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Oil Price Shocks, Durables Consumption, and China's Real Business Cycle

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Abstract

Motivated by the facts that the sharp volatility in international oil prices has become one of the important external sources in driving China's economic fluctuations, and in view of the strong correlation between oil and consumer durables, we build a real business cycle (RBC) model incorporating durable goods consumption in the context of oil price shocks. Using quarterly data on Chinese economy to conduct an empirical test, we examine China's cycle characteristics of macroeconomic volatility and the transmission mechanism of oil price shocks. The study shows: 1) In the RBC model the consumption will be divided into durables and non-durables, which plays a crucial role in explaining Chinese economic fluctuations. The core of the model is to improve the forecast of consumption volatility and weak pro-cyclicality, which is closer to the actual economy; 2) Oil price shocks mainly affect consumption volatility, but seldom influence output, investment and labor, the three variables of which are largely influenced by technology shocks; 3) The model reveals that the transmission mechanism is determined by intra-temporal income effects and inter-temporal effects of portfolio rebalanced between durable goods and capital goods.

Keywords

Oil Price Shocks, Durables Consumption, Real Business Cycle, The Chinese Economy

1. Introduction

Since its reform started in 1978, China's economy has sustained high growth about 8% - 10%[1], shoring up the demand for oil. As early as 2003, China has

[1]The statistics come from the National Bureau of Statistics of China.

surpassed Japan to become the world's second largest oil consumer after the United States. With a sharp rise in the consumption scale, external dependence of crude oil is also rising. Since the year 2011, China has surpassed the US as the world's largest oil importer; in 2012, China's net oil imports accounted for 86% of the global growth increment; its dependence on foreign oil in 2014 reached 59.5% of its overall consumption. From the beginning of this century, international oil prices have gone up and down for more than 50% for three times. Take the recent market for example, since the second half of 2014, the British Brent crude oil prices fell more than 60% in less than seven months, second only to the financial crisis in 2008. The sharp volatility in international oil prices has become one of the important external sources in driving business cycle fluctuations in China. As a major energy and raw material in modern industry, oil price volatility influences a nation's macro-economy through a variety of channels [1]. According to the analytical framework of "shock-transmission mechanism" for business cycle theory, oil price shocks belong to the supply-type of real business cycle. Compared to the RBC theory with technology shocks of the supply type [2] [3] [4], China's RBC literatures based on the oil shocks are still in great short, and besides, it lacks studies on RBC models established on China's economic data in empirical testing and prediction. In an attempt to shed light on the above issues, this paper accounts for the impact factors in driving the cyclical pattern of China's economy in the sight of oil price shocks.

It should be emphasized that, in recent years, the driving forces for China's oil consumption growth not only come from industrialization and urbanization, but also from changes in the structure of consumer demand. The consumption structure of Chinese residents has gone from subsistence to well-off, and then upgraded to be the consumer. On one hand, the proportion of total food consumption is on decline, with the Engel coefficient of urban residents decreasing from 57.5% in 1978 to 35.0% in 2013, and rural residents from 67.7% to 37.7% (from China Statistical Yearbook, 2014). On the other hand, the types of consumer goods continue to be enriched and the quality continues to be improved, among which the most obvious sign is that the various durable goods of residents have continued to be on increase. Not only has the amount of color television sets, refrigerators and other traditional home appliances are on fast rise[2], other newly developing household consumptions such as personal computers, mobile phones, sports cars and other entertainment equipment are significantly expanded[3]. Oil as a raw material is widely involved in the production of consumer durables sectors, but also used as input and fuel in durable goods. The consumption upgrading has led to the transformation of the industrial structure,

[2]In between 1985-2012, the numbers of refrigerators and color television sets owned by every 100 urban residents rise from 17.2 and 6.6 sets to 136.1 and 98.5 units respectively, seven times and 14 times higher respectively; the growth in rural households is faster due to its poor condition. Data sources: WIND information.

[3]Take personal computer for example, in 2012 the urban population per hundred units have 87.0 personal computers, every 100 rural households have 21.4 sets, nine times and 42.7 times than that of 2000 respectively.

and boosted the demand for oil.

Distinctive from consumer non-durable goods (non-durables) consumption, durable goods (durables) have higher prices and long-term use for each time. In addition, durables consumption behavior is obviously different from other consumer behaviors. On one hand, to those durables that do not belong to the necessities of life, households can selectively consume according to income in different periods, so the intertemporal elasticity of substitution is much bigger than that of non-durables [5]; on the other hand, adjusting durables consumption faces higher costs and has "investment irreversibility", and for individual families, durables consumption is discrete and the purchase decision can be triggered more diversely. Moreover, generally speaking, volatility of durables consumption is much larger than the non-durables. The characteristics of durables itself, exhibit different features than other consumer goods in response to oil price shocks. For example, under the impact of rising oil prices, production costs of durables partially increase, affecting the corresponding demand and investment, but also might postpone people's purchase of durables, thereby reducing consumption [6].

Firstly, with regard to oil price shocks, there are a series of influential works in the field of oil price shocks based on RBC framework [7] [8] [9]. She believes that high oil prices are equivalent to the negative impact of technology, and with a reasonable relations between capital utilization rate and oil usage, oil price rise will reduce firms' capital utilization, which in turn will decrease investment and output, leading to a variety of consequences such as interest rates rise and rising inflation. Moreover, Rotemberg and Woodford (1996) examine the proposition in the context of the imperfectly competitive market, and conclude that imperfect competition is very important for understanding the effects of oil shocks on US economy [10]. To examine the energy impact on the business cycle mechanisms, Kim and Lougani (1992), Dhawan and Jeske (2007) introduce endogenously energy input to the production function in the RBC model by transferring the traditional "capital-labor" type production function into the "capital-labor-energy consumption" type production function [11] [12]. By developing a RBC model of open economy, Backus and Crucini (2000) show that volatility in oil prices is responsible for trade volatility of the most of countries in the world during the last twenty five years in 20th century [13]. Wu (2009) follows Finn (2000) by developing a RBC model in line with China's national conditions, in order to explore impacts on China's energy efficiency fluctuations [14]. The numerical simulation shows that endogenous capital utilization rate change plays a key role in China's energy efficiency fluctuations, which is similar with the conclusion made by Finn's study on the US economy. Moreover, focusing on the Chinese economy under the RBC framework, Sun and Jiang (2012) find the energy price shocks would lead to higher inflation, and have negative impact on economic growth in the short term, but is of short persistence [15].

Secondly, as to durables consumption, mainstream literatures can be divided into durables and non-durables and its impact of macro-economy. Durables refer to the automobiles, household goods, sports equipment, jewelry and other goods that don't quickly wear out, while non-durables are the opposite of durables, such as a short or one-time consumption of goods and services. The motivation for scholars to make such a distinction lies in that in one way, different pace of expenditure and intertemporal elasticity of substitution between two kinds of goods will affect the growth speed of the actual economy; in another way, durables are much sensitive to the economic policy, particularly the monetary policy, than the non-durables, which will lead to changes in policy transmission mechanism and optimal economic policy. Studies are represented by Ogaki and Reinhart (1998), Erceg and Levin (2006), and Monacelli (2009) [16] [17] [18]. For China's economy, Fan *et al.* (2007) focus on durables consumption of urban and rural residents by using CHNS micro-database, and proves that empirical results support the (S, s) model [19]. Also, Yin and Gan (2009) use CHNS data to study the impact of housing reforms on household durables consumption, and find that housing reform significantly increased durables consumption [20]. Zhao and Hsu (2012) follow the method proposed by Cooley and Prescott (1995) to estimate consumer durables for China, and find that durables consumption is much more volatile than output [21] [22].

Throughout these studies, it can be found that for Chinese economy, discussion of the oil price volatility and durables consumption are separated in the study of economic relations, either simply on the oil price impact on the economy, or just on the role of durables in the economy. There is little literature discussing the complementary nature of them. Moreover, those studies exploring the macroeconomic effects through dividing the consumer goods into durables and non-durables are focused on quantitative analysis, whereas the study of the impact of consumer durables in RBC framework is not yet involved. Meanwhile, if missing the reality features described by the rising durables consumption of urban and rural residents in China, such modelling may bring forth error of fitting and it is difficult to accurately capture the oil price impact on China's macroeconomic mechanisms. In addition, when establishing the RBC theoretical framework of oil economy, the existing literature is silent on using actual economic data to test whether the model really applies to China's cyclical properties.

In view of this, based on RBC framework, our work complements these studies by incorporating non-durables and durables to investigate the transmission mechanism of oil prices on the economy, and moreover shows the patterns of China's business cycle in the context of oil price shocks. Compared with the most existing studies, the contribution of the paper is three-fold: first, we conduct an RBC exercise using quarterly data rather than annual data through the abundant studies in RBC models talking about China's business cycle [23] [24] [25], so it can better fit the characteristics of Chinese pro-cyclical weak consumption; second, we contribute to the existing literature by incorporating consumer durables into RBC theoretical framework, different drastically from the approach based on survey data from empirical analysis to investigate China's economic fluctuations; third, we follow Dhawan and Jeske (2007) by taking into account the correlation between oil and durables through building the three elements in the household sector "non-durables-durables-oil" into two nested CES consumption function. Our result shows that it does a fairly good job in capturing China's real business cycle.

The remainder of this paper is organized as follows. Section 2 describes cyclical properties of oil price and other macro series in China; Section 3 presents the RBC model of oil economy, including durables and non-durables consumption. Section 4 conducts on calibration for parameters. Section 5 discusses model results. Section 6 concludes the paper.

2. Cyclical Properties of Oil Price and China's Economy

This paper uses data from the databases of CICE and WIND, with the choice of quarterly data and a time span from 1997Q1 (1997Q1 means the first quarter of 1997, the same below) to 2016Q1, a total of 77. China has officially compiled quarterly data since the 1990s, while from 1997 the National Bureau of Statistics of China (NBS) began to announce monthly or quarterly consumer durables data, goods such as the car/furniture/appliances/sports and entertainment products. Durables data are crucial to the modeling and analysis of our work so the sample is selected from the beginning of 1997. In order to be consistent with the results of the DSGE theory below, seasonal adjustment of variables is made except oil prices and labor, and then all variables are in logarithms and have been de-trended with the HP filter.

According to CPI on a yearly basis and monthly series published by NBS, quarterly fixed base ratio based on 1997Q1 can be figured out, and quarterly GDP deflator is used to calculate the actual value of the relevant economic variables.

Firstly, the actual consumption is the outcome of the total quarterly retail sales of consumer goods divided by quarterly GDP deflator.

Secondly, unlike the US, Chinese consumption official statistics have not been carried out for durables and non-durables. With reference to the mainstream literature classification method and the availability of China data, four representative variables of durables, namely, the car/furniture/appliances/sports and entertainment products, can be divided by quarterly GDP deflator, and then comes out the actual durables investment.

Thirdly, since there is no quarterly or monthly private investment data in the statistics officially published, which is consistent with Wang and Zhu (2015), the domestic loans, self-financing, foreign investment, and other capitals will be taken as representative variables of the total funds for private investment [26]. If the variables are divided by quarterly GDP deflator, actual private investment (*i.e.* capital investment) is figured out.

Fourthly, the actual total investment is defined as the investment total of actual private investment and durables investment.

Fifthly, using "unit employees in total" as labor is applied in Huang (2005).

Sixthly, the actual GDP is nominal GDP divided by the quarterly GDP deflator.

Seventhly, "retail: enterprises over the quota: petroleum and petroleum products" can be obtained as representative variables for household oil consumption. If this series is further divided by the quarterly GDP deflator, the actual household oil consumption will be obtained.

Eighthly, the use of the West Texas Intermediate (WTI) crude oil spot prices[4] in which the monthly data using the geometric mean method become quarterly data, then converted to RMB price, and divided by quarterly GDP deflator to obtain actual oil prices.

From Figure 1, it can be seen that oil prices is obviously higher volatile than GDP. In particular, the standard deviation of GDP is 0.0376, whereas the standard deviation of oil prices is 0.2073, 5.51 times of that of GDP. Seen from the co-movement, oil prices and GDP show contemporaneous co-movement in irregular pattern. For example, from early 2007 to the end of 2009, oil prices experiences the greatest volatility; especially, during 2007Q3-2008Q2, oil prices and GDP have a positive contemporaneous co-movement, whereas during 2008Q4-2009Q3, oil prices and GDP have a negative contemporaneous co-movement; but another example is during the two periods of 1998Q1-1998Q4 and 2014Q1-2015Q3, oil prices and GDP show departure trend. Overall, we do not find obvious conclusion that supports traditional economic theory of rising (decreasing) oil prices leading to the fall (growth) in output.

Table 1 summarizes the statistical moments regarding the Chinese business cycle from 19997Q1-2016Q1, which can provide some stylized facts of China business cycles.

First, oil prices and household oil consumption are more volatile than capital investment, durables investment, and GDP, and volatilities of labor and consumption

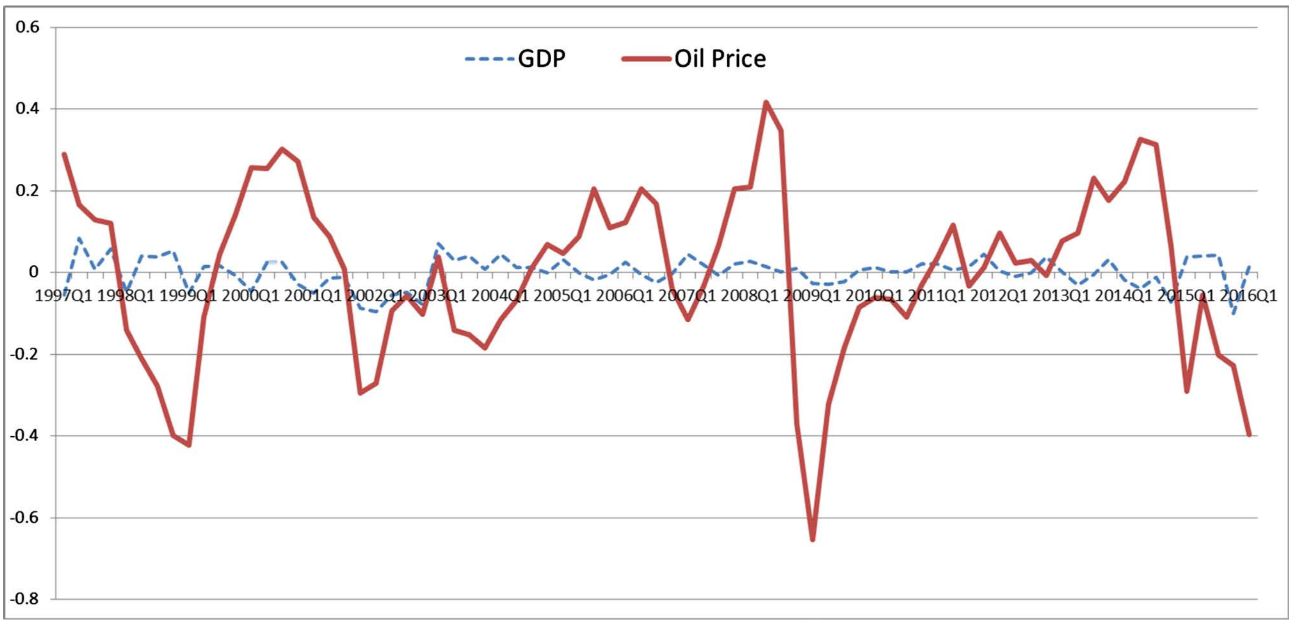

Figure 1. China's actual GDP and the actual oil price volatility (HP filter) between 1997Q1-2016Q1.

[4]Data resource: http://www.eia.gov/dnav/pet/pet_pri_spt_s1_m.htm.

Table 1. The statistical moments of China's economy between 1997Q1-2016Q1.

	GDP	Consumption	Capital investment	Durables investment	Total investment	Household oil consumption	Labor	Oil price
Standard deviation	0.0376	0.0174	0.0593	0.0528	0.0519	0.0796	0.0245	0.2073
Relative standard deviation	1.00	0.46	1.57	1.40	1.38	2.12	0.65	5.51
Autocorrelations	0.48	0.71	0.50	0.59	0.61	0.75	0.49	0.69
Contemporaneous correlations with GDP	1	0.15	0.74	0.52	0.88	0.04	0.78	0.06

Note: See the first paragraph in this section of the data sources and data processing described; relative standard deviation is the ratio of standard deviation of the variables to standard deviation of the GDP; autocorrelations refer to the first-order autocorrelation coefficient.

are the lowest. On one hand, capital investment and durables investment are more severe volatilities, 1.58 times and 1.40 times of the amplitude of GDP respectively, also showing a strong pro-cyclicality. On the other hand, volatility in labor is smoother, proving that China's features are different from business cycles in the developed markets as well as other emerging markets.

Second, one striking fact is that consumption is slightly pro-cyclical with a correlation of only 0.15, as opposed to China's strong pro-cyclicality derived from annual data produced by Rao and Liu (2014), as well as different from strong pro-cyclicality of the US data [27]. Actually, over the past 3 decades, China has achieved a remarkable growth primarily through investment and exports, whereas consumption has been always sluggish, and "high savings and low consumption" is China's important economic characteristics different from the US and other developed economies [28]. Therefore, it is believed that Chinese consumption is slightly pro-cyclical, which can be evidenced by the quarterly data. Other macro series are pro-cyclical, especially for household oil consumption, which is slightly pro-cyclical (0.04), indicating that there is a certain degree of rigidity in households' consumption of oil or its products (such as daily petrochemicals) which does not volatile significantly as incomes changes occur.

Third, the autocorrelations of consumption and durables investment are 0.71 and 0.59 respectively, indicating strong "consumer" inertia in both of them, which is in line with "Catch up with the Joneses" [29] [30]. Meanwhile, there is a strong autocorrelation of oil prices and household oil consumption, meaning both a degree of persistence in them.

Four, volatility in oil prices is as high as 0.2073, three times greater than capital investment, which shows the volatility of oil prices may be an important source of external shocks for China's economic fluctuations. Meanwhile, the low correlation (0.06) between oil prices and GDP may also indicate the asymmetry, the alternative and the complexity between oil prices and the economy, requiring comprehensive and dynamic researches on the inherent association between oil prices and China's macroeconomics, among which DSGE model is just able to provide an analytical framework that combines short and long term, overt and unity.

3. Modeling

Based on the canonical RBC model framework developed by Hansen (1985) and Cooley and Prescott (1995), this paper refers to the setting mode of Dhawan and Jeske (2007) model, thus set the production function into the form of "capital-oil-labor", which is a three elements double nested structure. The consumer goods of household sector are also divided into durables and non-durables in the utility function to build a DSGE model of oil economy containing both households and firms.

3.1. Households

The representative household consumption (C_t) consists of durables (D_t), oil and oil-products ($O_{h,t}$, hereinafter referred to oil) and non-durables (N_t). Assume the double nested CES functional form is constituted by three elements:

$$C_t = \left[\alpha_c (N_t)^{-\rho_c} + (1-\alpha_c)(F_t)^{-\rho_c}\right]^{-\frac{1}{\rho_c}} \tag{1}$$

$$F_t \equiv \left[\alpha_F (D_{t-1})^{-\rho_F} + (1-\alpha_F)(O_{h,t})^{-\rho_F}\right]^{-\frac{1}{\rho_F}} \tag{2}$$

$\alpha_c \in (0,1)$, $\alpha_F \in (0,1)$, $\rho_c \geq -1$, and $\rho_F \geq -1$, where $\frac{1}{1+\rho_c}$ is the elasticity of substitution between the composite of oil and durables (defined as F_t) and non-durables, and $\frac{1}{1+\rho_F}$ is the elasticity of substitution between oil and durables. There is an accumulative process of consumption for durables and the operating mode is similar to the capital (K_t) in the model, both belonging to the state variables.

The representative household utility function is as follows:

$$E_0\left\{\sum_{t=0}^{\infty}\beta^t\left[\log(C_t) - \frac{(L_t)^{1+\eta}}{1+\eta}\right]\right\} \tag{3}$$

where β denotes the discount factor, L_t is the labor supply variable, η is the inverse of the elasticity of labor supply. The budget constraint for households is:

$$N_t + I_{K,t} + I_{D,t} + P_{o,t}O_{h,t} = w_t L_t + r_t^k K_{t-1} \tag{4}$$

$I_{K,t}$ and $I_{D,t}$ are the investments of capital and durables respectively. w_t and r_t^k denote real wages and return on invested capital. $P_{o,t}$ is the actual price of oil. In addition, the stock of given capital and durables evolves according to:

$$I_{K,t} = K_t - (1-\delta_k)K_{t-1} + \frac{\varnothing_k}{2}\left(\frac{I_{K,t}}{K_{t-1}} - \delta_k\right)^2 K_{t-1} \tag{5}$$

$$I_{D,t} = D_t - (1-\delta_d)D_{t-1} + \frac{\varnothing_d}{2}\left(\frac{I_{D,t}}{D_{t-1}} - \delta_d\right)^2 D_{t-1} \tag{6}$$

δ_k and δ_d are discount factors of capital and durables respectively. In line with the setting mode of Atkeson and Kehoe (1999), it is assumed that the investments of capital and durables bring about additional adjustment costs, so $\varnothing_k$ and $\varnothing_d$ are defined as the parameters for adjustment costs [31].

The first order condition is obtained by solving the dynamic optimal choice problem of the representative household:

$$\lambda_t = \alpha_c \left(C_t\right)^{\rho_c} \left(N_t\right)^{-1-\rho_c} \tag{7}$$

$$\begin{aligned} \lambda_t Q_{D,t} = \beta \Big\{ &(1-\alpha_c)\alpha_F \left(C_{t+1}\right)^{1+\rho_c} \left(F_{t+1}\right)^{\rho_F-\rho_c} \left(D_t\right)^{-(1+\rho_F)} \\ &+ \lambda_{t+1} Q_{D,t+1} \left[(1-\delta_d) - \frac{\varnothing_d}{2}\left(\frac{I_{D,t+1}}{D_t} - \delta_d\right)^2 + \varnothing_d \frac{I_{D,t+1}}{D_t}\left(\frac{I_{D,t+1}}{D_t} - \delta_d\right) \right] \Big\} \end{aligned} \tag{8}$$

$$\lambda_t P_{o,t} = (1-\alpha_c)(1-\alpha_F)\left(C_t\right)^{\rho_c}\left(F_t\right)^{\rho_R-\rho_c}\left(O_{h,t}\right)^{-1-\rho_F} \tag{9}$$

$$\lambda_t w_t = \left(L_t\right)^{\eta} \tag{10}$$

$$Q_{K,t} = \beta \frac{\lambda_{t+1}}{\lambda_t} \left\{ r_t^k + Q_{K,t+1} \left[(1-\delta_k) - \frac{\varnothing_k}{2}\left(\frac{I_{K,t+1}}{K_t} - \delta_k\right)^2 + \varnothing_k \frac{I_{K,t+1}}{K_t}\left(\frac{I_{K,t+1}}{K_t} - \delta_k\right) \right] \right\} \tag{11}$$

$$Q_{K,t}\left[1 - \varnothing_k\left(\frac{I_{K,t}}{K_{t-1}} - \delta_k\right)\right] = 1 \tag{12}$$

$$Q_{D,t}\left[1 - \varnothing_d\left(\frac{I_{D,t}}{D_{t-1}} - \delta_d\right)\right] = 1 \tag{13}$$

where λ_t is the Lagrange multiplier of budget constraint, $Q_{K,t}$ and $Q_{D,t}$ are the shadow prices (*i.e.* the Lagrange multipliers of capital and durables accumulation equations) of capital and durables, respectively. (7), (8) and (9) are Euler equations of non-durables, durables and household oil consumption, which describe the optimal consumption choices of the household on these three goods. (10) is the supply equation of labor and (11) is the Euler equation of capital. (12) and (13) characterize the optimal dynamic investment behaviors of capital and durables.

3.2. Firms

Same with the settings of household sector, the production function of firms is a double nested CES[5] functional form constituted by three elements:

$$Y_t = A_t\left[\alpha_y\left(X_t\right)^{-\rho_y} + \left(1-\alpha_y\right)\left(L_t\right)^{-\rho_y}\right]^{-\frac{1}{\rho_y}} \tag{14}$$

[5]In general, there are three types of nested structures between capital, energy (E) and labor in the CES production function, *i.e.*, (K/E)/L, (K/L)/E, and (L/E)/K. According to the estimation on the total capital stock since China's reform and opening, based on optimization method, Lu *et al.* (2009) propose that (K/E)/L (*i.e.* the form of (14) and (15) in this paper) is in line with the actual situation of China. In addition, it is a fact that energy impacts and conducts other macroeconomic variables through the capital good market, so we choose the form of (K/E)/L [32].

$$X_t \equiv \left[\alpha_x \left(K_{t-1}\right)^{-\rho_x} + \left(1-\alpha_x\right)\left(O_{f,t}\right)^{-\rho_x}\right]^{-\frac{1}{\rho_x}} \tag{15}$$

Y_t is the production, $O_{f,t}$ is the oil consumption of firms, X_t is the composite of capital and oil (similar to F_t in household sector), A_t is neutral technology shock, also known as the so-called total factor productivity (TFP) and its logarithmic form follows the stochastic process below:

$$\ln\left(A_t\right) = \left(1-\rho_A\right)\ln\left(A\right) + \rho_A \ln\left(A_{t-1}\right) + u_{A,t}, \quad u_{A,t} \sim N\left(0, \left(\sigma_A\right)^2\right)$$

where $\rho_A \in (0,1)$ is the autoregressive coefficient, A is its steady state value, σ_A is the standard deviation of technology shocks. Also, $\alpha_y \in (0,1)$, $\alpha_x \in (0,1)$, $\rho_y \geq -1$, $\rho_x \geq -1$.

We can derive the first order condition with respect to L_t, K_t and $O_{f,t}$ by solving the profit maximization problem of firms:

$$w_t = \left(1-\alpha_y\right)\left(A_t\right)^{-\rho_y}\left(Y_t/L_t\right)^{1+\rho_y} \tag{16}$$

$$r_t^k = \alpha_y \alpha_x \left(A_t\right)^{-\rho_y}\left(X_t\right)^{\rho_x-\rho_y}\left(Y_t\right)^{1+\rho_y}\left(K_{t-1}\right)^{-(1+\rho_x)} \tag{17}$$

$$P_{o,t} = \alpha_y \left(1-\alpha_x\right)\left(A_t\right)^{-\rho_y}\left(X_t\right)^{\rho_x-\rho_y}\left(Y_t\right)^{1+\rho_y}\left(O_{f,t}\right)^{-(1+\rho_x)} \tag{18}$$

3.3. Equilibrium Conditions and Model Solution

So far, we have characterized the optimal choices of the households and firms under constraints: the maximization of expected utility of households and the maximization of expected profits of firms, so the market clearing of the final good is:

$$N_t + I_{K,t} + I_{D,t} + P_{o,t}\left(O_{h,t} + O_{f,t}\right) \leq Y_t \tag{19}$$

In recent years, oil coming from abroad has accounted for an increasing proportion of China's aggregate amount. Chinese external dependence of petroleum and crude oil both broke the point of 55% in 2011, surpassed the US as the highest in the world. Thus the oil price volatility is highly relevant with the international market of crude oil. In addition, China has started late on transactions of staple commodities, which results in some problems about the market like the few varieties, small size, low openness and the lack of pricing power. So the oil pricing in China depends on the international market to some extent. In order to focus on analyzing the impact of oil price on China's macro-economy, consistent with the assumptions of Rotemberg and Woodford (1996) on US crude oil, we assume that volatility of oil prices in China depends on the international market, that is to say the oil price is completely exogenous and follows the ARMA (1, 1) process (see the parameter calibration part in the next chapter). The final log-linearization is:

$$\hat{P}_{o,t} = \rho_o \hat{P}_{o,t-1} + \hat{u}_{o,t} + \rho_u \hat{u}_{o,t-1}, \quad u_{o,t} \sim N\left(0, \left(\sigma_o\right)^2\right)$$

ρ_o and ρ_u are the coefficients of the oil price ARMA (1, 1) respectively, σ_o

is the standard deviation of actual oil price shocks. At the same time, a part of the output components should be used to pay for the imported oil, so the relation is: $VA_t = Y_t - P_{o,t}\left(O_{h,t} + O_{f,t}\right)$. The difference value is defined as the value added of production (VA_t), combined with the market clearing equation of final good:

$$VA_t = N_t + I_{K,t} + I_{D,t} \tag{20}$$

Finally, by solving the log-linearized equations, optimal equilibrium path for each endogenous variable can be obtained:

$$\left\{C_t, N_t, D_t, O_{h,t}, F_t, I_{D,t}, I_{K,t}, w_t, L_t, r_t^k, K_t, Y_t, X, O_{f,t}, \lambda_t, Q_{D,t}, Q_{K,t}, VA_t\right\}$$

4. Calibration

4.1. Oil Prices and Technology Shocks

The purpose of this paper is to examine the relevance of oil prices and China's economy, thus how to determine the correlation coefficient of oil price shocks is particularly important. Through trial and error, it is found that ARMA (1, 1) model can fit the actual fluctuating trend of oil prices in the sample period, as seen in Figure 2. Specific estimation results are shown in Table 2: the parameter estimation results are very significant, while tests show residuals of the regression equation is a zero mean and the standard deviation for a smooth sequence is 0.12. According to its autocorrelation coefficient and partial correlation coefficient, it is found that no serial correlation exists and ARMA (1, 1) model can be identified. Thus the results are available: $\rho_o = 0.56$, $\rho_u = 0.46$ and $\sigma_o = 0.12$.

Based on quarterly frequency data, Wang *et al.* (forthcoming) find the first-order regression coefficient of China's technology shock is 0.8, which is slightly lower

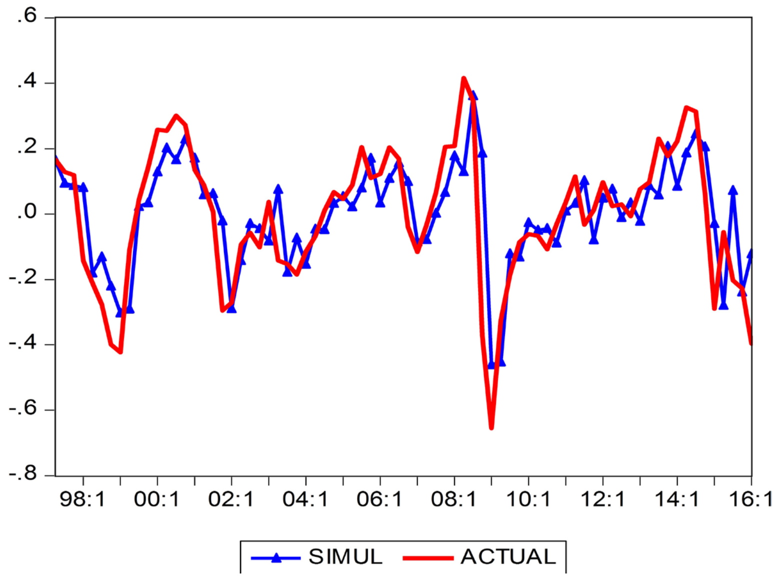

Figure 2. Actual value (solid line) of oil price volatility and its simulated value (dotted line + triangle) (HP filter) during 1997Q1-2016Q1; the horizontal axis is time, and the vertical axis is fluctuating values.

Table 2. Estimation results of actual oil prices by ARMA (1, 1) model.

Sample (adjusted): 1997Q2 2016Q1
Included observations: 76 after adjustments
Convergence achieved after 10 iterations
MA Backcast: 1997Q1
Sample (adjusted): 1997Q2 2016Q1

Variable	Coefficient	Std. Error	t-Statistic	Prob.
AR (1)	0.555378	0.122424	4.536497	0.0000
MA (1)	0.456640	0.134248	3.401468	0.0011
R-squared	0.579268	Mean dependent var		−0.003815
Adjusted R-squared	0.573582	S.D. dependent var		0.205956
S.E. of regression	0.134491	Akaike info criterion		−1.148676
Sum squared resid	1.338498	Schwarz criterion		−1.087341
Log likelihood	45.64970	Hannan-Quinn criter.		−1.124164
Durbin-Watson stat	1.894332			

than 0.95 of the US [33]. So we choose $\rho_A = 0.8$ and $\sigma_A = 0.03$ in line with Wang *et al.* (2019) [34].

1) The discount factor β

From 1997Q1-2016Q1, the average inflation growth rate on a quarter-to-quarter basis is 1%, so the quarterly discount factor is set at 0.99.

2) Capital depreciation rate δ_k and durables depreciation rate δ_d

In the study of China's economic fluctuations in the literature, the average life span of China's fixed asset is mostly set at 10 years, the capital depreciation rate is 0.1, and the corresponding quarterly value is 0.025 [35]. Previous studies have not yet estimated the depreciation rate of durables, but Chinese scholars also include assets of durables in estimating fixed assets, and therefore might assume it is the same as the rate of capital depreciation.

3) Substitution parameters ρ_c, ρ_y, ρ_F, ρ_x

Using data from the US and Japan respectively, Pakos (2011) show that elasticity of substitution between durables and non-durables is close to 1, *i.e.*, $\rho_c = 0$ [36]. Following Kim and Loungani (1992), elasticity of substitution between the production function of the composite of energy and capital and labor is set at 1, namely, $\rho_y = 0$. Using the US industrial data, Lee and Ni (2002) find that higher oil prices will not only reduce the supply of energy-intensive output, but also reduce the demand for durables such as cars, etc., which means oil products and durables are complementary in the actual economy, therefore, $\rho_F \geq 0$, in which we set at 0.7 [37]. Lu *et al.* (2009) and Yang *et al.* (2011) calculate the energy and capital substitution parameters of China to be 0.47 and 0.49 respectively, which is similar with that of Ma *et al.* (2008) estimation of 0.52 and 0.47 from the data of the US and E.U. [38] [39] [40]. However, there is considerable regulation on China's energy market, and the resulting energy price distortion is significantly higher than that of developed countries, implying such substitution relationship weaker than that of developed economies. In view of this, Huang and Lin (2011) use a meta-regression model to estimate the elasticity of substitution between energy and capital, and we refer to the value 0.25, and hereby $\rho_x = 3$ [41].

4) Share parameter α_y

We choose $\alpha_y = 0.5$ as in He *et al.* (2009). A combination of steady-state values and other parameters can pin down the other three share parameter values without calibration.

5) Investment adjustment cost parameters ϕ_k and ϕ_d

The larger the values of ϕ_k and ϕ_d, the greater the adjustment costs of investment of capital and durables, or vice versa, and when the value is 0, adjustment costs do not exist. Compared to $\phi_k = 1$ in Atkeson and Kehoe (1999) for the US economy, we set the two parameters as 3 in terms of China as a developing country with the incompleteness of financial markets.

6) Labor supply elasticity η

There are few Chinese empirical researches on the setting of η and the results differences are also large, but in the RBC literature, its value is generally set to 1, and we also choose this value.

7) Steady-state value (K/Y, N/Y, I_D/N, O_h/N, K/O_f)

To solve the differential equations system after log-linearization, five more steady-state values are needed to determine. According to (5), when it's steady-state there is $K = I_K/\delta_k$, then to calculate the mean capital investment data in the sample period, and the steady-state capital value K can be figured out when combining the previously calibrated capital depreciation rate. When utilizing mean data related to the output, durables investment, household oil consumption, non-durables consumption in the sample period, it is easy to obtain K/Y of 22, N/Y of 0.2, I_D/N of 0.61, and O_h/N of 0.31. In addition, as it is impossible to get oil consumption data from China firms, $K/O_f = 300$ is set with a reference of the estimation of the US economy by Kim and Loungani (1992). The differences of the capital accumulation and the level of economic development between Sino-US at this stage may be of nearly three decades, so the value set also has certain rationality.

In conclusion, all deep parameters of RBC model are summarized in Table 3:

5. Model Results

Toolkit package containing Matlab source code by Uhlig (1999) is used to obtain cyclical characteristic information for each macroeconomic variable in "Second

Table 3. Calibration of deep parameters.

β	δ_k	δ_d	α_y	η	ϕ_k	ϕ_d	ρ_F	ρ_x	ρ_c	ρ_y
0.99	0.025	0.025	0.5	1	3	3	0.7	3	0	0
ρ_A	ρ_o	ρ_u	σ_A	σ_o	$\frac{I_D}{N}$	$\frac{O_h}{N}$	$\frac{K}{Y}$	$\frac{K}{O_f}$	$\frac{N}{Y}$	
0.8	0.49	0.57	0.03	0.12	0.61	0.31	22	300	0.2	

Moment" after the model log-linearization, and the results are shown in Tables 4-8. For comparison purposes, it is treated as follows:

1) RBC model with durable goods consumption is taken as a benchmark model in this paper, and there exist two shocks (oil price and technology) which are denoted as DRBC.

2) Model structure is the same with 1), but with only the oil price shocks, denoted as DRBC-OIL; the purpose is not to investigate changes in the technology, but only to discuss the impact on the business cycle of oil price shocks.

3) Model structure is the same with 1), but with only technology shocks, denoted as DRBC-TFP; the purpose is not to investigate changes in oil price, but will only discuss the impact on the business cycle of technology shocks.

4) It contains RBC model with a single consumption structure, namely, a simple RBC type model, which means consumption is not distinguished between durables and non-durables, and also with two shocks, denoted as SRBC.

5) Model structure is the same with 4), but with only the oil price shocks, denoted as SRBC-OIL.

6) Model structure is the same with 4), but with only technology shocks, denoted as SRBC-TFP.

When introducing consumer durables into oil economy of RBC model, there are three questions to be answered: first, compare directly the artificial DRBC model (benchmark model) with the actual economy to see if it better predicts China's RBC? Second, compared with the standard oil economy model SRBC, are the predictions of DRBC benchmark model obviously improved? Third, compared to traditional RBC model which considers technology as the most important source of economic fluctuations, what kind of role is oil price shock playing in the business cycle, what impact differences on the core macroeconomic variables such as output and consumption, what is the transmission mechanism?

5.1. Comparison with the Actual Economy

The predicted results of DRBC, DRBC-OIL and DRBC-TFP are shown in Table 4 & Table 5, and when compared with the actual economy, several findings on economic variables can be achieved as follows:

From the point of volatility, the standard deviations of oil price and household oil consumption are 14.98% and 10.09% respectively, far greater than the volatility of output 3.75%, 4.00 times and 2.69 times of the output respectively; capital investment, total investment, durables investment are also higher than that of output, namely, 5.60%, 5.39% and 5.05%; output is ranked No. 6, and labor and consumption are low, with only 1.69% and 1.61%, of which consumption volatility the lowest reflects exactly the classical theory of household intertemporal smooth consumption behavior advocated by RBC[6]. Priorities of this volatility

[6]The RBC consumption smooth theory actually supports the life cycle hypothesis by Modigliani & Brumberg (1954) and the permanent income hypothesis by Friedman (1957), which means that the individual resources available over the entire lifetimes are important determinants of consumption, and when encountered by wealth shocks in life, rational consumers will adjust their spending to prevent the whole greater volatility of consumption.

Table 4. Business cycle properties of model DRBC.

Variable	Actual economy			Artificial economy (DRBC)			
	Standard deviation (%)	Autocorrelation	Correlations with output	Standard deviation (%)	Autocorrelation	Correlations with output	K-P ratio (%)
Output	3.76	0.39	1.00	3.75	0.48	1.00	99.73
Consumption	1.74	0.71	0.15	1.61	0.48	0.18	92.53
Capital investment	5.93	0.50	0.78	5.60	0.47	0.98	94.44
Durables investment	5.28	0.59	0.52	5.39	0.40	0.63	102.08
Total investment	5.19	0.61	0.88	5.05	0.50	0.99	97.30
household oil consumption	7.96	0.75	0.04	10.09	0.48	0.07	126.76
Labor	2.45	0.49	0.74	1.69	0.48	0.89	68.98
Oil price	20.73	0.69	0.06	14.98	0.48	-0.04	72.26

Note: Simulation results are average over 10000 simulations each with length 77 quarters, which is the same sample number of periods as the China sample. The K-P ratio denotes the ratio of standard deviation of artificial economy to that of actual economy, after using the HP filtering method proposed by Kydland and Prescott (1982). (Similarly for Tables 5-7).

Table 5. Business cycle properties of model DRBC-OIL and DRBC-TFP.

Variable	Actual economy			Artificial economy (DRBC-OIL)				Artificial economy (DRBC-TFP)			
	Standard deviation (%)	Auto-correlation	Correlations with output	Standard deviation (%)	Auto-correlation	Correlations with output	K-P ratio (%)	Standard deviation (%)	Auto-correlation	Correlations with output	K-P ratio (%)
Output	3.76	0.39	1.00	0.99	0.66	1.00	26.33	4.27	0.64	1.00	113.56
Consumption	1.74	0.71	0.15	1.58	0.67	0.98	90.80	0.45	0.77	0.76	25.86
Capital investment	5.93	0.50	0.74	0.69	0.14	−0.76	11.64	6.50	0.64	0.99	109.61
Durables investment	5.28	0.59	0.52	4.22	0.40	0.89	79.92	3.98	0.67	0.99	75.38
Total investment	5.19	0.61	0.88	0.26	0.71	0.99	5.01	6.04	0.64	0.99	116.38
Household oil consumption	7.96	0.75	0.04	10.05	0.67	0.99	126.26	0.50	0.75	0.82	6.28
Labor	2.45	0.49	0.78	0.63	0.62	−0.98	25.71	1.81	0.64	0.99	73.88
Oil price	20.73	0.69	0.06	14.93	0.67	0.99	72.02	0	0.86	0.59	0

completely coincide with the actual economy.

From the point of view of K-P ratio, the output volatility of DRBC is close to data from China, with its output K-P ratio reaching 0.9973, indicating that the model accounts for 99.73% of the volatility of output in the data. Table 6 shows that output K-P ratio of DRBC-TFP reaches 113.56%, while the corresponding DRBC-OIL only 26.33%, indicating that the main source of output volatility is technology shocks rather than oil price shocks. This conclusion is relatively consistent with the study under the framework of classical RBC by scholars that suggests that the main source of volatility of China's output since reform and opening up in 1978 is technology shocks. Consumption volatility under DRBC is slightly lower than data from China, and the K-P ratio is 0.9253, which means that the artificial economy can account for 92.53% of the volatility of China's consumption; it is worth noting that the K-P ratio of consumption in DRBC-OIL is up to 90.80%, while the K-P ratio of consumption in the DRBC-TFP is only 25.86%, indicating that the main source of consumption volatility is oil price shocks rather than technology shocks, as opposed to the output. The K-P ratio of three investment variables of DRBC are close to 1, marking that the artificial economy captures three types of investments. Also shown in **Table 5**, similar with output, capital investment and total investment are mainly driven by technology shocks, and oil price shocks can account for 79.92% of the volatility of durables investment. It is slightly higher than 75.38% of technology shocks, because durables investment is actually the future consumption of durables to households, and the impact of oil price shocks is bigger than technology shocks on consumption. K-P ratio of household oil consumption in DRBC is 1.2676, signaling that the model accounts for 126.76% of the household oil consumption, which somewhat exaggerates the volatility of that, and it is further discovered that DRBC-TFP is only 6.28%, and DRBC-OIL is 126.26%, demonstrating that the oil price shocks can almost capture all the volatility of household oil consumption, which is also consistent with the intuitive logic. The labor K-P ratio of DRBC is 0.6898, and moreover, DRBC-OIL and DRBC-TFP are 25.71% and 73.88% respectively, indicating that the volatility of labor is mainly driven by technology shocks. Finally, the K-P ratio of oil price in DRBC is 0.7226, proving that the benchmark model can account for the oil price volatility of 72.26%.

From the point of view of the correlations with output, the model DRBC shows that all series are pro-cyclical, except for oil prices, which is weakly counter-cyclical. The DRBC predicts this dimension closely. In particular, the correlations of labor, capital investment, the total investment and output are up to 0.99, 0.98, and 0.89 respectively, higher than in the actual economy, showing a strong pro-cyclicality. The correlation between durables investment and output is 0.63, slightly higher than 0.52 in the actual economy. As mentioned earlier, compared with the developed economies, China's consumption is weakly pro-cyclical, and DRBC better captures the feature, with the correlation between consumption and output in the artificial economy being 0.18, not far from 0.15 of the actual economy[7].

[7]We have searched for the main core economic journals for nearly a decade, and found in the literature of China's RBC theory study over 80% analysis shows a correlation between consumption and output above 0.8. China's consumption shows a strong pro-cyclicality, similar with the US economy. However, we believe this result is debatable, because the US is a "low savings and high consumption" economy, and their consumption is the largest engine in driving economic growth, once reached 70% of GDP, whereas China is a "low consumption and high savings" economy, and the consumption is below 40% of GDP for long term. Over the past three decades, the rapid growth is mainly drove by investment and exports of the "two carriages", therefore, so from the intuitive logic, China's consumption should be weak pro-cyclicality, different from a strong pro-cyclicality of the US economy. The main reason is probably largely based on the authors' estimation of annual data and analysis, in fact, the foundation work on RBC "Time to Build and Aggregate Fluctuations" written by Kydland and Prescott (1982), and besides, Hansen's work (1985) "Indivisible Labor and the Business Cycle" which has an important influence on RBC theory, are based on quarterly data for parameter calibration and "Second Moment" estimation (the former sample period is 1950Q1-1979Q2, the latter sample period is 1955Q3-1984Q1), which to some extent reflects the necessity and reasonableness of the paper in using quarterly data.

The correlation between household oil consumption and output is 0.07, close to 0.04 of the actual economy, showing a weak counter-cyclicality. The model underestimates the cyclicality of oil prices to output ratio and obtains −0.04, as opposed to 0.06 in the actual economy, nevertheless both closer to 0. The predicted correlations with output in the artificial economy are consistent with the actual economy in order.

From the point of view of the autocorrelations, the autocorrelations of variables of DRBC have shown a positive correlation, exhibiting persistency, which are also more matching with the actual economy.

In summary, the DRBC model can accurately simulate the "Second Moment" feature about the actual economy, and can be used as an appropriate model to capture the volatility of China's economy.

5.2. Compared with SRBC Model That Does Not Consider Consumer Durables

Simulated results that do not consider the consumer durables of SRBC, SRBC-OIL, and SRBC-TFP are shown in Table 6 & Table 7. The most salient feature when comparing DRBC with SRBC is DRBC has improved consumption prediction and made the results closer to the actual economy and better.

Starting with consumption comparison, volatilities in consumption prediction by DRBC (1.61%) are greater than that of SRBC (0.68%), closer to the actual economy (1.74%). Furthermore, with regard to the K-P ratio, the explanatory power of DRBC of 92.53% is much higher than SRBC of 39.08%; Eventually, SRBC shows a strong pro-cyclicality for consumption (a correlation between consumption and output is 0.84), which cannot fit a weak pro-cyclical consumption characteristic of China's actual economy, whereas DRBC can better fit the characteristics.

From the output comparison, SRBC predicts the standard deviation of output

Table 6. Business cycle properties of model SRBC.

Variable	Actual economy			Artificial economy (SRBC)			
	Standard deviation (%)	Autocorrelation	Correlations with output	Standard deviation (%)	Autocorrelation	Correlations with output	K-P ratio (%)
Output	3.76	0.39	1.00	3.72	0.48	1.00	98.94
Consumption	1.74	0.71	0.15	0.68	0.48	0.84	39.08
Capital investment	5.93	0.50	0.74	6.03	0.49	0.99	101.69
Durables investment	5.28	0.59	0.52	NA	NA	NA	NA
Total investment	5.19	0.61	0.88	NA	NA	NA	NA
Household oil consumption	7.96	0.75	0.04	NA	NA	NA	NA
Labor	2.45	0.49	0.78	1.64	0.48	0.92	66.94
Oil price	20.73	0.69	0.06	14.98	0.47	0.04	72.26

Note: NA denotes Undefined (Similarly hereinafter).

Table 7. Business cycle properties of model SRBC-OIL and SRBC-TFP.

Variable	Actual economy			Artificial economy (SRBC-OIL)				Artificial economy (SRBC-TFP)			
	Standard deviation (%)	Auto-correlation	Correlations with output	Standard deviation (%)	Auto-correlation	Correlations with output	K-P ratio (%)	Standard deviation (%)	Auto-correlation	Correlations with output	K-P ratio (%)
Output	3.76	0.39	1.00	0.99	0.65	1.00	26.33	4.23	0.64	1.00	112.50
Consumption	1.74	0.71	0.15	0.29	0.40	−0.99	16.67	0.81	0.71	0.93	46.55
Capital investment	5.93	0.50	0.74	0.34	0.39	0.99	5.73	7.08	0.64	0.99	119.39
Durables investment	5.28	0.59	0.52	NA	NA	NA	NA	NA	NA	NA	NA
Total investment	5.19	0.61	0.88	NA	NA	NA	NA	NA	NA	NA	NA
Household oil consumption	7.96	0.75	0.04	NA	NA	NA	NA	NA	NA	NA	NA
Labor	2.45	0.49	0.78	0.64	0.61	0.97	26.12	1.74	0.64	0.99	71.02
Oil price	20.73	0.69	0.06	14.93	0.66	0.93	72.02	0	0.86	−0.60	0

as 3.72%, almost the same level with DRBC, close to 3.76% in the actual economy, and thus these two models are also similar in explanatory power of the K-P ratio. Actually in Table 7 the K-P ratio of SRBC-TFP is as high as 112.50%, while the SRBC-OIL is only 26.33%, which further validates that the output is mainly technology-driven, with a weaker driver by oil prices. Both the autocorrelations of outputs from DRBC and SRBC are 0.48 and the output is showing a significant persistency. Both of models mimic this well.

From investment and labor, the standard deviations of these two series for SRBC are 6.03 and 1.64 respectively. When compared with the actual economy, DRBC is slightly better than SRBC in volatility forecasting. Investment volatility in SRBC increases mainly due to the lack of smooth durables investment, and households only rely on capital investment portfolio rebalanced, resulting in increased investment volatility. In Table 7, on capital investment and labor, the K-P ratios by SRBC-TFP are 119.39% and 71.02%, while the K-P ratios by SRBC-OIL are only 5.73% and 26.12% respectively, which further support the conclusion that technology shocks are the main source of volatilities in capital investment and labor.

5.3. Variance Decomposition

Table 8 shows the variance decomposition of technology and oil price shocks of DRBC in accounting for China's macroeconomic variables volatilities. In order to focus on the problem studied in this paper, only two exogenous shocks[8] are introduced in the model: one is technology shocks, the core of RBC theory, the

[8]In another study based on the New Keynesian DSGE model, we introduce more exogenous shocks (ten exogenous shocks such as government spending, demand preference, labor supply, investment, etc.) in doing variance decomposition analysis, and the conclusions also show that the oil price shocks on the macroeconomic variables is similar with the conclusions drawn from the body of this paper.

Table 8. Variance decomposition.

Unit: %

Shocks \ Variables	Output	Consumption	Capital investment	Durables investment	Total investment	Household oil consumption	Labor
Technology shocks	96.3	64.9	99.3	65.2	99.8	4.6	90.4
Oil price shocks	3.7	35.1	0.7	34.8	0.2	95.4	9.6

other one is oil price shocks, the theme of this paper. Variance decomposition results clearly show the extent of the impact of exogenous shocks on macroeconomic variables volatilities. It can be seen that the impact of oil price shocks is reflected in three variables, namely, consumption, durables investment and household oil consumption. Among them, the oil price shocks account for 35.1% of consumption volatility, 34.8% of durables investment volatility, 95.4% of household oil consumption volatility; oil price shocks account for less than 10% of volatility on output[9], investment, total investment and labor, which means that most of the volatilities are derived from technology shocks, and especially technology shocks account for 96.3% of the output, which is almost consistent with the traditional RBC theory that technology shocks can account for 100% of output volatility approximately.

In short, from the variance decomposition it can be found that output, investment and labor volatilities in this model are mainly dominated by technology shocks, and oil price shocks mainly affect consumption volatility, also can verify the conclusions made from Tables 4-7.

5.4. Impulse Response Analysis

Figure 3 plots the responses of the main macroeconomic variables to one standard deviation of positive oil price and technology shocks. By the contemporaneous effect and the household's intertemporal budget constraint, rising oil prices lead to a negative income effect and households reduce durables, nondurables, and household oil consumption, thus consumption fall and the labor supply increases. Notice that the rise in oil prices has triggered a running track of the capital investment "first rise and then the fall", rather than an immediate decline of traditional RBC model. Specifically, the impact has led to increased investment in the first two periods, and the decline from the third period. Economic logic behind this is the following: investment and accumulation process of durables are entirely decided by households, and capital goods are jointly decided by households and firms (households determine capital supply, and firms

[9]In fact, China's output is insensitive to oil price fluctuations, which is very similar with that of the US economy since 2000. According to Li (2008), in the rise of oil prices in the new century, the US economy shows "tolerance" to the continuous rising energy prices and "sustainability" of economic growth with high energy prices [42]. The reason may be that there is a strong complementary relationship between oil and durables consumption, and volatility in oil prices may be weakened by durables' stability, resulting in the weakening of oil transmission capacity in product markets, which has led to the weakening of the impact on output volatility.

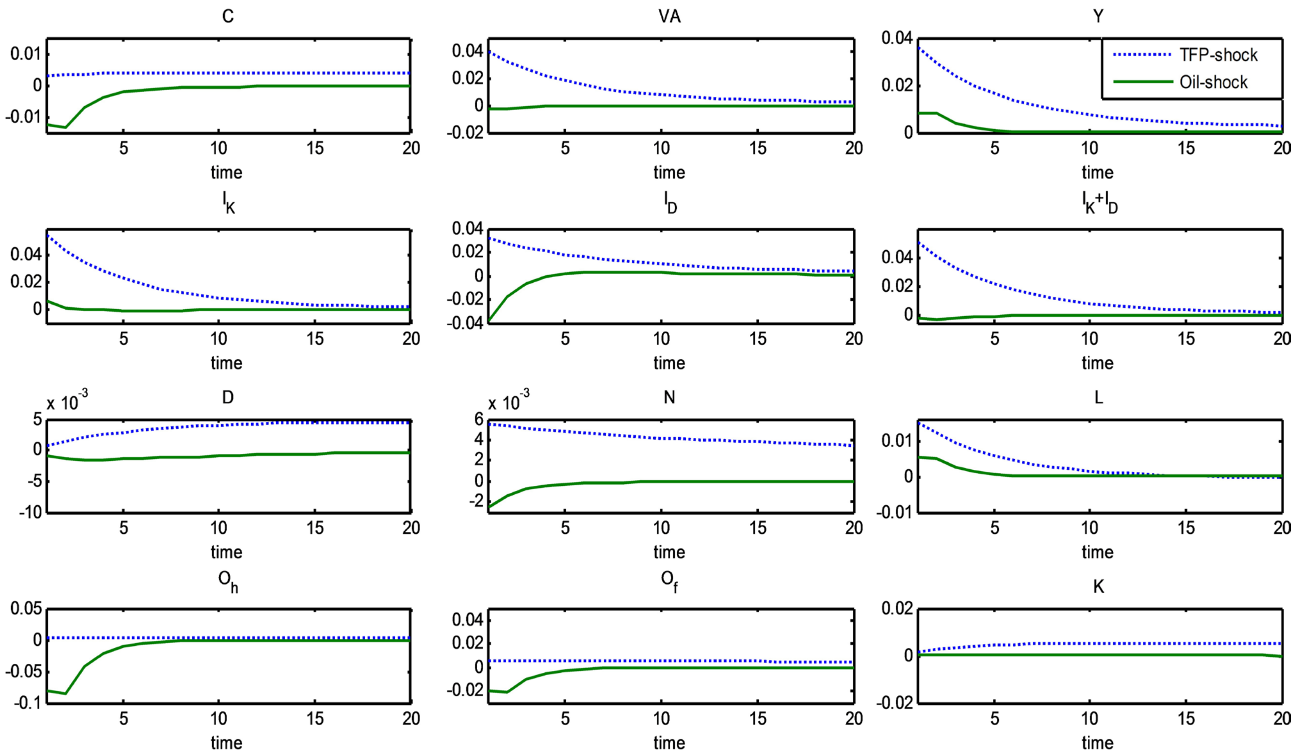

Figure 3. Impulse responses of main macroeconomic variables (dashed line indicates the positive technology shock, and the solid line denotes the positive oil price shock).

determine capital demand), therefore, it can be drawn that households need to rebalance its investment portfolio for durables and capital goods. According to the calibration study, in the initial steady state, the proportion between household oil and durables ($O_h/D = 0.013$) is much larger than the ratio of oil to capital in production ($O_f/K = 0.003$). The decline in marginal revenue of durables caused by oil price shocks is higher than the marginal revenue decline of capital goods. In order to balance the marginal income differences, households will immediately rebalance the portfolio, increase capital goods while reducing durable goods, and this capital increase will sufficiently offset the decrease in firms' demand of capital investment brought by high oil prices; meanwhile the ARMA (1, 1) of the oil price shocks determines that the propagation of oil price shocks is characterized by two periods in the time dimension, which together leads to a two-periods increase in capital investments (*i.e.*, greater than zero). Then starting from the third period, capital investment is switched into a negative trend, mainly because the high capital stocks K_t and low durables stocks D_t in the initial period have led to the fact that the portfolio rebalanced behavior of households cannot fundamentally reverse the huge gaps between those two, therefore, produce subsequent negative trends for two types of investment. The rise of capital and labor has increased the production, but brought forth the decline in the value added VA_t because the decline in durables investment and non-durables is greater than the short-term increase in the magnitude of capital investment.

Unlike oil price shocks, technology shocks have a direct impact on production function, but do not enter the utility function and do not directly influence durables investment. Therefore technology shocks do not affect the two portfolio reallocation by households, just leading to the rise in capital investment. Since our purpose is to study the impact of oil prices, and the impact mechanism of technology on the economy has been extensively studied in a large number of RBC literatures, it will not be discussed here due to limited space.

6. Conclusions

Existing literatures on China's RBC focus on the impact of macroeconomic cycle brought by technology, finance, monetary, international credit, and sunspot shocks, but lack discussion on energy price shocks represented by oil, and ignore the fact that the international oil price volatility in recent years is one source of external shocks of China's economic fluctuations. Especially in the past two decades, international crude oil prices are violently fluctuated within a wide range of repeated shocks between $ 20/barrel and $147/barrel, and early in 2011, China's dependence on foreign oil overtook that of the United States, being the world's number one. In view of this, we build oil economy RBC model with durables consumption, simulation and forecast, combining with economic data of 1997Q1 to 2016Q1 in China, with the following discoveries:

First, it is important to divide the RBC model into consumer durables and non-durables when studying China's economic fluctuations. According to the simulation results of model DRBC with consumer durables, the core finding is DRBC has improved consumption volatility and weak pro-cyclicality predicted closer to the actual economy. On one hand, the traditional SRBC containing oil price shocks can account for only about 40% of consumption volatility, while DRBC increases the explanatory power to more than 80% of the volatility; on the other hand, SRBC shows a strong pro-cyclicality and cannot predict the weak pro-cyclicality of China's actual economy, whereas DRBC can fit the feature.

Second, the oil price shocks mainly affect consumption volatility, but seldom influence output, investment and labor, the three variables of which are largely influenced by technology shocks. Specifically, the K-P ratio of consumption in DRBC-OIL is up to 90.80%, while K-P ratio of that in DRBC-TFP is only 25.86%; the K-P ratios of output, investment and labor in DRBC-TFP are 113.56%, 109.61%, and 73.88% respectively, while in DRBC-OIL the corresponding ratios are 26.33%, 11.64%, and 25.71% respectively.

Third, the benchmark model (DRBC) reveals that the transmission mechanism of oil prices is determined by intra-temporal income effects and inter-temporal effects of portfolio rebalanced between durable goods and capital goods.

It is implicated that the impact of oil price shocks on China's output volatility may not be so big, but the main impact is on consumption. Expanding domestic demand and boosting consumption become the main tone in the future of China's economic transition and growth; therefore great importance should be attached to the impact of oil price shocks on consumption levels.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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