

THE EXOGENOUS OIL SHOCKS TO CHINA AND OTHER COUNTRIES

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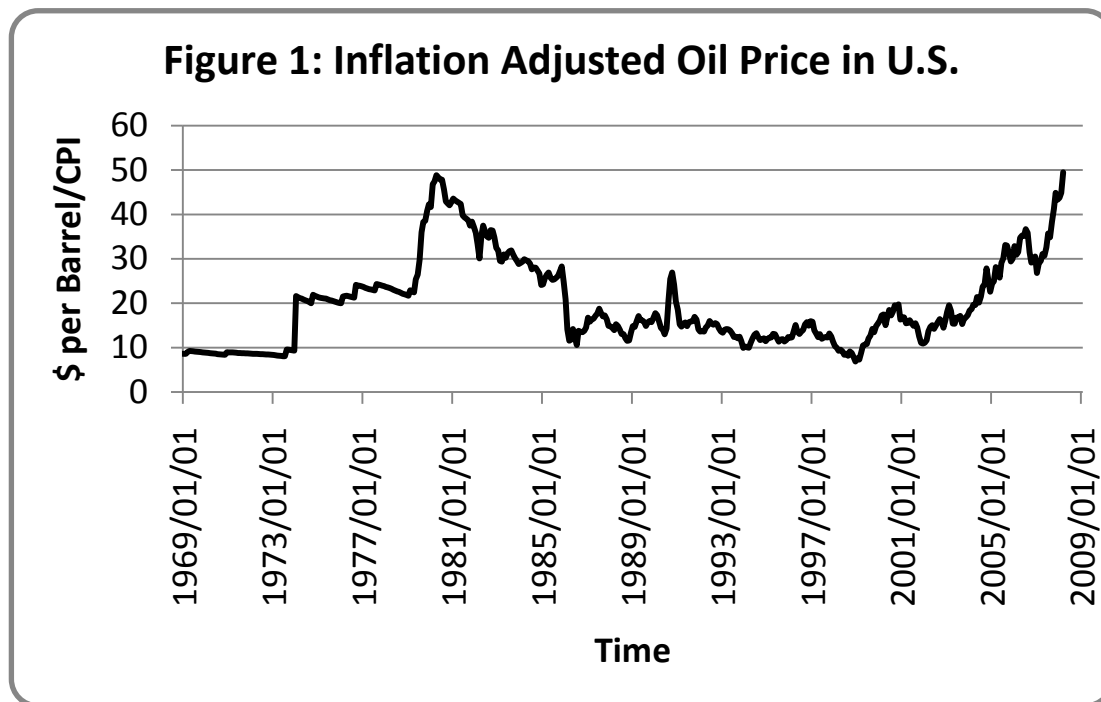
Abstract:

This paper is edited specifically for the 2009 Pacific Conference for Development Economics. Full version of the paper is located in the San Francisco State University Library¹.

The surging demand of oil from China has aroused enormous concerns from the world; however, the literature in the field mostly focuses on oil price shocks to the United States. This paper attempts to answer the question that has not been asked before, i.e. what is the effect of oil price shocks to China's output? Is it the same as a developed country such as the U.S.? This paper employs a Dynamic Stochastic General Equilibrium (DSGE) model to analyze the effect from the shocks. This DSGE model is an improved model over related literature, in that the functional forms that the model uses allows calibration of the parameters using data, and do not need to borrow parameters from other calibrated models. Using this DSGE model, this paper finds that a 27% positive oil price shock will reduce about 1.6% of the real GDP of China. This paper also finds that if the TFP shock is present at the same time, the TFP shocks will dominate the shock effects to the economy. The paper also discovers that an oil price shock affects the U.S. and China differently, this paper then decomposes the differences between U.S. and China in order to study the role that economic growth and oil usage play in the different responses of China and U.S. to an oil price shock.

¹ J. Paul Leonard Library of San Francisco State University

Introduction



Oil is one of the major resources in the world, and, as shown in the figure 1 above, the price of the oil has fluctuated since the 1970s. The effect of oil has always been considered as an important topic in economics research. The rich history in the economics literature about oil price shocks, which has been developed since the mid-1970s, has shown that each time a developed economy experienced an oil shock, significant impacts occur. China, on the other hand, being a mixed—planned and market—economy, a rapidly emerging and developing country with a surging “hunger of energy”, has aroused enormous concerns from the world. While most studies focus on researching the effect of oil or an oil shock on the U.S., the question still remains unanswered, i.e. what is the exogenous effect of oil shock to China? Is this effect the same as U.S. experienced? Answering these questions would be useful in complementing the existing research on oil and the economy.

To be more specific, this paper is aimed at answering the following question:

- What is the effect of an oil price shocks to China’s output?

In order to answer the above question, a number of sub-questions below need to be investigated, namely,

- Is the oil price shock exogenous to the Chinese economy?
- Is the effect different for a developing country vs. a developed country?
- If there is a difference, what factor(s) contributes the difference?
- What if a TFP shock is present at the same time with oil price shock?

This paper is structured into seven sections. The first section captures the key findings of related literature about oil shocks, and provides a literature summary to direct our analysis. The second section introduces the model and the economic intuition behind it. The third section describes and analyzes the economic structure of China, discusses the issues of Chinese Macro data, demonstrates her oil demand and oil share parameter through data and generates the moments for the calibration. Section Four calibrates the parameters that are used in the estimation. Section Five simulates the effect of both an oil price shock and a TFP shock by assigning different correlations between them, this section also provides a comparative analysis of China and the United States and attempts to answer the different response to an oil price shock between China's and U.S.'s model by performing sensitivity analysis on different parameters. Section Six discusses the strengths and weakness of this paper, and the last section concludes the findings and develops further research questions.

This paper employs a Dynamic Stochastic General Equilibrium (DSGE) model to analyze the effect from the shocks. Our model is an improved model from previous literature, in that the functional forms that this model uses allows this paper to calibrate the parameters using data, and does not need to borrow parameters from other calibrated models. Under this DSGE model, this paper estimated that a 27% increase in oil price –one standard error in historical prices – leads to a decrease of 1.6% in Chinese output, it also able to capture the dynamic effect of

positive oil price shock to other endogenous variables such as consumption, capital. Moreover, our model also allows the study of a joint productivity and oil price shock, which can be possibly correlated. The paper also discovers that an oil price shocks affects the U.S. and China differently, this paper then decomposes the differences between U.S. and China and studies the role that economic growth and oil usage play in the different responses of China and U.S. to oil price shocks.

1. Related Literature

The related literature, which mostly focuses on studying the effects on the U.S., tackles the question by 1) employing econometrics/empirical models, or 2) using structural micro-foundations models.

Table 1: Summary Table for related literature

Methodology	Structural micro-foundations models	Econometrics/empirical models
Examples	<ul style="list-style-type: none"> • Finn (2000) • MMM² (2003) 	Mork(1989), Lee, Ni Ratti (1995), Hooker (1999), Hamilton (2003), Kilian (2005)
Model	Calibrated DSGE	Time series
Economic Mechanism	<ul style="list-style-type: none"> • Oil is an input in the productions function. • Price of oil is a stochastic variable, with known distribution. • Oil price shocks affects the input mix and productivity 	<ul style="list-style-type: none"> • Prices of oil (and perhaps its lags) enter as regressor in regression to Real GDP. • Different oil shocks variable are used and tested.
Main findings	<ul style="list-style-type: none"> • Long term effects; • Oil price shocks account for some percentage of the observed volatility of real output 	<ul style="list-style-type: none"> • The effect of oil price shocks to output is asymmetric and nonlinear.

The majority of studies use econometric models to investigate the effect of an oil price shock to economy. These econometric models are time series models such as a Vector Autoregressive model (VAR) or an Autoregressive Distributed Lags (ADLs) model, where the price of oil, and perhaps its lags, enters as a regressor(s) in a regression using Real GDP as the dependent variable. The main findings from these prior studies are that the effect of an oil price shock to

² Carlos De Miguel, Baltasar Manzano and José M Martín-Moreno (2003)

output is asymmetric and nonlinear, in other words the relationship between oil price shocks and GDP is not simple and straight forward. As a result they conclude that a simple Ordinary Least Square (OLS) model is not a suitable analytic approach. They then developed and tested different instrumental oil shock variable to overcome this issue. Using the models suggested by Hamilton (2003) and Kilian (2005), the econometric models find that the “oil shocks” and its lags coefficients are either statistically insignificant or too small to affect the real GDP of China³.

In order to understand more explicitly on how the oil price shock affects the economy of China, our paper chooses to follow the structural micro-foundation approach. Past studies using similar calibrated DSGE model are Finn (2000) and MMM (2003), in which oil is an input in the production function and the price of oil is a stochastic variable with known distribution. In other words, an oil price shock affects the input mix and productivity of the country. The main finding from Finn (2000) and MMM (2003) are that, an oil price shock has a long-term effect on the economy and also accounts for a large percentage of the observed volatility of real output. Both Finn (2000) and MMM (2003) use parameters from other calibrated models. The main differences between these two studies are that Finn (2000) investigates the effect of oil price shock on the U.S. economy, incorporating a novel relationship in between energy and capital. This allows her to capture the effect of an oil price shock on output through its effect on capital. On the other hand, MMM (2003) investigates the Spanish economy which includes the international trade component, imports and exports, in their model.

2. Economic Intuition behind the model

Before a DSGE model is constructed, one needs to understand how the oil price affects the economy. This section describes the economic intuition behind such a model

³ For the result of the econometric models, please refer to appendix I of the full version of this paper, which is located in the San Francisco State University Library.

2.1. Oil Share Parameter

Elasticity of production function

The production function relates the inputs to the outputs in the macro-economy.

As will be shown, understanding the rate of change of output with respect to the rate of change of oil, that is the elasticity of production function with respect to oil, is essential for measuring the impact of oil price shock on the economy. This framework also gives a general picture on what effects should be expected from oil supply disruption towards the output of the economy.

Referring to the framework for the effects of energy disruptions suggested in Hamilton (2005), a more generalized production function can be developed as follows:

Let the aggregate output be modeled in the following production function.

$$Y = F(x_1, x_2, \dots, x_n) \quad (1)$$

Where

Y is the total output of the economy

x_i is the input i

Based on this production function, mathematical proof⁴ shows that the output elasticity of any production function, under the perfect competition assumption, is equal to the relative spending on that particular input relative to the total revenue. In this paper, suppose that x_i is oil, denoted by (o). Then the elasticity of GDP with respect to oil is equal to the spending on oil as a fraction of nominal GDP:

$$\eta_o = \frac{p_o \cdot o}{P \cdot Y} \quad (2)$$

⁴For the details of this mathematical proof, please refer to the section 2.1 of the full version of this paper, which is located in the San Francisco State University Library.

Where

η_o is the elasticity of GDP w.r.t. oil as an input factor

p_o is the price of the oil

o is the quantity of oil

$P \cdot Y$ is the nominal GDP

In other words, the elasticity of output with respect to a given change in oil use can be inferred from the dollar share or the nominal value of the oil expenditures to the nominal output of the economy.

Cobb-Douglas assumption between inputs

Next, mathematical proof⁵ also shows that if the production function is Cobb-Douglas, then it implies that the elasticity of the output per input factor is fixed and equal to the input share parameter α_i for the production function. Applying this equation to the oil input equation:

$$\eta_o = \frac{P_o \cdot o}{P \cdot Y} = \alpha_o \quad (4)$$

Where α_o is the oil share parameter in production function.

For simplicity and clarity, let the oil share parameter $\alpha_o = \nu$ throughout this paper.

2.2. How does oil price affect the production?

Elasticity of real GDP with respect to price of an input i

The elasticity of real GDP with respect to price of an input i can then be derived in a similar way⁶

Mathematical proof⁷ shows that if we assume the production function is Cobb-Douglas, then

⁵ For the details of this mathematical proof, please refer to section 2.1 of the full version of this paper, what is located in the San Francisco State University Library.

⁶ For the details of the proof, please refer to appendix III of the full version of this paper, which is located in the San Francisco State University Library.

⁷ For the details of the proof please refer to section 2.2 of the full version of this paper, which is located in the San

the elasticity of output with respect to the price of oil is a transformation from its oil share

parameter:

$$\eta_{po} = \frac{\alpha_o}{\alpha_o - 1} = \frac{\eta_0}{\eta_0 - 1}$$

where η_{po} is the elasticity of output with respect to the price of the oil

These elasticity equations, however, only show the partial equilibrium model which neglects the demand side of the economy. Therefore, in order to consider effect of oil price shock to the real GDP, a general equilibrium model needs to be constructed.

2.3. The Model Economy

This section constructs a general dynamic stochastic general equilibrium (DSGE) model, under the Cobb-Douglas production function and a perfect competition assumption. These functional forms allow us to calibrate the parameters using data, instead of borrowing parameters from other calibrated models. The constructed DSGE model can also capture both Total Productivity Growth (TFP) shocks and oil price shocks as the shock variables that will affect the model economy. Again, for simplicity and clarity, let the oil share parameter $\alpha_o = \nu$ throughout this paper.

2.3.1. Structure

Stochastic TFP shock

Using the classic definition, this paper assumes the TFP shock includes a deterministic trend

$(1 + \gamma_A)^t$ and a stochastic part e^{z_t} , which follows a first-order autoregressive process:

$$A_t = (1 + \gamma_A)^t e^{z_t}$$

Let : $\ln(A_t) = z_{1,t}$ where : $z_{1,t} = m_1 + \rho_1 z_{1,t-1} + \varepsilon_{1,t}$ and $\varepsilon_{1,t} \sim i.i.d. \quad N(0, \sigma_1^2)$

A_t is the TFP (total factor product) at time t

γ_A is the growth rate of TFP.

$z_{1,t}$ is based on an AR(1) autoregressive process

Stochastic oil price shock

Similar to other models in the oil literature⁸, this paper assumes the oil price shock variable p_t to be the relative price of oil, and that also follows a stochastic first-order autoregressive process

$z_{2,t}$ is based on an AR (1) autoregressive process

where: $p_t = e^{z_{2,t}}$ and $z_{2,t} = m_2 + \rho_2 z_{2,t-1} + \varepsilon_{2,t}$

and: $m_2 = \ln(p_0)$, $\ln p_t = z_{2,t}$ and $|\rho_2| < 1$ and $\varepsilon_{2,t} \sim i.i.d. \ N(0, \sigma_\varepsilon)$

2.3.2. Social Planner's Problem

The Social Planner's Problem becomes⁹

$$\max_{\{c_t, h_t, o_t, k_{t+1}\}_{t=0}^{\infty}} E_0 \sum_{t=0}^{\infty} \beta^t u(c_t, 1 - h_t)$$

s.t.

$$[\text{Feasibility}]: c_t + k_{t+1} + p_t o_t = A_t (k_t^\theta h_t^{1-\theta-\nu} o_t^\nu) + (1 - \delta)k_t$$

$$: u(c_t, 1 - h_t) = [\alpha \ln(c_t) + (1 - \alpha) \ln(1 - h_t)]$$

Where TFP shocks: $z_{1,t} = m_1 + \rho_1 z_{1,t-1} + \varepsilon_{1,t}$ and $\varepsilon_{1,t} \sim i.i.d. \ N(0, \sigma_1^2)$

Oil price Shocks = $z_{2,t} = m_2 + \rho_2 z_{2,t-1} + \varepsilon_{2,t}$ and $\varepsilon_{2,t} \sim i.i.d. \ N(0, \sigma_2^2)$

$$\begin{bmatrix} \varepsilon_{1,t} \\ \varepsilon_{2,t} \end{bmatrix} \sim N \left(\begin{bmatrix} 0 \\ 0 \end{bmatrix}, \begin{bmatrix} \sigma_1^2 & \sigma_{12}^2 \\ \sigma_{21}^2 & \sigma_2^2 \end{bmatrix} \right)$$

Where

t is the time variable

α is the percentage parameter that household allocates between consumption and leisure time

⁸ For example MMM (2003)

⁹ The proof of the deterministic NGM model to DSGE social planner's problem, please refer to appendix IV of the full version of this paper, which is located in the San Francisco State University Library.

β is the discount factor such that $(0 < \beta < 1)$

c_t is consumption at time t

k_t is the capital or physical capital per worker at time t

δ is the constant depreciation rate of capital

w_t is the wage rate in unit of consumption per unit of time

h_t is the labor unit per time t

$k_{t+1} = (1 - \sigma)k_t + x_t$ is the law of motion of capital

$k_0 > 0$ represents that initial capital is positive

$l_t + h_t = 1 \quad \forall t$ is the time constraint for labor

o_t is the quantity of oil at time t

θ is the share parameter of physical capital per worker at time t

ν is the share parameter¹⁰ of oil at time t

The Sufficient Equations for the DSGE model

Let $u(c_t, 1 - h_t) = [\alpha \ln(c_t) + (1 - \alpha) \ln(1 - h_t)]$, the sufficient equations¹¹ become,

$$[\text{Labor}] \quad : \quad \left(\frac{1 - \alpha}{\alpha} \right) \frac{c_t}{1 - h_t} = (1 - \theta - \nu) A_t k_t^\theta h_t^{-\theta - \nu} o_t^\nu = (1 - \theta - \nu) \frac{y_t}{h_t}$$

$$[\text{EE}] \quad : \quad \frac{1}{c_t} = \beta E_t \frac{1}{c_{t+1}} \left(\theta A_{t+1} k_{t+1}^{\theta-1} h_{t+1}^{1-\theta-\nu} o_{t+1}^\nu + 1 - \delta \right)$$

$$[\text{Oil}] \quad : \quad p_t = \nu A_t k_t^\theta h_t^{1-\theta-\nu} o_t^{\nu-1} = \nu \frac{y_t}{o_t}$$

$$[\text{Feasibility}] \quad : \quad c_t + k_{t+1} + p_t o_t = A_t \left(k_t^\theta h_t^{1-\theta-\nu} o_t^\nu \right) + (1 - \delta) k_t = y_t + (1 - \delta) k_t$$

Where : Labor — Equation for Optimal allocation of time

¹⁰ For clarity purposes, let the oil share parameter $\alpha_0 = \nu$.

¹¹ For the proof of the DSGE model to its sufficient equation, please refer to appendix V of the full version of this paper, which is located in the San Francisco State University Library.

- EE — Euler Equation
 Oil — Inverse Oil Demand Equation
 Feas — Feasibility Constraint

Solving the model numerically, using Time Detrended Variables

Simulation techniques rely on the model to converge to a steady state. In order to calibrate the parameters and to simulate the model with observed data, the model therefore, needs to be solved numerically.

This can be done using the two conditions.¹² First, if there is an one time shock and that is observed, no matter if it is a TFP shock or an oil price shock, the expected value of its

stochastic component, given enough time periods, will converge to the value $E(z_{t+k}|z_t) = \frac{m}{1-\rho}$.

Second, when the model is on the Balanced Growth Path (BGP), the time detrended variables are all constant; in other words, the variables are all in steady state¹³ all the input factors are growing at the same rate as output. Based on these two conditions, the steady state equations¹⁴ for the DSGE Model are solved to the following:

Steady State Equations

$$[\text{Labor}] \quad : \quad \left(\frac{1-\alpha}{\alpha} \right) \frac{\hat{c}}{1-\hat{h}} = (1-\theta-\nu)\hat{A}_t \hat{k}^\theta \hat{h}^{1-\theta-\nu} \hat{\omega}^\nu$$

$$[\text{EE}] \quad : \quad \frac{\hat{c}_{t+1}}{\hat{c}_t} (1+\gamma) = \beta \left(\theta \hat{A}_t \hat{k}^{\theta-1} \hat{h}^{1-\theta-\nu} \hat{\omega}^\nu + 1 - \delta \right)$$

$$[\text{Oil}] \quad : \quad p_0 = \nu \hat{A}_t \hat{k}^\theta \hat{h}^{1-\theta-\nu} \hat{\omega}^{\nu-1}$$

$$[\text{Feasibility}] \quad : \quad \hat{c} + \hat{k}(\gamma + \delta) + p_0 \hat{\omega} = \hat{A}_t \hat{k}^\theta \hat{h}^{1-\theta-\nu} \hat{\omega}^\nu$$

¹² For the mathematical solving of the model, please refer to appendix of the full version of this paper, which is located in the San Francisco State University Library.

¹³ The model would behave as the deterministic model and approach a stationary solution, if there is only a one time shock and it is observed.

¹⁴ For the proof of the steady state equations, please refer to the appendix IX of the full version of this paper, which is located in the San Francisco State University Library.

Where : Labor — Equation for Optimal allocation of time
 EE — Euler Equation
 Oil — price of oil at steady state
 Feas — Feasibility Constraint

2.3.3 Expected relationship

The expected relationship between an oil price shock and other parameters

The oil demand equation is derived from the price of oil at steady state equation.

$$o_t = \left(\frac{vA_t k_t^\theta h_t^{1-\theta-v}}{p_t} \right)^{\frac{1}{1-v}}$$

The oil price is inversely related with the oil demand, which is as expected by economic theory.

When there is a positive oil price shock, the demand for oil will have to decrease. The economic intuition behind the oil demand equation is that people will consume less oil when there is a price increase in oil.

This is a testable equation. By taking logarithm to both sides and forming a linear relation between quantity of oil and the price of oil, the coefficient of oil price is $-\frac{1}{1-v}$, which is clearly negative.

Substituting the demand for oil into the steady state equations generates the analytical equations that show the relationships of the oil price shock to the other parameters.

Relationship with output

Substituting the oil demand into the production function gives:

$$y_t = A_t^{\frac{1}{1-v}} k_t^{\frac{\theta}{1-v}} h_t^{\frac{1-\theta-v}{1-v}} \left(\frac{v}{p_t} \right)^{\frac{v}{1-v}}$$

This above equation illustrates that in this model, the oil price shock affects the economy in a similar fashion to a negative productivity shocks, assuming that both shocks are independent, i.e. the correlation between two shocks is zero.

The economic intuition is that two sides of the economy will be affected when the oil price has a positive shock. First, people are expected to consume less in the future periods, which leads to a decrease in investment, and results in a decrease in the total output of the economy. Second, as a positive oil price shock appears, oil demand will decrease; and, since oil is an input factor for the production, total output will decrease immediately. Then, as the economy regains confidence, consumption and output will start to converge to the steady state, along with the oil demand.

Direct relationship of output and oil price shock

The relationship of an oil price shock to output can be rewritten as:

$$y_t = \tilde{A}_t k_t^\phi h_t^{1-\phi}$$

where: $\tilde{A}_t = A_t^{\frac{1}{1-\nu}} \left(\frac{\nu}{p_t} \right)^{\frac{\nu}{1-\nu}}$, $\phi = \frac{\theta}{1-\nu}$

Taking the logarithm for both sides gives the direct relationship:

$$\ln y_t = \left(\frac{\nu}{1-\nu} \right) \ln \nu + \left(\frac{1}{1-\nu} \right) \ln A_t + \left(\frac{\theta}{1-\nu} \right) \ln k_t + \left(\frac{1-\theta-\nu}{1-\nu} \right) \ln h_t - \left(\frac{\nu}{1-\nu} \right) \ln p_t$$

The elasticity of the output¹⁵ with respect to price of oil is $\left(\frac{-\nu}{1-\nu} \right)$.

Therefore, if the oil intensity of a country is higher, then the predicted loss of GDP will be higher. A regression model may not account for these dynamic effects as oil prices increases because an econometric model does not specify this relationship. The DSGE model, taking into account the fact that oil is one of the substitutes in production, has the advantage over the

¹⁵ For the mathematical proof, please refer to appendix III of the full version of this paper, which is located in the San Francisco State University Library.

regression model that it can predict these dynamic effects of oil shock.

Relationship with Consumption growth

If the expectation of c_{t+1} is known, that is when perfect foresight is assumed, substituting the oil demand into the Euler equation gives:

$$\frac{c_{t+1}}{c_t} = \beta \left(\frac{v^{\frac{v}{1-v}} \theta^{\frac{1}{1-v}} A_{t+1}^{1-v} k_{t+1}^{1-v} h_t^{1-\theta-v}}{P_{t+1}^{\frac{v}{1-v}}} + 1 - \delta \right)$$

The above analytical equation shows that the oil price shock variable in time $t+1$ is inversely related to the consumption growth rate. It can be interpreted as when there is a positive oil price shock, then the consumption growth rate will be reduced, and will start to converge back to its steady state when the shock effect is over. The economic intuition is that as people experience a positive oil price shock, they will consume less and will continue to consume much less in the future period before the price shock effect is over. When the price shock effect is over, the people start to regain confidence, and the consumption will start to converge back in the next time period until it reaches its steady state.

Relationship with the capital and the cost of capital

Assuming that at time t the shock is observed and there are no additional shocks onward, the DSGE model would then behave as a deterministic model and approach a stationary solution.

The neoclassical growth model shows that¹⁶ the rent or cost of capital equation under the Cobb

Douglas assumption is:

$$r_t k_t = \theta y_t$$

Where: r_t is the rent/cost of capital at time t

¹⁶ For the details of the NGM model, please refer to appendix IV of the full version of this paper, which is located in the San Francisco State University Library.

Since the oil price shock variable is inversely related to the output, the nominal value of the capital in the production function will also be inversely related to oil price shocks. The economic intuition is that when the economy is experiencing a positive oil price shock, output will fall and reduce the demand for capital. However, since oil and capital are assumed to be substitutes in the production function, some capital will be used to substitute for oil in producing goods. Also, by the assumption that the capital for the current time period is decided in the previous time period, a positive oil price shock will not have an immediate effect on the capital, but capital in the next time period will decrease, since the output has decreased. When the shock is over and the people again regain their confidence, and the output will converge back to the steady state. Therefore, the demand for capital is driven up and the cost of capital increases after the initial shock. At some point of this adjustment time period, the demand of capital and the cost of capital must be higher than the steady state before converging back, indicating that the economy is increasing its output, and moving back to the steady state.

Relationship with wage and working hours

Turning to the labor market effects and referring to the NGM model¹⁷, the wage equation for labor is

$$w_t h_t = (1 - \theta - \nu) y_t$$

Similar to the analysis in capital and its cost, when all other input variables are kept constant, a positive oil shock is inversely related to output; in other words, it is inversely related to the nominal value of labor productivity, as shown in the analytical function above. The economic intuition is similar to the earlier discussion of the capital and its cost, as labor is also treated as a perfect substitute for capital in the production function. As a result, similar effects to the capital and rent must occur in response to a positive oil shock. However since working hours (h)

¹⁷ For details of the NGM model, please refer to appendix IV of the full version of this paper, what is located in the San Francisco State University Library.

is relatively invariant, the proportion and its time period of convergence must be smaller and shorter than the capital, and a large proportion of the oil price shock effect will fall to the relatively flexible variable in the labor market, the wage. The wage is expected to drop after the shock effect and move back to the steady state when the output converges. At some point of this adjustment time period, the demand of labor and wage must be higher than the steady state before converging back, indicating that the economy is increasing its output, and moving back to the steady state

Relationship with investment

$$x_t = y_t - c_t$$

The oil price shock affects investment through output and consumption. Since investment is defined to be the difference between output and consumption, when both output and consumption fall after a positive oil price shock, investment should also drop, converging back when output and consumption regain the steady state. The economic intuition is that when there is a positive oil price shock, output and consumption will fall, decreasing investment. This effect will remain until the oil price shock effect on output and consumption is over.

Relationship with the TFP

$$A_t = \frac{Y_t}{K_t^\theta L_t^{1-\theta-\nu} o_t^\nu}$$

Since the oil price is not directly related to the TFP, but through the oil share in the output function, it is reasonable to assume that a positive oil price shock will not have or will have only a slight effect on the TFP. A short and one time oil price shock should not affect the technological growth of the economy.

Relationship with TFP shocks

$$y_t = A_t (k_t^\theta h_t^{1-\theta-\nu} o_t^\nu)$$

Since a TFP shock is similar to a negative oil price shock, one may expect that if TFP shock and oil price shock are correlated, positively or negatively, and if both shocks are present in the same time period, they will either create a bigger impact to the economy or it may eliminate the effects of each other. However, as shown in the equation above, since TFP shocks affect output directly, when a TFP shock is present in the same time period as the oil price shock, the TFP shock is expected to have a larger effect and dominates the oil price shock effect on the economy, no matter if they are correlated or not.

3. China

This section describes the economy of China with special attention to oil. Differences between China and other developed countries, such as United States, with respect to oil will be highlighted. Lastly, this section provides analysis and calculates the data needed to calibrate the parameters for the model suggested in the previous sections.

3.1. Economic Structure of China

The People's Republic of China (China), which has one fifth of the population in the world, was established in 1949 as a centrally planned economy. Reform to a more market-oriented economy started in 1978, shifting China from a planned economy to a mixed economy. Since joining the World Trade Organization (WTO) in 2001, China has rapidly developed her economic power, doubling its share of global manufacturing output. At the end of 2005, China's economy became the fourth largest in the world; however, with its large population, its estimated average GDP per person in 2006 is only about US\$2,400¹⁸. In terms of international

¹⁸ From IMF Ranking

trade, China is the world's largest consumer of steel, concrete and copper and also the world's second largest importer of petroleum. Finally, counting all products, China is the third largest importer and the second largest exporter in the world

Although there has been considerable economic growth, economic problems include her developing a modern financial system and problems accounted with a relatively fixed exchange rate, an aging population, rapid environmental degradation, and large income disparities because of lack of growth in rural areas. Also, the growing Chinese economy is showing symptoms of overheating, and its export-dependent structure and valuation of the Chinese Yuan are putting limits on the economy.

FACTS ON CHINA THAT IS RELATED TO OIL

Labor supply in China

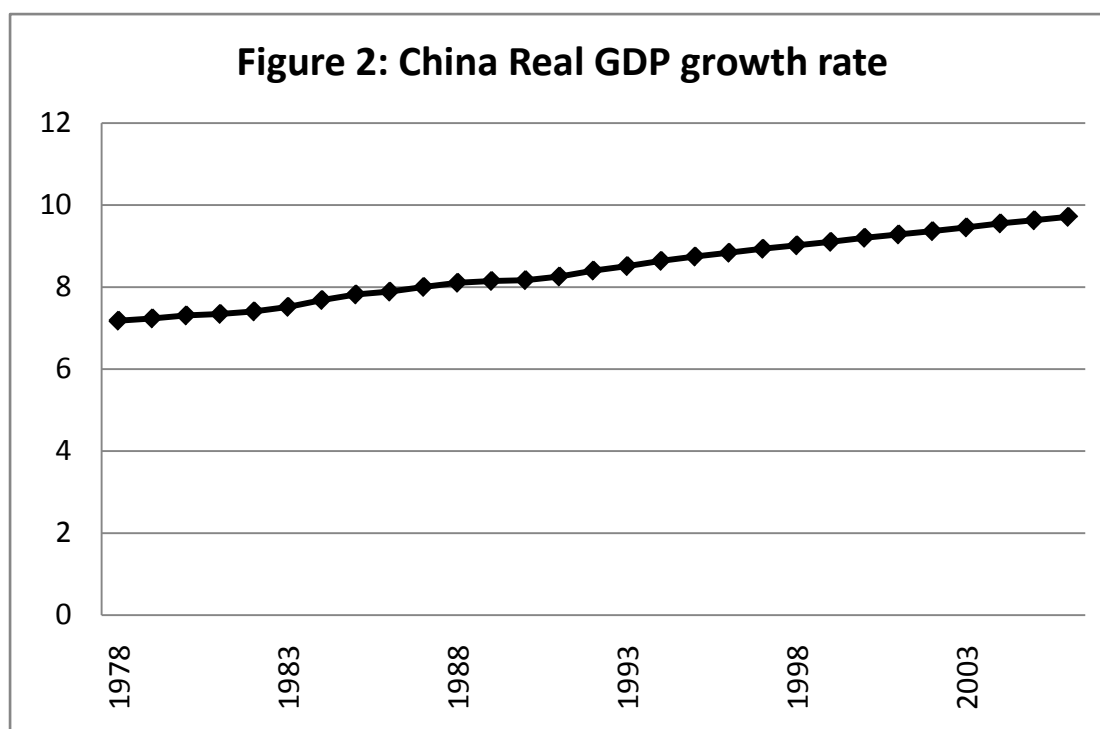
Before the economic reform in 1978, China's labor supply was rigid and inelastic under the social planning system. From 1978 until the 1990s, the Chinese government controlled the exchange of the residency from non-urban areas to urban areas. Even within urban areas, the government literally employed all the workers for its state-owned enterprises.

For the 1990s onward, the labor supply in the urban area of China is considered to be elastic. Li and Zax (2003), studying the market for urban Chinese workers, and reached this conclusion in 1995. However, they also find that the elasticity of labor to be relatively low compared to developed countries.

Operationally, this characteristic of China means that the DSGM model should employ an elastic labor supply assumption rather than an inelastic labor supply assumption.

Rapid growth in China's output

The rapid pace of economic growth in China may result in a different response to oil price shock compared with other developed countries with a much lower growth rate such as the United States. Average real GDP growth per capita from the China's official data¹⁹, for the period 1978 – 2006, is about 7.75%, compared to the U.S., which averaged 2% in the same period.

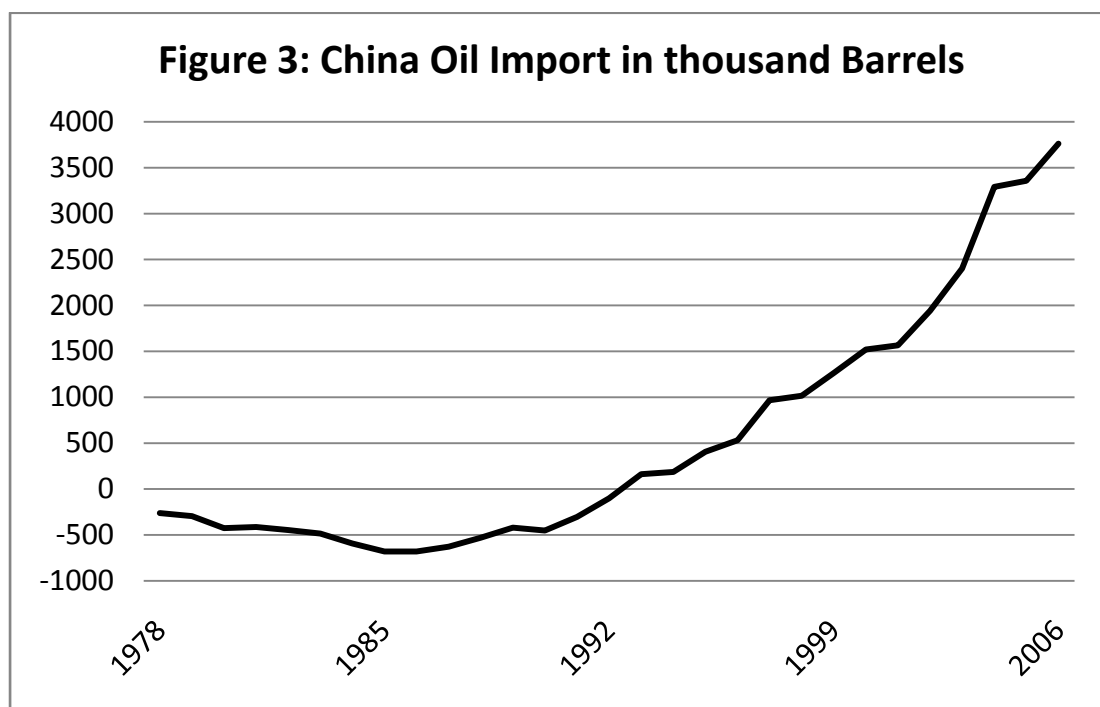


¹⁹ Chinese Statistical Year Book 2007

Surging demand of Oil

Since the reform in 1978, China's oil demand has surged along with her economic growth. This increase in demand of oil has increased the significance of the effect of oil shocks on China.

Figure 3 based on BP Plc²⁰ Plc Statistical Report 2007 data illustrates the Chinese rapid increase in oil demand.



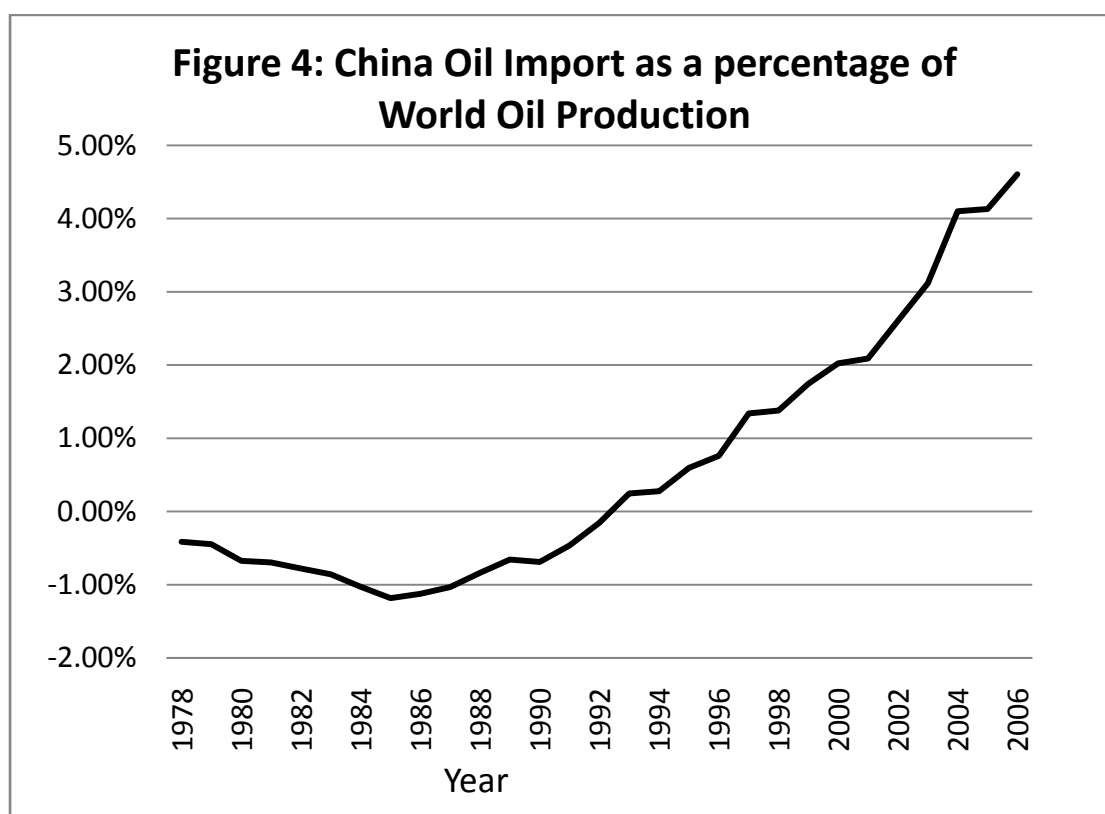
The U.S. was a large importer of oil in 1978-2006. China, on the other hand, was a net exporter of oil until the late 1980s. However, the rapid pace of economic growth led to a shift into China becoming a net importer of oil. Should an oil price shock be treated exogenously given China's surge of demand in oil? How does this surge of demand in oil affect its component in China's Cobb Douglas production function? The first question is answered in the following section, whereas the second question is answered in later section when estimating the oil share parameter.

²⁰ **BP plc** (LSE:BP, NYSE: BP, TYO: 5051, TSX: BPU), formerly known as **British Petroleum**, is the world's third largest global energy companies and is a multinational oil company ("oil major") with headquarters in London, England, UK.

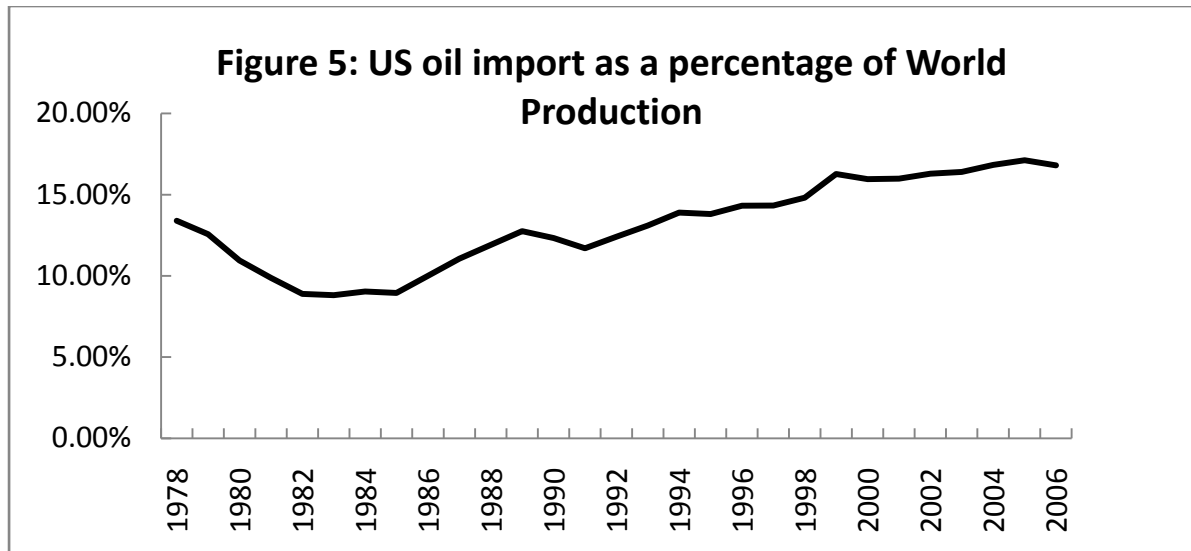
3.2. Exogeneity of Oil Price to China

China Oil demand vs. the world demand

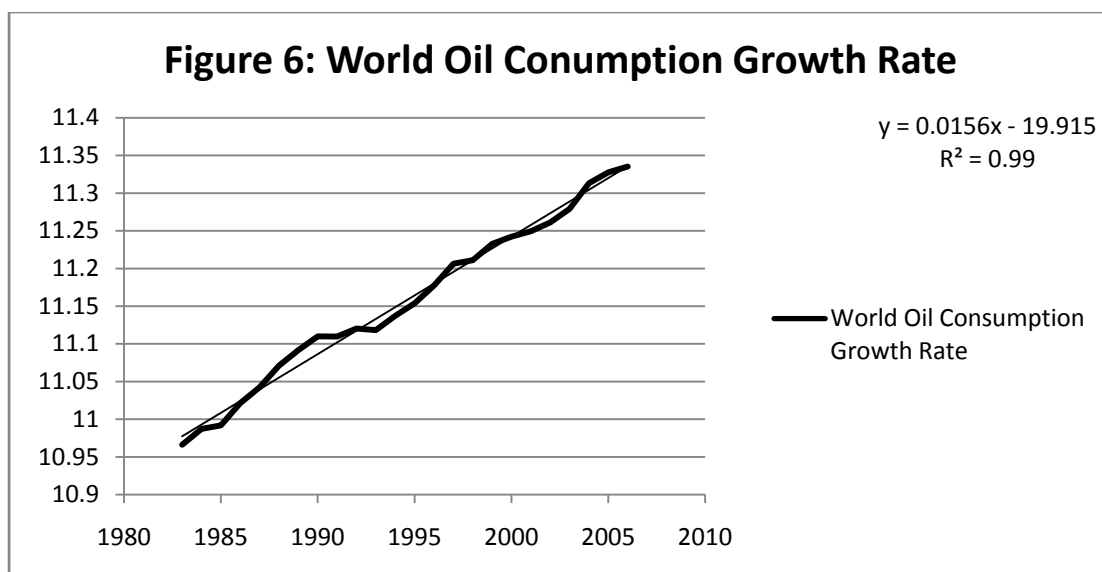
China has a relatively small demand for oil compared with developed countries such as the United States. As shown in the figures²¹ below, China in 2006 imported only 5% of the world oil production, whereas the U.S. imported about 17% of the world oil production, triple the size of China's import percentage. While existing literature using DSGE model assumes oil price shock as exogenous to U.S. This relatively small demand for oil versus the world production makes the exogeneity of the oil price shocks for China also valid. This assumption of exogeneity is important in that it makes modeling easier. Price shocks considered to be endogenous to the Chinese economy would require a significantly more complex structural model.



²¹ From BP plc Statistical Report 2007



Moreover, the world demand for oil does not show an enormous increase in the recent 10 years, even though China may have contributed a certain amount to the increase in world consumption on oil. In fact, as shown in the graph below, the world oil demand has a steady growth rate at about 1.6% every year. Also, compared with the fluctuation of oil price presented at the beginning of this paper, one can conclude that the oil demand does not drive the fluctuation of oil prices, but some other factors, for example political events, wars etc, are responsible. Since the demand of oil is not the most significant factor affecting the oil prices, oil price effect can be considered exogenous to China's economy.



3.3. Issue of China Macro Data

Systematic statistical reporting by the National Bureau Statistic of China (NBS) started in 1952. Because of the reform in 1978, the data differs considerably for the years 1952-77 compared to data after 1978. Data quality is also likely to be worse in at least some of the pre-reform years.

Besides data issue stemming from the reform, the Chinese macro data still has other issues that need to be addressed. Based on Holz (2003), (2006), who has done a detailed study of Chinese macro data reliability, there are four recurrent data issues for the macro data in China, namely:

- the changes in sectoral classification;
- the benchmark revision following the 2004 economic census;
- the multitude of data ambiguities if not inconsistencies; and
- the different definitions for the “fixed assets” of China

Because of these data issues, the data used for simulation as well as for the econometric analysis in the Appendix I²² in this paper are handled with special care. The assumption in this paper is that the latest data that comes from the NBS of China is the most reliable data. Other Chinese macro data are collected from well recognized international organization or research team, such as the International Financial Statistic (IFS) of the International Monetary Fund (IMF), BP plc or the estimated data from Holz (2003) and Holz (2006).

3.4. The oil share parameter of China

Elasticity of production function w.r.t. oil vs. w.r.t the price of oil

Based on the oil share equation suggested by the previous sections, $\nu = \frac{P_o \cdot o}{P \cdot Y}$, I calculates

China's elasticity of production with respect to oil Using data from BP Plc, China's oil share

²² For the result of the econometric models, please refer to appendix I of the full version of this paper, which is located in the San Francisco State University Library.

over time is shown below in figure 7:

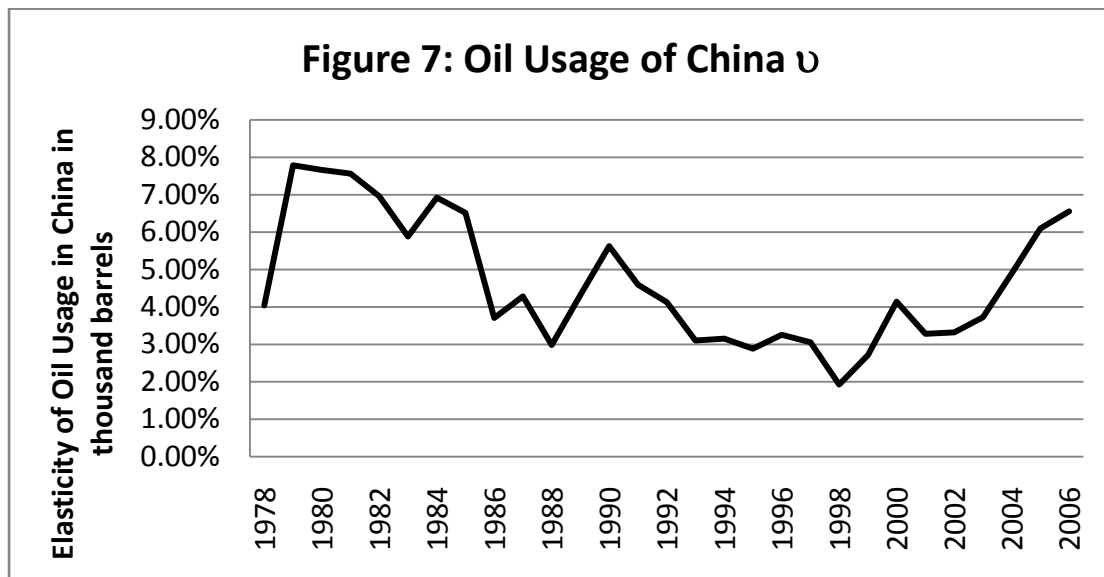
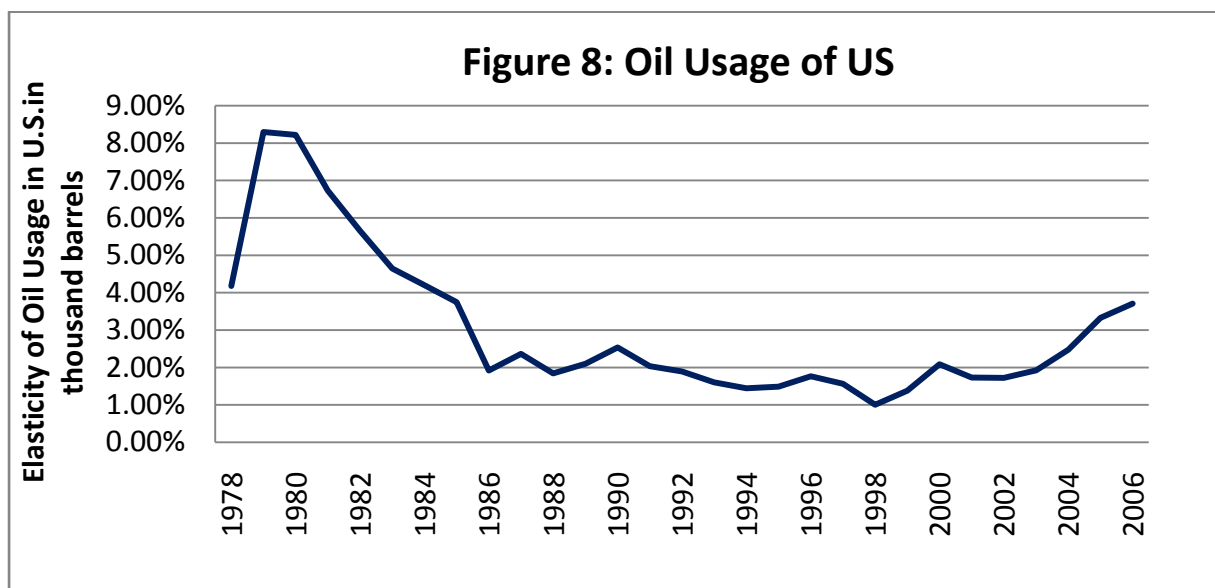


Figure 7 shows that China’s dependence on oil or their oil usage with respect to output does not change much through 1978-2006, although there is a surge in the demand of oil in 1978-2006.

The surge of oil demand appears to be based more on their high GDP growth, as the share of the oil in output does not increase as much. Moreover, since the graph appears to indicate no trend on oil usage in China, it is valid to assume that the oil usage is stationary and the average of the oil usage can be used for further analysis. Again, using data from BP Plc, the U.S.

elasticity of production function is plotted in the next page. Similar to the Chinese oil usage, the oil usage of the U.S. does not change much through 1978-2006.



Thus, China's oil share parameter is, on average 4.6% while the U.S.'s oil share parameter is, on average, 3%.

3.5. Physical Capital in China

Moments of the Chinese Macro Data

Before moving on to the calibration of the parameters, the moments of the models must be computed. The data is collected in the period from 1978 - 2006 from the Chinese Statistical Book 2007, the most updated official data from the NBS of China. To verify the accuracy, China's data from IFS is also collected and computed.

Computed moments from the data are as follows:

Table 2: Moments from China Data

Parameter	Estimated Value (Chinese Statistical Year book 2007)	Estimated Value (IFS Data)
Y/C	1.603492	1.638978
C/K	1.969618	1.969591
Y/K	3.117155	3.18664

The moments generated from both data sources have a slight difference after 2 decimal places, but overall, these pairs of statistics can be considered as matching well with each other.

However, while the output-consumption ratio (Y/C) is reasonable, the consumption-capital ratio (C/K) and the output-capital ratio (Y/K) do not appear to be valid. Economic theory states that capital could only produce as much as its production value, which means that the output-capital ratio and the consumption-capital ratio should be less than one. Since the data from both data sources are similar, the unreasonable output-capital and consumption-capital ratios may therefore come from an incorrect estimate of the common factor, capital (k).

According to Holz (2003), the fixed asset definition of China is different from the usual

definition. In China's accounting system, the term "fixed assets" is (guding zichan) denoted as the sum of the following:

- (i) net fixed assets (guding zichan jingzhi);
- (ii) correction to fixed assets (guding zichan qingli) due to, for example, the sale, damage, or decommissioning of the fixed asset;
- (iii) fixed assets under construction (zaijian gongcheng); and
- (iv) unresolved net losses on fixed assets (dai chuli guding zichan jing sunshi).

The first term, net fixed assets, which is the largest component in Chinese "fixed assets", is officially defined as "the difference between the original value of fixed assets (guding zichan yuanzhi) and cumulative depreciation (leiji zhejiu)."

Holz (2003) claims that these non-productive or accounting artifact components in China's definition of "fixed assets" means that the official artifact of "fixed assets" cannot be constituted as a measure of the contribution of physical capital to production, as it will lead to an overestimation of capital value. Therefore, the moments, the output-capital ratio and the consumption-output ratio appear to be invalid in the data, if the official data is used.

According to Holz (2006), the "true" value of physical output cannot be directly computed because of two complications from the original value of the fixed assets measures. First, only a few data points on fixed assets are available for specific enterprise groups of sectors, using different production processes. Second, the series of revaluations in 1990s²³, led an unknown mix of fixed assets valued either at nominal prices or real prices.

Since the value of physical output cannot be directly obtained from the official or the IFS data,

²³ According to Holz (2006), because of rapid inflation in the late 1980s and mid 1990s, in 1993 the government asked state-owned enterprises (SOEs) to revalue all fixed assets purchased before 1991 to market prices. Enterprises were allowed to spread the revaluations over several years if they could not afford to implement them immediately.

this paper uses the estimated “economy-wide fixed asset values”²⁴ in Holz (2003). Using these values as measures of capital, the moments are computed as follows:

Table 3: Corrected Moments for China

Parameter	Estimated Value (Chinese Statistical Year book 2007)	Estimated Value (IFS Data)
Y/C	1.603492	1.638978
C/K	0.288337	0.288337
Y/K	0.452299	0.462002

By using Holz (2003) physical capital estimates, the moments generated from both data sources become reasonable and will be used for the calibration of parameters.

As a comparison, the moments of U.S.²⁵ are also computed and listed below:

Table 4: Moments from U.S. Data

Parameter	Estimated Value
Y/C	1.165203
C/K	0.29011
Y/K	0.3381904

4. Calibration of parameters

4.1. For China

The data used in calibrating the parameters for the time period between 1978-2006 includes: the oil data from the BP Plc Statistical Report 2007, the latest official data published by the NBS China in “China Statistics Year Book 2007”, the population data from the “China

²⁴ This paper chose to use the preferred estimates series of physical capital, “The cumulative approach with non-SOU effective investment values” in Holz (2003), Table 3, under B-C.3 approach.

²⁵ U.S. data is collected from BEA Table 6.3 from the U.S. Department of Commerce, Bureau of Economic Analysis (BEA) website.

Population Statistical Yearbook” for both 1995 and 2005, the IFS data series for China, and the labor share and working hours calculated in Holz (2006).

As mentioned in the previous section, this paper assumes that the most updated version of data published by the NBS China provides the most accurate records for Chinese Macro data.

However, to check the validity of the Chinese Data, IFS data is also collected and compared.

Calibration For Chinese Parameter

Based on the model, the parameter $\theta, \gamma, \delta, \beta$, and ν , the must be calibrated.

Table 5: Summary Table for calibrated parameters for China

Technology Parameter	Description	Calibrated Value	
		Official Data	IFS Data
γ	Growth rate	0.07519	0.07796
θ	Capital Share	0.358436	
$1 - \theta - \nu$	Labor share	0.594979	
ν	Oil share	0.046	
δ	Depreciation rate (Calibrated)	0.079374	0.074846
δ^*	Suggested Depreciation rate	0.046	
h	Working hours per week	0.44	
Oil Shock Variable $z_{2,t} = m_2 + \rho_2 z_{2,t-1} + \varepsilon_{2,t}$			
m_2	constant parameter	0.590315	
ρ_2	AR1 parameter	0.897641	
σ_{2t}	Standard deviation for ε_t	0.267589	
TFP Shock Variable $z_{1,t} = m_1 + \rho_1 z_{1,t-1} + \varepsilon_{1,t}$			
m_1	Constant term	-0.001181	
ρ_1	ARI parameter	0.5079654	
σ_{1t}	Standard deviation for ε_t	0.02407	
Preference parameter			
α	Weight on utility from consumption	0.451623	0.446208
β	Discount factor	0.993018	0.987664
β^*	Discount factor as $\delta = 4.6\%$	0.963324	0.962217

The oil share parameter (ν)

The oil share parameter (ν) is calibrated by the equation: $\nu = \frac{P_o \cdot O}{P \cdot Y}$.

Using either the IFS data or the Chinese Official Data, the calibrated average oil usage ν of China for 1978 - 2006 is 0.046.

The common growth rate (γ)

The growth rate (γ) is the average of the real GDP growth rate, deflated by the Chinese GDP deflator (Year 2000 = 100).

The range of the average real GDP per capita growth rate, based on the IFS data for 1978-2006, is 0.07796.

The range of the average real GDP per capita growth rate, based on the official data for 1978-2006 is 0.07519

The Labor Share ($1 - \theta - \nu$)

The labor share in the production function referred in the model is ($1 - \theta - \nu$), based on table 31 and appendix 32-33, of Holz (2006). The average labor share for 1978-2006 is calibrated as 0.594979.

The Capital Share (θ)

The Capital share in the production function, referred in the models is (θ). Assuming a Cobb Douglas production function, it is calculated as 1 minus the labor share and the oil share.

That is, $1 - (1 - \theta - \alpha_o) - \alpha_o = \theta$. The calibrated capital share is 0.400421

The Depreciation Rate (δ)

The depreciation rate δ is the average of the economy-wide depreciation rate calculated by

using the equation $\frac{c}{k} + \gamma + \nu \frac{y}{k} = \frac{y}{k} + \delta$. The depreciation rate δ calibrated from the IFS data

is 0.074846, and the calibrated value from the official data is 0.079374

However, according to Holz (2006), in the time period from 1978 to 2003, a more realistic

value is 0.046

The working hours (h)

According to Holz (2006), the average working hour from the official average in the 1995, 1% Population Sample Survey is 40.7 hours per week. However, from the Population Statistical Year Book 2005, the working hours in 2001 to 2004 average is 45.4 hours per week. As a convenience, the average, 44 hours per week will be used.

$$\text{Thus, } h = \frac{44}{100} = 0.44$$

The Discount factor (β)

The discount factor is calibrated by the feasibility equation, $\beta = \frac{1 + \gamma}{(\theta \eta_{yk} + 1 - \delta)}$

Using IFS Data and its calibrated depreciation rate, the calibrated β is 0.987664. However, if depreciation rate are set at 4.6%, then the discount factor calibrated is 0.962217.

Using the Chinese Official Data and its calibrated depreciation rate, the discount factor is 0.993018. If the depreciation rate 4.6% as suggested by Holz is used, then the calibrated discount factor is 0.963324.

The Weight on consumption in Utility function (α)

The α is calculated from the optimal labor equation $\left(\frac{1 - \alpha}{\alpha}\right) = (1 - \theta - \nu) \frac{y}{c} \frac{1 - h}{h}$

The calibrated α from the IFS Data is 0.446208.

The calibrated α from the Official Data is 0.451623.

Parameters in the stochastic equations

Oil price shock

Following the assumption in the previous section, the oil price shock in AR(1) process

$$\text{where: } z_{2,t} = m_2 + \rho_2 z_{2,t-1} + \varepsilon_{2,t}$$

$$\text{and: } m_2 = \ln(p_0) \text{ and } |\rho_2| < 1 \text{ and } \varepsilon_{2,t} \sim i.i.d. \quad N(0, \sigma_\varepsilon)$$

The annual oil price data is collected from BP plc Statistical Reports 2007, and converted to Chinese Yuan, deflated by Chinese GDP deflator (2000 = 100). The calibrated parameters are $m_2 = 0.590315$, $\rho_2 = 0.897641$ and $\sigma_\varepsilon = 0.267589$.

TFP shock

TFP shock in AR(1) Process

$$A_t = (1 + \gamma_A)^t e^{z_{1,t}} \text{ Let } : \ln(A_t) = z_{1,t}$$

where : $z_{1,t} = m_1 + \rho_1 z_{1,t-1} + \varepsilon_{1,t}$ and $\varepsilon_{1,t} \sim i.i.d. \quad N(0, \sigma_1^2)$

The TFP data is constructed from the IFS data. The annual data is converted to Chinese Yuan and then deflated by a GDP deflator (2000 = 100). Also, because of its deterministic component, a time-detrended TFP variable has been constructed and used. The calibrated parameters are $m_2 = -0.001181$, $\rho = 0.5079654$ and $\sigma_\varepsilon = 0.02407$.

As shown by the table 5, the official data and the IFS data estimate very close values, which provides a measure of robustness for the data. As they are quite close, the official data is chosen for use in the simulation of the model.

One of the major puzzles in the data is the depreciation rate. The depreciation rate calibrated from the China data using the feasibility equation, is about 0.07 or 7%. However, as suggested by Holz (2006), which has done a thorough analysis and estimated the depreciation rate from the province and state-owned enterprise data of China, the average annual depreciation rate should be 4.6%. Different depreciation rates will calibrate different discount factors β s, since the discount factor from the calibrated depreciation rate is very close to 1. Therefore, the more reasonable depreciation rate 4.6% and its associated beta are being used in the simulation of the models in next section.

4.2. For the U.S.

For the purposes of comparison and sensitivity analysis, similar calibrations using the same methods are done for the United States. Data for the U.S. parameters come from the BEA 6.3 data.

Table 6: Summary Table for calibrated parameters for the United States

Technology Parameter	Description	Calibrated Value
γ	Growth rate	0.02
θ	Capital Share	0.35
$1 - \theta - \alpha_o$	Labor share	0.62
ν	Oil share	0.03
δ	Depreciation rate calibrated	0.017315
δ^*	Depreciation rate suggested	0.05
h	Working hours per week	0.4
Preference parameter		
α	Weight on utility from consumption	0.480016
β	Discount factor calibrated	0.926884
β^*	Discount factor using $\delta = 0.05$	0.955241

A similar problem found in the calibration of China's parameters has the depreciation calibrated by the model to be only 1.7% with a discount factor of 0.92. The widely accepted depreciation rate for the U.S. is 5%, with an associated discount factor of 0.95. For consistency, the 5% depreciation rate and its accompanying discount factor will therefore be used in the later sections to generate simulation and estimation results.

Comparing the two countries' parameters, the differences between the parameters are the

growth rate of the country, which leads to a different discount factor, the different oil usage and the different α , the weight on utility for consumption. I consider the following important questions: Do these differences result in different effect of oil shocks to the countries? How about TFP shocks?

5. Results

5.1. Oil Price Shocks

This section estimates the effect of an one time oil price shock on the economy. The shock is equal in size to the standard deviation of past price shocks, $\varepsilon_{2,t} = 0.27$ calculated previously.

The suggested depreciation rates discussed earlier and their respective discount factors are used for both countries.

Impulse Response Function for oil price shock for China

The following sections describes the response of the different endogenous variables of the model in the presence of a positive oil price shock, which is an initial increase of 27% in oil price with respect to its steady state value, using the parameters of China.

When simulation²⁶ is done for 100 periods and a one-time positive oil shock is inputted at the initial time period, the figure shows that the TFP is not affected, while the consumption drops around 0.7% immediately after the shock is imposed. Consumption continues dropping in the first few time periods, then it starts to converge back to the steady state. It reaches its steady state after 60 time periods. The working hours drops for 0.5% immediately and starts to increase in the next time period. At time period 10, the working hours is higher than the steady state, reflecting the increase in labor as the economy converges back to the steady state.

²⁶ For details of the impulse response function of the positive oil price shock to China, please refer to the figure 14-15 of the full version of this paper, which is located in the San Francisco State University Library.

Working hours converges back around the 25 periods to the steady state after the shock occurs. Capital drops from the initial period about 1.1% in the first 10 periods. After the consumer regains confidence in the economy, capital starts to converge back to its steady state, reaching its steady state around 60 periods. After the shock, oil demand dropped immediately about 24% when the positive price shock is imposed, converging back to the steady state demand in 74 time periods.

The impulse response function²⁷ also show that output drops 1.6% immediately after the oil shocks is imposed converging back to its steady state at about time period 55. Wage also drops about 1.1% right after the shocks, and again converges to the steady state wage in 50 time periods. The cost of capital drops 1.5% right after the oil shocks and starts to increase back in the next time period, at the 6th period after the shocks, the cost of capital is higher than the steady state, reflecting the surging of demand in capital and investment in order for the economy to converge back to steady state. The cost of capital finally converges to its steady state at about time period 50. Investment drops right after the shocks by 3% and converges back to the steady state at around the 50th time period.

Overall, all of the estimated effects of the endogenous variables are aligned with the predicted relationships. In addition, the magnitude of the changes seems reasonable compared to previous studies.

Impulse Response Function for positive oil price shock for U.S.

For the purposes of comparison, the impulse response functions for the U.S.²⁸, under the same

²⁷ For the impulse response function of the positive oil price shock to China, please refer to the figures 16-17 of the full version of this paper, which is located in the San Francisco State University Library.

²⁸ using the U.S. calibrated parameter

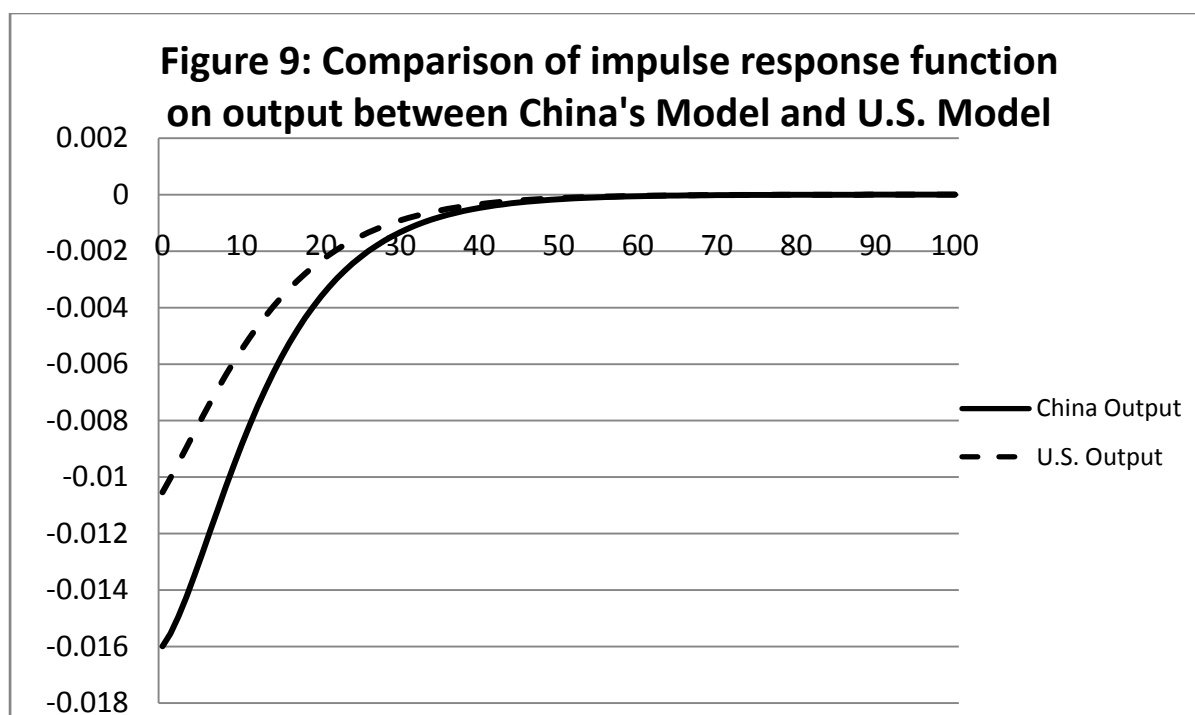
size of a positive oil price shock are also simulated²⁹.

Table 7: Comparison table for a positive oil price shock

Change in Endogenous Variables	China		United States	
	Estimated Effect (%)	Time for convergence in t time periods	Estimated Effect (%)	Time for convergence in t time periods
TFP	0	0	0	0
Consumption	-0.7	60	-0.4	60
Work Hours	-0.5	50	-0.3	50
Capital (max)	-1.1	60	-0.78	60
Output	-1.6	55	-1	52
Wage	-1.1	50	-0.7	55
Cost of capital	-1.5	50	-1	50
Investment	-3.5	30	-3	30
All of the estimated effects are initial effects immediate after an positive oil price shock , except for Capital, which recording the maximum drops of the capital				

From the comparison of the figures generated, the patterns of all the endogenous variables are the same for both countries except for the magnitude of the effects. Generally, China's responses to oil shock seem to have higher estimated effects than the United States.

²⁹ For the impulse response function of the positive oil price shock to U.S., please refer to the figures 18-21 of the full version of this paper, which is located in the San Francisco State University Library.



The comparison of the China and U.S. models and the confirmation for the expected relationship between the oil price shock variable and the other endogenous variables show that the theoretical model suggested in this paper is valid and is able to estimate the dynamic effect of the oil price shocks.

The predictions of the model lead to further questions.

One, what are the effects on the economy if a TFP shock happens at the same time as an oil price shock? Two, does the correlation between TFP shock and oil price shock makes a difference? This question is essential because China had a surge in GDP accompanied by oil price shocks, in 1986 and 2002. Three, what causes the differences between the results of the China Model versus the U.S. model?

In comparing the parameters for both countries, they are generally the same except for the real

GDP growth rate, the oil usage and the weight on utility from consumption.

Table 8: Difference in Parameters between China and U.S.

Difference in Parameters between China and U.S.		
	China	US
Real GDP Growth Rate	7.5%	2%
Oil Usage	4.6%	3%
Weight on Consumption	0.45	0.48

Can their different growth rate of real GDP, which is low GDP growth in US (about 2%) versus the high GDP growth in China (about 7.5%) explain the difference of their estimated effects? Or are the differences of the effects derived from their different level of oil usage? Finally, how about the different weight on consumption?

5.2. Oil price shock and TFP shock

The paper attempts to answer the first and second question by generating the positive TFP shocks and positive oil price shocks together using the model and shocks equal to the historic standard errors – 2.4% of GDP for a TFP shock and 27% of average price for the oil shock. In order to have a yard stick, simulations of impulse response function just for TFP shocks are generated under the China model first and are described below.

Effect on TFP Shocks

Impulse response functions for just TFP Shock

The impulse response function³⁰ shows that a TFP shock effect are similar to a response to a negative oil price shock except that the TFP shock has a larger impact to the economy and also

³⁰ For the impulse response function of the, just, TFP shocks, please refer to the figure 22-25 of the full version of this paper, which is located in the San Francisco State University Library.

positively affects oil demand as shown in the oil demand analytical equation.

Impulse response functions for both positive shocks

This section generates 3 types of simulations on positive oil price shock and positive TFP shock under the China's Model. The first simulation assumes both shocks are independent. The second simulation assumes both shocks are positively correlated and the last simulation in this section assumes that both shocks are negatively correlated. The simulations are illustrated in the full version of this paper.

This sensitivity analysis³¹ shows that the correlation between the two different shocks does not offer much of a difference in the patterns of the effects. The TFP shock dominates the effects in all of the simulations, which aligns with economy theory that suggests that TFP shocks have a more direct effect on the economy. This result seems to explain that because of China's technological growth after the reform period, the effect of the oil price shocks between 1978-2006 were less apparent due to the TFP shocks that China was simultaneously experiencing.

5.3. The different effects from oil price shock to China and U.S. model

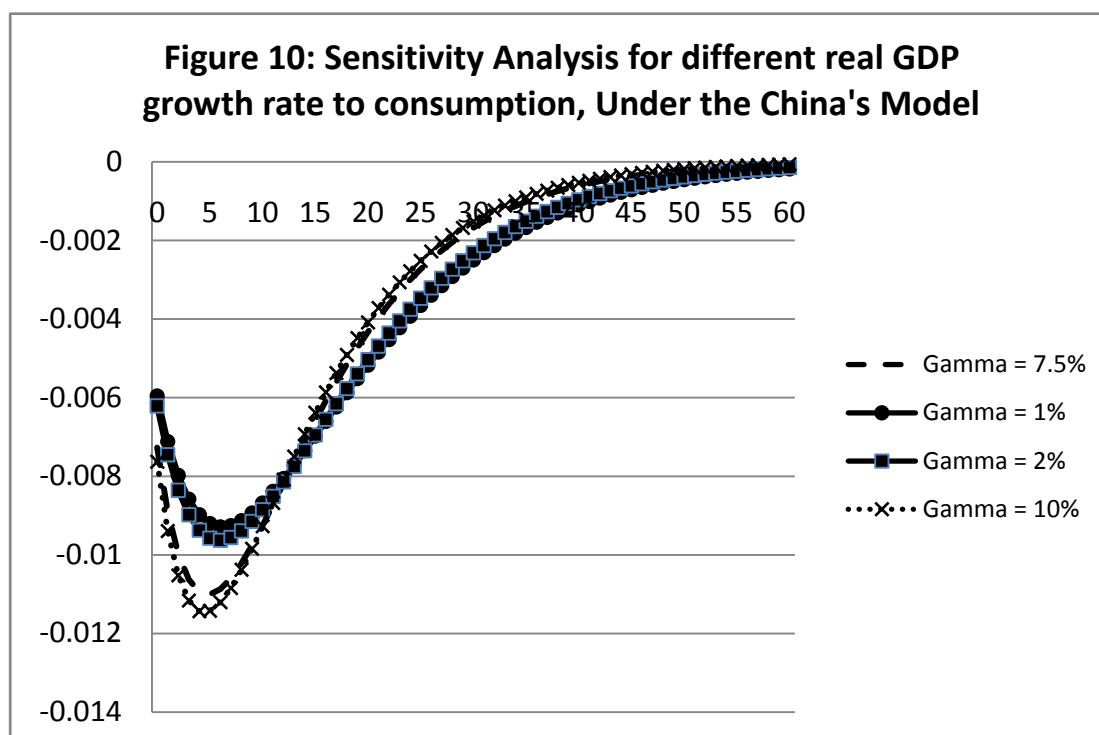
In order to address the third question: Why do the two countries experience different responses to oil price shock? This paper attempts to answer the question by performing sensitivity analysis on their different parameters, the real GDP growth rate and the oil usage, under the China Model, holding all other parameters constant.

5.3.1. Sensitivity Analysis for real GDP growth rate

This section simulates the effect from a one-time oil price shock, a 27% increase in oil price in the initial period, under the China Model with 1%, 2%, 7.5% and 10% real GDP growth rate,

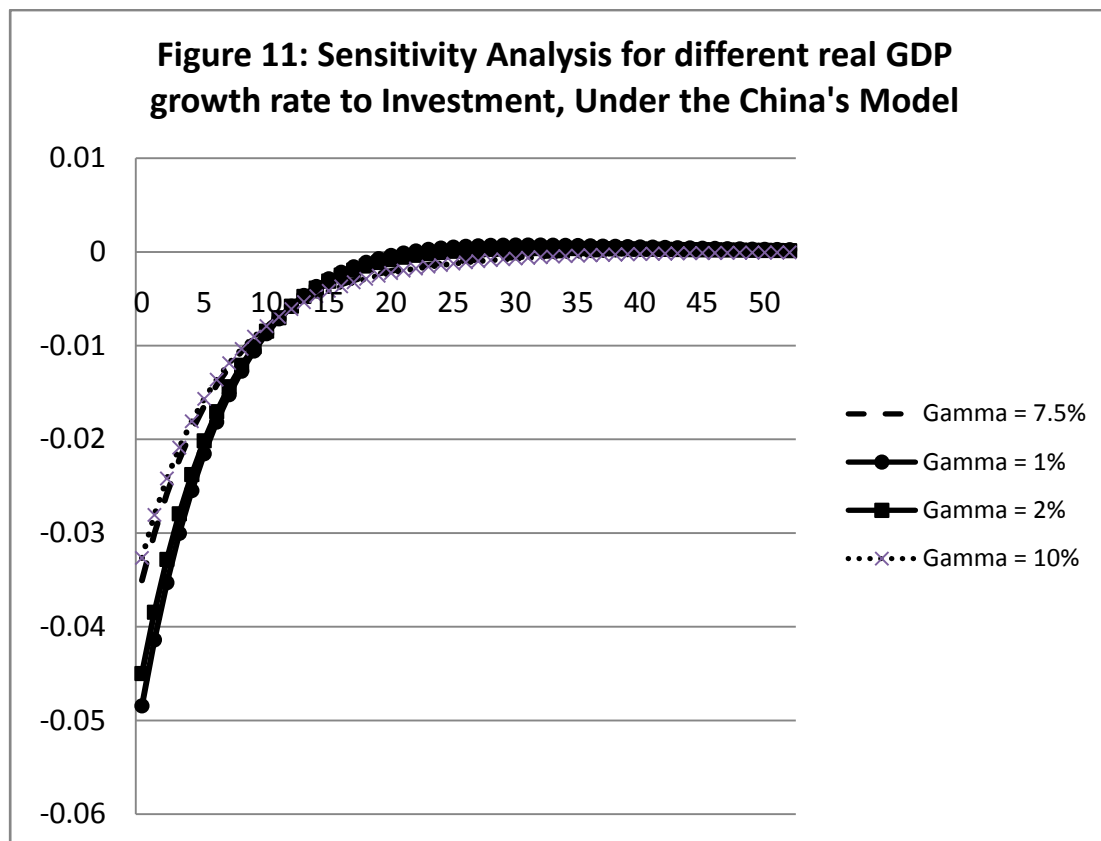
³¹ For details of the sensitivity analysis, please refer to the Figure 26-37 in the full version of this paper, which is located in the San Francisco State University Library.

holding all other parameters constant.³²

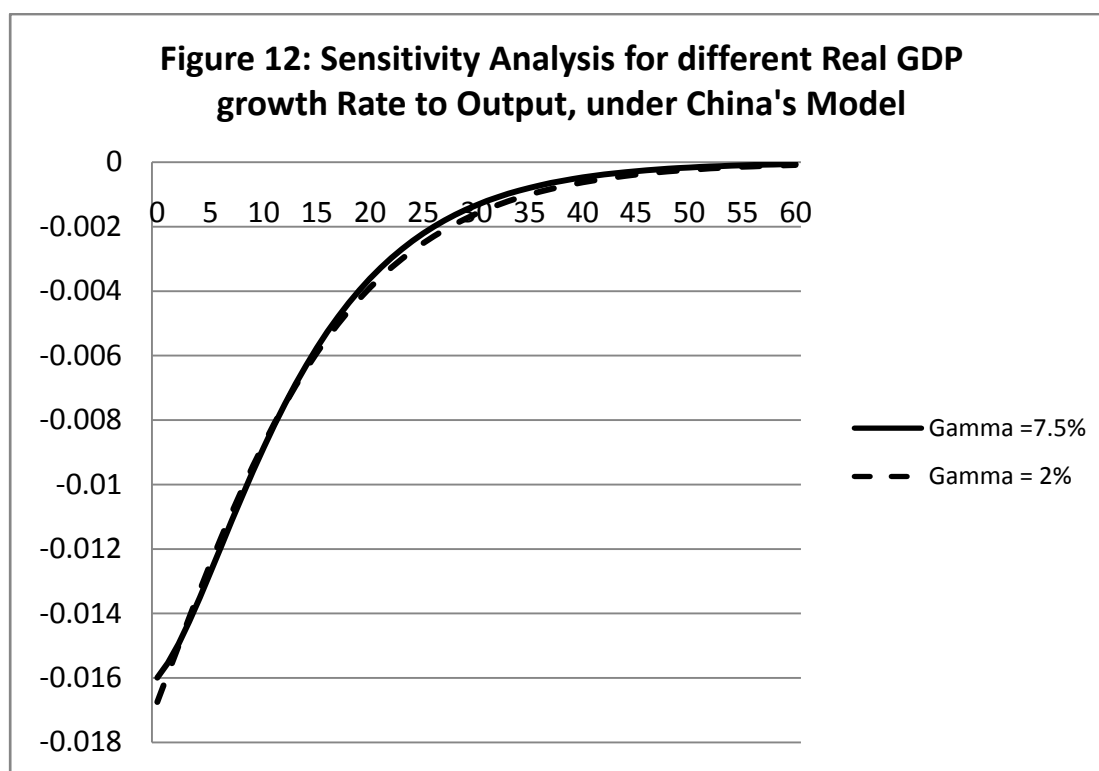


The above graph shows that with higher real GDP growth rate, gamma, the magnitude of the effect on consumption that deviated from the steady state is higher, and it converges to its steady state at a faster rate. The economic intuition is that when people are expected to have a higher income in the future, they will care less about the smoothing of their consumption under the shock. However, with higher real GDP growth rate, the opposite effect happens on investment, which is shown in the graph below. The economic intuition for investment is that when people expect their income grow quickly, they tend to smooth their investment more, in other words, they invest less compared to people in economies with slower growth.

³² For detailed results, please refer to figure 38-45 in the full version of this paper, which is located in the San Francisco State University Library.



Since the output of the economy is equal to the consumption plus investment, $y = c + x$, the combined effect of the consumption and investment offset each other, and creates only a slight change in the real output, which is shown in the figure 12 below.



This sensitivity analysis on real GDP growth rate under the China model, therefore shows that the real GDP growth rate is not able to explain the difference in output between the U.S. and China model under the same oil price shock.

5.3.2. Sensitivity Analysis for oil usage

This section simulates the effect from a one-time oil price shock, a 27% increase in oil price in the initial period, under the China Model with 3% oil usage (US oil usage) and 4.6% oil usage (China Oil Usage), holding all other parameters constant.

Impulse Response Functions for China's Output with different oil usage

Holding other parameters constant, the simulation on output under different oil usage parameters, 3% (US oil usage) and 4.6% (China Oil Usage), in the China Model is shown below³³. Using the China model, if the oil usage is assigned at 3%, the U.S. oil usage, holding other parameters constant, the model simulates the exact effect that the U.S. model experienced in the previous section.

³³ For detailed results, please refer to figure 46-49 in the full version of this paper, which is located in the San Francisco State University Library.

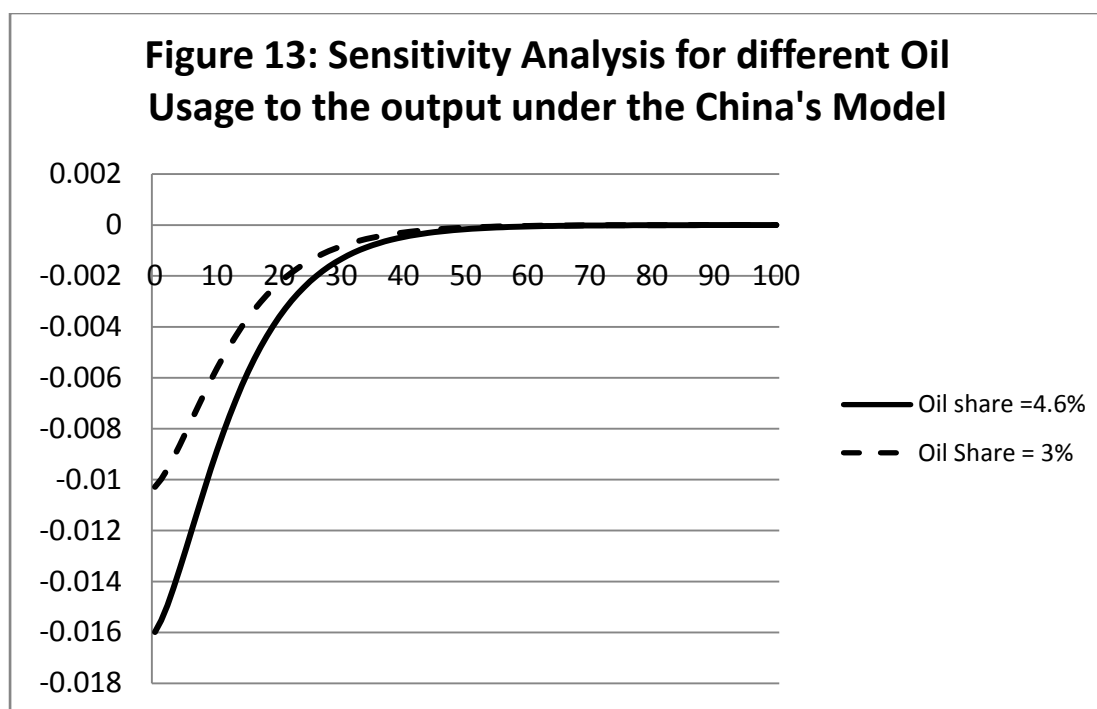


Figure 13 shows that the difference in oil usage between China and the U.S. Models is able to explain the difference in the magnitude, of effects on output between the China and U.S. find in the earlier analysis of an oil price shock.

To summarize the results, these sensitivity analyses show that although the different real GDP growth rates between the China and the U.S. model are responsible for the difference in the consumption and investment between the two countries models, the different real GDP growth rate only leads to a slight difference in the output under the same oil price shock. The difference in oil usage, on another hand, is responsible for the difference in the output when the two countries experience the same oil price shock.

6. Strengths and Weaknesses for the paper

Strengths

The effect of oil shocks to China's GDP has not been asked before and this paper has answered this question using a DSGE model. This paper uses a simple and direct method, under a

Cobb-Douglas assumption and perfect competition assumption, to obtain the oil share parameter, then it employs a DSGE model to estimate the exogenous effect of oil price shock on China's output. This DSGE model can capture the dynamic effect of the oil price shocks, whereas, econometric models cannot.

The estimation results are encouraging since all the endogenous variables responded as theory expected. As the same methodology is applied to both developing countries and developed countries, the result allows a direct comparison between China and the U.S. responses to oil shocks.

Another strength for the DSGE model is that the TFP shock can also be added to the model and the effects can be estimated along with an oil price shock with different correlation effects between the shocks. The results also align with the theory's expectation that the TFP shocks will dominate among the shocks effect. This also helps to explain why oil price shocks have not found to have a major impact on China's macro-economic performance.

Moreover, the model in this paper also has an advantage in allowing sensitivity analysis for different real GDP growth rate and oil usage. Given the same oil price shock to models of U.S. and China, different effects on the magnitude of the endogenous variables have been generated in the models. By imposing different real GDP growth rate and different oil usage to the China Model, this paper concludes that the difference in real GDP growth rate of an economy may be able to explain the different effect from oil price shock on consumption and investment. But the different oil usage rates are responsible for the difference in the shock effects on output. More advanced computational technique in generating the confidence intervals can be added in this model to give more detailed results. This result is useful in explaining why different countries

respond differently to oil shocks.

Weaknesses

Many questions suggested by the literature are not answered in this model. For example, with the surge of oil demand in the 2007 and 2008, can oil price classified as exogenous? Is oil a complement of capital in the production function or is it a substitute? Should the novel relationship suggested by Finn (2000), that is “between energy usage and capital services energy is essential to obtaining the service flow from capital, and then capital services as a factor for the economy” be included in the oil analysis? Is the assumption of perfect competition valid for the model of oil? Also, should the depreciation rate be set as the widely accepted rate or should the model use the rate that was calibrated by the model? Is the inelastic labor supply a better assumption in the case of China?

The data issue in China is another weakness of this paper. Although this paper treats the Chinese data with care, the reliability of the Chinese data is still questionable. Different definition of physical capital in China and the difference between the nominal GDP of the official data and the IFS data are not fully resolved in this paper.

7. Conclusion

This paper uses a DSGE model to estimate the effect of oil price shocks on China’s output. Using the model, the paper estimate that a 27% positive oil price shock will reduce about 1.6% of the real GDP of China. It also captures the dynamic effects of other endogenous variables in the economy, such as consumption, capital, labor hours, wages, cost of capital, and investment. The result is encouraging as the patterns of the simulation are as expected by the theory. This paper also demonstrated that when a positive TFP shock is also present with an oil price shock

in the same time period, the TFP shocks will dominate the shocks effects to the economy no matter what the correlations between the shocks. Moreover, this paper also discovers that the difference of the real GDP growth rate between a developing country and a developed country may be able to explain the difference of the oil price shock effect on the consumption and investment, whereas the different rates of oil usages between the countries are responsible for the differences of the shock effects on the real output of the economies.

Further research in the field of oil on China can attempt to investigate issues such as: the inelastic labor supply as a better assumption for the Chinese oil model, the consequences of government and international (import and export) components added into the DSGM model for China, the differences in effects if the novel relationship suggested in Finn (2000) is included in the model, differences if a monetary shock is included in the Chinese model. In addition, empirical research can also investigate such as: the effect of oil shocks towards China's labor supply or the effect of oil shocks on the urban area of China versus the rural area of China.

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