged. However, if any institutional change benefitting the economic development occurs, the steady-state equilibrium growth path of the economic system will be improved. Since factors of production follow the law of diminishing marginal productivity, if an institutional change that facilitates economic development happens when real diminishing marginal productivity occurs, the economic system will continue to grow at a high rate as its steady-state equilibrium growth path improves overall, and the rate of economic development is faster than that before the institutional change. The actual economic growth will present the course as shown in Figure 1.

China has experienced many institutional changes since the reform and opening-up. The direction and efficiency of institutional changes have become the main drivers explaining China's economic fluctuations. By combining the process of institutional changes with China's economic growth, it can be found that the intermittent emergence of institutional innovation is the root cause of China's economic fluctuations. We illustrate this with the GDP growth rates for each year in the following figure, Figure 2.

Figure 2 indicates that China's economy was in a clear upswing from 1981 to 1985. The then institutional driver of the robust economic growth was the household contract responsibility system in rural areas. In December 1978, farmers in Xiaogang Village, Fengyang County, Anhui Province, pioneered a system that features the responsibility for production under the household contract. This institutional innovation had not received endorsement by the central government in the first two years until the Central Committee of the Communist Party of China (CPC) issued the document "Several Issues on Further

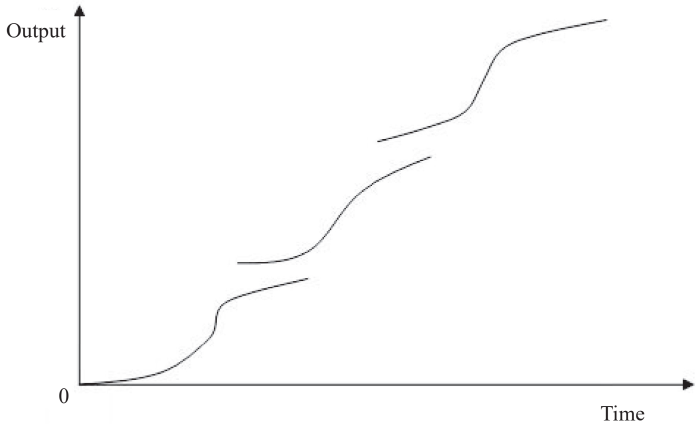

Figure 1.
Economic growth path including institutional changes

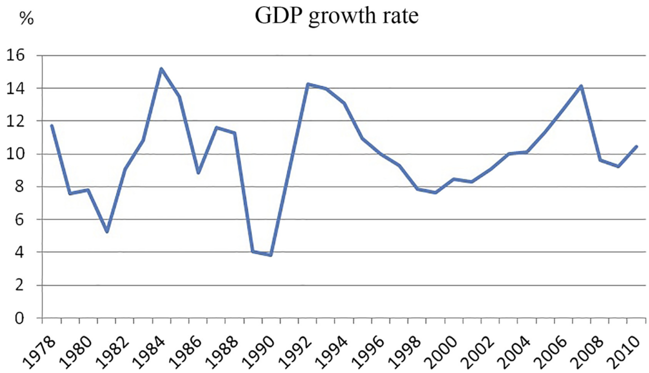

Figure 2.
China's GDP growth rate from 1979 to 2010

Strengthening and Improving the Agricultural Production Responsibility System" in September 1980. After that, the agricultural production responsibility system based on the household contract was established formally and gradually rolled out nationwide. By early 1983, 93% of production teams had implemented the "double contract" (work and production contracted to households) system. This new institutional arrangement significantly released and boosted the productive forces. The household contract responsibility system marks the beginning of China's economic system reform.

From 1985 to 1991, the difficulty of selling grain, low grain price hurting the farmers and mismatch of various institutional arrangements regarding the "dual-track institution" in the agricultural product purchasing and distribution system in China led to a significant decline in value added in agriculture and, in general, a continuous drop was seen in China's GDP growth. Among them, China's economic growth rate was above 11% in both 1986 and 1987, probably because the central government issued two "No.1 Central Document" in 1985 and 1986 consecutively, which emphasized the development of agriculture, and the rise in the unified purchasing prices of agricultural products might strengthen the ability of agriculture to develop and the motivation of farmers to produce.

From 1991 to 1994, China's economy experienced another boom. The main drivers of the then economic growth were the sudden rise of township enterprises and the institutional innovation of state-own enterprises (SOEs). China's development of township enterprises is exploring the industrial path in rural areas with Chinese characteristics beyond the conventional system. The township enterprises are market oriented and have the flexibility in operation, like "a small boat that is easier to turn round". The rapid development of township enterprises provided valuable experience for China's institutional changes under the market economy and a strong impetus for the further deepening of reform and made the reform advance to cities rapidly. At this stage, the institutional innovation of the SOEs was manifested in the reform of breaking the "Three Irons" that started in 1992 and the corporatization of the SOEs that started in 1993. Breaking "Three Irons", namely, eliminating lifetime employment (the "iron rice bowl"), a lifetime position of the executives (the "iron chair") and guaranteed pay (the "iron wage") in the SOEs, was essentially the reform of labor employment, personal system and income distribution system in enterprises. The reform of breaking the "Three Irons" was implemented when the social security system and re-employment mechanism had not yet been established. Although it caused many social problems, this reform targeted all employees of enterprises for the first time and stimulated the motivation of the management and ordinary staff. After 1993, the reform of SOEs advanced to the second stage, namely "corporatization". In November 1993, the 3rd Plenary Session of the 14th Central Committee of the CPC adopted the *Resolution on Several Issues Concerning the Establishment of a Socialist Market Economic System*, which marked the change of thought on reforming SOEs from devolution of power and profit to innovation of the enterprise system. The reform of establishing a modern enterprise system with "clearly established ownership, well-defined power and responsibility, separation of enterprise from administration, and scientific management" improved the operational efficiency of SOEs. The economic downturn from 1995 to 1999 was due to the lack of efficient institutional innovation.

China's economic boom between 2000 and 2007 was attributed to the rapid development of the private-sector economy and the comprehensive promotion of opening to the outside world. During this period, all institutional barriers in the development of the private sector were eliminated, and the private sector was treated the same as the public sector. In November 2002, a report of the 16th National Congress of the CPC clearly stated that ". . .. must unswervingly encourage, support, and guide the development of the non-public sector", "expand the areas for the market access of domestic nongovernmental capital", and "improve the legal system for protecting private property". In February 2005, the State Council issued the *Several Opinions on Encouraging, Supporting and Guiding the Development of the Individual, Private and Non-Public Ownership Economy*, which was the most comprehensive and systematic document on the policy for promoting the development of the nonpublic sector in China. The rapid growth of the non-state-owned enterprises provided an excellent institutional example for the reform of the state owned enterprises and a strong driver for the formation of China's market economy system. Since the 1990s, the opening-up strategy has been upgraded constantly and rolled out widely from coastal areas to inland China. On December 11, 2001, China officially became a member of the World Trade Organization (WTO). The accession of China to the WTO marked a new stage of China's reform and opening-up, as it indicated that China's reform and opening-up was further expanded and, more importantly, changes that China moved from unilateral opening-up to bilateral opening-up with WTO member countries in a reciprocal way and from limited domestic rules to the general international rules. From 2007 onwards, while China's economy has been deeply affected by the financial crisis in the USA and the world and facing a severe lack of market demand in the foreign trade and external sector, the Chinese government has provided more intervention in the economy and taken various measures to boost domestic demand. In general, the output effect of institutional innovation in China since 2007 is not significant, and the economy tends to move from high growth to steady growth.

In a word, by linking China's GDP growth rates during the period 1979–2010 to the practice of institutional changes in China since the reform and opening-up, it is evident that there is a strong correlation between the intermittent emergence of China's institutional innovation and the growth and fluctuations of China's economy. We will attempt to formalize this relationship in the following section by introducing the institutional factor into the RBC model.

3. Model establishment

The RBC theory introduces the stochastic shock on productivity into the neoclassical growth model, thus closely integrating the study of economic growth with the analysis of economic fluctuations. The RBC model focuses on the economic growth and fluctuations caused by the real components of the economy (as opposed to the monetary part). The significance of research and debate on the RBC theory is by no means limited to clarifying the causes of economic fluctuations (or business cycles) but rather laying the microfoundations of macroeconomics and revealing the dynamic correlations and interactions of various economic variables. The central idea of this paper is that the intermittent emergence of institutional innovation is the root cause of China's economic growth and fluctuations. Hence, it is reasonable to introduce the institutional innovation factor into the RBC model. To this end, the first step is to make the following assumptions:

Assume that the production function has constant returns to scale; then, the utility function of economic actors is a constant relative risk aversion (CRRA) utility function. We regard technology as an exogenous stochastic shock that follows the process of a first-order autoregressive process, written as AR(1); institutional evolution during China's transition period is also regarded as an exogenous stochastic shock that follows an AR(1) process, which is set for the following two reasons: Firstly, the analysis in the previous section indicates that a series of institutional changes have occurred in China since the reform and opening-up, which itself will drive the continuation of the reform once it begins; secondly, this is a temporary and convenient handling way, which can be improved continually and closer to reality in the future. However, it is worth noting that previous studies generally treated all "Solow residual" as the technological variable of stochastic shocks. Nevertheless, in the real economy, "Solow residual" should include the effects of institutional shocks, besides that of technological shocks. The model established in this paper attempts to strip out the influence of technology from the "Solow residual" to measure the impact of the institutional factor on economic fluctuations.

We assume that all actors in the economy are homogeneous. In other words, they are subject to the same consumption constraints and have the same utility function. The utility function of a representative consumer takes the following form:

$$E_0 \sum_{t=0}^{\infty} \beta^t U(C_t, L_t) \tag{1}$$

$$U(C_t, L_t) = \frac{C_t^{1-\eta} - 1}{1-\eta} + \theta \ln(1 - \mathrm{L}_t)$$

where β^t indicates the subjective discount rate in period t, and $\beta \in (0, 1)$; C_t is the actors' consumption in period t; L_t is the actors' labor time in period t; η is the coefficient of CRRA, $\eta > 0$, and particularly, when $\eta = 1$, the first term of the CRRA utility function, $\frac{C_t^{1-\eta} - 1}{1-\eta}$, becomes logarithm $\ln C_t$, which can be considered as a special form; θ is the relative value of consumption and labor, $\theta \in (0, 1)$, which reflects the degree of preference toward consumption or labor in the actors' utility function.

Chow and Li (2002) estimated the aggregate production function by using China's macroeconomic data from 1952 to 2008 and found that the Cobb–Douglas production function with constant returns to scale fits well with the actual situation in China. Hence, we adopt the Cobb–Douglas production function in this paper. When affirming the significant role of the institutional factor on economic growth, Ostrom *et al.* (1992) illustrated that the institution is the fourth factor of economic growth. Considering this idea and the purpose of this paper, we set the production function as follows:

$$Y_t = A_t W_t^{\gamma} K_t^{\rho} L_t^{1-\rho} \tag{2}$$

where A_t represents the exogenous technological variable, W_t the exogenous institutional variable, K_t, the actual capital input and ρ, the output elasticity of capital. As this paper adopts the constant returns to scale production function, the output elasticity of labor is $1-\rho$; γ, the impact factor (IF) of the system, is used to reflect the "elasticity" of the system on output. At this point, $A_t W_t^{\gamma}$ is the "Solow residual" in the traditional sense.

The budget constraint faced by actors in period t is

$$Y_t = C_t + I_t \tag{3}$$

The equation for the evolution of the capital stock is

$$K_{t+1} = I_t + (1-\delta)K_t \tag{4}$$

where δ is the depreciation rate of capital, $\delta \in (0,\ 1]$, which reflects the depreciation of capital, and I_t indicates the amount of investment in period t.

The classic RBC-related literature by Kydland and Prescott (1982), King *et al.* (1988), and Long and Plosser (1983) assumed that the evolution of technology over time followed the AR (1) process. Strictly speaking, whether the evolution of technology follows the AR (1) still needs to be tested. Our test of total factor productivity (TFP) changes in China indicates that AR(1) can fit the process of technological change well. Hence, the equation for the evolution of technology is assumed to be

$$\ln A_t = (1-\psi_A)\ln \overline{A} + \psi_A \ln A_{t-1} + \varepsilon_{At} \tag{5}$$
$$\varepsilon_{At} \sim i.i.d.N\left(0,\ \sigma_{\mathrm{A}}^2\right)$$

where $\overline{A}$ is the steady-state value of the technological shock variable A_t; ψ_A is the regression coefficient that indicates the relationship between variables in the current period and those in the previous period, $\psi_A \in (-1,\ 1)$; ε_{At} is the stochastic disturbance term, which follows the white noise process and reflects the influence of exogenous stochastic shocks on technology.

The emergence of innovations in institutional arrangements in a certain period is quite similar to that of a single individual technological innovation. Hence, by simulating the equation for the evolution of technology, we can assume that the equation for the evolution of institutions over time is an AR(p) process, even though both their number distributions follow the Poisson distribution. In addition, if the evolution of institutions is assumed to obey the Poisson process and is introduced into the RBC model, the problem of the stability and existence of the solution will be caused. We assume the path equation for institutional changes as

$$\ln W_t = (1-\psi_W)\ln \overline{W} + \psi_W \ln W_{t-1} + \varepsilon_{Wt} \tag{6}$$
$$\varepsilon_{Wt} \sim i.i.d.N\left(0,\ \sigma_{\mathrm{W}}^2\right)$$

where $\overline{W}$ is the steady-state value of the technological shock variable W_t; ψ_W is the regression coefficient, indicating the relationship between the values of variables in the current period and those in the previous period, $\psi_W \in (-1, 1)$; ε_{Wt} is the stochastic disturbance term, which follows the white noise process and reflects the impact of exogenous stochastic shocks on institutional variables.

Based on the assumptions of various equations above, the planning problem faced by typical households is

$$Max_{(K_t,L_t)} E_0 \left\{ \sum_{t=0}^{\infty} \beta^t \left[\frac{C_t^{1-\eta} - 1}{1-\eta} + \theta \ln(1 - \mathrm{L}_t) \right] \right\} \tag{7}$$

Constraints:

$$C_t + K_{t+1} - (1-\delta)K_t = A_t W_t^{\gamma} K_t^{\rho} L_t^{1-\rho}$$

$$\ln A_t = (1-\psi_A)\ln \overline{A} + \psi_A \ln A_{t-1} + \varepsilon_{At},\ \varepsilon_{At} \sim i.i.d.N\left(0,\ \sigma_{\mathrm{A}}^2\right)$$

$$\ln W_t = (1-\psi_W)\ln\overline{W} + \psi_W \ln W_{t-1} + \varepsilon_{Wt},\ \varepsilon_{Wt} \sim i.i.d.N\left(0,\ \sigma_{\mathrm{W}}^2\right)$$

Given K_0

It is the RBC model containing institutional shocks. In this paper, the equilibrium solution of the model is obtained by solving the decentralized equilibrium. The corresponding first-order conditions can be obtained through the Lagrangian function maximizing the typical household utility as follows:

$$\rho \frac{Y_t}{K_t} + (1-\delta) = R_t \tag{8}$$

where R_t represents the actual return on capital in period t. In terms of the economic implications of the equation, besides the capital–output ratio corresponding to the current period, R_t contains the capital surplus after capital depreciation in the previous period.

$$\theta L_t = (1-\rho)(1-L_t) Y_t \mathrm{C}_t^{-\eta} \tag{9}$$

$$\mathrm{C}_t^{-\eta} = \beta E_t(R_{t+1}) \tag{10}$$

$$\beta E_t \left(\left(\frac{C_t}{C_{t+1}} \right)^{\eta} R_{t+1} \right) = 1 \tag{11}$$

The first-order condition expressed in Equation (11) can be regarded as the Euler equation, which means that the ratio of the marginal utilities of the actor's intertemporal consumption is equal to the product of the actor's subjective discount rate and the rate of actual return on capital. Equations (8)–(11) jointly form a system of nonlinear difference equations. The existence of a solution to the system of equations requires several boundary conditions as follows: (1) Initial capital input K_0, $K_t|_{t=0} = K_0$; (2) cross-sectional condition of the economy: $\lim_{i\to\infty} E_t \beta^i C_{t+i}^{-\eta} K_{t+i+1} = 0$ [1]; and (3) the actors' labor supply in the steady state is a constant.

We log-linearize the constraints and first-order conditions near the steady state and obtain the following:

$$\overline{Y} \cdot y_t = \overline{C} \cdot c_t + \overline{I} \cdot i_t \tag{12}$$

$$\overline{K} \cdot k_{t+1} = \overline{I} \cdot i_t + (1-\delta)\overline{K} \cdot k_t \tag{13}$$

$$y_t \approx a_t + \gamma w_t + \rho k_t + (1-\rho) l_t \tag{14}$$

$$a_t = \psi_A a_{t-1} + \varepsilon_{At} \tag{15}$$

$$w_t = \psi_W w_{t-1} + \varepsilon_{Wt} \tag{16}$$

$$l_t \approx \left(1-\overline{L}\right)(y_t - \eta \cdot c_c) \tag{17}$$

$$E_t[r_{t+1} + \eta(c_t - c_{t+1})] = 0 \tag{18}$$

$$\overline{R} \cdot r_t = \rho \frac{\overline{Y}}{\overline{K}}(y_t - k_t) \tag{19}$$

After log-linearization, there are a total of eight equations and eight variables in Equations (12)–(19), where k_t and c_t are endogenous control variables; a_t and w_t are exogenous state variables; y_t, r_t, l_t and i_t are system state variables. Therefore, the economic system depicted by the economic planning issue can be approximated by the system of the above eight stochastic linear equations.

4. Quantitative measurement of institutional changes and calibration of model parameters

To introduce the institutional variables into the RBC model in this paper, we must face the problem of how to measure institutional changes, which Chinese economists have studied. Lu and Hu (1993) first proposed the marketization index; Gu (1997) and Jiang and Song (1995) explored the degree of marketization of China's economy and its estimates, and Fan *et al.* (2001, 2003) and Fan and Wang (2004) studied the relative progress of marketization in various regions of China and its metrics. The issue of measuring the development and innovation of China's market economy system has been addressed in the literature on the degree and index of marketization in China. Kang *et al.* (2007) and Li *et al.* (2008) used the proportion of non-state-owned industrial value added in the industrial value added to measure China's property rights system. Kang *et al.* (2007) also pointed out that the transition from the planned economy system to the market economy system since China's reform and opening-up was generally carried out in four aspects: the government's change of function and role and withdrawal from microeconomic activities; the promotion of the denationalization (or privatization) of the economy; the improvement of the openness of the economy, and the cultivation of product-oriented markets. Jin (1998, 2001) proposed a method to measure China's institutional changes and created a set of institutional change indexes from these four aspects of China's economic transformation mentioned above.

We draw on the method of Jin (2001) to introduce four institutional variables, measure their correlations with macroeconomic fluctuations by applying the gray dynamic correlation theory, and finally establish a representative and comprehensive institutional indicator based on their respective degrees of correlation. The four institutional variables are as follows:

(1) Nonnationalization ratio (NNR) is an indicator reflecting the level of diversification of economic components and the activity of the non-state-owned sector. The proportion of the gross output value (or value added) of the non-state-owned sector in the gross output value (or value added) of the industry is used to represent the level of nonnationalization, which is calculated according to the following formula:

$$NNR = \frac{\text{Gross output value (or value added) of non} - \text{state} - \text{owned sector}}{\text{Gross output value (or value added) of non} - \text{state} - \text{owned sector}}$$

(2) Marketization degree (MD), which reflects the breadth and depth of marketization in the resource allocation process is calculated according to the formula

$$\text{MD} = \text{Marketization index of factors of production} \times 60\% + \text{Marketization index of economic parameters} \times 40\%$$

When measuring the "marketization index of the factors of production", we adopt the marketization degree of investment, which is measured by the proportion of free investment (including foreign investment utilized, self-financed investment and other investment) in total investment in fixed assets in the whole country. The "marketization index of economic parameters" is expressed by the marketization of weighted prices, whose weight is equal to the quantities corresponding to the prices, and this index is calculated by the ratio of the price of freely-priced commodities to the price of all commodities in society. Due to data limitations, the prices of agricultural products are used in this paper instead.

(3) The share of fiscal revenue (RS) is an inverse indicator. The larger value of this indicator indicates greater the administrative power of the state. It reflects the state's share in the distribution of economic interests and is calculated according to Formula [2] as follows:

$$RS = \frac{\text{Fiscal revenue (excluding debts)}}{\text{GDP}}$$

(4) Economic openness degree (ID) uses the weighted number of the opening-up index of international trade to measure the degree of economic openness to the outside world, which is calculated according to the following formula:

$$ID = \frac{\text{Total value of imports and exports}}{GDP}$$

As various statistical data are incomplete, it is impossible to measure the data of China's institutional changes from the founding of the People's Republic of China to the period of reform and opening-up. Hence, the data in this paper range from 1978 to 2011. This paper adopts the dynamic correlation analysis method in the gray theory analysis to measure the impact of various variables. Corresponding correlation coefficients can be obtained through the calculation method of the gray dynamic gray correlation analysis. The value of a gray correlation coefficient is between 0 and 1, and the greater value indicates that the indicator has more impact on the institutional indicator. From the mean of the above four indexes, it can be observed that the opening-up factor has the most significant impact on China's economy, followed by the marketization, and then the ownership structure and the income distribution system. This is also in line with the reality of China's economic development. Of course, it does not rule out that the impact of any factors on the economy may deviate from its mean in any specific period.

To transform these four institutional measurement indexes into a comprehensive indicator, we calculate them by weighted average according to the following formula:

$$\mathrm{W}_t = \frac{NNR_t \times NNRf_t + RS_t \times RSf_t + MD_t \times MDf_t + ID_t \times IDf_t}{NNRf_t + RSf_t + MDf_t + IDf_t}$$

where $\mathrm{NNR_t}$, $\mathrm{RS_t}$, $\mathrm{MD_t}$ and $\mathrm{ID_t}$ indicate the nonnationalization ratio, the share of fiscal revenue, the marketization degree and the degree of openness in period t, respectively, while $\mathrm{NNRf_t}$, $\mathrm{RSf_t}$, $\mathrm{MDf_t}$ and $\mathrm{IDf_t}$ indicate the IFs of each corresponding index in period t, respectively. Thus, a relatively comprehensive value that measures institutional changes was obtained from time samples from 1978 to 2011. During China's institutional changes, official institutional changes often tended to occur at a particular time point but had a sustained impact on economic growth. Hence, after we weighted the four institutional measurement indexes into one comprehensive indicator, the characteristics of volatility will be diminished. Cyclical volatility data regarding the institutional changes are obtained after the Hodrick-Prescott (HP) filter removes the trend data.

The institutional changes in China present a wave-like upward trend, and the accumulation of institutional changes leads to an increase in indicator data. However, volatility is also evident during the process of growth. Whether such volatility in terms of institutional changes can impact the economy is the focus of this research paper.

It is necessary to calibrate the parameters of the system of eight stochastic linear equations mentioned above, obtain the numerical solutions of the system through an iterative approach and finally test the accuracy of the model against these numerical solutions.

4.1 Estimation of output elasticity, technological and institutional shocks

Assuming that the production function is a Cobb–Douglas type function with the constant returns to scale, and it is replaced with $Z_t = A_t W_t^{\gamma}$ to obtain the following production function:

$$Y_t = e^{Z_t + \mu \cdot T} K_t^{\rho} L_t^{1-\rho} \tag{20}$$

where T represents the time variable trend, $T = 1, 2, \ldots$, and μ is the parameter value of the variable T. To exclude the linear correlation among the regression variables, we transform the production function by using an intensive form of output and capital. After log-linearization, actual output, capital stock and labor force data are calculated based on the constant prices in 1978. For the selection of capital stock, the calculation method of Lei (2009) is adopted, and the capital stock in period t is calculated according to the following formula:

$$K_t = K_{t-1} + RGI_t \times \frac{NI_t}{GI_t} \tag{21}$$

where RGI_t is the actual total investment, NI_t is the net investment calculated based on the price in that year and GI_t is the total investment calculated based on the price in that year. According to the data obtained, the estimated production function is specified as follows:

$$\ln \frac{Y}{L} = 3.028 + 0.5116 \ln \frac{K}{L} + 0.0305T \tag{22}$$

Both the parameters and the model pass the test. The econometric results indicate that the output elasticity of capital is 0.5116; thus, the output elasticity of labor is 0.4884.

The time series of "Solow residual" $Z_t = A_t W_t^{\gamma}$ can be further obtained according to Equation (22):

$$\ln Z = \ln \frac{Y}{L} - 0.5116 \ln \frac{K}{L} - 0.0305T \tag{23}$$

Based on the established series data of institutional shocks from 1978 to 2011, the first-order autoregressive coefficient of technological shocks can be obtained according to Equation (6), i.e. $\psi_W = 0.9228$, and its standard deviation σ_W is 5.5123%.

The impact factor of institutional variables γ can be obtained through data calibration, which is the first set to a specific value, and the real impact factor, γ is eventually determined through subsequent data simulations. After calibration, it can be obtained that γ = 0.248 is obtained.

The predetermined $Z_t = A_t W_t^{\gamma}$ is used to obtain the following:

$$\ln A = \ln Z - \gamma \cdot \ln W \tag{24}$$

We can obtain the time series data of technological shocks A_t from the above equation. Through A_t and the autoregressive equation of Equation (5), we can calculate that the first-order autoregressive coefficient of technological shocks ψ_A = 0.7608 and its standard deviation σ_A = 2.8176%.

4.2 Estimation of other parameter values

Based on China's constant CPI in 1978, we calculated that the average growth rate of China's CPI during the period 1978–2011 was 5.39%. Hence, the discount factor of the model can be set as β = 94.70%. From $\beta = \frac{1}{\overline{R}}$ in the equilibrium state, $\overline{R}$ = 1.056 can be obtained. According to the research findings of Huang (2005), on equilibrium labor supply, when the normalized labor supply is 1, the steady-state labor supply is $\overline{L}$ = 0.542. According to the research findings of Chen *et al.* (2005) on Chinese residents' consumption savings behavior, the coefficient of CRRA, η = 0.77. The annual depreciation rate in foreign countries is 0.1, while in the literature studying the economic fluctuations in China, the depreciation rate selected by Chen and Gong (2006) is 0.1, and the one selected by Lei (2009) is 0.09732. With reference to the above literature, δ = 0.09732 is set herein.

In summary, the calibration results of model parameters are shown in Table 1.

5. Analysis of empirical results

Based on the above parameters calibrated in the model, we can have a system of equations in numerical form through the numerical iteration method and further use the MATLAB program [3] to solve the standard deviation of each variable under the equilibrium conditions and the correlation coefficients between them, as shown in Tables 2 and 4. Through comparison with the variables of actual macroeconomic data, we can determine whether the RBC model introducing the institutional shock factor can simulate the real economy appropriately.

ρ	η	δ	β	ψ_A	σ_A
0.8951	0.77	0.09732	94.70%	0.7608	2.82%
ψ_W	σ_W	$\overline{A}$	$\overline{W}$	$\overline{R}$	$\overline{L}$
0.9228	5.51%	1	1	1.056	0.542

Table 1. Model parameters

	Real economy		Simulated economy		
Variables	Standard deviation (%)	Contemporaneous correlation coefficient with output	Standard deviation (%)	Contemporaneous correlation coefficient with output	Kydland–Prescott ratio
Capital	4.0908	0.2404	0.6321	0.685	15.45%
Consumption	3.4318	0.6412	0.7217	0.8465	21.03%
Output	2.6546	1	2.507	1	94.44%
Labor	4.0178	0.1179	0.9426	0.9896	23.46%
Investment	9.8366	0.6614	6.499	0.9924	66.07%

Table 2. Cyclical characteristics of a simulated economy

The actual economic data and simulation-generated data for the macroeconomic variables (i.e. capital, consumption, output, labor and investment) in Table 2 are obtained after the HP filter removes the trend effect from variables. Among them, the Kydland–Prescott ratio is the standard deviation of variables in a simulated economy over the standard deviation of the corresponding variables in a real economy, reflecting the degree of the model's explanatory power. When the Kydland–Prescott ratio is less than 100%, the larger ratio indicates that the model matches the real economy better.

From the simulation of the above five variables, the fluctuation of investment is relatively drastic, up to 6.4990%, much larger than that of output (2.5070%); the fluctuation degree of labor is 0.9426%, much smaller than that of investment and output and followed by that of consumption. The fluctuation degree of capital is the smallest.

As shown by the Kydland–Prescott ratio, the ratio of output is the largest (94.44%), which means that the model can explain 94.44% of the cyclical fluctuations in output; similarly, the model can explain 66.07%, 23.46%, 21.03% and 15.45% of the cyclical fluctuations in investment, labor, consumption and capital, respectively. The reason why the model can explain the fluctuations of output and investment, well, is that on the one hand, consumption is assumed to be the sum of household consumption, government consumption and net exports in the model, while consumption in the real economy only refers to household consumption, leading to a low degree of the explanatory power of the model to consumption; on the other hand, regarding the influence of the institutional factor, investment has a relatively significant influence on the economy. Investment in China is greatly affected by the government's macroeconomic policies, and the government has a rather significant impact on China's economic growth and fluctuations through imposed institutional changes.

We noticed that the magnitude of the Kydland–Prescott ratio is related to the measurement method for variables and parameters, so we prepared a sensitivity analysis table of the Kydland–Prescott ratio in the case where the method of measuring variables and parameters are changed, as shown in Table 3. The so-called "change of labor, investment and consumption" in Table 3 refers that household consumption expenditure, gross fixed capital

Table 3.
Different Kydland–Prescott ratios: sensitivity analysis on changing measurement methods for variables and parameters

	Benchmark data	Change of labor, investment and consumption	Change of labor, investment and consumption	Change of labor, investment and consumption
	$\overline{L} = 0.542$ $\overline{R} = 1.056$	$\overline{L} = 0.562$ $\overline{R} = 1.166$	$\overline{L} = 0.542$ $\overline{R} = 1.166$	$\overline{L} = 0.542$ $\overline{R} = 1.156$
Capital	15.45%	42.33%	43.76%	45.38%
Consumption	21.03%	35.46%	37.12%	38.28%
Output	94.44%	68.30%	73.14%	75.25%
Labor	23.46%	23.41%	26.32%	27.15%
Investment	66.07%	106.46%	114.50%	114.02%

Table 4.
Relationship between variables and output in a real economy

Variable/lag period	−4	−3	−2	−1	0	1	2	3	4
Capital	−0.53	−0.84	−0.79	−0.24	0.2	0.35	0.41	0.2	−0.1
Consumption	−0.44	−0.13	0.32	0.54	0.63	0.546	0.19	−0.13	−0.23
Output	−0.69	0.24	0.59	0.71	1	0.68	0.22	−0.23	−0.39
Labor	−0.12	0.13	0.38	0.64	0.78	−0.01	−0.37	−0.36	−0.26
Investment	−0.65	0.06	0.14	0.52	0.67	0.51	−0.07	−0.24	−0.29

formation, and the total number of employed persons are replaced by final consumption expenditure, the total investment calculated according to Lei Hui's capital calculation method (2009), and the proportion of employed persons to the total population, respectively, in terms of the measures of consumption, investment, and labor. The reasons for changing the variables and parameters are as follows: (1) The final consumption expenditure is a metric of consumption used by Chinese scholars widely. (2) Changing investment data is mainly for the consistency with the calculation method of capital stock K, namely, to make both capital and investment be calculated based on the method of Lei (2009). (3) The main reason for changing the metric of labor to the proportion of the occupied population is that labor has been formalized as 1. (4) According to the computational formula of average return on capital, $\overline{R} = \left(\sum_{t=1978}^{2011} \frac{(1-\alpha)Y_t}{K_t}\right) \Big/ 34 + 1 - \delta$, the estimated $\overline{R}$ is 1.166. (5) The value of $\overline{L}$ is taken to be 0.562 mainly because the employment rate in China has been generally stable at 0.562 in recent years. (6) Regarding the value of $\overline{R}$, Chinese scholars have not reached a consensus, and the value of $\overline{R}$ basically ranges from 1.06 to 1.2. After trying all values in this range, we find that the fit of $\overline{R}$ was relatively high when the value of $\overline{R}$ was taken as 1.156.

The sensitivity analysis in Table 3 indicates that, by changing the measurement method for variables and parameters, the Kydland–Prescott ratio will change in varying degrees, and the fit to capital and consumption improves significantly, from 15% and 21% to 45% and 38%, respectively. Also, the fit to investment is closer to 1 (from 66% to 106% and 114%), which is consistent with the stylized fact that investment in China features high fluctuations, indicating that the accuracy has improved.

By comparing the contemporaneous correlation coefficients of capital, consumption, labor and investment with output in the real economy and the model economy, it can be found that the corresponding correlation coefficients of all variables are in the consistent order of magnitude of the variables, and all macroeconomic variables are positively correlated to the output, indicating that the fluctuations of investment in fixed asset and consumption are highly consistent with that of output, much in line with the relationship among variables in the real economy.

By comparing Tables 4 and 5, we can compare the cyclical relationship between variables and output in the model economy and that in the real economy and find that consumption, investment, capital, labor and output are procyclical. The autocorrelations among variables in different lag periods indicate that the model economy fits well with the real economy, and the model has good predictive power.

With the data simulated by model parameters, impulse responses to fluctuations in different variables can be plotted. Figures 3 and 4 below show the impulse response to institutional fluctuations and technological.

In the theoretical model, both technology and institution are regarded as exogenous shock variables; however, the impulse responses to them differ significantly according to the graphs. Firstly, the initial shock of technology is greater than that of institutions. This is understandable since technology can be quickly transformed into real productivity to significantly influence the economy, which is eventually reflected in output fluctuations.

Variable/lag period	−4	−3	−2	−1	0	1	2	3	4
Capital	−0.07	−0.28	−0.51	−0.34	0.69	0.58	0.16	−0.11	−0.2
Consumption	−0.09	−0.28	−0.47	−0.23	0.85	0.44	0.01	−0.16	−0.18
Output	−0.12	−0.24	−0.31	0.05	1	0.05	−0.31	−0.24	−0.12
Labor	−0.12	−0.22	−0.25	0.13	0.99	−0.05	−0.38	−0.25	−0.1
Investment	−0.12	−0.2	0.21	0.16	0.98	−0.11	−0.41	−0.25	−0.09

Table 5. Relationship between variables and output in a simulated economy

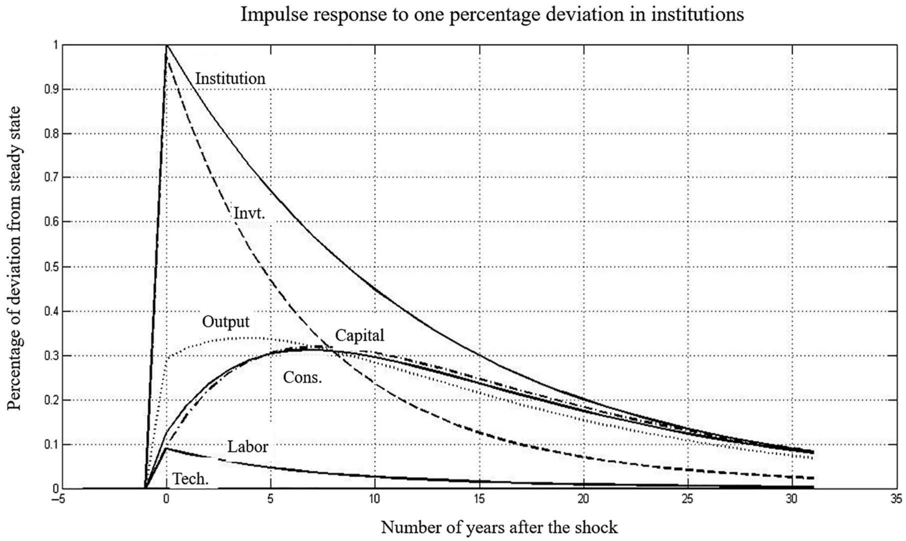

Figure 3.
Impulse response to institutional shocks

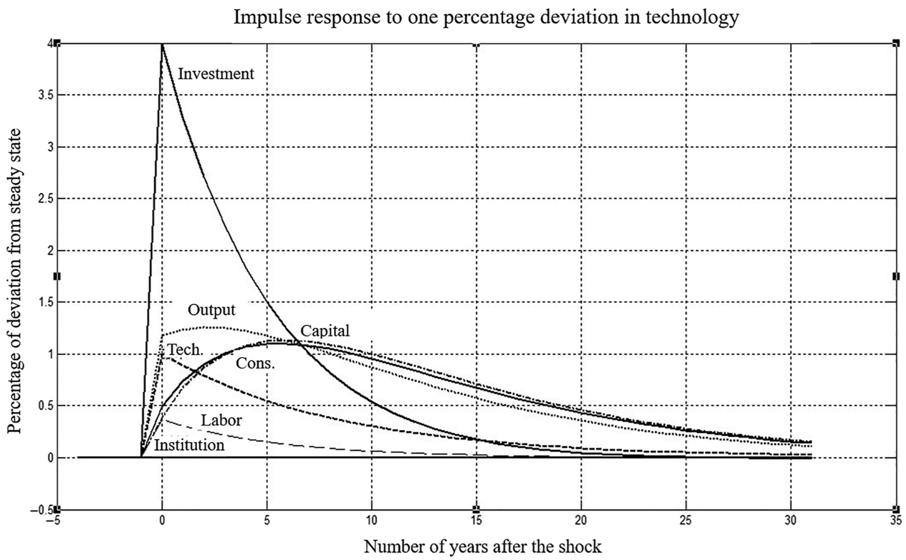

Figure 4.
Impulse response to technological shocks

Thus, the fluctuation effect regarding technology is obvious. In contrast, the institutional shock needs to be transmitted within the economic system through certain mechanisms, and this transmission process is relatively slow, whose effect on output fluctuations is not as significant as that of technology. Furthermore, regarding the duration of the impact of stochastic shocks on output, institutional shocks have a long-lasting influence for almost 30 years, while the effect of technological shocks will be relatively weak after ten years, which is highly consistent with our theoretical expectations. Finally, in terms of the declining process of shocks, the institutional shocks present a steady downward trend when the institutional influence continues to wane, while technological shocks decline more rapidly.

6. Conclusion

Since the founding of the People's Republic of China, China's economic growth has undergone a tortuous process and experienced multiple large fluctuations, mainly during the periods of the "Second Five-Year Plan", "Cultural Revolution", "reform and opening-up" and "Deng Xiaoping's Southern Tour speeches". Hence, the institutional changes are the key to explaining China's economic fluctuations. In this paper, we develop an RBC model introducing the institutional factor based on the DSGE (dynamic stochastic general equilibrium) theory and incorporate the institutional factor into the theoretical framework of economic growth and fluctuations, then solve the impact factor of institutions through the calibration method based on quantifying the institutional variables by utilizing the gray dynamic correlation theory and finally establish an economic cycle model containing the institutional shocks. In addition, we simulate economic data through computer technology and test the accuracy and robustness of the model by comparing the simulated economic data with actual economic data.

The empirical results of the model indicate that the RBC model containing the institutional factor has a good fit for the real economy and can explain the output and investment fluctuations in China properly. This model can explain 94.44%, 66.07%, 23.46%, 21.03% and 15.45% of cyclical fluctuations in output, investment, labor, consumption and capital, respectively.

Simulated economic data can be generated by simulating the values of dynamic economic system indicators. The cyclical relationship between the variables and output in a simulated economy and the relationship among the variables in a real economy shows that the simulated economy is highly consistent with the real economy, where consumption, investment, capital, labor and output are all procyclical, which proves the accuracy of the model and the role of the institutional factor in explaining economic fluctuations.

According to the analysis of the impulse responses to the exogenous stochastic shock variables of the model, the initial shock of institutions is smaller than that of technology. However, the institutional shocks can last for a long time (approximately 30 years), and the degree of shocks of institutional variables shows a steady decline when the influence of institutions is fading. In contrast, the technological shocks decline relatively fast, and the influence of the technological factor becomes relatively weak after nearly ten years of shock on the output, reflecting the importance of introducing the institutional factor in the model.

The economic cycle model introducing the institutional factor established in this paper can provide the macroeconomic policymakers with useful insight to some extent – that is, the long-term influence of policies should be considered during policymaking to reduce adverse economic fluctuations caused by institutional changes, to the greatest extent possible. Institutional innovation should be promoted appropriately to promote long-term and stable economic growth.

The assumptions about the pathway to institutional evolution in this paper are based on considering that China is undergoing an economic transition. During such a period, everything, from the institutional environment to the specific institutional arrangements, is in the process of change, just like the change of technology. Although each institutional innovation is one leap at a time, the continuous results of frequent changes in multiple institutional arrangements and the continuous role of institutional changes in economic growth can be regarded as constant. The main idea behind adopting Equation (6) is that the imitation of the equations for the evolution of technology in the classical literature is also a tentative, less mature assumption. We will change this assumption in future studies to improve the model if possible.

Notes

1. If the discounted marginal utility at the infinite horizon is greater than 0, i.e. $\lim_{i\to\infty} E_t\beta^i C_{t+i}^{-\eta} > 0$, it is still possible for an actor to increase personal utility at the end of his life. The optimal choice of a rational economic man must be consumption instead of capital accumulation, thus making $\lim_{i\to\infty} K_{t+i+1} = 0$.

   This cross-sectional condition implies that the actors' utility level at the infinite horizon cannot further increase.
2. In the processing of numerical processing, numerical transformation is required to achieve the positive index value.
3. Rewritten based on the program provided by Uhlig (1997).

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