
Munich Personal RePEc Archive

China's Business Cycles between 1954 – 2004: Productivity and Fiscal Policy Changes

Hsu, Minchung and Zhao, Min

National Graduate Institute for Policy Studies (GRIPS), World Bank

2009

Online at https://mpra.ub.uni-muenchen.de/21283/
MPRA Paper No. 21283, posted 12 Mar 2010 00:55 UTC

China's Long-term Business Cycles and the 1978 Reform: Productivity and Fiscal Policy Changes

Min Zhao[a,b] Minchung Hsu[a*]

Abstract

We study the real business cycles in China between 1954-2006, and examine the changes after China's market-oriented reforms starting in 1978. We overcome some data problems and find that the economic volatility is generally moderated after 1978. However, the relative volatility of each variable to output diverges. We undertake a neo-classical approach to investigate factors that can drive the features of long-term fluctuations and the differences between the pre-1978 and the post-1978 periods. We find that TFP process can explain the main features of fluctuations and the general moderation but not the relative volatility changes. We show that policy changes in government expenditure can account for the relative volatility divergency. Counterfactual experiments are also provided to discover the role of each factor in explaining the long-term fluctuation features in China.

JEL Classification: E32, E62, C82, N15
Keywords: business cycles, fiscal policy, market-oriented reforms, China

*Corresponding author. We thank Gary Hansen, Selahattin Imrohoroglu, participants of the 2008 International Conference of Economic Growth, Dynamics, and Policies in Tokyo, the 2009 Econometric Society North America Summer Meeting in Boston, the 15th International Conference on Computing in Economics and Finance in Sydney, and the 2009 Far East and South Asia Meeting of the Econometric Society, for their useful comments. All errors are ours. [a] National Graduate Institute for Policy Studies (GRIPS), Tokyo. [b] World Bank, Beijing Office. Min Zhao's email: mzhao1@worldbank.org; Minchung Hsu's email: minchunghsu@grips.ac.jp.

1 Introduction

China's high economic growth has attracted the world's attention. In particular, after China started its market-oriented economic reforms in 1978, the average annual GNP growth rate reached 9% between 1978 and 2006. Nevertheless, business cycles and economic fluctuations in China are rarely studied although they are important issues. Moreover, studies on China usually suffer from problems in data availability and consistency. Therefore, the long-term features of Chinese business cycles are still not well understood in the literature. Since the 1978 reform significantly affected China's growth, it is natural to ask whether the reform had impacts on economic fluctuations. In this paper, we first make our effort to improve the business cycle measurement of China and discover the long-term features of Chinese real business cycles from 1954 to 2006 and the differences between the pre-1978 and the post-1978 periods. We find that economic fluctuations were significantly moderated after 1978. However, the pattern of relative volatility of each variable to output diverged. Particularly, relative volatility of household consumption became much higher while that of private investment became much lower after 1978.

To further understand the business cycle features, we adopt the standard approach of real business cycle research.[1] We use neo-classical growth models to study the factors that can generate the long-term economic fluctuations in China and the differences between the pre-1978 (1954- 1977) and the post-1978 (1978-2006) periods. Our baseline model with population growth , technology growth and TFP shocks successfully explains the moderation of volatility after 1978. The counterfactual experiments also indicate that the TFP growth rates (productivity changes) are the main reason for the moderation in China's economic volatility. However, these factors cannot explain the relative volatility changes. We suggest that the policy changes in government expenditure may account for the changes in relative volatility. We study the government expenditure process and find a significant policy pattern change between the pre-1978 and post-1978 periods. Both the government consumption and government investment processes in the pre-1978 period were significantly pro-cyclical, but they became counter-cyclical in the post-1978 period. In addition, we find the expenditure allocation between government consumption and government investment was reversed in the post-1978 period. We then extend the model to incorporate the government expenditure process. We show that the changes in fiscal policies help to explain the relative volatility changes.

Our first task in this paper, probably the most difficult, is to collect and manage the data for studying the real business cycle features in China. We face several problems of

[1] Rebelo (2005) provides a detailed survey of real business cycles research.

data. For example, 1) there are no direct statistics for consumer durables; 2) the data of employment are not consistent over time; 3) the data of labor hours are very limited; 4) the classification of consumption category and the consumer price index are not consistent over time. To keep the measurement of Chinese business cycles consistent to the real business cycle literature, we need to do calculation and estimation by ourselves, and adjust the corresponding changes to every related economic variable.[2]

Our study shows that the economic fluctuations have been largely moderated since 1978. Compared with the volatility in the pre-1978 period, the volatility of output decreased by 78%, consumption decreased by 60%, investment decreased by 83%, and employment decreased by 84% in the post-1978 period.[3] We also find that, although the volatility was in general moderated, the consumption became more volatile relative to the output in the post-1978 period. The relative volatility of consumption increased from 55% in the pre-1978 to 102% in the post-1978.[4] Meanwhile, the relative volatility of investment decreased from 276% in the pre-1978 to 217% in the post-1978.[5]

To further understand the long-term economic fluctuations in China, we first use a standard neo-classical growth model with population growth , technology growth and TFP shocks, which is widely used in the real business cycle literature.[6] We estimate the growth and shock factors separately for the pre-1978 and the post-1978 periods, and keep all other calibrated parameters the same across the two periods. We find that this standard model can explain the main statistical features of Chinese business cycles well. It also successfully generates the moderation of volatility in the post-1978 economy. However, the model cannot explain the relative volatility changes - in the model economy, the relative volatility of every variable does not change much from the pre-1978 to the post-1978 economy.

We suggest that government expenditure is a reason for the relative volatility changes. With an analysis of China's government expenditure, we find that there is a significant policy change after 1978. In the pre-1978 period, both government consumption and investment were significantly and positively correlated with the pervious period pro-

[2]For example, the adjustment of consumption durables will affect the values of consumption, investment, capital stock, output and the estimation of TFP.

[3]We also estimate the average work hours for the post-1978 period. Taking into account the volatility of work hours, total labor hours would be more volatile. However, we do not have work hour data for the pre-1978 period. If we assume that work hours were constant in the pre-78 period because of the socialism planning economy, then the decrease in labor volatility becomes 8%.

[4]The relative volatility of household consumption increased from 53% in the pre-1978 to 103% in the post-1978

[5]The relative volatility of non-government investment decreased from 375% in the pre-1978 to 277% in the post-1978.

[6]For example, Hansen (1985).

ductivity (TFP). However, in the post-1978 period, both government consumption and government investment were negatively correlated with the pervious period productivity. We also apply econometric methods to estimate the processes of government consumption and investment. The results also confirm our data analysis.

The pattern change in government expenditure indicates that the Chinese fiscal policy was pro-cyclical between 1954 and 1977, and became counter-cyclical from 1978 to 2006. In addition, the expenditure allocation between government consumption and government investment was reversed in the post-1978 period – government consumption increased to more than 60% as of total government expenditure from 40% in the pre-1978 period. We extend the baseline model to incorporate government consumption and government investment. We characterize government consumption and investment into the model as shock processes in addition to the TFP shocks. Our simulation shows that the addition of government expenditure helps to explain the relative changes in volatility.

It is necessary to note that because data of work hours are very limited, to provide consistent comparison between the pre-1978 and post-1978 periods, we focus employment fluctuations rather than fluctuations of labor hours in the main text.[7] In the appendix, we use the limited observations to estimate the hours worked in the post-1978 period and redo the analysis with the estimated labor hours. The estimated labor hours are more volatile than employment. We find that our analysis results are still preserved except that the model can not generate a comparable labor volatility as that we estimated.

There are few related studies on Chinese business cycles. We briefly describe them here. Zhang and Wan (2005) studies China's business cycles of 1985 - 2000 by using a VAR approach based on an AD-AS model. Gao (2007) uses a business cycle accounting approach to study China's economic fluctuations between 1978 and 2006, and suggests that efficiency wedge are the main source driving fluctuations. The two studies both suggest that government policies did not play an important role of generating fluctuations. However, this paper, which extends the analysis to the period prior 1978, suggests that government expenditure is important in explaining the relative volatility differences between the pre-1978 and the post-1978 periods. Imai (1996) studies China's business cycles in a longer period from 1955 - 94 that covers years prior to 1978 as us. Because the GDP data was not available when the author did the research, calculation of annual economic growth rates were based on net material product. The author also found a significant moderation in output volatility after 1978 although the paper focused on identifying each cycle in the studied period. We use a neoclassical approach to analyze

[7] The data of hours worked before 1978 are not available at all. Some data are available for 1991 – 98 and 2001 – 06.

China's economic fluctuations through the postwar period. A similar approach is also used by Otsu (2008) to analyze Korea's economic crisis in the most recent literature. The author also faced a highly volatile consumption process relative to output process, and suggested that the GHH preference and interest rate shocks can account for it.[8] We, however, suggest that government fiscal polices can help to explain the high consumption volatility relative to output.

Regarding the effects of government expenditure on household consumption, Gali et al. (2007) show that government expenditure has an crowding-in effect on private consumption with a New Keynesian Model. Some empirical studies, e.g. Blanchard and Perotti (2002) using the US data, support this proposition. On the other hand, Rossi (2007), Coenen et al. (2007) and Horvath (2009) do not show supportive results with the Keynesian framework. In this paper, we show that the crowding out effect of government expenditure on consumption in a neo-classical envelopment is consistent with the business cycle features in the Chinese economy.

The rest of the paper is organized as follows. Section 2 describes the data and our estimation. Section 3 presents the stylized facts of the Chinese real business cycles, and provides a comparison between the pre- and post-1978 periods. A comparison between China and the other economies is also provided for reference. Section 4 describes the baseline model, calibration, and the simulation results. Section 5 provides an analysis on China's government expenditure process, and extends the model to examine the effects of the government expenditure. The quantitative results and a discussion of the effects of government expenditure are also presented in this section. Section 6 performs counterfactual experiments to understand the role of each factor in explaining the economic fluctuations. Section 7 concludes.

2 The Data

We obtain data from various sources and do crosscheck among them. Most data are collected from Data of Gross domestic Product of China 1952-2004. Data of employment and labor hours are also acquired from annual issues of China Labor Statistics Yearbook (CLSY). The most recent national account data in 2005 and 2006 are obtained from the 2006 and 2007 issues of China Statistical Yearbook (CSY). The above are all published by the National Statistical Bureau (NSB) of P.R.C. We collect fiscal data from annual issues of the Finance Yearbook of China (FYC) published by Ministry of Finance. To keep the measurement of Chinese business cycles consistent to the real business cycle

[8] See Greenwood et al. (1988) for the GHH preference.

literature, we need to do calculation and estimation by ourselves, and adjust the corresponding changes to every related economic variable. Because many statistics are not consistent over time or with different sources, adjustment is needed. We have talked to Chinese statistical officials to find out the reasons for the inconsistency to make adequate adjustment.

2.1 Output, Consumption, and investment

We obtain the GDP data from DGDPC and CSY. NSB also provides GNP at current price for years after 1978. Since China traded little with the rest of the world before the reform in 1978, the GNP would be very close the GDP during the pre-1978 period. We estimate the real GDP at price of year 2000 with GDP deflator.

To be consistent with the growth theory, we adjust the consumption, investment and output from the original data as follows:

$$Y = Yo \ \ (\text{original data}) + Yg + Yd; \tag{1}$$

$$C_h = Co \ \ (\text{original data}) + Yg + Yd - Id; \tag{2}$$

$$C = C_h + G; \tag{3}$$

$$Ip = Io \ \ (\text{original data}) + Id; \tag{4}$$

$$I = Ip + Ig; \tag{5}$$

where Y is aggregate output, Yg is service provided by government capital, Yd is service provided by consumer durables. C is aggregate consumption, including household consumption C_h and government consumption G, Id is consumption on consumer durables, Ip is private (or non-government) investment, and Ig is government investment.

We derive nominal government consumption from the national account and the nominal government investment Ig from government expenditure under the construction account of its budget. The nominal government consumption and government investment are then converted to 2000 yuan using the estimated consumption deflator and investment deflator, respectively. The remaining of the investment is the measured private (non-government) investment.

2.2 Consumer durables (Id)

Consumption on durables is classified in investment. Estimating the consumer durables is a daunting task. In the literature, no one has ever estimated the consumer durables for China. Items we include in consumer durables are daily article durables, entertainment durables, transport equipment and telecommunication equipment of all residents

and urban households' consumption on construction and decoration materials. The rural households' consumption on construction and decoration materials is not included because rural residents in China often construct houses by themselves, the expenditure on construction and decoration materials is counted in the residential investment in national accounts already.

We first estimate the urban households' consumption on durables. CSY provides the data of per capita consumption on daily article durables and entertainment durables from 1986 through 2006, but construction and decoration materials are only available from 1985 to 1991. For the rest, CSY only provides aggregated data of their upper categories. Fortunately, CSY provides consumer price index (CPI) for all categories and sub-categories from 1985 to 2006. Before 1985 CPI data are not available, and we use retail price index (RPI) instead. The price index information can be used to estimate the weights of each durable good. For instance, the category of housing from 1994 through 2000 contains two subcategories-rent and construction materials. We would like to estimate the expenditure on construction materials, but only the expenditure on housing is available. Because price of housing (Ph) is the weighted average of price of rent (Pr) and price of construction (Pc), we can have the equation:

$$Ph = w \times Pc + (1-w) \times Pr. \tag{6}$$

With rearrangement of the equation, we get the weight w of construction materials:

$$w = (Ph - Pr)(Pc - Pr)^{-1}. \tag{7}$$

Then we can calculate the expenditure on construction materials with the weight . When there are n subcategories, we need at least n-1 observations to estimate the weights, and assume that the weights are stable in the n-1 years. We successfully estimate the weights for most cases. There are few occasions that the calculated weights are not consistent. In such cases, we estimate the weights by linear interpolation.

For the rural residents' durable consumption, we use price index of all households to estimate the weight of urban residents' expenditure, w_u, and rural residents' expenditure, 1-w_u, for all durables goods. Multiplying the urban residents' expenditure on durable goods by $(1-w_u)/w_u$, we have the rural residents' expenditures on those durable goods. With the CPI index, we convert the durables in current price to constant price of year 2000. For consumer durables before 1981, the data are limited and we cannot have precise estimation. So we simply assume the share of consumer durables in household consumption (C_h) increase exponentially from 1952 to 1981. Because the share of durables in 1981 is already small (less than 2% as of total household consumption

in constant price of year 2000), the estimation of consumption durables does not make noticeable changes.

2.3 Stock of Capital (K)

Stock of capital (K) consists of private (non-government) physical capital (Kp), government physical capital (Kg), stock of consumer durables (Kd). We estimate them by their laws of motion:

$$K_t = Kp_t + Kg_t + Kd_t; \tag{8}$$

$$Kp_{t+1} = Ip_t + (1-\delta_p)Kp_t; \tag{9}$$

$$Kg_{t+1} = Ig_t + (1-\delta_g)Kg_t; \tag{10}$$

$$Kd_{t+1} = Id_t + (1-\delta_d)Kp_t; \tag{11}$$

where δ_p, δ_g and $\delta_d$are the corresponding depreciation rates. We adopt Chow (1993)'s estimation of the depreciation rate of physical capital (δ_p and δ_g), 0.05, and his estimation of the initial value of capital (Kp and Kg) at the end of 1952 including land value, about 2.7 times of the year 1952's output. We assume that consumer durables depreciate faster, and we set at 0.2. The initial value of Kd at the end of year 1952 is assumed 4 times of Id in 1952. Because the consumer durables depreciate faster, the estimation of the sequence of Kd is not sensitive to the initial value of Kd.

2.4 Values of services from Kg and Kd

Because the official data do not include the return of consumer durables and government capital, we need to estimate the return values (equivalently values of their service) Yd and Yg, and add the values into consumption and output. We want a proxy of rate of return for Kg and Kd. It is intuitive to use the rate of return of Kp. We do this in the following steps. First, we estimate the income share of capital (θ_p) for Kp:

$$\theta_p = \text{ gross return of capital}/(Yo - \text{ production tax}) \tag{12}$$

Because there is a production tax in addition to capital income and labor income in original GDP data, we need to deduct it when we estimate the income share. The necessary data are available from statistics of flow of funds account (FOF) for the period 1992-2004 released by NBS. In the second step, we then calculate the net rate of return (r) of Kp:

$$r = Ykp/Kp - \delta_p = \theta_p Yo/Kp - \delta_p; \tag{13}$$

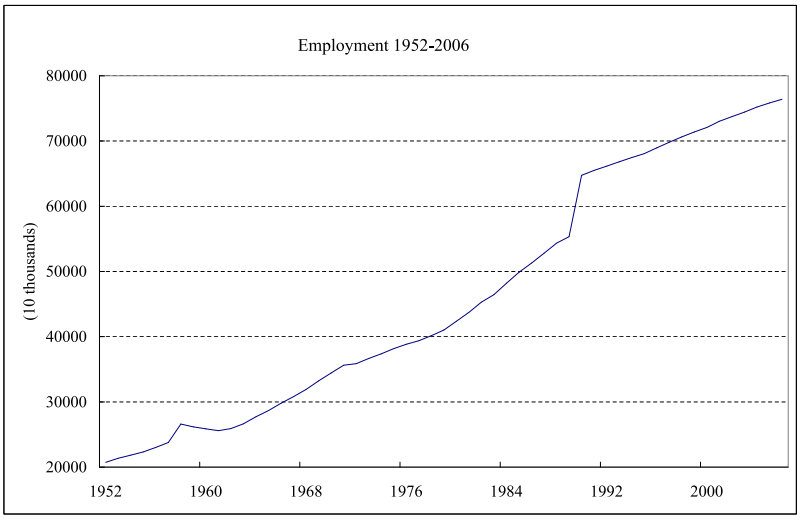

Figure 1: Employment

where Ykp denotes the income of Kp. We use r with and to form income shares for Kg and Kd. Then we calculate the flow of services of government capital (Yg) and consumer durables (Yd):

$$Yg_t = (r_t + \delta_g)Kg_t = \theta_p Yp_t/Kp_t - \delta_p + \delta_g)Kg_t; \tag{14}$$

$$Yd_t = (r_t + \delta_d)Kd_t = \theta_p Yp_t/Kp_t - \delta_p + \delta_d)Kd_t; \tag{15}$$

Employment

We use the data of employment in annual issues of CSY. It is obvious to notice that there is a jump of employment in 1990, a sudden increase of 942 million workers. There is no economic reason for this increase (see figure 1). After a contact with China NSB officials, we found that NSB changed the methodology of data collection from firm survey to household survey. This change resulted in an inconsistency of the employment data. To prevent the unreasonable fluctuation, we have to adjust the employment data. We suppose that the increase in 1990 contains two components: employment growth and previous under-estimation by the firm survey. We assume that the employment growth rate is the same as in 1989 to calculate the proportion of previous under-estimation. Assuming that the gap between firm survey and household survey (in proportion) is constant over time, we use it to adjust the employment data before 1990.

In addition, we found that the official employment data include some hidden unemployment. A large number of laid-offs from the state-owned enterprises (SOE) have been observed since the SOE reform started in 1993. These laid-offs were often paid

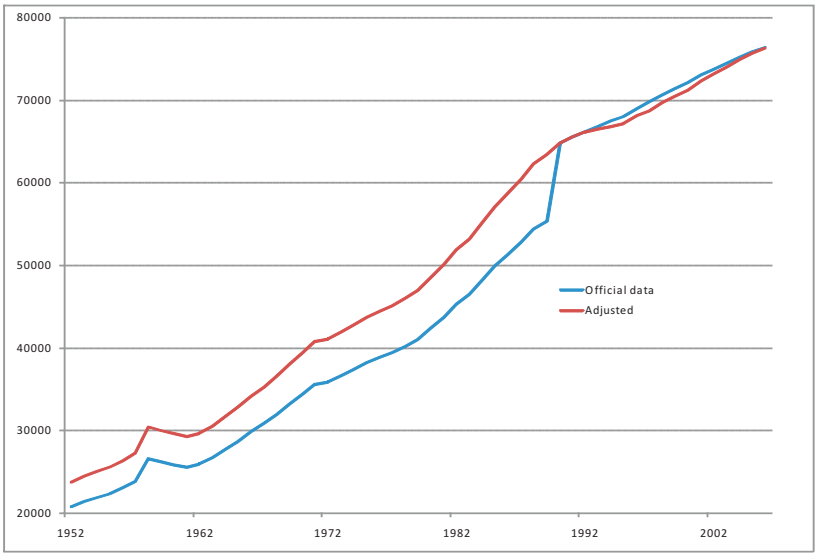

Figure 2: Employment – official and adjusted

by their working units at a minimum living allowance until they found new jobs or retired. They were counted in employment by NSB. This transitional arrangement ended in 2007 because of the establishment of unemployment insurance. It is necessary to adjust the employment during the period 1993 - 2006 to subtract the SOE laid-offs. CLSY releases the numbers of the SOE laid-offs for the years 1996 through 2006, but figures from 1993 to 1995 are absent. We assume that China started to accumulate the hidden unemployment from 1993, and simply apply the linear interpolation to estimate the missing laid-off figures between 1993 and 1995. Figure 2 depicts the official and out adjusted employment.

Hours worked

The data of hours worked are very limited. CLSY releases the surveyed data of hours worked per worker week in urban areas for the years from 1991 through 1998 and from 2001 through 2006. It provides data for each sector. We use sector shares in national employment as weighs to compute aggregated weighted hours per worker. However, these limited observations are not sufficient to perform analysis for the period 1954-2006. Therefore we decide to focus on employment in our analysis in the main text. However, we apply an econometric method to estimate the average hours worked for the post-1978 period, and perform the same neo-classical analysis in the appendix for comparison. We show that, except the labor fluctuation, our analysis results in the text still hold when we consider the hours worked in the model.

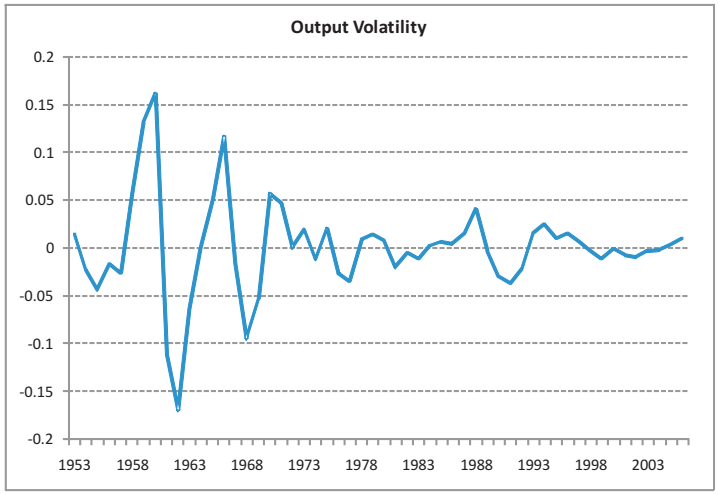

Figure 3: Deviations from the trend of output

Total Factor Productivity (TFP)

TFP series is calculated by using Solow residuals:

$$\ln(A_t) = \ln(Y_t) - \theta \ln(K_t) - (1-\theta) ln(H_t). \tag{16}$$

To provide consistent comparison between pre-1978 and post-1978 periods, we use employment to represent labor input H. Hence changes in hours worked will be captured by the Solow residuals.

3 Stylized Facts

We use H-P filter to remove the growth trends of each variable. Because only annual data are available in China, as suggested by Ravn and Uhlig (2002), we set the H-P filter lambda coefficient as 6.25 so that the statistical features of annual data can be comparable with quarterly data.[9] We present the main features of China's economic fluctuations for periods 1954 to 1977 and 1978 to 2006 in this section. The detailed report is shown by table 14 in the appendix.

[9]If we do H-P filter with lambda 100 instead of 6.25, the calculated volatility would be much higher than we present in the paper, but the relative volatility and pattern changes after 1978 would be the same.

Table 1: Standard deviation from the trend (%)

Variable	Pre-1978	Post-1978	Change
Output (Y)	7.4	1.7	-78
Consumption ($C_h + G$)	4.2	1.7	-60
Household (C_h)	3.9	1.7	-57
Government (G)	9.1	3.0	-67
Investment ($I_p + I_G$)	20.3	3.6	-83
Private (non-Govt) (I_p)	27.6	4.6	-83
Government (I_g)	20.9	6.5	-69
Labor* (L)	1.6	0.3	-84

Notes: * Labor is employment only. We also estimate the labor hours for the post-1978 period with limited data. The volatility of the estimated labor hours is 1.5% in the post-1978 period.

3.1 Economic Fluctuations - Great Moderation after 1978

It is well known that the 1978 reform in China has brought high growth. When we compare the fluctuations in the pre-1978 and post-1978 periods, it is clear to observe that the market oriented reform started in 1978 was also accompanied with a sharp fall in economic volatility. Figure 3 presents output fluctuations in 1954-2006 by H-P filtered series. The annual output growth rate increases from 6 percent to 9 percent in the post-1978 period, while its volatility (measured by the standard deviation of the H-P filtered series) falls by 78%, from 7.4% to 1.7%.

Not only output, in fact, fluctuations of all economic variables, including household consumption, government consumption, private investment, government investment and employment, are generally moderated compared with those in the pre-1978 period. The standard deviation of household consumption drops from 3.9% in the pre-1978 period to 1.7% in the post-1978 period, output drops from 7.4% to 1.7%, and employment decreases from 1.6% to 0.3%. The volatility reduction in private investment is even sharper, from 27.6% to 4.6%. Table 1 presents the general moderation in volatility clearly.

3.2 Relative Volatility Changes

Although the economic volatility is generally moderated after 1978, the relative volatility (with respect to output) of each variable diverges. The relative volatility of a variable is defined as the standard deviation of the variable relative to the standard deviation of output. If the variable is more volatile than output, its relative volatility will be greater than one. Table 2 reports the relative volatility of each variable and a comparison be-

Table 2: Standard deviation relative to output (%)

Variable	Pre-1978	Post-1978
Output (Y)	100	100
Consumption ($C_h + G$)	**55**	**102**
Household (C_h)	53	103
Government (G)	121	182
Investment ($I_p + I_g$)	**276**	**217**
Private (non-Govt) (I_p)	375	277
Government (I_G)	278	395
Labor* (L)	22	16

Notes: * Labor is employment only.

tween the pre-1978 and post-1978 period. We can observe that the relative volatility of household consumption increases from 0.53 (less volatile than output) to 1.03 (more volatile than output), while the private investment falls from 3.8 to 2.8.

3.3 World Comparison

We also compare the business cycle features of China with other economies. Chinese economy in the pre-1978 period is excessively volatile compared with other countries, both the developed and the developing (See table 3). Nevertheless, its economic volatility in the post-1978 period does not differ from other economies too much. China's output volatility in the post-1978 period is comparable with the UK and the US; the volatility of household consumption is a bit higher than other economies but not far from the UK; investment in China is less volatile than many countries and similar to India and Malaysia. China stands out in volatility of government consumption and is similar to Pakistan. Table 3 presents the comparison. In general, after China opened up its economy and started the market-oriented reform in 1978, its business cycle features became comparable with the rest of world.

3.4 Discussion

It is natural to ask why the volatility reduction go along with the development of markets. We can view the introduction of price mechanism as a new technology adopted in China that can guide resource allocation more efficiently and quickly. In a centrally-planed economy, misallocation is usually realized when it becomes very obvious, and then necessary adjustment comes too late to prevent worsened situations. This is basically what happened during the "Great Leap Forward" and the "Cultural Revolution" in the

Table 3: World Comparison (%)

Country	Y	C_h	G	I
Asian countries				
India	1.12	0.91	1.08	3.34
Korea	1.50	1.42	1.30	5.56
Malaysia	0.88	1.27	1.50	3.28
Developed countries				
Canada	1.56	1.22	0.88	6.40
France	0.96	0.82	0.75	5.21
Japan	1.39	1.26	1.23	4.29
UK	1.72	1.88	0.91	7.41
USA	1.73	1.41	0.66	6.68
China (1954-1977)	7.36	3.92	9.10	27.59
China (1978-2006)	1.65	1.70	3.00	4.57

Notes: Numbers for countries other than China are from Rand and Tarp (2002) and calculated from data for the period 1970-97.

pre-1978 period in China. Therefore, it is intuitive to expect that China's technology or TFP process would reflect this progress and moderate the economic volatility. To better understand how the technology change can affect China's economic fluctuations, we use a neo-classical approach to provide further analysis.

4 Analysis I – Growth model with TFP shocks

We start with a standard neo-classical model with population growth, productivity growth, and TFP shocks. In this baseline model, the TFP process is the main factor for explaining economic fluctuations. We construct two separate economies for the pre-1978 and the post-1978 periods. They share the same model structure, but differ from each other in population growth, productivity growth, and TFP process.

4.1 The Model

The economy is populated by a large number, N_t, of agents at time t. The population grows at a constant rate $\eta - 1$. Each individual is endowed an unit of time, which can be spent on leisure or working, in each period. The technology for production is assumed as Cobb-Douglas type with stochastic TFP shocks. We also assume a constant productivity growth for production with the growth rate $g - 1$. In this economy, the social planner's problem is to maximize the lifetime discounted aggregate utility by choosing

representative consumption c_t, investment i_t, and labor supply h_t in each period:

$$\max_{\{c_t,i_t,h_t\}_{t=0}^{\infty}} \quad E_0 \left\{ \sum_{t=0}^{\infty} \beta^t N_t \left[\ln(c_t) + \alpha \ln(h_t) \right] \right\} \tag{17}$$

subject to

$$Y_t = e^{z_t} (K_t)^{\theta} (g^t H_t)^{1-\theta}; \tag{18}$$

$$C_t + I_t = Y_t; \tag{19}$$

$$K_{t+1} = (1-\delta)K_t + I_t; \; K_0 \text{ given}; \tag{20}$$

$$N_{t+1} = \eta N_t; \tag{21}$$

$$z_t = \rho_z z_{t-1} + \varepsilon_t; \tag{22}$$

where $C_t = N_t c_t$, $K_t = N_t k_t$, $I_t = N_t i_t$ and $H_t = N_t h_t$. N_t is the working-age population at time t and grows at η. C_t, K_t, I_t and H_t are aggregate consumption, aggregate capital stock, aggregate investment and aggregate labor supply at time t, respectively. z_t is a stochastic productivity shock which follows an AR(1) process, and ε_t is a white nose with mean zero and standard deviation σ_ε.

4.2 Calibration

Following the methodology that was introduced by Cooley and Prescott (1995), we calibrate the preference and production parameters by using the data of 1978–2006 when Chinese economy is more market-oriented and less distorted. Parameters of growth and TFP process are calibrated separately for the pre-1978 and the post-1978 periods. The basic rule of our calibration is that we select the parameters so that properties of the balanced growth path of the model economy can match certain long-term features of the real economy.

Growth and Shocks

The population growth η is calculated from the average of growth of adult population in China. The productivity growth g is selected so that the per capita output growth in the model can match the per capita GDP growth in the data.

We use an AR(1) process as equation (22) to approximate the TFP shock process z. Literature has suggested that z is highly persistent. We follow Hasen (1985) and set the persistence ρ_z at 0.95. Based on this setting, our estimation shows that the standard deviation of the disturbance ε is 0.105 in the pre-1978 period and is reduced to 0.025 on average after 1978.

Table 4: Model Parameters 1

Parameter	(1954-1977)	(1978-2006)
Growth		
η	1.0194	1.0152
g	1.0322	1.0607
Shocks		
σ_z	0.105	0.025

Note: η – average population growth; g – per-capita GDP growth; σ_z – standard deviation of TFP shock process.

Table 5: Model Parameters 2

Parameter	(1954-1977)	(1978-2006)
Preference		
β	0.955	0.955
α	1.443	1.443
Production		
δ	0.0545	0.0545
θ	0.456	0.456
Shock persistence		
ρ_z	0.95	0.95

Note: These parameters are invariant in both economies for the pre-1978 and the post-1978 periods.

Preference

We assume that preferences do not change over time. The utility discount parameter has the following property from the first order conditions:

$$\beta = \frac{g}{\theta(\bar{y}/\bar{k}) + 1 - \delta}; \tag{23}$$

where $\bar{y}$ is per capita output and $\bar{k}$ is per capita capital in the non-stochastic steady state of the model. Given that the average capital-output ratio is 2.768 in the data, we have that $\beta = 0.955$.

Also from the first order conditions, the leisure utility parameter α can also be ex-

Table 6: Simulation results – Standard deviation from trend (%)

	Data			Model		
Variable	Pre-78	Post-78	change	Pre-78	Post-78	change
C	4.1	1.7	-59	3.4	0.9	-74
(Household C)	(3.9)	(1.7)				
I	20.3	3.6	-82	16.0	3.6	-77
(Private I)	(27.6)	(4.6)				
L	1.6	0.3	-84	2.8	0.6	-77
Y	7.4	1.7	-78	7.7	1.8	-76

Notes: C – aggregate consumption; I – aggregate investment; L – labor; Y – output. Labor L is approximated by employment.

pressed as follows:

$$\alpha = \frac{(1-\theta)(1/\bar{h}-1)}{1+(1-\delta-\eta g)(\bar{k}/\bar{y})}; \tag{24}$$

where $\bar{h}$ denotes the hours worked in the steady state. We assume that an agent is endowed 16 hours per day for working and leisure and normalize the time endowment to one in the model. In the data the average hours worked are 2172 hours per worker per year that yields the value 0.372 for the $\bar{h}$. Then we can calculate the above equation and have $\alpha = 1.443$.

Production

We have estimated the returns of non-government physical capital, government capital and consumer durables ($\theta_p Y p$, Y_g and Y_d, respectively). The aggregate capital income share θ can be simply calculated as follows:

$$\theta = (\theta_p Y p + Y_g + Y_d)/Y; \tag{25}$$

where Y is the adjusted total output. We find that the capital share is stable during 1992 – 2004, and use the average 0.456 for θ. Hence the labor income share is 0.544. We also used a restricted regression to estimate the factor income share of the production function in the post 1978 period and found a similar result.

The parameters are summarized in table 4 and table 5.

4.3 Model solution and quantitative analysis

To solve the model, we apply Uhlig's toolkit, which is widely used for analyzing nonlinear dynamic discrete-time stochastic models. The toolkit provides a device for solving

such models easily. The general procedure is first log-linearizing the necessary equations that characterize the equilibrium, and then solving for the recursive equilibrium law of motion with the method of undetermined coefficients. Please see detailed information provided in Uhlig (1999).

With the approximated law of motion solved from the model, we do simulations and calculate the moments of each variable for analysis. Table 6 shows the standard deviations of each variable from model simulations and from the data. We find that the simple model successfully generates the big moderation on fluctuations after the 1978 reform. The deviations generated by the model are also close to the data in general. With the simple and standard settings, we are surprised by the model's performance. However, if we take a closer look, the magnitude of some variables' volatility does not match the data very well. The volatility of C is lower than the data: 4.1% and 1.7% for the pre-1978 and the post-1978, respectively, in the data versus 3.4% and 0.9% in the model. The volatility of I is also lower than the data: 20.3% and 3.6% in the data versus 16% and 3.6% in the model. The private investment even has a higher volatility: 28.5% and 4.4% for the pre-1978 and the post-1978, respectively.

Moreover, if we look at the relative volatility changes, we find a significant difference between the model and the data. Relative volatility of variable x (to output) is defined as the standard deviation of x as of a percentage of the standard deviation of output Y. Table 7 presents the comparison clearly. In the model, although the economy indeed becomes less volatile in the post-1978 period as the data show, volatility of each variable is moderated by a similar proportion and so the relative volatilities in both the pre-1978 and the post-1978 are very similar. In the data, the relative volatility of each variable actually shows a diverge trend. As we mentioned in section 3.2, the relative volatility of household consumption increases from 53% to 103% in the post-1978 period while the private investment falls from 375% to 277%.

5 Analysis II – Government Expenditure Shocks

Our experiment shows that the standard growth model with TFP shocks can not match the magnitude of volatility in consumption and investment very, and fails to explain the relative volatility changes. It is natural to ask what factor(s) additional to the TFP can explain those facts. We suggest that Chinese government might play an important role for further understanding the economic fluctuations. This suggestion is based on the facts that the economy was centrally-planned until 1978 and the direct government expenditure was constantly around 20% of its GDP in both pre-1978 and post-1978 periods. To examine this point, we extend the model to incorporate government expenditure,

Table 7: Relative volatility to output (%)

	Data		Model	
Variable	Pre-78	Post-78	Pre-78	Post-78
C	55	102	44	47
(Household C)	53	103		
I	276	217	208	197
(Private I)	375	277		
L	22	16	37	35
Y	100	100	100	100

Notes: Notes: C – aggregate consumption; I – aggregate investment; L – labor; Y – output. Labor L is approximated by employment.

which consists of government consumption G and government investment I_G. They are modeled as shocks to households in the economy. Now the constraints to the planner who tries to maximize the aggregate welfare (as equation (17) described) become:

$$C_t + I_t + I_{Gt} + G_t = Y_t; \tag{26}$$

$$K_{t+1} = (1-\delta)K_t + I_t + I_{Gt}; \tag{27}$$

$$N_{t+1} = \eta N_t; \tag{28}$$

$$Y_t = e^{z_t}(K_t)^{\theta}(g^t H_t)^{1-\theta}; \tag{29}$$

$$G_t = \bar{G}(\eta g)^t e^{z_{G_t}}; \tag{30}$$

$$I_{Gt} = \bar{I_G}(\eta g)^t e^{z_{I_{Gt}}}; \tag{31}$$

$$z_t = \rho z_{t-1} + \varepsilon_t; \tag{32}$$

$$z_{G_t} = \rho_g z_{G_{t-1}} + (\rho_{zG}) z_{t-1} + \varepsilon_{G_t}; \tag{33}$$

$$z_{I_{Gt}} = \rho_{I_G} z_{I_{Gt-1}} + (\rho_{zI_G}) z_{t-1} + \varepsilon_{I_{G_t}}; \tag{34}$$

Equation (30) describes the law of motion of G, which consists of a constant component $\bar{G}$, a growth component $(\eta g)^t$ and a stochastic shock component $e^{z_{G_t}}$. Equation (31) is the law of motion of I_G, which has the same constructer as G. We assume G and I_G grow with the economy. The growth rates are the same as the output's rate. On the non-stochastic balanced growth path, the G/Y and the I_G/Y ratios are constant and denoted by τ_G and τ_{I_G}, respectively. The shock components of government consumption and government investment, z_G and z_{I_G}, follow the processes as described by equation (33) and (34), where ε_{G_t} and $\varepsilon_{I_{G_t}}$ are white-noise and i.i.d. disturbances with standard deviation σ_G and σ_{IG}, respectively.

Table 8: Estimation results of government shocks I

	Gov't consumption		Gov't investment	
Period	σ_G	τ_G	σ_{IG}	τ_{I_G}
pre-1978	0.089	7.8%	0.173	11.7%
post-1978	0.037	11.9%	0.081	6.8%

Table 9: Estimation results of government shocks II

	Gov't consumption		Gov't investment	
Period	ρ_g	ρ_{zG}	ρ_{I_G}	ρ_{zI_G}
pre-1978	-0.12	0.74^{***}	-0.26	2.04^{***}
post-1978	0.39^{**}	-0.58^{*}	0.17	-0.61

Notes:Estimated by three-stage regressions. * significant at 10%; ** significant at 5%; *** significant at 1%.

5.1 Estimation of Government Shock Processes

We use long-term averages on the G/Y and the I_G/Y ratios for the values of τ_G and τ_{I_G} in the pre-1978 and the post-1978 periods. We can observe the changes in the expenditure allocation: Government consumption's share in output increased from 8% to 12%, while Government investment's share in output decreased from 12% to 7% (see table 8).

We use de-trended sequences of $\log(G)$ and $\log(I_G)$ from the data for the estimation of z_G and z_{I_G} processes.[10] We adopt three-stage least square regressions to reduce the endogeneity problem. The estimated coefficients are robust to various model specifications. The estimation results are not significantly different from the results delivered by other methods such as ordinary least square and seemingly-unrelated regressions. Table 9 present the results. We can observe that government consumption changes from pro-cyclical before 1978 to counter-cyclical after 1978. ρ_{zG} measures how the government consumption responses to TFP shocks, and its value is 0.74 in the pre-1978 period but becomes -0.58 in the post-1978 period. A similar pattern is also observed in the government investment. The value of ρ_{zI_G} switches from 2.04 to -0.61. The values of

[10]From equation (30) and (31), we can have:

$$\log(G_t) = \log(\bar{G}) + t\log(\eta g) + z_{G_t};$$
$$\log(I_{Gt}) = \log(\bar{I_G}) + t\log(\eta g) + z_{I_{Gt}}.$$

Table 10: Simulation results – Standard deviation from trend (%)

	Data			Model 1		Model 2 (with $G\&I_G$)		
Var	pre-78	post-78	change	pre-78	post-78	pre-78	post-78	change
C	3.9	1.7	-57	3.4	0.9	4.1	1.2	-67
I	27.6	4.6	-83	16.0	3.6	20.3	4.0	-84
L	1.6	0.3	-84	2.8	0.6	1.6	0.3	-88
Y	7.4	1.7	-78	7.7	1.8	7.3	1.7	-78

Notes: C of the data is household consumption. I of the data is the private (non-government) investment. Labor L of the data is employment.

parameter σ_G and σ_{IG} are selected so that the standard deviations of z_G and z_{I_G} are equal to the data. We can see that the volatility of government expenditure is also decreased in the post-1978 period (see table 8).

In sum, we find that the government expenditure becomes less volatile, switches from pro-cyclical to counter-cyclical, and is allocated more on government consumption rather than government investment in the post-1978 period.

5.2 Quantitative Results

We use the same method to solve the model with government expenditure shocks and perform quantitative analysis. As in the baseline model, we simulate the model economy and compare it with the data. Table 10's columns under 'Model 2' show the volatility of each variable in the model economies and the changes from the pre-1978 to the post-1978. We observe that the extended model can still generate the general moderation on economic fluctuations after 1978 as that we observed from the data. Compared with the baseline model (columns under 'Model 1'), we can find that the values of volatility of C and I are closer to the data with the addition of government expenditure.[11]

Table 11 presents the relative volatility in the data and model economies. As we mentioned, the baseline model can not explain the divergent relative volatility changes from the pre-1978 to the post-1978 (see columns under 'Data' and 'Model 1'). With taking into account the government expenditure shocks, the model performance is largely improved. The simulated economy (columns under 'Model 2') also shows a divergency in relative volatility – an increase in consumption's relative volatility (from 48% to 71%) and a decrease in investment's relative volatility (from 342% to 242%).

[11] Because we have government consumption (G) and investment (I_G) in the model, for C, we compare the values in the model economies with household consumption of the data; for I, we compare the model values with the private (non-government) investment of the data.

Table 11: Simulation results – Relative volatility (%)

	Data		Model 1		Model 2 (with $G\&I_G$)	
Variable	Pre-78	Post-78	Pre-78	Post-78	Pre-78	Post-78
C	53	103	44	47	**48**	**71**
I	375	277	208	197	**342**	**242**
L	22	16	37	35	30	16
Y	100	100	100	100	100	100

Notes: C of the data is household consumption. I of the data is the private (non-government) investment. Labor L of the data is employment.

Responses to the real shocks

We also simulate the model economy with real shocks (TFP and government expenditures) that are computed from the data. Responses to the shocks in the model are compared with the data and shown in figure 4. The output fluctuations in the model are very close to those observed in the data. The famous historical event "Great Leap Forward," which brought a sudden and sharp increase in the investment, and the following up disaster "Great Chinese Famine," which resulted in millions of deaths, happened between 1958 and 1961.[12] These events are likely the reason for that the model does less well on consumption and investment fluctuations during this time period. We also observe that the model matches employment fluctuations less well compared with other variables.

5.3 Discussion – the effects of government expenditures

The quantitative analysis has shown that the government expenditure processes improve the model's performance and explains a large part of the relative volatility changes from the pre-1978 period to the post-1978 period. To understand the mechanism, let us use a case of a bad productivity shock to illustrate.

Suppose that a bad TFP shock happens at current period (z drops). The direct effect is that output Y, labor input L, consumption C and investment I will all decrease. In the post-1978 period, since the government expenditures have been counter-cyclical, G and I_G are expected to increase. The increase in G is a negative income shock to

[12]The Great Leap Forward is an economic and social plan used from 1958 to 1961 which aimed to use China's vast population to rapidly transform China from a primarily agrarian economy into a modern communist society. The fail of the Great Leap Forward followed with the Great Chinese Famine, officially referred to as the Three Years of Natural Disasters. According to government statistics, there were 15 million excess deaths in this period. Unofficial estimates are even higher.

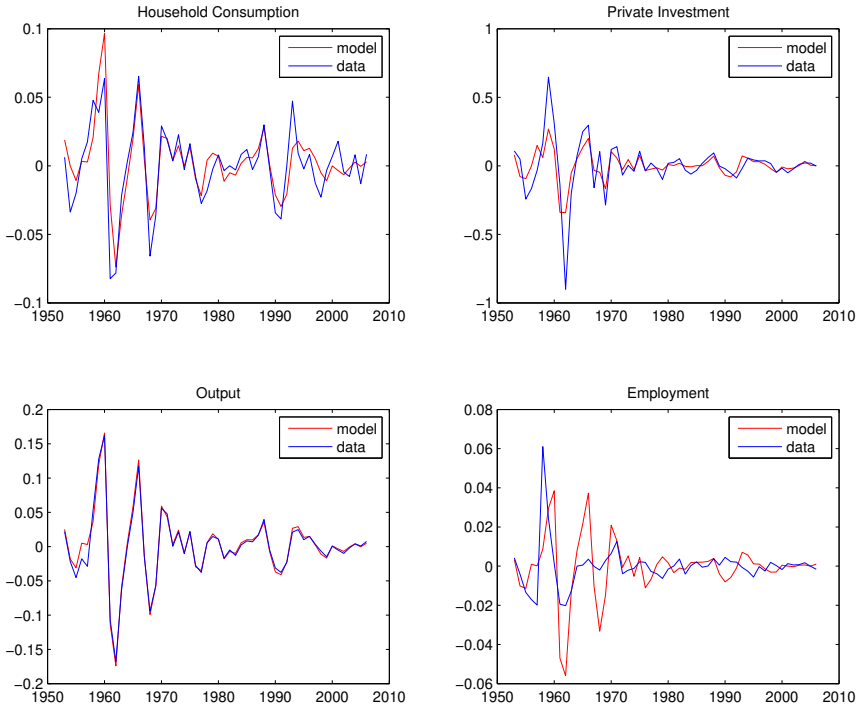

Figure 4: Responses to real shocks: deviation from the trend

households, and so household will save more (increase I), consume even less (decrease C) and work more (increase L). Therefore, the response to the future increase in G reduces the negative effects on I and L caused by the bad TFP shock, but worsens the negative effect on C.

The same mechanism applies to a case with a positive shock. Counter-cyclical G is expected to decrease. It is a positive income effect that encourages more consumption and reduces savings and labor supply. Figure 5 and 6 present the impulse responses to a positive TFP shock in the pre-1978 model economy and the post-1978 model economy, respectively.

Compared with the pre-1978 period, the pattern change in G process makes consumption more volatile in the post-1978 period because it reinforces consumption's fluctuations with TFP shocks, but it moderates the volatility of investment, labor input. Because the fluctuations of factor inputs are moderated, output volatility is also reduced in the post-1978 but the reduction is smaller than it on factor inputs. This mechanism gives an explanation of why consumption becomes more volatile relative to output while

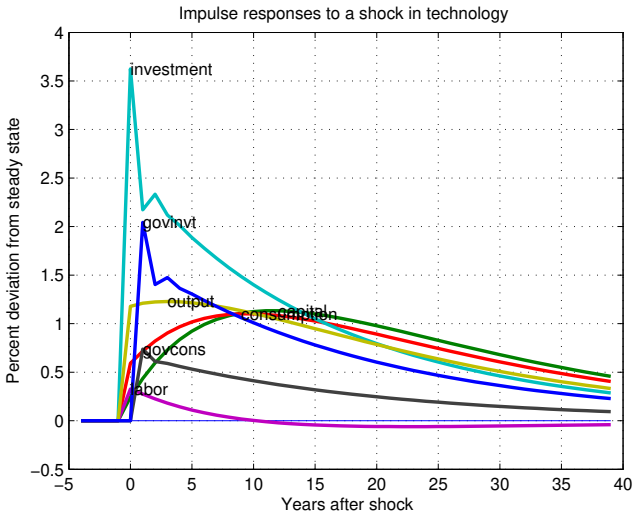

Figure 5: Impulse responses to a positive TFP shock (pre-1978)

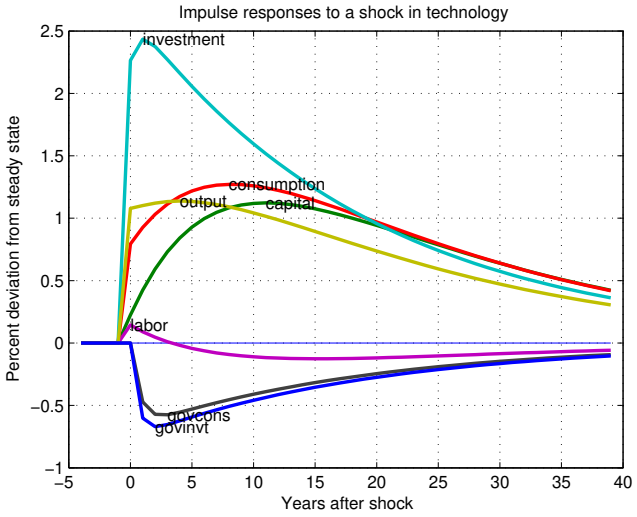

Figure 6: Impulse responses to a positive TFP shock (post-1978)

investment becomes relatively less volatile in the post-1978.

The government investment I_G in the model only has a crowding-out effect on private Investment. It makes private investment more volatile in both pre-1978 and post-1978 periods that helps the model to match the magnitude of investment volatility in the data.

In addition, the fact that Chinese government re-allocates more spendings on G from I_G in the post-1978 period also strengthens the effects of the counter-cyclical G process.

6 Counterfactual Experiments

In the model, we take into account four factors that drive the changes from the pre-1978 period to the post-1978 period. They are two growth factors – population growth, technology growth, and two shock processes – TFP and government expenditure (including G and I_G). To disentangle the effects of these factors, we perform several counterfactual experiments. In each experiment, we do the same simulation as we did with the extended model for the pre-1978 economy, but in the post-1978 economy we only allow one factor to change and keep all other factors the same as in the pre-1978 economy. Table 12 summarizes the experiment results. The first column shows the volatility changes from the pre-1978 to the post-1978 in the data. Column 2 – 4 present the four counterfactual experiments. The last column shows the volatility changes with taking into account all the four factors in the model.

The results suggest that the moderation in economic volatility is mainly explained by the TFP process. However, it cannot explain the relative changes in volatility (see the fourth column in table 12). It generates more reduction in the consumption than in the investment that is contrary to what we observe in the data. In the 5th column we can see how government fiscal policy changes affect the economic fluctuations. The pattern change from pro-cyclical to counter-cyclical policies reduces the volatility in the investment, the employment and the output, but increases the volatility of consumption. Although itself can not explain the main changes after 1978, it provides an explanation to the relative volatility changes. We also observe that growth factors play a minor role in explaining the economic fluctuations.

7 Conclusion

This paper has studied the economic fluctuations in China and presented the features of Chinese real business cycles between 1954 and 2006. We have also examined the changes after 1978 when China started its market-oriented economic reforms. It is

Table 12: Counterfactual experiment: volatility changes after 1978 (%)

	Data	Counterfactual experiment				Model 2
		η growth	g growth	TFP process	Fiscal policies	
C	-56.63	-0.86	6.29	-75.43	28.00	-66.86
I	-83.44	1.75	-10.01	-59.61	-36.22	-84.23
L	-84.15	1.35	-9.87	-75.34	-42.60	-87.89
Y	-77.58	0.41	-2.04	-75.51	-7.62	-77.69

Notes: C of the data is household consumption. I of the data is the private (non-government) investment. Labor L of the data is employment.

well known that this structural change led to a significant improvement on economic growth. Our study shows that the economic fluctuations were also largely moderated in the period between 1978 and 2006. We also find that the magnitude of the volatility reduction in each economic variable diverges - consumption relative to output became more volatile while investment relative to output became less volatile compared with the period before 1978.

To further understand the factors that can account for the fluctuation features in China, we perform several theoretical and quantitative analyses. We first use a standard neoclassical growth model with TFP shocks and show it can explan the main features of fluctuations in the Chinese economy. We find that the simple model not only can match the business cycle features in the market-oriented period (1978-2006), but also performs well in explaining the fluctuations during the centrally-planned period (1954-1977). The great volatility moderation in the post-1978 period is also successfully generated in the model economy. However, the model cannot explain the relative volatility changes well. It predicts similar figures of relative volatility for both periods that is not consistent with the data in which the relative volatility changes between the pre-1978 and the post-1978 periods, and the change diverges with each variable.

We suggest that the process of government expenditure can account for the relative volatility divergence. Our study shows that there is a policy change from a pro-cyclical policy in the pre-1978 period to a counter-cyclical policy in the post-1978 period. We also find that the expenditure allocation between government consumption and government investment is reversed in the post-1978 period. The government consumption becomes the major expenditure after 1978. We then incorporate the government consumption and government investment processes into the model and perform a quantitative analysis. Our simulation results show that the counter-cyclical government consumption process further moderates the fluctuations of investment, employment and output, but it increases the volatility of consumption in the post-1978 period. The expenditure

allocation change further strengthens the effects that provide an explanation to the relative volatility changes. The government investment process does not affect the relative volatility but improves the model in matching the magnitude of the volatility.

We also provide counterfactual experiments to examine the role of each factor for the changes in economic fluctuations from the pre-1978 to the post-1978. We take into account two growth factors, population and productivity growth, and two shock processes, TFP and government expenditure, for driving the differences between the two periods. The experiment results suggest the TFP process as the main reason for the general moderation in economic volatility, but also indicates that the relative changes in volatility can not be generated only by the TFP process. The government expenditure process gives an explanation to the relative volatility changes.

References

Blanchard, Olivier and Roberto Perotti (2002). An Empirical Characterization of the Dynamic Effects of Changes in Government Spending and Taxes on Output. Quarterly Journal of Economics, 117 (4), 1329-1368.

Chow, Gregory C. (1993). Capital Formation and Economic Growth in China. Quarterly Journal of Economics 108, 809-42.

Chow, Gregory C. and Li, Kui-Wai (2002). China's economic growth: 1952-2020. Economic Development and Cultural Change, 51(1), 247-256.

Coenen, G., McAdam, P., Straub, R. (2007). Tax reform and labour-market performance in the euro area: a simulation-based analysis using the new area-wide model. European Central Bank Working Paper No.0747.

Cooley, Thomas F. and Edward C. Prescott (1995). Economic Growth and Business Cycles. In Frontiers of Business Cycle Research, edited by Thomas F. Cooley, ch. 1. Princeton: Princeton University Press.

Gali, Jordi, J. David Lopez-Salido, and Javier Valles (2007). Understanding the Effects of Government Spending on Consumption. Journal of the European Economic Association, 5(1), 227-270.

Greenwood, J., Z. Herocowitz, G. Huffman (1988). "Investment, capacity utilization, and the real business cycle." American Economic Review 78 (3), 402-417.

Hansen, Gary D. (1985). Indivisible labor and the business cycle. Journal of Monetary Economics, 16 (3), 309-327.

Hiroyuki Imai (1996). Explaining China's Business Cycles. The Developing Economies, XXXIV-2 (June 1996).

Horvath, Michal (2009). The effects of government spending shocks on consumption under optimal stabilization. European Economic Review 53, 815-829.

Otsu, Keisuke (2008). A neoclassical analysis of the Korean crisis. Review of Economic Dynamics 11, 449-471.

People's Republic of China, Ministry of Finance of China (2007). Finance Yearbook of China. (Zhongguo caizheng nianjian). China Finance Publishing House.

People's Republic of China, National Bureau of Statistics of China.(1982-2006) China Statistical Yearbook (Zhongguo tongji nianjian). China Statistics Press.

People's Republic of China, National Bureau of Statistics of China. (1992-2006) China Labor Statistical Yearbook (Zhongguo laodong tongji nianjian). China Statistics Press.

People's Republic of China, National Bureau of Statistics of China (2000), Comprehensive Statistical Data and Materials on 50 years of New China. (Xinzhongguo 50 nian tongji ziliao huibian). China Statistics Press

People's Republic of China, National Bureau of Statistics of China (2007), Data of Gross Domestic Product of China 1952-2004. (Zhongguo guoneishchzongzhi hesuan lishi ziliao). China Statistics Press

People's Republic of China, National Bureau of Statistics of China (2008), Data of Flow of Funds Accounts of China 1992-2004. (Zhongguo zijin liuliang hesuan). China Statistics Press

Rand, J. and F. Tarp (2002). Business Cycles in Developing Countries: Are They Different? World Development 30 (12), 2071-2088.

Ravn, M. O., and Uhlig, H. (2002). On adjusting the HP-filter for the frequency of observations. Review of Economics and Statistics, 84, 1138-1151.

Rebelo, Sergio (2005). Real Business Cycle Models: Past, Present, and Future. Scand. J. of Economics, 107 (2), 217-238.

Rossi, R., 2007. Rule of thumb consumers, public debt and income tax. Mimeo, University of Glasgow.

Uhlig, Harald (1999). A Toolkit for Analyzing Nonlinear Dynamic Stochastic Models Easily. In Computational Methods for the Study of Dynamic Economies, edited by Ramon Marimon and Andrew Scott. Oxford: Oxford University Press.

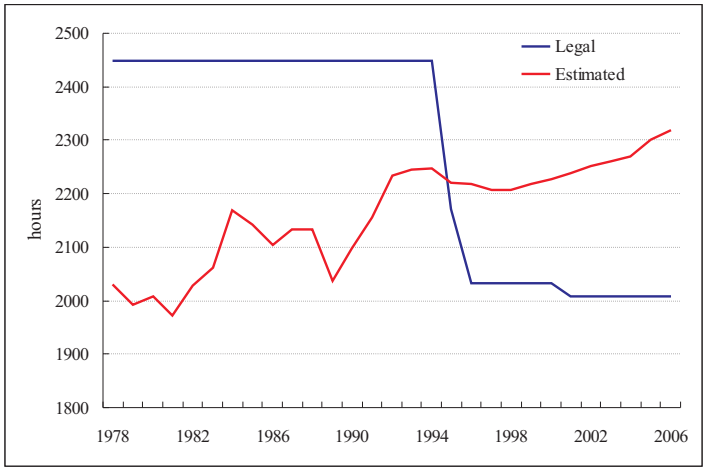

Figure 7: Estimated hours worked, 1978 – 2006

Appendix

Analysis with Estimated Labor Hours

As we mentioned in the data part, the data of hours worked are very limited. Only observations in urban area between 1991 – 1998 and between 2001 – 2006 are available. To estimate hours worked in the post-1978 period (1978 – 2006), we assume that logarithm of hours worked per worker is a function of GDP real growth rate, logarithm of non-agriculture employment and real growth of wage. We use a regression to estimate the function with the available data, and then use this function to predict hours per worker for years 1978 – 1990, 1999 and 2000. For the period prior to 1978, China was a centrally-planned economy, and the hours were also supposed to be planned. With currently available data, we are not able to estimate the actual hours worked in the pr-1978 period. Figure 7 presents the estimated hours worked in the post-1978 period. We find that the cut of legal working days from 6 days per week to 5 days per week in 1995 does not affect the total hours worked significantly.

With the estimated hours worked, we recalculate the labor input and TFP process. The estimated labor hours are much more volatile than the employment. The standard deviation from its trend is 1.53% compared with the 0.27% of the employment. We then perform the same analysis as we did in the section 5 with the model in which the government expenditure is characterized. The results are listed in table 13. We can see that our previous simulation results are still valid with the estimated labor hours and the corresponding TFP process. However, the estimated labor hours are more volatile and the model can not generate a comparable labor volatility. One reason could be the data

Table 13: Simulation with labor hours, post-1978 (%)

	Data		Model 2	
	SD	Relative SD	SD	Relative SD
C	1.70	103	1.18	72
I	4.57	277	3.97	241
L	1.53 (0.27)	92 (16)	0.27	16
Y	1.65	100	1.65	100

Notes: C of the data is household consumption. I of the data is the private (non-government) investment. Labor L of the data is estimated labor hours. In parenthesis is employment volatility.

problem since we use limited observations to estimate the hours worked in the whole post-1978 period. Another reason might be that some institutional changes in China's labor market are not characterized in the model. For example, reforms of state-owned enterprisers (SOEs), reforms of labor laws and other changes in institutional factors are all likely to affect the labor demand and supply. It still needs further research to better understand the institutional changes in the labor market and the effects on labor volatility.

Table 14: Standard deviation and correlation with output

Variable	Volatility (SD, %)	Cross correlation of GNPS with $x(-1)$	x	$x(+1)$
Before 1978 (1954-1977)				
Output				
GDP (GNP)	7.6	0.40	1.00	0.37
GNPS	7.4	0.38	1.00	0.39
Consumption				
CNDSG	3.9	0.33	0.93	0.33
CONS	3.2	0.51	0.76	0.05
CNDS	4.0	0.44	0.93	0.24
GOVT	9.1	-0.19	0.59	0.49
Investment				
INV	20.8	0.37	0.97	0.44
INVD	20.7	0.37	0.97	0.44
INVG	20.9	0.23	0.91	0.38
INVP	27.6	0.42	0.83	0.42
Labor				
EMP	1.6	0.56	0.54	0.08
After 1978 (1978-2004)				
Output				
GDP	1.7	0.46	0.93	0.43
GNP	1.6	0.50	0.98	0.40
GNPS	1.6	0.48	1.00	0.42
Consumption				
CNDSG	1.7	0.51	0.71	0.12
CONS	1.9	0.39	0.63	0.14
CNDS	1.7	0.44	0.70	0.15
GOVT	3.0	0.50	0.44	-0.03
Investment				
INV	3.4	0.18	0.66	0.41
INVD	3.6	0.21	0.75	0.44
INVG	6.5	0.12	0.17	-0.06
INVP	4.6	-0.03	0.40	0.50
Labor				
EMP	0.3	-0.31	-0.28	-0.13
HOURS*	1.5	0.25	-0.01	-0.56

Note: GNPS – GNP including service of durables and service of government capital; CNDSG – household consumption plus service of durables and of government capital; CONS–household consumption expenditure; CNDS – household consumption of nondurables and services; GOVT – government consumption; INV – investment including net exports; INVD – INV plus consumer durable expenditure; INVG – government investment; INVP – private investment plus consumer durable expenditure; EMP – employment; HOURS – total labor hours (employment times average hours worked). *Estimated. The data of hours worked are only available for few years in the post-1978 period.