國立臺灣大學社會科學院經濟學系在職專班

碩士論文

Mid-Career Master Program

Department of Economics

College of Social Sciences

National Taiwan University

Master Thesis

以動態一般均衡模型評估石油稅對台灣經濟之影響

The Impact on Oil Tax of Taiwan: A Dynamic Stochastic General Equilibrium Model Approach

黃孝怡

Hsiao-Yi Huang

指導教授：林建甫博士

Advisor: Chien-Fu Lin, Ph.D.

中華民國 102年 1月

January, 2013

Content

List of Figures

List of Tables

國立臺灣大學 · 敦品勵學 · 愛國愛人

誌謝

本文得以完成，主要感謝指導教授林建甫教授的辛勤指導，林建甫教授兩年來以言教與身教引領我進入經濟學的領域,林老師恢宏的視野與深刻的學術涵養永遠是我們所追尋的目標。在口試過程中，感謝政治大學經濟系翁永和教授、台灣海洋大學海洋事務與資源管理研究所莊慶達教授和台灣師範大學環境教育研究所葉欣誠學長的對於本文的精闢建議與寶貴意見,使本文能夠更為充實。尤其感謝亦師亦友的葉欣誠學長，在此也祝葉教授在環保署副署長的任內政躬康泰。

轉換跑道進入智慧財產局從事專利審查工作以來，由於專利審查業務的複雜與專業性，不可避免的需要長官與同仁的指導與協助,尤其是本科的杜科長在國、負責複核新進人員審查意見的耀文與人傑學長，以及其他的同事與先進,感謝他們平時對我的照顧與協助,使我在工作上能夠減少許多錯誤，讓我能有足夠的時間與心力完成在職班的課業。

最後，由於銘揚同學的鼓勵,美絨、藝閒同學的協助,使論文與口試可以順利完成，在此一併感謝。

摘要

本文試圖以發展並估計一個新凱恩斯動態隨機一般均衡模型以探討石油稅對台灣經濟的影響。本文主要依循 ChristianoChristiano、Eichenbaum and Evans(2005）、Ireland (1997) 與 Peersmanand Stevens (2012)發展的模型，模型的結構參數以 Bayesian 方法估計，模型構建假設調整工資的頻率較少。在此模型中，石油作為生產的輸入，也是消費的一部分，石油和其他類型的消費產品之間有靈活的替代彈性。我們並模擬具有石油稅時動態隨機一般均衡模型的結果並和比較根據不同的石油稅率假設時動態隨機一般均衡模型的結果。

本文的主要結果是生產要素的衝擊，消費者偏好衝擊，工資調整成本衝擊將立即引起輸出和附加價值的生產消費的提升。資金利用率造成輸出的提升導因於的勞動量的改變。價格調整成本衝擊、石油價格衝擊將升通貨膨脹和減緩消費。利率調整的成本衝擊將使輸出和附加值商品下降。石油稅會影響消費者的偏好並加強價格調整的負面影響，石油稅也將減少工資調整的效應、消費和生產。不同石油稅率造成的估計衝擊沒有明顯的不同。在政策的意義上來說，石油稅可能會降低石油的消費量並衝擊經濟成長，但不同類型的石油稅間不會有明顯的差別。

關鍵字：New Keynesian、DSGE 模型、石油稅

Abstract

This paper is an attempt to develop and estimate a New Keynesian dynamic stochastic general equilibrium model of Taiwan. In this paper, the model is following Christiano, Eichenbaum and Evans(2005), Ireland (1997) and Peersman and Stevens (2012).The structural parameters of this model are estimated by using a Bayesian approach and the model is constructing by being assumed to adjust wages infrequently. Oil is used as an input to production and is also a part of the household's consumption in this paper.There is a flexible elasticity of substitution between oil and other types of consumption goods in the consumption bundle. We also simulate the DSGE model including oil tax and compare the results under various oil tax rules.

The main results of this paper are the production factor shock, consumer preference shock, wage adjustment cost shock will immediately rise output and the value-add production consumption. The capital utilization shock will rise output due to the raise of number of labor. The price adjustment cost shock, oil price shock will rise inflation and fall consumption. The interest rate adjustment cost shock will fall output and added-value goods.Then the oil tax will affect the consumer preference and strengthen the negative effects of price adjustment, and the oil tax will reduce the effects of wage adjustment, the consumption and production. The estimated impulses between the oil tax rule which the amount of oil tax is proportion to oil price and the oil tax rule which is that the amount of oil tax is proportion to the amount of oil are not obviously different.

The main contribution of this paper is that we simulate how the exogenous shocks would affect macroeconomic by using the estimated DSGE model. And the numerical results show that the variables are not substantially affected by the presence of nominal rigidities. This paper also aims to explore the complications of the effects between these exogenous shocks. The suggestions of this paper are followings. First, the oil tax would reduce oil consumption and impact economic growth. Second, the effects of different types of oil tax are not obviously different.

Keywords：New Keynesian, DSGE model, oil tax

Chapter 1 Introduction

1.1 Oil and Macroeconomic

The macroeconomic effects of oil include oil price and oil consumption. Oil can usually be used for several applications. Petrolasconsumption goodscan be used as fuel and oilas production goods can be usedas raw materials forpetrochemical industries.Oil price fluctuations are usually treated as a exogenous disturbances where are unrelated to any economic fundamentals (Peersman and Stevens, 2012). Sudden and protracted oil price increases are generally accompanied by economics contractions and high inflation (Hamilton, 1983).Researchers and policymakers are often interesting in the impacts of oil price shocks on output and the effects related to the endogenous policy responses of monetary policy and tax policy.Changes in oil prices have a direct impact on the price level of the economy, they affect consumption decisions, and also influence the cost structure of firms and through this channel have a second-rounded effect on domestic prices. Wage and price indexation can propagate the effects of oil-price shocks on inflation and output. Recent empirical studies have revealed that the effects of oil shocks became muted after the mid-1980s. These studies obtained similar conclusions: the typical response to an oil shock is a decrease in the real GDF growth rate and real wage, leading to inflation and so on. (Hongzhi, 2010).

In general, oil tax would induce the rising of oil price and inflation. The contractionary effect of oil price shock can be due to the endogenous tightening of the monetary policy.However,oil tax would induceoil consumption and carbon dioxide emissions, so it is important for energy saving and carbon reduction.

1.2 DSGE model

The function of a model of analysis and simulation for economy is twofold : to serve as a tool for policy analysis and to serve as a tool for forecasting key macroeconomic variables (Medina an Soto, 2011). Not only the first-round effects of different shocks can be understood but also second-round effects can be considered.In the past, general economic forecasting models of business cycle are in the form ofsimultaneous-equations structural models. The linear structures of these models are as the same as the Vector Autoregressive model. So the Vector Autoregressive model is used to be as the main analytic tool for economic forecasting. However, there are some of the following problems: first the correct number of variables needs to be excluded, and second the projected future values are required for the exogenous variables in the system.

One of advantages of the model is that the structural interpretation of the disadvantage of the Luca's critique on the traditional analysis of policy effects (Medina and Soto,2006)(Liao and Teng, 2008). Lucas(1976) indicated that estimated functional forms obtained for macroeconomic models in the Keynesian tradition and the Vector Autoregressive model do not correctly account for the dependence of private agent's behavior on anticipated government policy rules. The famous "Lucas critique"pointed out:

"Given that the structure of an econometric model consists of optimal decision rules of economic agents, and that optimal decision rules vary systematically with changes in the structure of series relevant to the decision maker, it follows that any change in policy will systematically alter the structure of econometric models."

Relatively, DSGE models can handle both the possibilities of structural changes and the problems of nonlinearities, since DSGE models are able to identify that the actions of rational agents are not only dependent on government policy variables, but also on government policy rules (Liu and Gupta, 2007). The purpose of DSGE models is to interpret how the microeconomic principles derive aggregate economic phenomena including business cycles, economic growth, and the effects of monetary and fiscal policy. Figure 1.1 shows the typical structure of a DSGE model. DSGE models also study how the economy evolves over time and how the economy is affected by random shocks such as technological change, fluctuations in the price of oil, or macroeconomic polices. The decision-makers in DSGE model, often called 'agents', may include households, firms, and governments or central banks and DSGE models are constructed on the basis of assumptions about agents' preferences. There are two issues considered in DSGE models: one is that it is possible to ask whether the policies considered are Pareto optimal, another is or how well agents satisfy some other social welfare criterion derived from preferences. In recent years, the DSGE model has been the baseline framework used for theoretical analysis of monetary policy and tax policy.

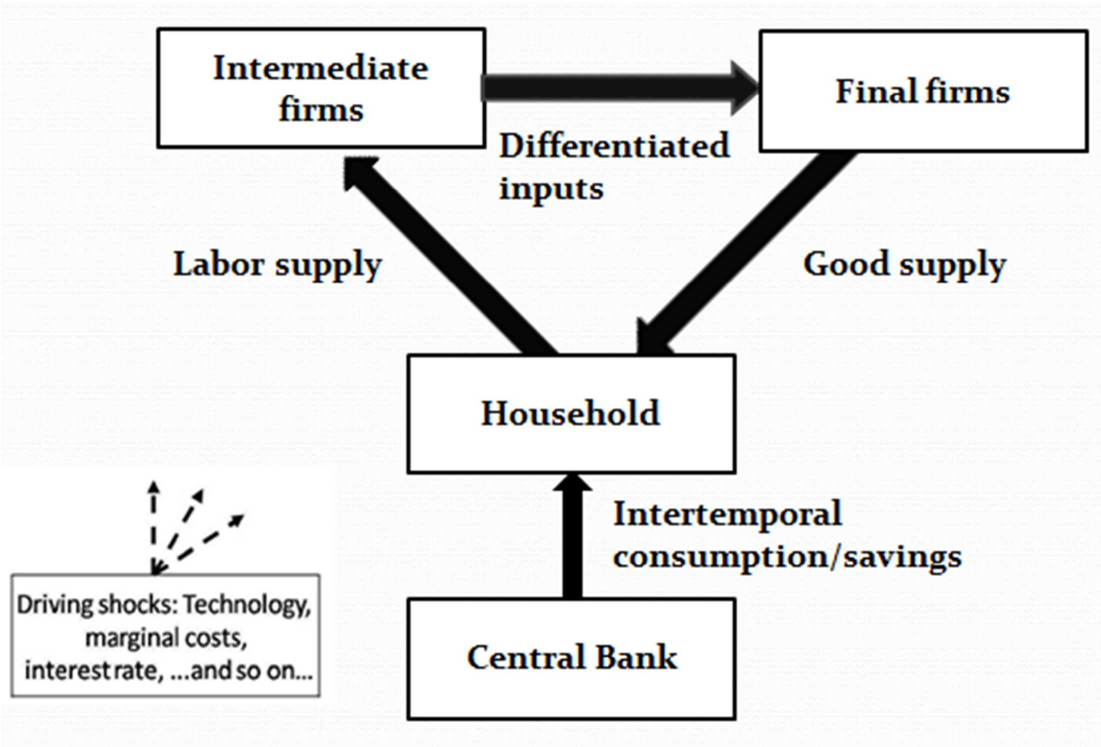

Fig 1.1 The structural chart of a DSGE model

The DSGE model is the best decision of households' utility and firms'profit in different constraints. But the original DSGE model is nonlinear so that it will be log-linearized to obtain a linearized steady state model. Then the first order Taylor's expansion of a DSGE model will be transfer to simultaneous equations. The deviations of endogenous variables, which be obtained by solving the simultaneous equations present the fluctuations of endogenous variables. In fact, there are many uncertainties in real economic environment and these uncertainties could be presented by applying exogenous shocks.

The hypotheses of the RBC-DSGE model includes rationalexpectation, perfect elasticity of wage and price, and the market is clean. However, the hypotheses of the new Keynesian DSGE model includes rational expectation, nominal rigidityof wage and price, and the market is not always clean. There are three methods for estimating the structural parameters of a DSGE model: calibration, maximum likelihood estimation and Bayesian estimation. And the log-linearized model of the DSGE model can be solved by Blanchard and Kahn method.

1.3 Oil Tax and DSGE model

The DSGE model has been used to analyze these issues for several countries' economic model in some literatures. The model is framed in the New Keynesian assumption where firms are assumed to adjust prices infrequently and wages are set. Oil is used as an input in production and also a part of the technology used by domestic firms. The oil-price shock can generate an income effect that affects consumption and labor decisions. It also affects the marginal costs faced by domestic firms and through this channel, their pricing decisions. As well as, monetary policy modeled as a Taylor's rule endogenously reacts to the movements in inflation and output caused by the oil-price shock. There are several DSGE models related to oil-price, including Smets and Wouters(2003), Liu and Gupta (2007), De Fiore and Beidas-Storm and Poghosyan (2009), Unalmis and Unsa (2009), and Hongzhi (2010)in recent decades. The DSGE model including oil -price let us better understand the mechanisms through which oil-price shocks affect inflation, output and the endogenous responses of monetary policy. We can make policy analysis overcoming the Lucas Critique by using this methodology approach. In this paper, we present the dynamic stochastic general equilibrium model (DSGE model) which is the model of Taiwanese economy. The main building blocks of the model will be described and the results of the estimation of key parameters will be discussed.

1.4 Literature review

Many central banks set monetary policy which means interest rates by operating directing on bank reserves to achieve lower prices and stable inflation. In order to carry out this job, many central banks have used a variety of macroeconomic models to understand what drive inflation and how changes in monetary policy feed through the economy into inflation.

In the 80's, Hamilton (1983) provided sudden and protracted oil price increases are generally accompanied by economics contractions and high inflation. An important factors to drive inflation is oil prices. As the rise in oil prices from $75 a barrel in 2007 Q3 to $121 a barrel in 2008 Q2 was associated with a rise in CPI inflation from 1.8% in 2007 Q3 to 4.8% in 2008 Q3. Millard (2011) estimated a DSGE model of the United Kingdom, the model was estimated using Bayesian techniques on data for the period 1996 Q2 to 2008 Q4.

De Fiore, Lombardo and Stebunovs(2006)built a DSGE model characterized by two oil importing countries and one oil-exporting country and evaluated the performance of simple Taylor-type interest rate rules when the economy is hit by oil price shocks and calibrated the model. Unalmis et al. (Unalmis, Unalmis and Unsa, 2009) develop a strickly-price DSGE model through which they analyze the effects of various shocks, namely, the increase in aggregate demand,unexpected oil supply disruption and the precautionary oil demand on an oil importing small open economy and on the rest of the world. The study shows the impacts of the productivity and fiscal policy shocks which leading to a rise in the world aggregate demand and a subsequent surge in the real price of oil are different on inflation.

Because the oil-importing country is a standard new Keynesian economy model, the structure of the economy is closely related to the closed economy models of Christiano, Eichenbaum and Evans(2005) and Smet and Wouters(2003). Peersmanand Stevens (2012)developed and estimated a structural model of US and oil producing countries including a well-specified oil market in which oil prices are endogenously determined.

By investigating the dynamics induced by the various oil shocks, the results which show the real oil prices fluctuations are mostly exogenous with respect to US macroeconomic developments. Beidas-Storm andPoghosyan(2009) presented and estimated a small open economic DSGE model for the Jordanian economy. The model features nominal and real rigidities, imperfect competition and habit formation in the consumer's utility function, and oil imports are explicitly modeled in the consumption basket and domestic production. This study used Bayesian methods to estimate the model, by combining priors and the likelihood function to obtain the posterior distribution of structural parameters. Golosov, Hassler, Krusell,and Tsyvinski(2011) analyze a DSGE model with an externality through climate change from using fossil energy. The results of this study is an analytical derivation of a simple formula for the marginal externality damage of emissions. The formula allows the optimal tax to be easily parameterized and computed.

1.5 Structure of the paper

This paper is an attempt to develop and estimate a New Keynesian dynamic stochastic general equilibrium model of Taiwan. In tis paper, following Christiano, Eichenbaum and Evans(2005), Ireland (1997) and Peersman and Stevens(2012).The structural parameters of this model are estimated by using a Bayesian approach and the model is constructing by being assumed to adjust wages infrequently.Oil is used as an input to production and is also a part of the household's consumption.

The rest of the paper is organized as follows: Chapter 2 presents the basic structure of the DSGE model. Chapter 3 describes the basic theorems of numerical simulation and parameter estimations of the DSGE model. Chapter 4 studies the effects of different economic shocks to the DSGE model. Chapter 5 discusses the influences of oil tax on the DSGE model and the main results are explained in chapter 6.

Chapter 2 The DSGE model

The dynamic stochastic general equilibrium （DSGE）model with the Keynesian rigid prices assumption was used in the real business cycle to lie at the heart of the workhorse New Keynesian models of macroeconomics analysis. By log-linearizing the first-order conditions of optimizing households and firms they allow to handle small and mid-scale models with excellent predictive properties. DSGE models are also used in macroeconomics forecasting.

2.1 Household

Households obtain utility from consuming the final goods C_t and disutility from supplying hours of labor N_t and M_t corresponds to the total nominal balances held at the beginning of period t. Households own the capital stock and make investment and capital utilization decisions.

Household's lifetime utility function

$$E_0\sum_{t=0}^{\infty}\beta^t\left\{b_t[\frac{\sigma}{\sigma-1}(C_t-hC_{t-1})^{\frac{\sigma-1}{\sigma}}+\frac{\gamma}{\gamma-1}\left(\frac{M_t}{P_t}\right)^{\frac{\gamma-1}{\gamma}}-\frac{\phi}{\phi+1}(N_t)^{\frac{\phi}{\phi+1}}]\right\} \tag{2.1}$$

E_o denotes the rational expectation operator using information up to time *t=0*, $\beta\in[0,1]$ is the discount factor. The utility function displays external habit function, $b\in[0,1]$ denotes the importance of the habit stock, which is the last period's aggregate consumption. $\sigma>0$ capturesintertemporal substitution attitudes of households and $\phi>0$ is the elasticity of the labor supply which respect to the real wage and $\gamma>0$ is the interest rate elasticity of the monetary demand which respect to the real wage. Preferences display habit information, whose strength is measured by the parameter *h*.

The consumption bundle is a composite of core (non-fuel) consumption goods and imported fuel:

$$C_t(j)=\left\{(1-\delta)^{\frac{1}{\eta}}C_{Z,t}(j)^{\frac{\eta-1}{\eta}}+\delta^{\frac{1}{\eta}}C_{O,t}(j)^{\frac{\eta-1}{\eta}}\right\}^{\frac{\eta}{\eta-1}} \tag{2.2}$$

where $C_{O,t}$ represents fuel consumption, and $C_{Z,t}$ is a bundle non-fuel consumption. The parameter η is the elasticity of substitution between oil and core consumption, and δ defines their corresponding share. Households maximize their utility subject to the following budget constraint:

$$C_t^j + I_t^j + \frac{B_t^j}{P_t R_t} + \frac{M_t^j}{P_t} = \frac{M_{t-1}^j}{P_t} + \frac{B_{t-1}^j}{P_t} + \frac{W_t^j}{P_t} + \frac{1}{P_t}[R_t^k u_t - P_t f(u_t)]K_t^j + \frac{T_t^j}{P_t} + \frac{Div_t}{P_t} \tag{2.3}$$

where I_t^j denotes investment expenditure, W_t^j is the nominal wage, B_t^j denotes holdings of a riskless bond that costs the inverse of the gross nominal interest rate ($R_t > 1$) and pays one unit of currency next period. T_t^j denotes nominal transfers from (or lump-sum taxes paid to) the government, K_t^j denotes holdings of the capital stock, u_t denotes capital utilization rate and R_t^k is the rental rate which households rent capital to the firms that produce intermediate goods, Div denotes dividends that intermediate firms pay to households. And $[R_t^k u_t - P_t f(u_t)]K_t^j$ is the rent of the net capital.

Household's capital accumulation equation is

$$K_{t+1} = (1-\delta_K)K_t + (1 - S(\frac{z_t I_t}{I_{t+1}}))I_t \tag{2.4}$$

where δ_k is capital deprecation rate, $S(\frac{z_t I_t}{I_{t+1}})$ is investment adjustment cost and $S(\frac{z_t I_t}{I_{t+1}}) = S^{'}(\frac{z_t I_t}{I_{t+1}}) = 0$ in steady state.

The following is a Langrange function including representative household's utility and budget constraint.

$$V = E_0 \sum_{t=0}^{\infty} \beta^t \left\{ \begin{array}{l} b_t[\frac{\sigma}{\sigma-1}\left(C_t - hC_{t-1}\right)^{\frac{\sigma-1}{\sigma}} + \frac{\gamma}{\gamma-1}\left(\frac{M_t}{P_t}\right)^{\frac{\gamma-1}{\gamma}} - \frac{\phi}{\phi+1}\left(N_t\right)^{\frac{\phi}{\phi+1}}] - \lambda_t[P_t(C_t^j + I_t^j) + \frac{B_t^j}{R_t} + M_t^j - M_{t-1}^j \\ - B_{t-1}^j - W_t^j N_t^j - [R_t^k u_t - \Psi(u_t)]K_{t-1}^j - T_t^j - Div_t] - Q_t[K_{t+1} - (1-\delta_I)K_t - (1 - S(\frac{z_t I_t}{I_{t\_1}}))I_t] \end{array} \right\}$$

(2.5)

And we can obtain first order condition of by maximizing the Langrange function.

$$\frac{\partial V}{\partial C_t} = b_t (C_r - hC_{t-1})^{\frac{-1}{\sigma}} - \lambda_t P_t = 0 \tag{2.6}$$

$$\frac{\partial V}{\partial (\frac{M_t}{P_t})} = b_t (\frac{M_t}{P_t})^{\frac{-1}{\sigma}} + \beta P_t E_t \{\lambda_{t+1}\} - \lambda_t P_t = 0 \tag{2.7}$$

$$\frac{\partial V}{\partial B_t} = \beta E_t \{\lambda_{t+1}\} - \frac{\lambda_t}{R_t} = 0 \tag{2.8}$$

$$\frac{\partial V}{\partial K_t} = \beta E_t \{\lambda_{t+1} (R_{t+1}^k u_{t+1} - f(u_{t+1})) + P_{t+1} Q_{t+1} (1-\delta)\} - \lambda_t P_t Q_t = 0 \tag{2.9}$$

$$\frac{\partial V}{\partial I_t} = Q_t (1 - S(\frac{z_t I_t}{I_{t-1}})) = 1 + Q_t S^{'} (\frac{z_t I_t}{I_{t-1}}) \frac{z_t I_t}{I_{t-1}} - \beta E_t \{Q_{t+1} \frac{\lambda_{t+1}}{\lambda_t} \frac{P_{t+1}}{P_t} S^{'} (\frac{z_{t+1} I_{t+1}}{I_t}) \frac{z_{t+1} I_{t+1}}{I_t} \frac{I_{t+1}}{I_t}\} \tag{2.10}$$

$$R_t^k = P_t f^{'}(u_t) \tag{2.11}$$

where Q_t is Langrange multiplier and it means the value of capital investment. Calvo(1983) claimed the assumptions of fully flexible prices and wages are sometimes inconsistent with some empirical evidences on prices and wage adjustment. The Calvo model assumes that there is a fixed probability $1-\xi_w$ that a household canre-optimize its nominal wage in each period.In the constraint of aggregate demand for labor is

$$N_t = (\int_0^1 N_t(j)^{\frac{\theta_t^w - 1}{\theta_t^w}} dj)^{\frac{\theta_t^w}{\theta_t^w - 1}} \tag{2.12}$$

, the labor demand of the household j is

$$N_t(j) = (\frac{W_t(j)}{W_t})^{-\theta_t^w} N_t \tag{2.13}$$

,where $N_t(j)$ is the demand of the jth labor, $W_t(j)$ is the price , W_t is the wage and θ_t^w is the wage elasticity of the labor demand. The aggregate wage is

$$W_t = [\int_0^1 W_t(j)^{1-\theta_t^w} dj]^{\frac{1}{1-\theta_t^w}} = [\xi_w(\pi_{t-1}W_{t-1})^{1-\theta_t^w} + (1-\xi_w)W_t^{*1-\theta_t^w}]^{\frac{1}{1-\theta_t^w}} \tag{2.14}$$

where W_t^* is the optimum wage,

$$W_{t+1} = \begin{cases} \pi_t\pi_{t+1}......\pi_{t+k-1} & k \geq 1 \\ 1 & k = 0 \end{cases}$$

A household choose the optimal wages to maximize the real value of the sum of utility from period t to period $t+k$:

$$\max E_t \sum_{k=0}^{\infty} (\beta\xi_w)^k U(C_{t+k/t}, \frac{M_{t+k/t}}{P_{t+k/t}}, N_{t+k/t}) \tag{2.15}$$

And the first order condition is

$$\max E_t \sum_{k=0}^{\infty} (\beta\xi_w)^k E_t \left\{ N_{t+k} U_t \left(\frac{W_t^*}{P_{t+k}} X_{tk} + \mu_{t+k}^w \frac{-b_{t+k} N_{t+k}^{\frac{1}{\phi}}}{b_{t+k}(C_{t+k} - hC_{t+k-1})^{\frac{-1}{\sigma}}} \right) \right\} = 0$$

where $\mu_{t+1}^* = \dfrac{\theta_{t+k}^w}{\theta_{t+k}^w - 1}$ . . (2.16)

2.2 Firms

The firms of a country which is a gross oil importer produce non-oil goods. Intermediate goods producers combine oil with other input factors in the production process of non-oil goods. Each of these different type of goods is produced by a single firms, which faces monopolistic competition.

2.2.1 Final firms

The production function of the final goods producers is

$$Y_t = \left(\int_0^1 Y_t(i)^{\frac{\theta_t^P - 1}{\theta_t^P}} di \right)^{\frac{\theta_t^P}{\theta_t^P - 1}} \tag{2.17}$$

θ_t^P is the variable demand elasticity. The aggregate demand of the ith intermediate input goods for final goods producers from maximizing final goods profits is

$$Y_i(i) = \left(\frac{P_t(i)}{P_t} \right)^{-\theta_t^P} Y_i \tag{2.18}$$

substituting (2.17) into (2.18) to obtain the relation between the prices of intermediate goods and the prices of final goods:

$$P_t = \left(\int_0^1 P_t(i)^{\theta_t^P - 1} di \right)^{\frac{1}{1-\theta_t^P}} \tag{2.19}$$

2.2.2 Intermediate firms

The technology of the intermediate firm is given by production function

$$Y_t^i = \left(\eta_t^{\frac{1}{\alpha}} (VA_t^i)^{\frac{\alpha-1}{\alpha}} + (1-\eta_t)^{\frac{1}{\alpha}} (O_{gt}^i)^{\frac{\alpha-1}{\alpha}} \right)^{\frac{\alpha}{\alpha-1}} \tag{2.20}$$

with $\quad VA_t^i = \varepsilon_t^{TFP} (N_t^i)^{\theta} (K_t^{S,i})^{1-\theta}$

,where VA_t is the value added output, O_{gt} is oil, $\alpha > 0$ defines the elasticity of substitution between value-add and oil in production, θ captures the share of labor in GDP, η_t represents the share of the added-value production factors in gross output, and ε_t^{TFP} is the total factor productivity.

The following demand curves for labor and oil are implied by cost minimization:

$$\hat{n}_t = -(\hat{w}_t - \hat{r}_t^k) + (1 + \hat{r}_t^k)\hat{k}_t \tag{2.21}$$

$$O_{gt} = -\alpha(\hat{p}_t^o - \hat{s}_t) + V\hat{A}_t \text{ with } \quad \hat{s}_t = (1-\theta)\hat{r}_t^k + \theta\hat{w}_t - \hat{\varepsilon}_t^{TFP} \quad . \tag{2.22}$$

The real marginal costs of intermediate firms equal is

$$MC_t = \left(\eta_t (VA_t^i)^{1-\alpha} + (1-\eta_t)(O_{gt}^i)^{1-\alpha}\right)^{\frac{1}{1-\alpha}} = \left\{\eta_t \left[\varepsilon_t^{TFP} (L_t^i)^{\theta_f} (K_t^{S,i})^{1-\theta_f}\right]^{1-\alpha} + (1-\eta_t)(O_{gt}^i)^{1-\alpha}\right\}^{\frac{1}{1-\alpha}}, \qquad (2.23)$$

The Calvo model assumes that each period there is a fixed probability ξ_p that a household canre-optimize its price. The inflation adjustment is $P_t(i) = \pi_{t-1} P_{t-1}(i)$. A firm choose the optimal price to maximize the real value of the sum of profits from period *t* to period *t*+*k* :

$$\max E_t \sum_{k=0}^{\infty} \xi_{t.t+k} \left(P_t^* X_{tk} - P_{t+k} MC_{t+k}\right) Y_{t+k}(i) \qquad (2.24)$$

where $\zeta_{t,t+k} = \beta^k \frac{\lambda_{t+k}}{\lambda_t}$, and $\zeta_{t,t+k} = \beta^k$ in steady state.

And the first order condition from maximizing profits is

$$\sum_{k=0}^{\infty} \xi_p^k E_t \left\{ \zeta_{t,t+k} Y_{t+k}(i) \left(\frac{P_{t+k-1}}{P_{t-1}} P_t^* - \mu_t^p P_{t+k}(i) MC_{t+k} \right) \right\} = 0 \qquad (2.25)$$

and

$$E_t \left\{ \beta^0 \frac{\lambda_{t+0}}{\lambda_t} Y_t(i) \left(\frac{P_{t-1}}{P_{t-1}} P_t^* - \frac{\theta_{t+0}^p}{\theta_{t+0}^p - 1} P_{t+k}(i) MC_{t+0} \right) \right\} + E_t \left\{ \beta^1 \frac{\lambda_{t+1}}{\lambda_t} Y_t(i) \left(\frac{P_t}{P_{t-1}} P_t^* - \frac{\theta_{t+1}^p}{\theta_{t+1}^p - 1} P_{t+1}(i) MC_{t+1} \right) \right\} = 0$$

where $\mu_{t+k}^P = \frac{\theta_{t+k}^p}{\theta_{t+k}^p - 1}$

The followings are the exogenous shocks of the DSGE model:

investment adjustment cost shock : $\ln z_t = (1-\rho_z)\ln z + \rho_z \ln z_{t-1} + \eta_t^z$

(2.26)

production facto shock : $\ln \varepsilon_t^{TEP} = (1-\rho_\varepsilon)\ln \varepsilon^{TFP} + \rho_\varepsilon \ln \varepsilon_{t-1}^{TFP} + \eta_t^\varepsilon$

(2.27)

consumer preferences shock : $\ln b_t = (1-\rho_b)\ln b + \rho_b \ln b_{t-1} + \eta_t^b$

(2.28)

price adjustment cost shock : $\ln \mu_t^p = (1-\rho_{\mu p})\ln \mu^p + \rho_{\mu p} \ln \mu_{t-1}^p + \eta_t^{\mu p}$

(2.29)

wage adjustment cost shock : $\ln \mu_t^w = (1-\rho_{\mu w})\ln \mu^w + \rho_{\mu w} \ln \mu_{t-1}^w + \eta_t^{\mu w}$

(2.30)

interest rate adjustment cost shock : $\ln v_t = (1-\rho_v)\ln v + \rho_v \ln v_{t-1} + \eta_t^v$

(2.31)

capital utilization shock : $\ln u_t = (1-\rho_u)\ln u + \rho_u \ln u_{t-1} + \eta_t^u$

(2.32)

real oil price shock : $\ln p_{O,t} = (1-\rho_{pO})\ln p_O + \rho_{pO} \ln p_{O,t-1} + \eta_t^{pO}$

(2.33)

where $\rho_x \in (-1,1)$ and x are the values of the exogenous shocks in steady state.

η_t^x isdistributed (iid) series with mean 0 and standard deviation is variance σ_z.

All households are consistent in symmetrical equilibrium, such as $P_t(i) = P_t$, $N_t(i) = N_t$, $Y_t(i) = Y_t$, $K_t(i) = K_t$, and all parameters are constant in steady state.

2.3 Log-Linearized Model

Log-linearization producer is in line with the one presented in Campbell (1994) and Uhig (1995). Variables are denoted in the letters without subscript t denote steady state vales. Big letters with subscript t denote variables without any transformation. Letters with subscript t and hat above denote log deviations of particular variable from steady state. Below I present how log-linearization procedure is applied. Deviation of capital from steady state is equal:

$$\hat{X}_t = \ln X_t - \ln X$$

$$\ln X_t = \ln X + \hat{X}_t$$

Taking exponents of both sides we get:

$$e^{\ln X_t} = e^{\ln X_t + \hat{X}_t} = e^{\ln X_t} e^{\hat{X}_t}$$

Thus:

$$X_t = X e^{\hat{X}_t} \Rightarrow e^{\hat{X}_t} = \frac{X_t}{X}$$

Next step is to take the first order Taylor approximation of $e^{\hat{X}_t}$ around the steady state thus $\hat{X}_t = 0$, though we get:

$$e^{\hat{X}_t} = e^0 + e^0(\hat{X}_t - 0) = 1 + \hat{X}_t$$

Thus:

$$1 + \hat{X}_t = \frac{X_t}{X} \Rightarrow X_t = X(1 + \hat{X}_t) \text{ or } \hat{X}_t = \frac{X_t - X}{X}$$

The variable $\hat{K}_t$ multiplied by 100 informs by what percentage capital at time t diverges from the steady state. So for example if $\hat{K}_t$ is equal 0.2 we interpret that capital is 20% above the steady state.

The followings are log-linear equations of the DSGE model. Combine (2.5) ,(2.6) and (2.7) to obtain monetary demand equation:

$$-\frac{1}{\gamma}\hat{m}_t + \frac{1}{\sigma(1-h)}(\hat{c}_t - h\hat{c}_{t-1}) = \frac{\beta}{1-\beta}\hat{r}_t \quad (2.34)$$

Combine (2.5) and (2.7) to obtain Euler's equation:

$$\hat{c}_t = \frac{1}{1+h}E_t\{\hat{c}_{t+1}\} + \frac{h}{1+h}\hat{c}_{t-1} + \frac{\sigma(1-h)}{1+h}(-\hat{r}_t + E_t\{\hat{\pi}_{t+1}\} - E_t\{\hat{b}_{t+1} - \hat{b}_t\}) \quad (2.35)$$

Obtain investment equation from (2.10) and (2.11):

$$\hat{i}_t = \frac{\beta}{1+\beta}E_t\{\hat{i}_{t+1}\} + \frac{1}{1+\beta}\hat{i}_{t-1} + \frac{\psi}{1+\beta}\hat{q}_t + \frac{1}{1+\beta}E_t\{\beta\hat{z}_{t+1} - \hat{z}_t\}) \quad (2.36)$$

where $\hat{r}_t^k = \hat{u}_t / \psi_u \qquad \psi_u = f'(1) / f''(1)$

Obtain capital process equation from (2.4):

$$\hat{k}_{t+1} = (1-\delta_K)\hat{k}_t + \delta_K\hat{i}_t \quad (2.37)$$

Combine (2.14) and (2.17) to obtain real wage equation:

$$\hat{w}_t = \frac{1}{1+\beta}(\hat{\pi}_{t-1} + \hat{w}_{t-1}) - \hat{\pi}_t + \frac{\beta}{1+\beta}E_t\{\hat{w}_{t+1} + \hat{\pi}_{t+1}\} - \frac{(1-\beta\xi_w)(1-\xi_w)}{(1+\beta)\xi_w}(\hat{w}_t - \hat{\mu}_t^* - \frac{1}{\phi}\hat{n}_t - \frac{1}{\sigma(1-h)}(\hat{c}_t - h\hat{c}_{t-1})) \tag{2.38}$$

Technology equation of the intermediate firm is：

$$\hat{y}_t = \eta_t(V\hat{A}_t) + (1-\eta_t)\hat{o}_{gt} \tag{2.39}$$

where $V\hat{A}_t = \hat{\varepsilon}_t^{TEP} + \theta\hat{n}_t + (1-\theta)\hat{k}_t$

the demand curves for labor and oil by minimizing cost

$$\hat{n}_t = -(\hat{w}_t - \hat{r}_t^k) + (1+\hat{r}_t^k)\hat{k}_t \quad , \tag{2.40}$$

$$\hat{O}_{gt} = -\alpha(\hat{p}_{O,t} - \hat{s}_t) + V\hat{A}_t \quad , \text{ where } \hat{s}_t = (1-\theta)\hat{r}_t^k + \theta\hat{w}_t - \hat{\varepsilon}_t^{TEP} \quad . \tag{2.41}$$

Combine(2.19) , (2.13) and (2.25) to obtain inflation equation:

$$\hat{\pi}_t = \frac{1}{1+\beta}\hat{\pi}_{t-1} + \frac{\beta}{1+\beta}E_t\{\hat{\pi}_{t+1}\} - \frac{(1-\beta\xi_w)(1-\xi_w)}{(1+\beta)\xi_w}(-\hat{a}_t + \alpha\hat{r}_t^k + (1-\alpha)\hat{w}_t - \hat{\mu}_t^p) \tag{2.42}$$

The balance condition of goods market is:

$$\hat{y}_t = \frac{\mu^p(1-\beta(1-\delta)) - \alpha\beta\delta}{\mu^p(1-\beta(1-\delta))}\hat{c}_t + \frac{\alpha\beta\delta}{\mu^p(1-\beta(1-\delta))}\hat{i}_t \tag{2.43}$$

The Taylor’s rule of Central Bank’s monetary policy is :

$$\hat{r}_t = (1-\gamma_r)(\gamma_w\hat{\pi}_t + \gamma_y\hat{y}_t) + \gamma_r\hat{r}_{t-1} + \hat{v}_t \tag{2.44}$$

The followings are the log-linearized equations of exogenous shocks, including

investment adjustment cost shock $\quad \hat{z}_t = \rho_z\hat{z}_{t-1} + \eta_t^z$

$$\tag{2.45}$$

production factor shock $\quad \hat{\varepsilon}_t^{TEP} = \rho_\varepsilon\hat{\varepsilon}_{t-1}^{TEP} + \eta_t^\varepsilon$

$$\tag{2.46}$$

consumer preferences shock $\hat{b}_t = \rho_b \hat{b}_{t-1} + \eta_t^b$

(2.47)

price adjustment cost shock, $\hat{\mu}_t^p = \rho_{\mu p} \hat{\mu}_{t-1}^p + \eta_t^{\mu p}$

(2.48)

wage adjustment cost shock $\hat{\mu}_t^w = \rho_{\mu w} \hat{\mu}_{t-1}^w + \eta_t^{\mu w}$

(2.49)

oil price shock $\hat{p}_t^o = \rho_{po} \hat{p}_{t-1}^o + \eta_t^{po}$

(2.50)

interest rate adjustment cost shock $\hat{v}_t = \rho_v \hat{v}_{t-1} + \eta_t^v$

(2.51)

capital utillzation shock $\hat{u}_t = \rho_u \hat{u}_{t-1} + \eta_t^u$. (2.52)

Chapter 3 Estimation methodology

3.1 Parameter estimation

The structural parameters of a DSGE model must be estimated before the model is numerically solved. There is a maximum likelihood function to translate the prior distribution of observablesrepresented by a vector of fictitious observationsinto a distribution for the modelparameters. In principleone could use the likelihood function of the DSGE for this purpose. First the log-linearized model of the DSGE model is solved by Blanchard and Kahn method and the form of the solution is presented as the following:

$$x_t = Fx_{t-1} + D\varepsilon_t$$

$$X_t = Hx_t$$

where x_t is the state variables, ε_t is random perturbations, $X_t = \{\hat{y}_t, \hat{c}_t, \hat{r}_t, \hat{m}_t, \hat{\pi}_t, \hat{w}_t, \hat{n}_t, \hat{i}_t\}$ is observable variables. Coefficient matrices F,D,H depend on the structural parameters of the model. The number of observable variables is equal to the number of exogenous shocks. There is a maximum likelihood function derived by using Kalman filter method.

$$L(X_i|\theta) = (2\pi)^{-\frac{\pi}{2}} \left|Q_{t|t-1}\right|^{\frac{-1}{2}} \cdot \exp\left[-\frac{1}{2}(X_t - X_{t|t-1})' Q_{t|t-1}^{-1}(X_t - X_{t|t-1})\right]$$

where $X_{t|t-1} = H' x_{t|t-1}, Q_{t|t-1} = E(X_t - X_{t|t-1})(X_t - X_{t|t-1})'$. In general, we can use Bayes theorem to estimate the parameters of the DSGE model. The main result of the estimation is posterior probability distribution.The posterior probability is the probability of the parameters θ given the evidence $X : p(\theta|X)$. It contrasts with the likelihood function, which is the probability of the evidence given the parameters $p(\theta|X)$ .We have a prior belief that the probability function is $p(\theta)$ and observations X with the likelihood $p(\theta|X)$, then the posterior probability is defined as

$$p(\theta|X|) = \frac{p(\theta)\,p(X|\theta)}{p(X)}$$

The posterior probability can be written in the memorable form as

$$Posterior \quad probability \quad \propto \quad P \quad rior \ \times Likelihood$$

In the followings we use calibration and historical data to set priors distribution of the model's parameters, then estimate posteriors distributionof the model's parameters.

3.2 Priors distribution

In estimation, each parameter will be estimated a prior distribution. There are usually four common prior distributions used in estimation: Beta distribution for parameters between 0 and 1, Gamma distribution for parameters restricted to be positive, inverse Gamma distribution for the standard deviation of theshocks, and Normal distribution. There are three methods to estimate the parameters of the DSGE model: calibration, maximum likelihood estimation and Bayesian estimation. For calibration, some economic model's parameters in past literatures will be used .

The period of calibration corresponds to a quarter. The value for habit h is given by 0.65 in Teo(2009) and elasticity of wage of labor supply is given by 0.42 in Smets and Wouters(2003). The capital deprecation rate δ_k is given by 0.025 in CEE*et al*(2003). We also analyze Taiwanese historical data to obtain regression model. The observable variables include the output y, the consumption c, the interest rate r ,the nominal wage w, the nominal inflation(CPI) π, the nominal labor n, the nominal investment i, the monetary m. We use the data use quarterly data for Taiwan from 1997Q1 to 2011Q4 provided from Directorate-General of Budget, Accounting and Statistics,ROC (DGBAS). The output y is measured as seasonally adjusted real gross domestic product(GDP), the consumption c is measured as per capita consumption expenditure, the interest rate r is measured as overnight call loan rate, the nominal wage w is measured as average monthly earnings of employees on payrolls - industry &services, the nominal inflation(CPI) π is measured as consumer price indices by basic group, the nominal labor n is measured as numbers of employees, the nominal investment i is measured as gross domestic fixed capital formation, the nominal m is measured as monetary aggregates M2. We take log value of this data, then de-trend these values by HP filtering and carry out seasonal adjustment. These data are shown in Fig3.1~Fig3.8 and the priors distributions of parameters are presented in Table 3.1.

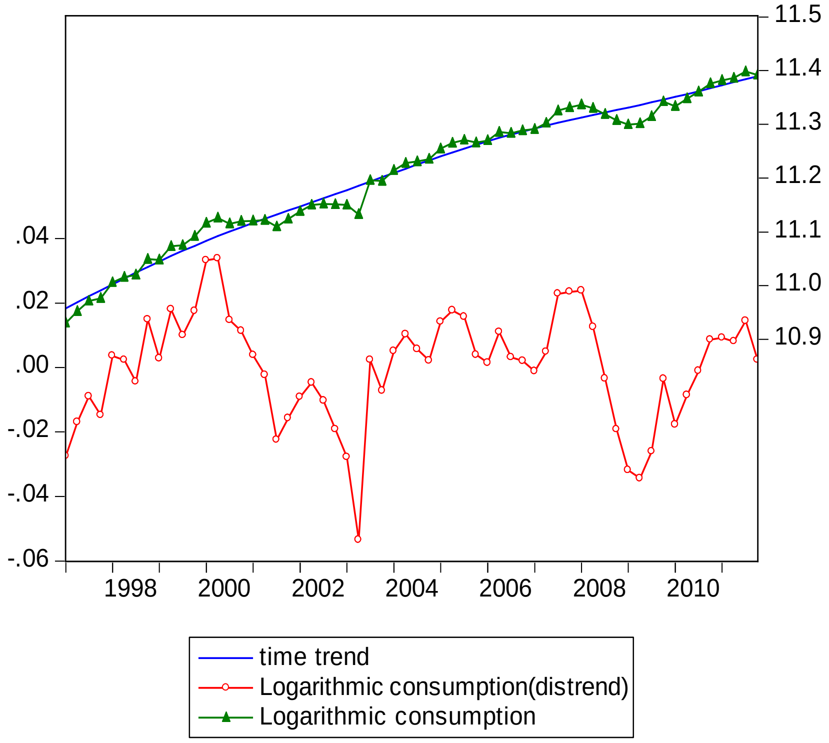

Fig 3.1Taiwan's quarterly data from 1997Q1 to 2011Q4－Consumption
Sources: Directorate-General of Budget, Accounting and Statistics (DGBAS), ROC

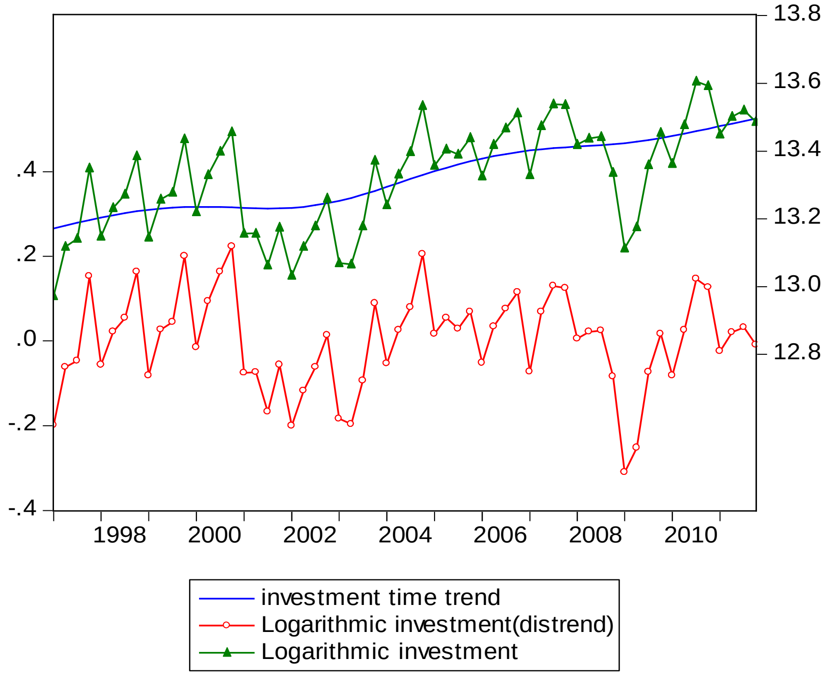

Fig 3.2Taiwan's quarterly data from 1997Q1 to 2011Q4－Investment

Sources: Directorate-General of Budget, Accounting and Statistics (DGBAS),ROC

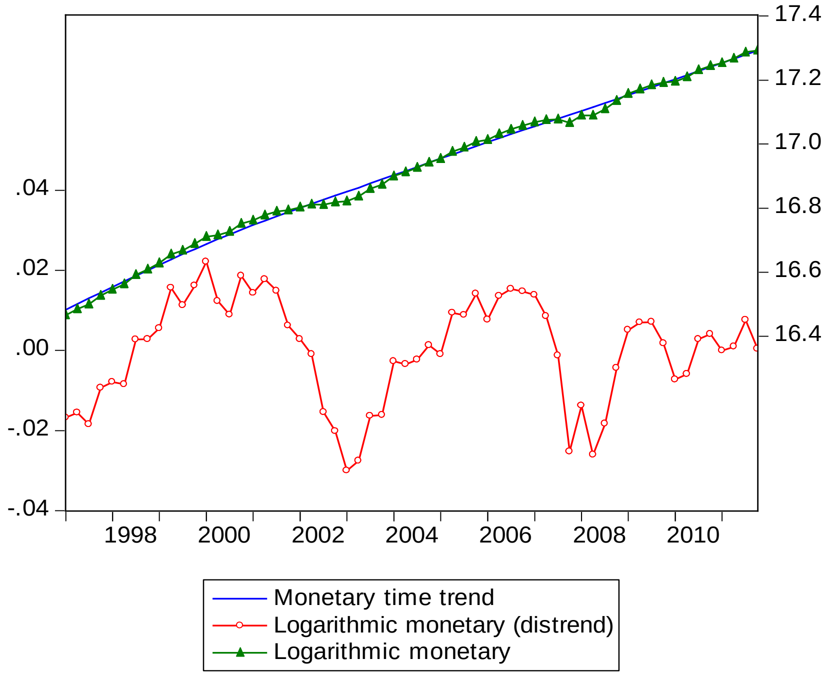

Fig 3.3Taiwan's quarterly data from 1997Q1 to 2011Q4－Monetary

Sources: Directorate-General of Budget, Accounting and Statistics (DGBAS),ROC

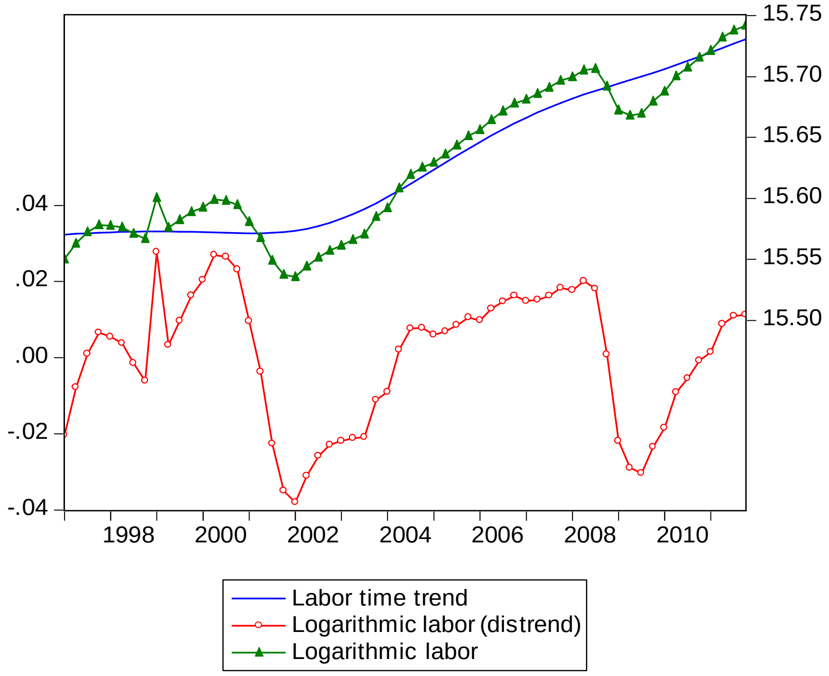

Fig 3.4Taiwan's quarterly data from 1997Q1 to 2011Q4－Labor

Sources: Directorate-General of Budget, Accounting and Statistics (DGBAS), ROC

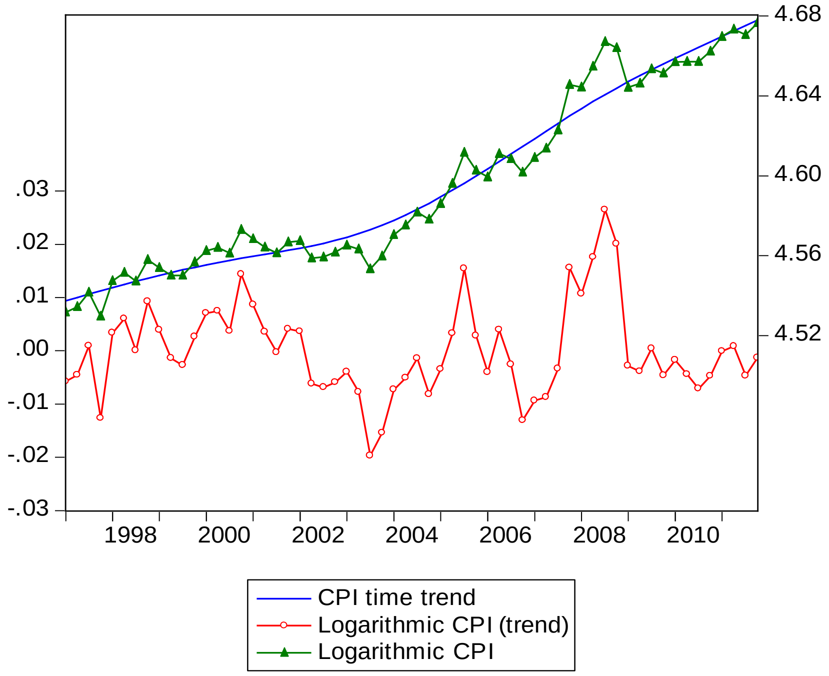

Fig 3.5Taiwan's quarterly data from 1997Q1 to 2011Q4－CPI

Sources: Directorate-General of Budget, Accounting and Statistics (DGBAS), ROC

Fig 3.6Taiwan's quarterly data from 1997Q1 to 2011Q4－Interest rate

Sources: Directorate-General of Budget, Accounting and Statistics (DGBAS), ROC

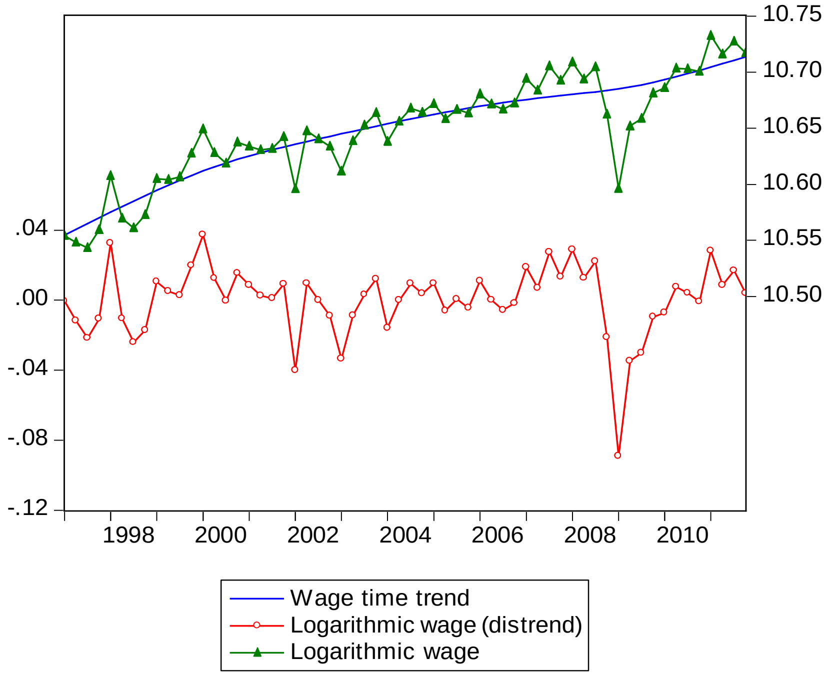

Fig 3.7Taiwan's quarterly data from 1997Q1 to 2011Q4－Wages

Sources: Directorate-General of Budget, Accounting and Statistics (DGBAS), ROC

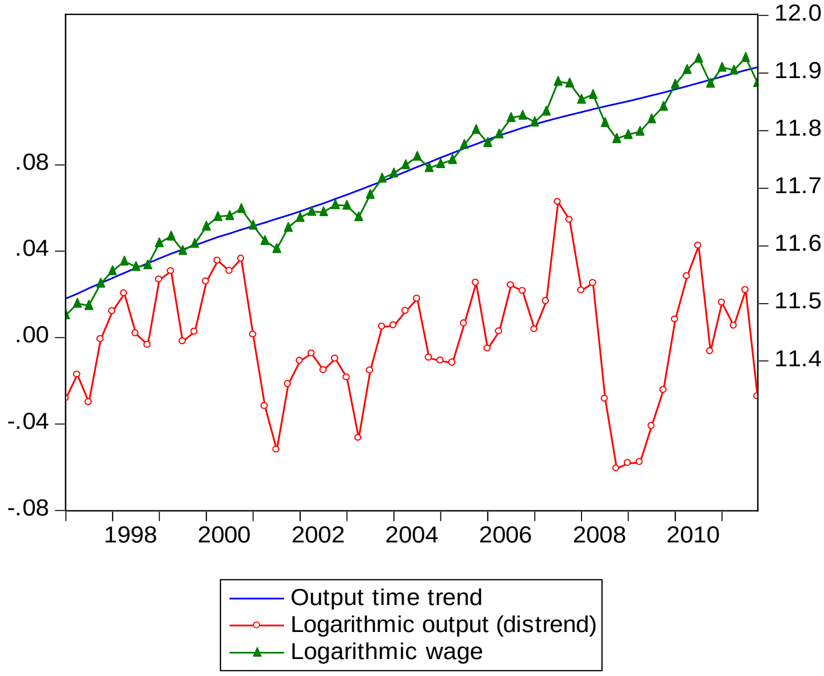

Fig 3.8Taiwan's quarterly data from 1997Q1 to 2011Q4－Output

Sources: Directorate-General of Budget, Accounting and Statistics (DGBAS), ROC

Table 3.1 The priors distribution of parameters of the DSGE model

Para-meter	prior mean	Prior distribution	definition	Para-meter	prior mean	Prior distribution	definition
γ	0.599	β	interest rate elasticity of the monetary demand	γ_r	0.782	β	influence coefficient of interest rate last period
σ	0.420	β	cross-elasticity of substitution	γ_w	1.700	γ	influence coefficient of interest rate to inflation
h	0.650	β	habit formation	γ_Y	0.289	β	influence coefficient of interest rate to output
β	0.990	β	discount factor	ρ_z	0.410	β	exogenous shock

							parameter
ψ	0.148	β	User cost of capital	ρ_e	0.410	β	exogenous shock parameter
δ_k	0.025	β	capital deprecation rate	ρ_b	0.41	β	exogenous shock parameter
δ	0.100	β	share of fuel consumption	ρ_{μ_w}	0.410	β	exogenous shock parameter
η_t	0.900	β	share of the domestic production factors in gross output	ρ_{μ_P}	0.410	β	exogenous shock parameter
ϕ_1	0.420	β	elasticity of wage of labor supply	ρ_{po}	0.410	β	exogenous shock parameter
α	0.410	β	Elasticity of substitution between value-added and oil	ρ_u	0.410	β	exogenous shock parameter
θ	0.350	β	share of labor in GDP	ρ_v	0.410	β	exogenous shock parameter
ξ_w	0.828	β	Probability of not setting best wage	φ	0.400	β	
ξ_P	0.905	β	Probability of not setting best wage best price	μ_P	1.200	γ	Steady state price markup rate

3.3 Posteriors distribution

We can estimate variants of the model by using Bayesian methods. The Bayesian approach provides a framework for making model comparisons and yields posterior adds for each models. When a prior $p(\theta_i)$ and a sample of data Y, the posterior density of the model parameters θ_i is the proportional to the likelihood of the data multiplied by the prior $p(\theta_i)$,

$$p(\theta_i|Y) \propto L(\theta_i|Y)\,p(\theta_i)$$

the likelihood function can be estimated using the Kalman filter by combining the state-space representation of the model solution with a measurement equation, linking the state vector to the observed data. The model solution will be written as

$$V_t = \Phi_1(\vartheta_i)V_{t-1} + \Phi_\varepsilon(\vartheta_i)\varepsilon$$

A measurement equation then relates the model variables V_t to a vector of observables x_t. All observables are measured in percentage deviations from steady state levels. The vector of observables x_t is composed of log output (y_t^{ob}), annualized log quarterly changes in the consumption(c_t^{ob}), annualized log quarterly changes in the monetary (m_t^{ob}), annualized log quarterly changes in the wages (w_t^{ob}), annualized log quarterly changes in the CPI(π_t^{ob}), annualized log quarterly changes in the interest rates (r_t^{ob}), annualized log quarterly changes in the labors (n_t^{ob}), and annualized log quarterly changes in the investments (k_t^{ob}). The linear trends of this observables has been removed. The model variables are scaled to be measured in the same units as the observables. The measurement equations relating the model variables to the observables are

$$
\begin{pmatrix} y_t^{ob} \\ c_t^{ob} \\ m_t^{ob} \\ w_t^{ob} \\ \pi_t^{ob} \\ r_t^{ob} \\ n_t^{ob} \\ k_t^{ob} \end{pmatrix} = \begin{pmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} y_t \\ c_t \\ m_t \\ w_t \\ \pi_t \\ r_t \\ n_t \\ k_t \end{pmatrix}
$$

Posterior draws are obtained using Markov Monte Carlo methods and made from the posterior distribution using the random walk Metropolis Hastings algorithm. After estimating the posterior distribution of the N models, each model is compared how well they fit the observable variables by using Bayes factors. The Bayes factor of model i over model j is

$$
\hat{L} = \frac{P(Y|i)}{P(Yj)}
$$

where $P(Y|i)$ is the marginal likelihood of model i:

$$
P(Y|i) = \int L(\vartheta|Y) p(\vartheta_i) d\vartheta_i \,.
$$

3.4 Solving the DSGE model

The log-linearized model of the DSGE model can be solved by Blanchard and Kahn method. This method is based on the idea of solving linear systems by searching for the stable manifold of the system of nonlinear equations. In all cases the equilibrium conditions describing the models need to be linearized.

The solution of the rational expectations model is unique if the number of unstable eigenvectors of the system is exactly equal to the number of forward-looking variables. The Blanchard and Kahn condition is that the number of eigenvalues in L greater than 1 must be equal to number of forward-looking variables.

The log-linearized model of the DSGE model must be satisfied in Blanchard and Kahn condition. We estimate and solve the DSGE model using Dynare 4.3.0. Dynare is a software platform for handling a wide class of economic models, in particular dynamic stochastic general equilibrium (DSGE) and overlapping generations (OLG) models. The models is estimated and solved by using Dynare. Dynare is not its own program but is rather basically a collection of Matlab code, so we first must install Matlab and Dynare and create .mod files then run the Dynare code to obtain the solutions.

Chapter 4 Experiment result

4.1 Estimated results

We estimate the mode the posterior distribution by maximizing the log posterior function, which combines the priors with the likelihood given by the data and then use the Metropolis-Hastings algorithm to obtain the posterior distribution. Table 4.1 shows the posterior distribution and means for the structural parameters. Table 4.2 shows the theoretical moments. Fig 4.1 and Fig 4.2 shows the prior distribution. Fig 4.3 and Fig 4.4 shows the prior distribution and the posterior distribution. Fig 4.5 shows the smoothed shock and Fig 4.6 shows estimated output and historical data.

Table 4.1 The posterior distribution of structural parameters of the DSGE model (by Bayesian estimation)

	prior mean	post. mean	conf. interval		Prior distribution	pstdev
γ	0.599	0.6116	0.6114	0.6118	β	0.0020
σ	0.420	0.4125	0.4125	0.4126	β	0.0020
h	0.650	0.6471	0.6471	0.6472	β	0.0020
β	0.990	0.9718	0.9718	0.9718	β	0.0020
ψ	0.148	0.1473	0.1472	0.1473	β	0.0020
δ_k	0.025	0.0143	0.0143	0.0143	β	0.0020
δ	0.100	0.1021	0.1021	0.1021	β	0.0020
η	0.200	0.2040	0.2040	0.2040	β	0.0020
η_t	0.900	0.8996	0.8995	0.8996	β	0.0020
α	0.410	0.4137	0.4137	0.4138	β	0.0020
θ	0.350	0.3425	0.3425	0.3426	β	0.0020
ϕ_1	0.420	0.4153	0.4153	0.4154	β	0.0020
ξ_w	0.828	0.8165	0.8164	0.8166	β	0.0020
ξ_P	0.905	0.9048	0.9048	0.9049	β	0.0020
γ_r	0.782	0.7843	0.7843	0.7843	β	0.0020
γ_w	1.700	1.7118	1.7117	1.7119	γ	0.0020
γ_Y	0.289	0.2944	0.2943	0.2944	β	0.0020
ρ_z	0.410	0.4137	0.4136	0.4138	β	0.0020
ρ_e	0.410	0.4066	0.4065	0.4065	β	0.0020

ρ_b	0.410	0.4026	0.4025	0.4028	β	0.0020
ρ_{μ_w}	0.410	0.4072	0.4071	0.4072	β	0.0020
ρ_{μ_P}	0.410	0.4144	0.4144	0.4145	β	0.0020
ρ_{po}	0.410	0.4108	0.4106	0.4109	β	0.0020
ρ_u	0.410	0.3973	0.3973	0.3973	β	0.0020
ρ_v	0.410	0.4112	0.4112	0.4112	β	0.0020
φ	0.400	0.4049	0.4049	0.4050	β	0.0020
μ_P	1.200	1.2112	1.2111	1.2113	γ	0.0020

Table 4.2 – Theoretical moments of the DSGE model (HP filter, lambda = 1600)

VARIABLE	MEAN	STD. DEV.	VARIANCE
m	0.0000	5.0717	25.7221
c	0.0000	0.1232	0.0152
m	0.0000	0.0813	0.0066
π	0.0000	0.0075	0.0001
b	0.0000	0.0502	0.0025
q	0.0000	2.5124	6.3122
i	0.0000	0.3198	0.1023
z	0.0000	0.0502	0.0025
k	0.0000	0.0422	0.0018
po	0.0000	0.0502	0.0025
n	0.0000	0.1609	0.0259
VA	0.0000	0.0701	0.0049
y	0.0000	0.0727	0.0053
w	0.0000	0.0672	0.0045
ε_{TFP}	0.0000	0.0502	0.0025
μ_p	0.0000	0.0502	0.0025
μ_w	0.0000	0.0502	0.0025
u_t	0.0000	0.0502	0.0025
v	0.0000	0.0502	0.0025

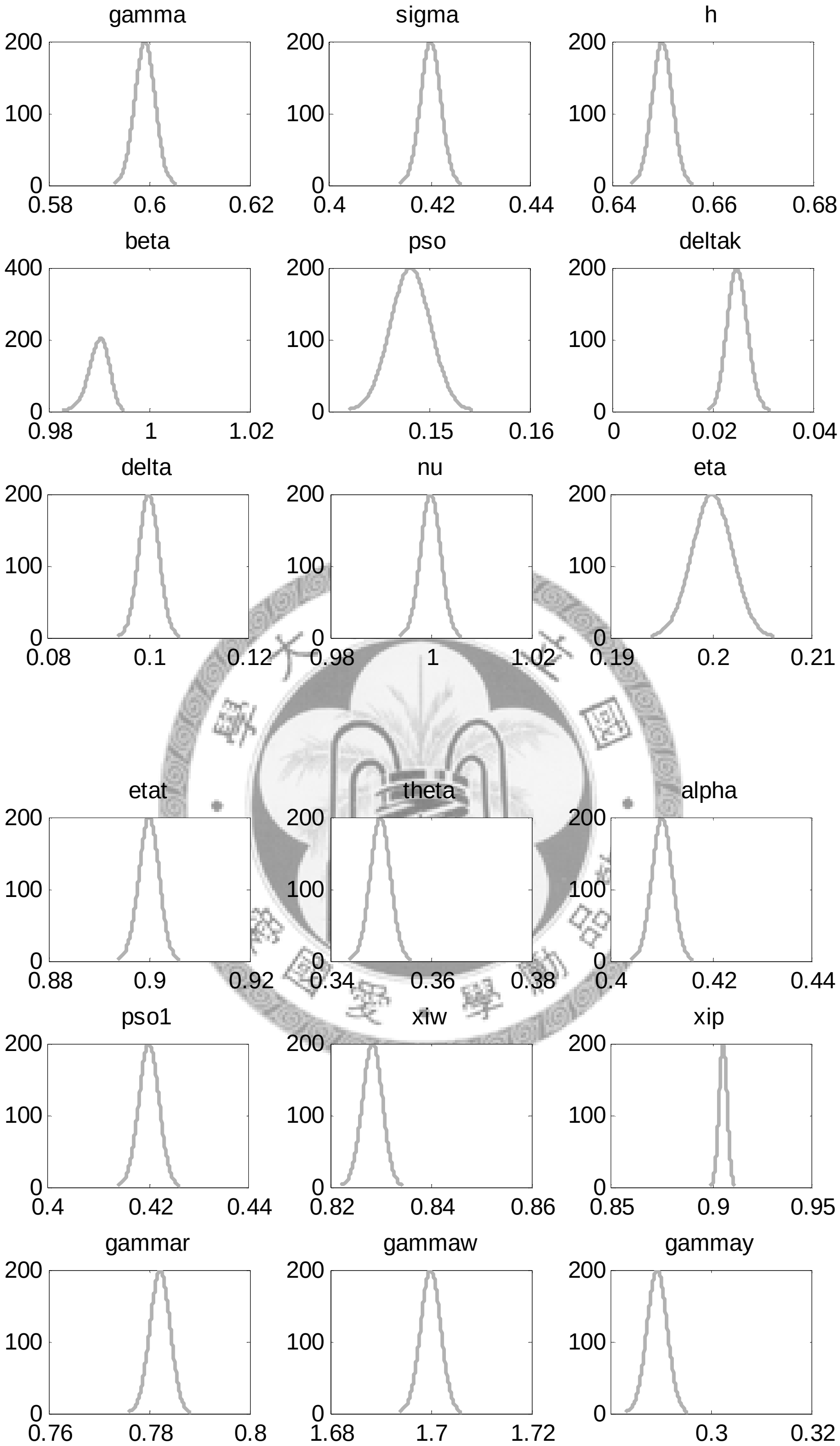

Fig4.1 The prior distributions of the DSGE model (1)

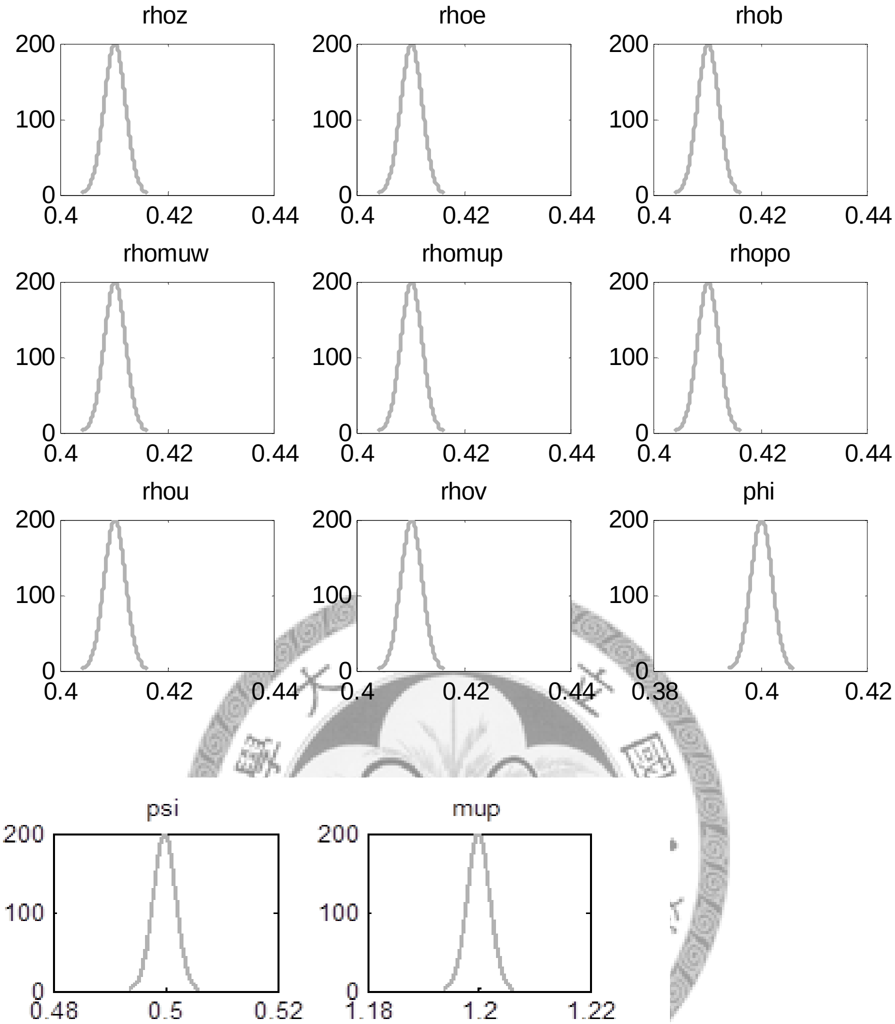

Fig 4.2The prior distributions of the DSGE model (2)

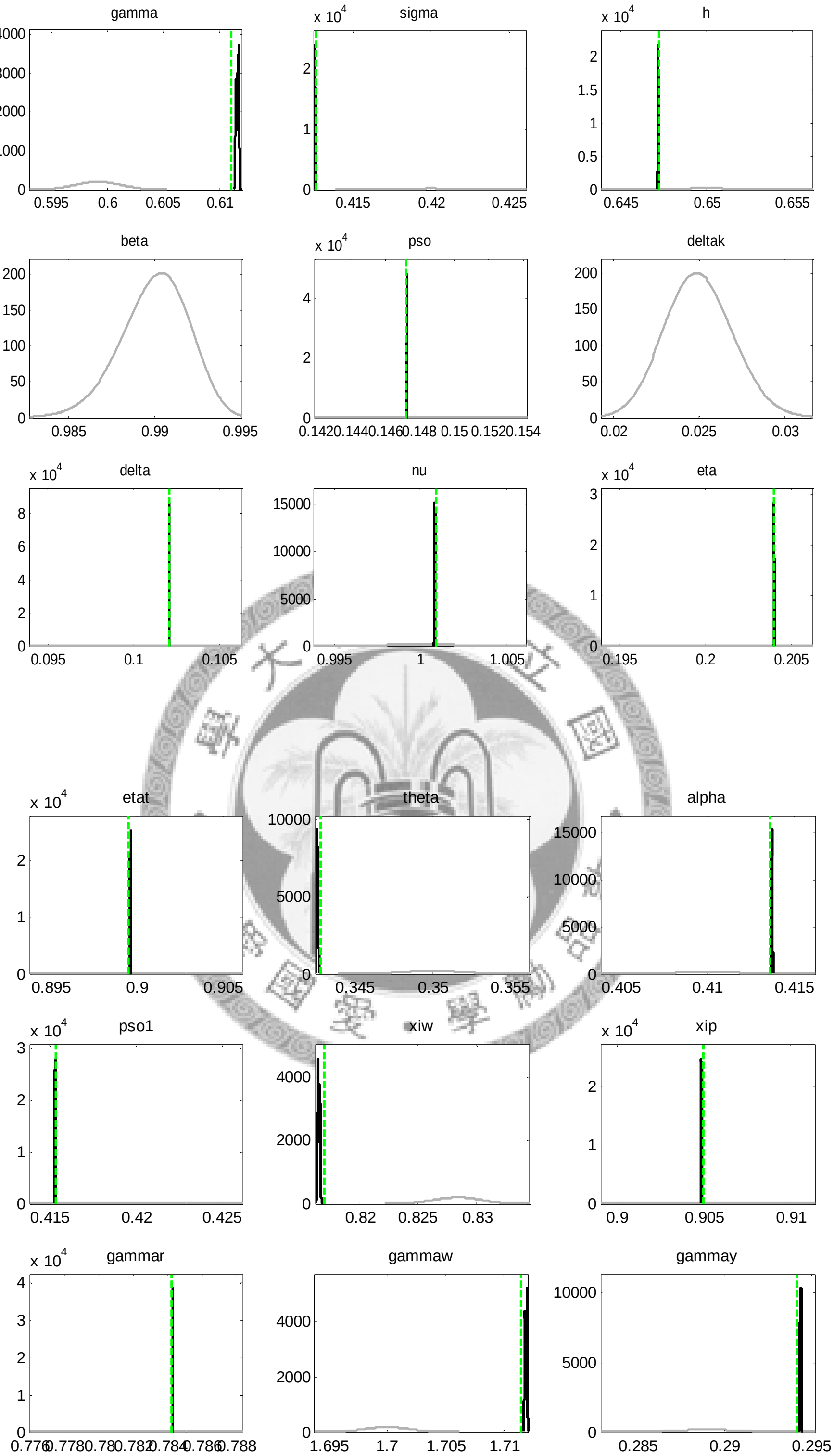

Fig 4.3The prior distributions and posteriors of the DSGE model (1) (by Bayesian estimation)

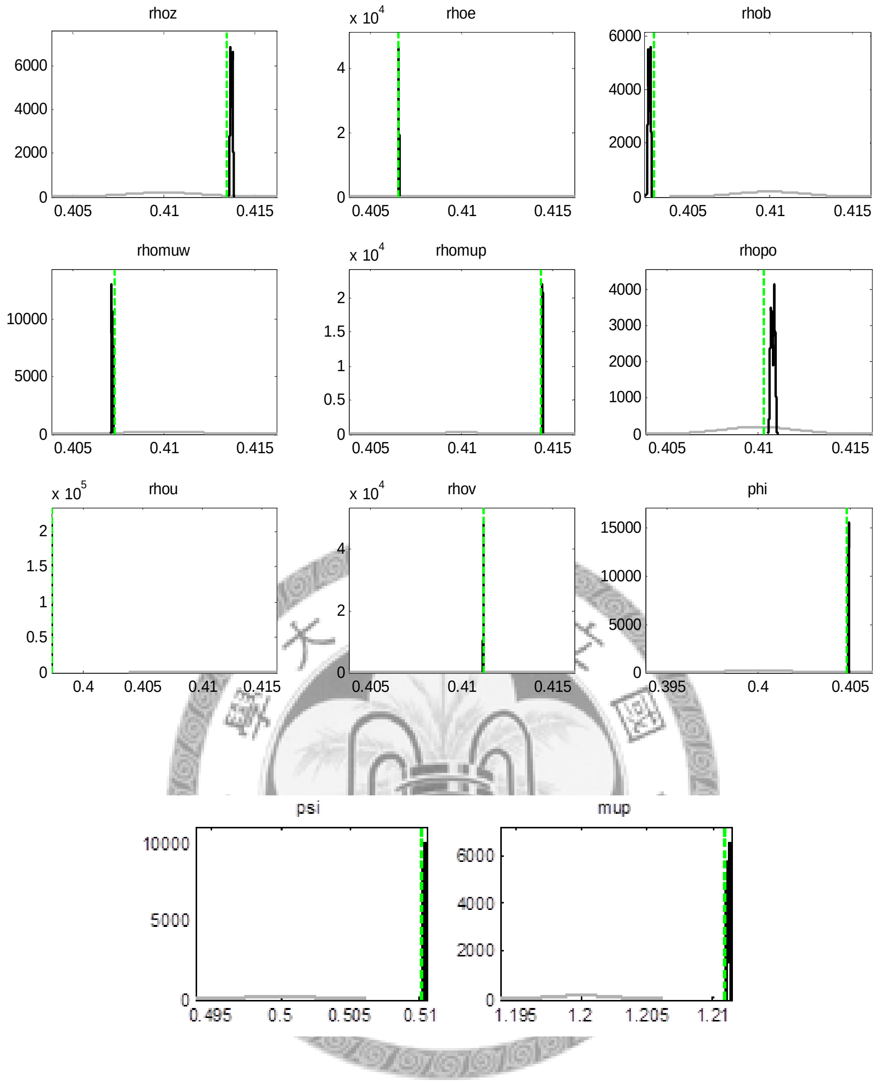

Fig 4.4The prior distributions and posteriors of the DSGE model(2) (by Bayesian estimation)

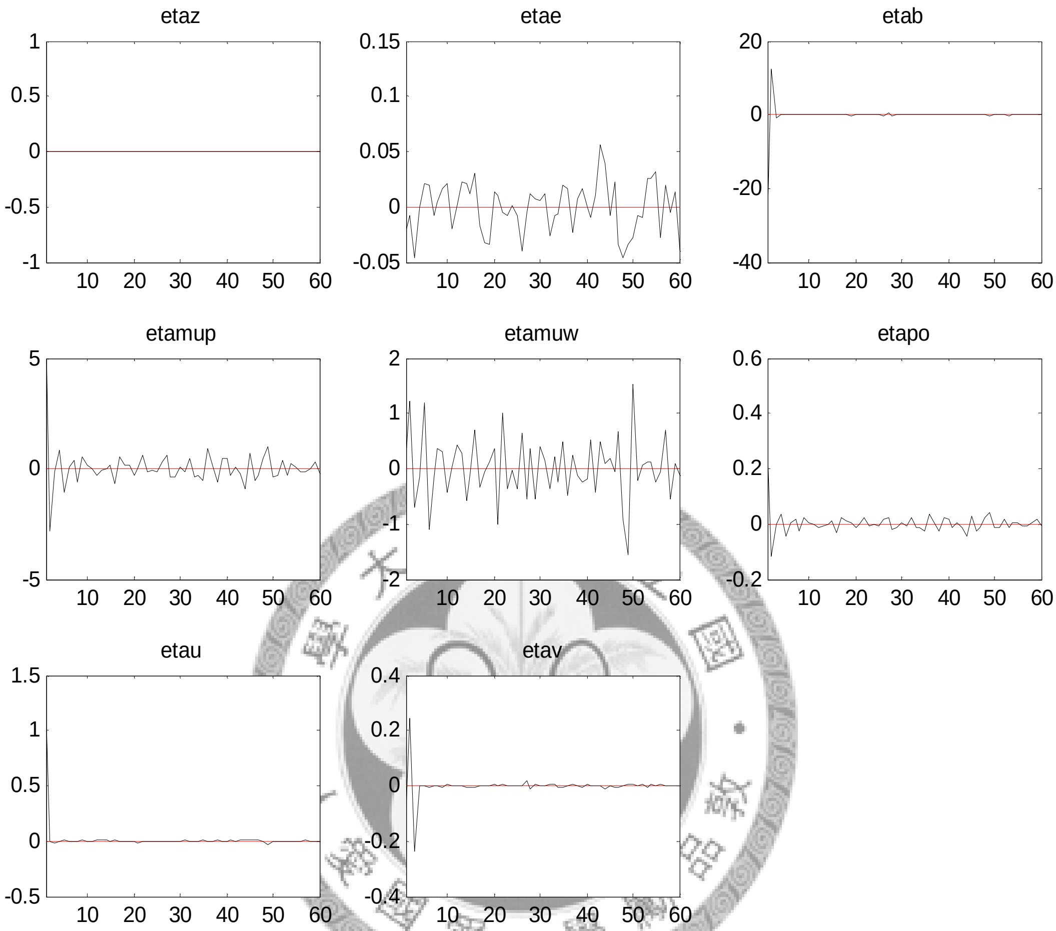

Fig 4.5The smoothed shock of the DSGE model
(iid distribution,mean 0 and standard deviation is variance sigma)

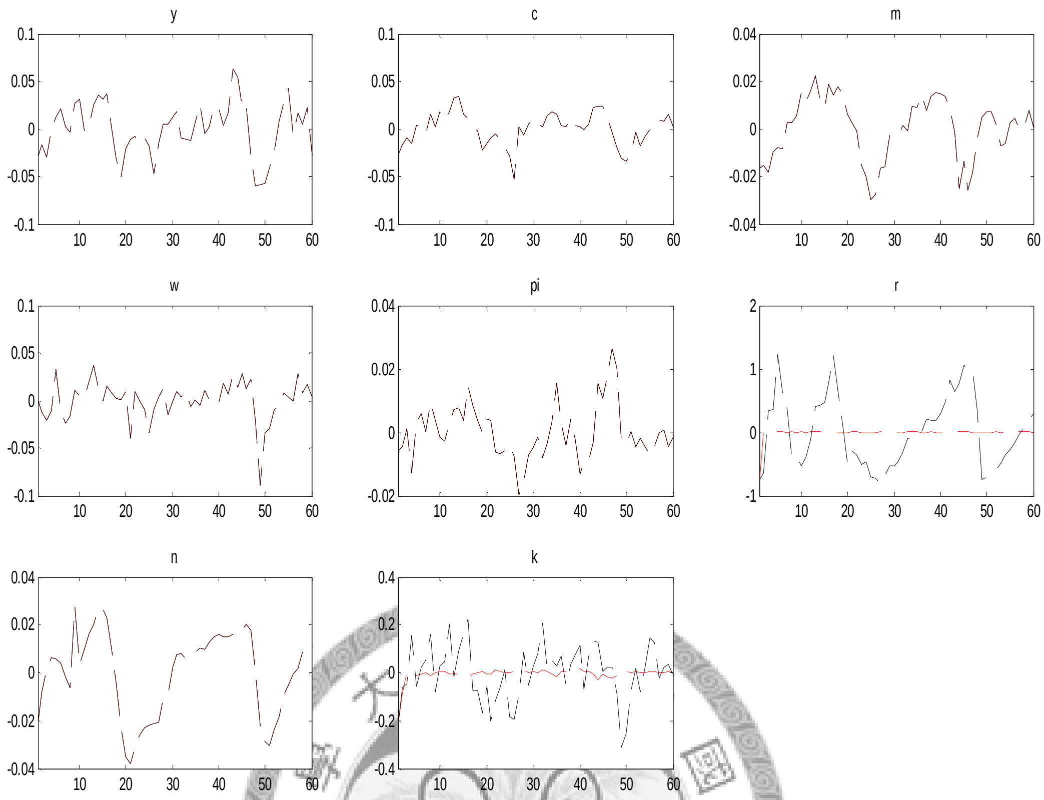

Fig 4.6The comparison between estimated output and Taiwan's quarterlyhistorical data

4.2 Estimated Impulse responses of structural shocks

4.2.1 The production factor shock

Figure 4.7 presents the estimated response of output, aggregate consumption, money supply, the nomial wage, inflation, interest rate, number of labor, investment, and value-add production to an preference exogenous shock is to raise production factor by 1 percent. The maximum response of real variables to the shock occord almost immediately. The effect of this preference shock is to raise output by 0.8 percent, value-add production by 0.8 percent and interest rate 0.05percent. The effect of this production factor shock is to fall monery supply by 0.15 percent, wage by 0.01percent , number of labor by 0.1 percent, investnent by by 0.1 percent and inflation 0.02 percent. But monery supply, consumption,wage will reverse to rise after 1 or 2 years. The rising effect of output, value-add production and number of labor will be back to base after about 2 years and the other items will be back to base after about a few more years. From aforementioned results, we know the inflation will fall due to technology process and firm's marginal costs of production. The output and the value-add production will rise immeand the wage will rise after half a year.

4.2.2 The consumer preference shock

Figure 4.8 presents the estimated response of output, aggregate consumption, money supply, the nomial wage, inflation, interest rate, number of labor, investment, and value-add production to an preference exogenous shock is to raise consumer preference by 1 percent. The maximum response of real variables to the shock occord almost immediately. The effect of this preference shock is to raise output by 0.025 percent, value-add production by 0.01 percent, monery supply by 0.3 percent , wage by 0.04percent,investnent by 0.03 percent, inflation by 0.001 percentand interest rate 0.0025percent. The effect of this preference shock is to fall number of labor. But monery supply will reverse to rise after 1 year. The rising effect of output, value-add production and number of labor will be back to base after about 2 years and the other items will be back to base after about a few more years. From aforementioned results, we know the consumer preference will rise consumption and output. And money supply will fall after about 1 year.

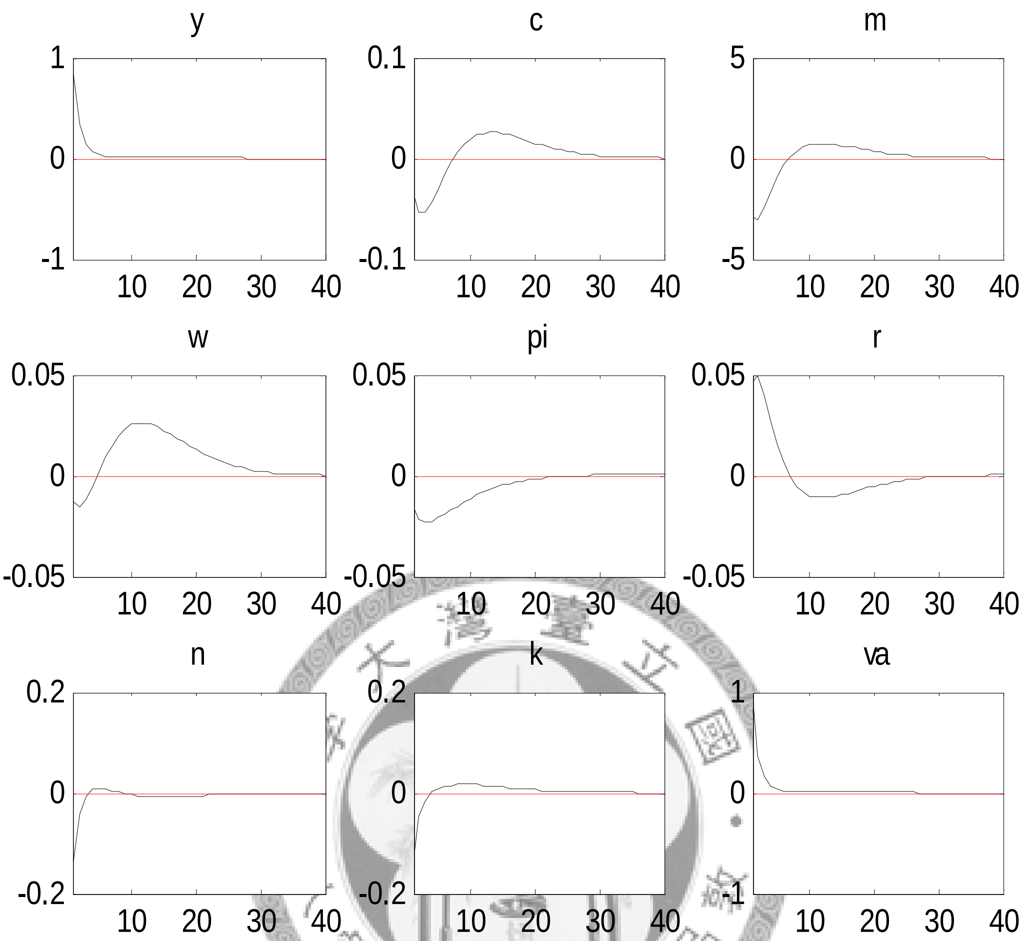

Fig 4.7 Impulse response to a 1%production factor shock
(y: Output; c: Consumption; m: Monetary; w:Wage; pi: Inflation; r: Interest rate; n: Labor; K: Investment; va: added value production)

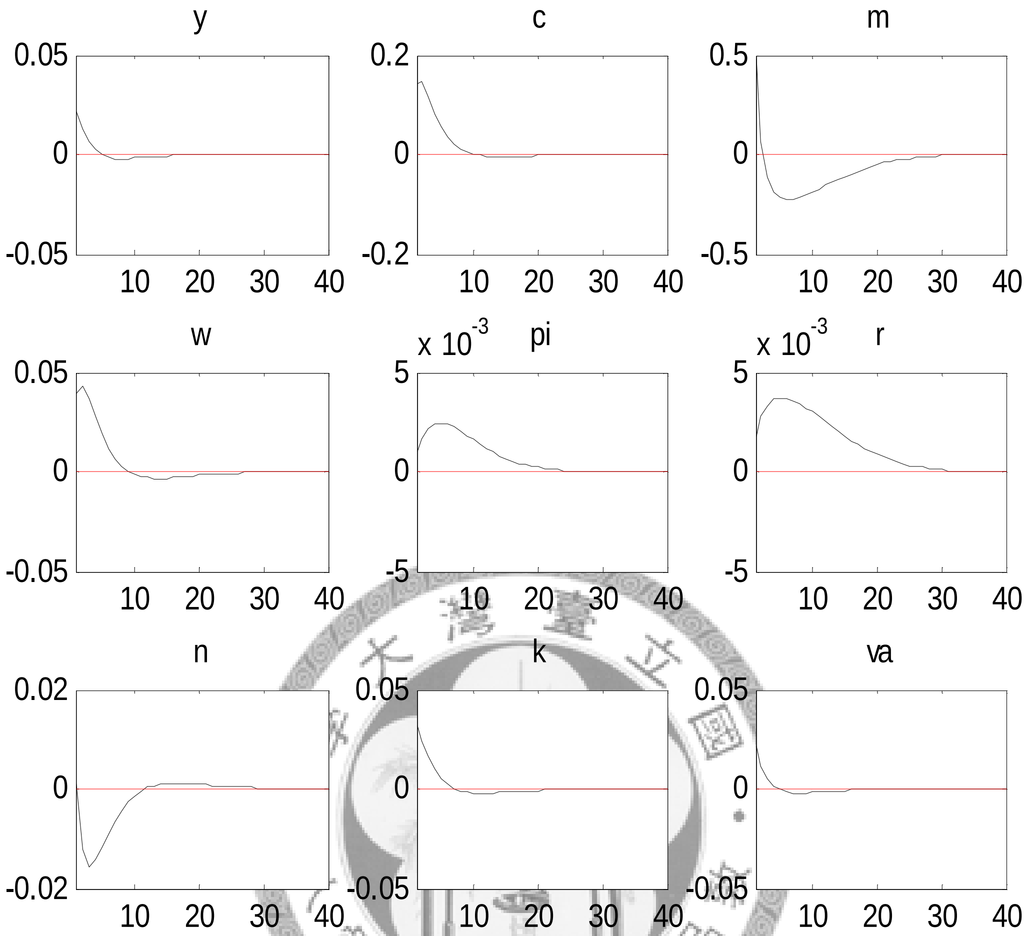

Fig 4.8 Impulse response to a 1%consumer preferences shock
(y: Output; c: Consumption; m: Monetary; w:Wage; pi: Inflation; r: Interest rate; n: Labor; K: Investment; va: added value production)

4.2.3 The price adjustment cost shock

Figure 4.9 presents the estimated response of output, aggregate consumption, money supply, the nomial wage, inflation, interest rate, number of labor, investment, and value-add production to an preference exogenous shock is to raiseprice adjustment cost by 1 percent. The effect of this preference shock is to fall output by 0.015 percent, value-add production by 0.015 percent, monery supply by 0.1 percent ,and number of labor by 0.04 percent. The effect of this preference shock is to rise wage by 0.04 percent , inflation by 0.02 percent and inflation by 0.015 percent. All effects will be back to base after about several years. From aforementioned results, we know the price adjustment cost shock will rise inflation and fall consumption. And money supply will fall after about 1 year.

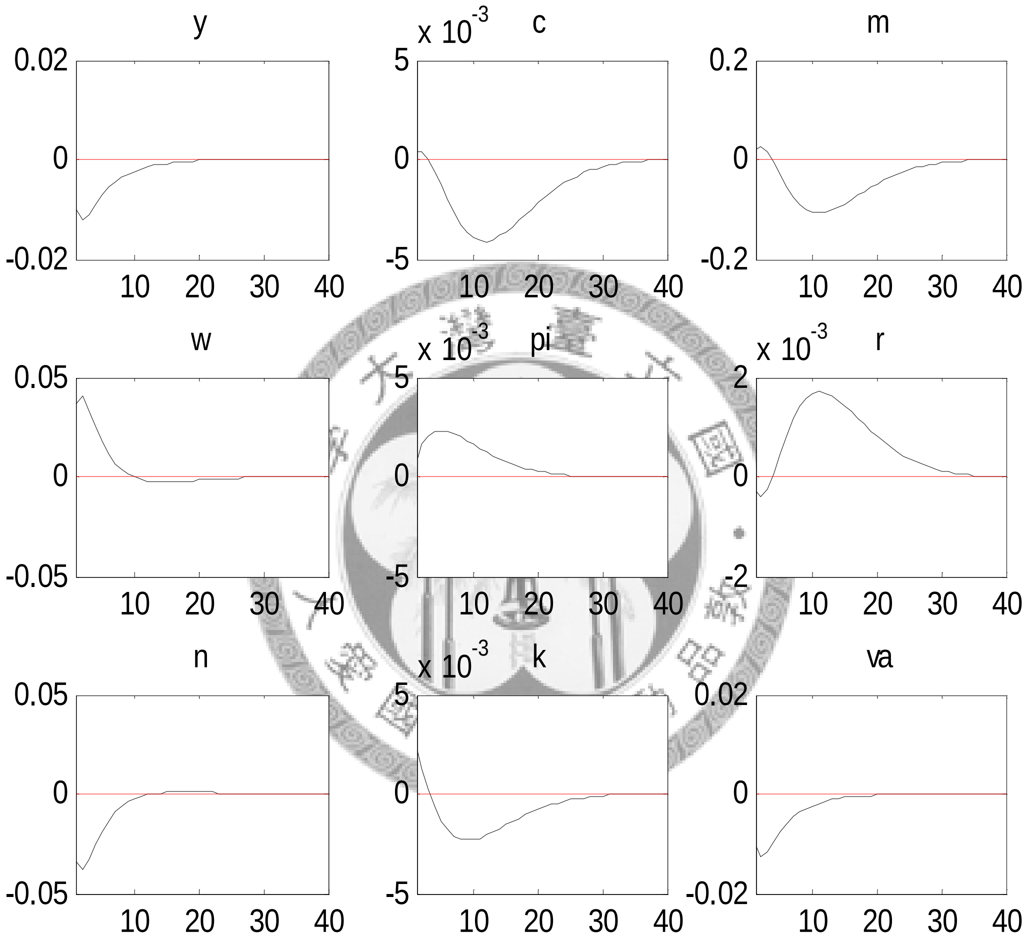

Fig 4.9Impulse response to a 1% price adjustment cost shock
(y: Output; c: Consumption; m: Monetary; w:Wage; pi: Inflation; r: Interest rate; n: Labor; K: Investment; va: added value production)

4.2.4 The wage adjustment cost shock

Figure 4.10 presents the estimated response of output, aggregate consumption, money supply, the nomial wage, inflation, interest rate, number of labor, investment, and value-add production to an preference exogenous shock is to raise wage adjustment cost by 1 percent. The effect of this preference shock is to raise output by 0.025 percent, value-add production by 0.025 percent, monery supply by 1 percent , wage by 0.04 percent,andinvestnent by 0.03 percent. The effect of this preference shock is to fall number of labor, interest rateby 0.01percent and inflation by 0.015 percent. All effects will be back to base after about several years. From aforementioned results, we know thewage adjustment cost shock will rise consumption, inflation and output. And money supply will fall after about 1 year.

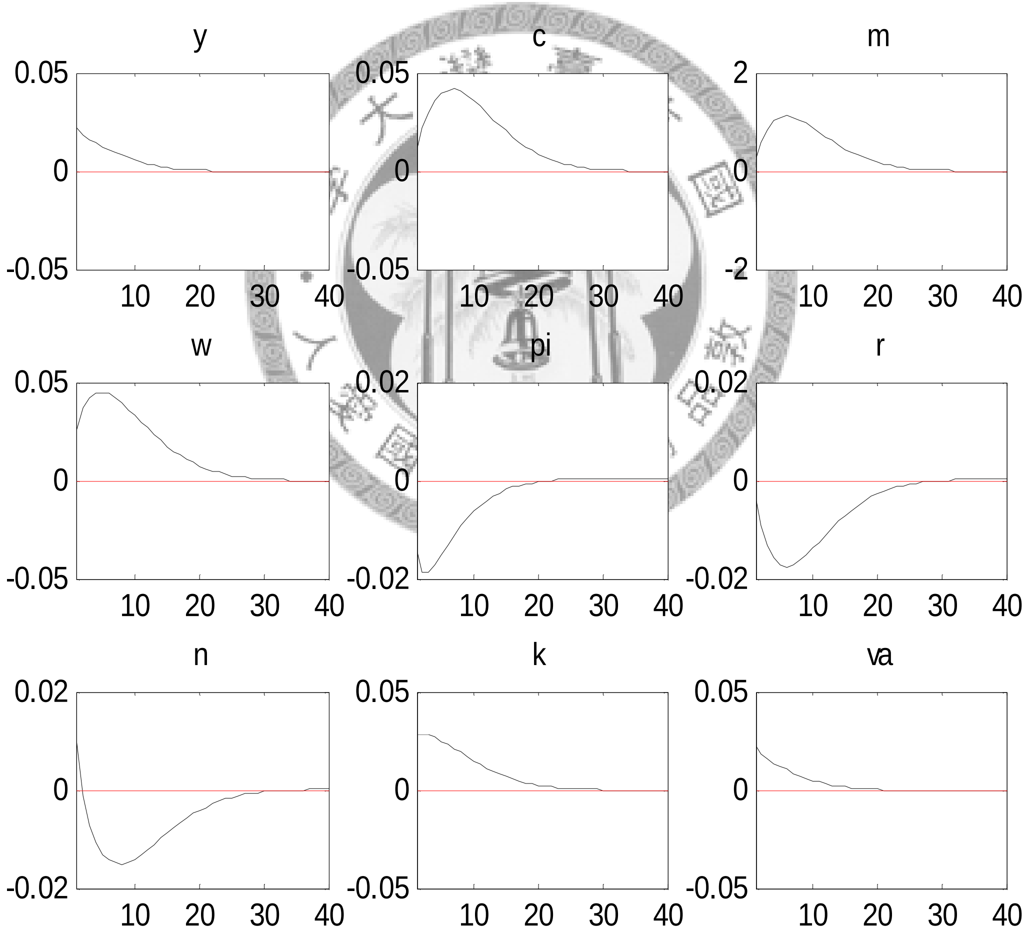

Fig 4.10Impulse response to a 1% wage adjustment cost shock
(y: Output; c: Consumption; m: Monetary; w:Wage; pi: Inflation; r: Interest rate; n: Labor; K: Investment; va: added value production)

4.2.5 The oil price shock

Figure 4.11 presents the estimated response of output, aggregate consumption, money supply, the nomial wage, inflation, interest rate, number of labor, investment, and value-add production to an preference exogenous shock is to raiseoil price by 5 percent. The effect of this preference shock is to raise consumption by 0.015 percent, value-add production by 0.03 percent, monery supply by 0.8 percent , wage by 0.01 percent, inflation by 0.0015 percent, number of labor by 0.025 percent, andinvestment by 0.03 percent. The effect of this preference shock is to fall output by 0.15 percent, and interest rateby 0.015 percent. All effects will be back to base after about 1 or 2 years. From aforementioned results, we know theoil price shock will rise inflation andmoney supply. And output will fall due oil price shock.

4.2.6 The capital utillzation shock

Figure 4.12 presents the estimated response of output, aggregate consumption, money supply, the nomial wage, inflation, interest rate, number of labor, investment, and value-add production to an preference exogenous shock is to raise capital utillzationby 1 percent. The effect of this preference shock is to fallconsumption by 0.1 percent, money supply by 5 percent, and investment by 0.2 percent. The effect of this preference shock is to rise wage by 0.3 percent, inflation by 0.04 percent, interest rate by 0.1 percent, wage by 0.01 percent, number of labor by 3 percent, andoutput by 1 percent. Output and number of labor will be back to baseabout 1 or 2 years, other iterms will be back to base about more years From aforementioned results, we know thecapital utillzation shock will rise output due to the raise of number of labor.

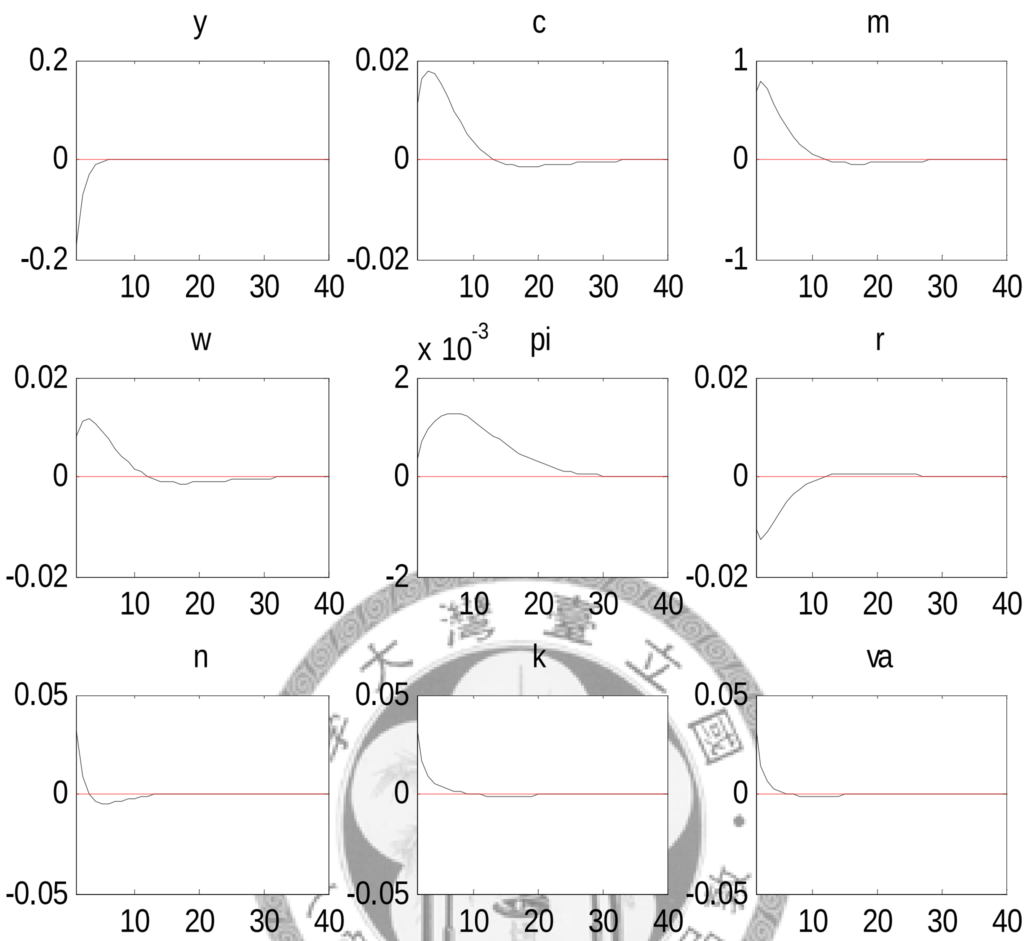

Fig 4.11Impulse response to a 5% oil price shock
(y: Output; c: Consumption; m: Monetary; w:Wage; pi: Inflation; r: Interest rate; n: Labor; K: Investment; va: added value production)

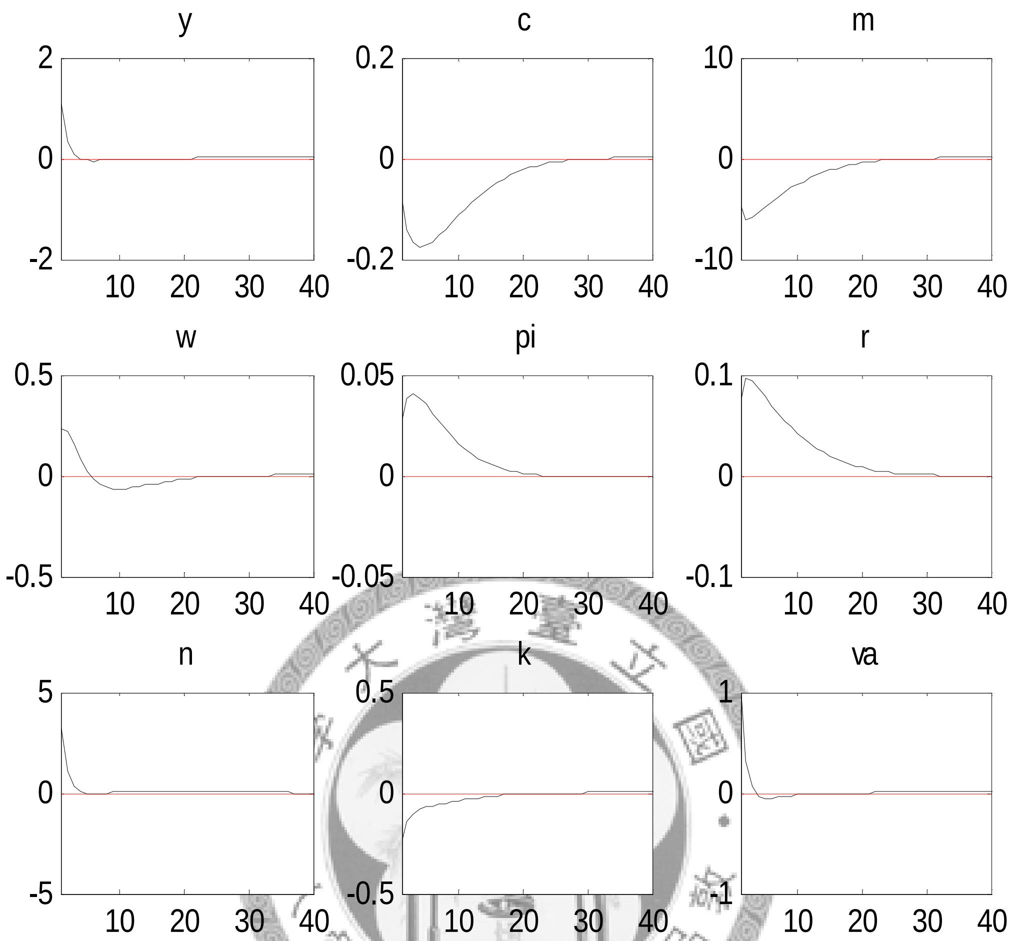

Fig 4.12Impulse response to a 1% capital utilization shock
(y: Output; c: Consumption; m: Monetary; w:Wage; pi: Inflation; r: Interest rate; n: Labor; K: Investment; va: added value production)

4.2.7 The interest rate adjustment cost shock

Figure 4.13 presents the estimated response of output, aggregate consumption, money supply, the nomial wage, inflation, interest rate, number of labor, investment, and value-add production to an preference exogenous shock is to raise interest rate adjustment costby 0.5 percent. The effect of this nterest rate adjustment cost is to fallconsumption by 0.5 percent, money supply by 25 percent, wage by 0.3 percent ,investment by 0.25 percent, inflation by 0.2 percent. The effect of this interest rate adjustment cost is to rise interest rate by 0.5 percent, and number of labor by 0.15 percent. All effects will be back to base after about 1 or 2 years. From aforementioned results, we know theinterest rate adjustment cost shock will fall output and added-value goods.

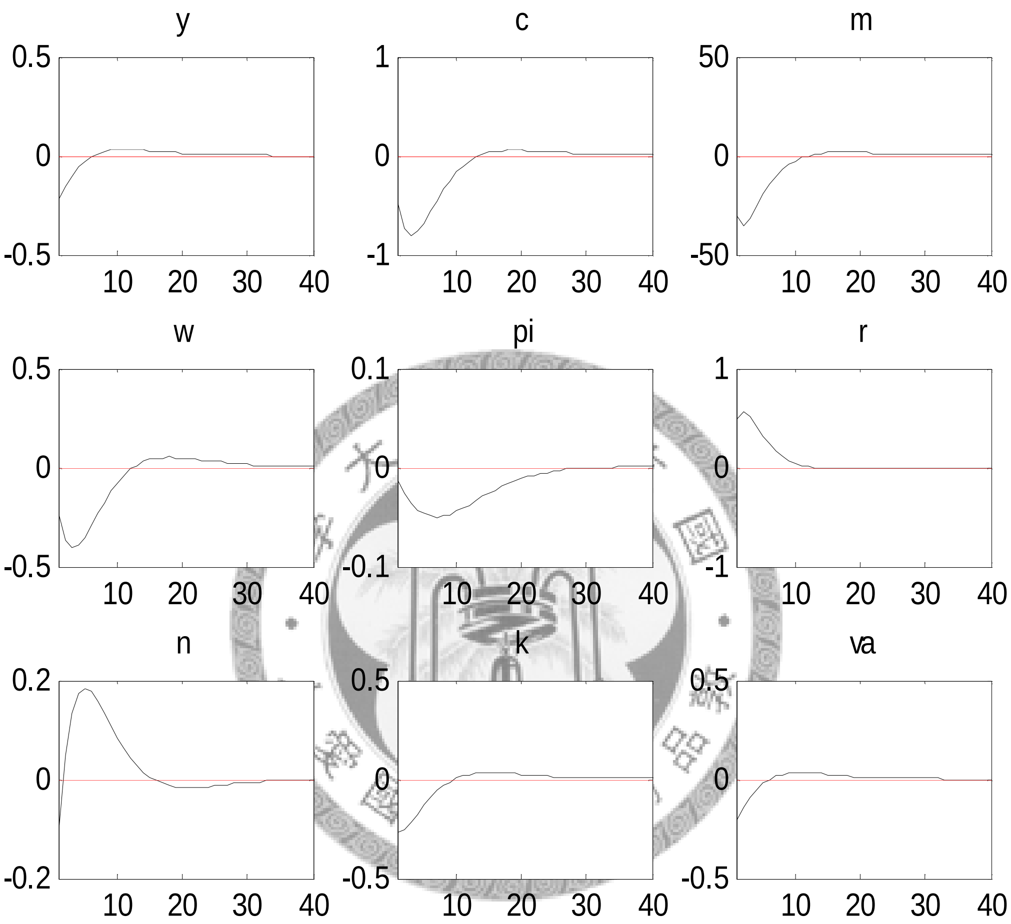

Fig 4.13Impulse response to a 1% interest rate adjustment costshock
(y: Output; c: Consumption; m: Monetary; w:Wage; pi: Inflation; r: Interest rate; n: Labor; K: Investment; va: added value production)

Chapter 5 Discussion about Oil Tax

5.1 Oil tax and the DSGE model

In this chapter, we will discuss the influence of oil tax on the DSGE model. There are two cases discussed in this chapter: one is that the amount of oil tax is proportion to oil price, the other is that the amount of oil tax is proportion to the amount of oil consumption. The two model's posterior distributions are estimated by maximizing the log posterior function, which combines the priors with the likelihood given by the data and then use the Metropolis-Hastings algorithm to obtain the posterior distribution. Table 5.1 shows the posterior distribution and means for the structural parameters. Then the estimated impulse responses of structural shocks will be shown in section 5.2 and section 5.3.

Table 5.1 posterior distribution and means for the structural parameters.

	prior mean	Mode (the amount of oil tax is proportion to oil price)	Mode (the amount of oil tax is proportion to the amount of oil)	Prior distribution	pstdev
γ	0.599	0.5992	0.5992	β	0.0020
σ	0.420	0.4171	0.4187	β	0.0020
h	0.650	0.6550	0.6523	β	0.0020
β	0.990	0.9830	0.9833	β	0.0020
ψ	0.148	0.1480	0.1480	β	0.0020
δ_k	0.025	0.0145	0.0345	β	0.0020
δ	0.100	0.1032	0.0897	β	0.0020
η	0.200	0.2000	0.2000	β	0.0020
η_t	0.900	0.9000	0.9003	β	0.0020
α	0.410	0.4147	0.4124	β	0.0020
θ	0.350	0.3499	0.3498	β	0.0020
ϕ_1	0.420	0.4195	0.4198	β	0.0020
ξ_w	0.828	0.8251	0.8277	β	0.0020
ξ_P	0.905	0.9019	0.9032	β	0.0020
γ_r	0.782	0.7842	0.7811	β	0.0020

γ_w	1.700	1.700	1.6999	γ	0.0020
γ_Y	0.289	0.2887	0.2893	β	0.0020
ρ_z	0.410	0.4100	0.4100	β	0.0020
ρ_e	0.410	0.4099	0.4073	β	0.0020
ρ_b	0.410	0.3984	0.4072	β	0.0020
ρ_{μ_w}	0.410	0.4101	0.4101	β	0.0020
ρ_{μ_P}	0.410	0.4111	0.4100	β	0.0020
ρ_{po}	0.410	0.4100	0.4237	β	0.0020
ρ_u	0.410	0.4105	0.4121	β	0.0020
ρ_v	0.410	0.4088	0.4089	β	0.0020
φ	0.400	0.4000	0.4000	β	0.0020
μ_P	1.200	1.1985	1.2049	γ	0.0020

5.2 Impulse responses of structural shocks -the amount of oil tax is proportion to oil price

5.2.1 The production factor shock

Figure 5.1 presents the estimated response of output, aggregate consumption, money supply, the nomial wage, inflation, interest rate, number of labor, investment, and oil consumption to an preference exogenous shock is to raise production factor by 1 percent in the DSGE model including oil tax. With comparison to the DSGE model without oil tax, it is obvious that the upraised amptitudes of output is smaller. The aforesaid fact shows the oil tax will affect the production's increasing.

5.2.2 The consumer preference shock

Figure 5.2 presents the estimated response of output, aggregate consumption, money supply, the nomial wage, inflation, interest rate, number of labor, investment, and value-add production to an preference exogenous shock is to raise consumer preferences by 1 percent in the DSGE model including oil tax. With comparison to the DSGE model without oil tax, it obvious that the upraised amptitudes of output and consumption are smaller, and the unemployment rate is rising. The aforesaid fact shows the oil tax will affect the consumer preference.

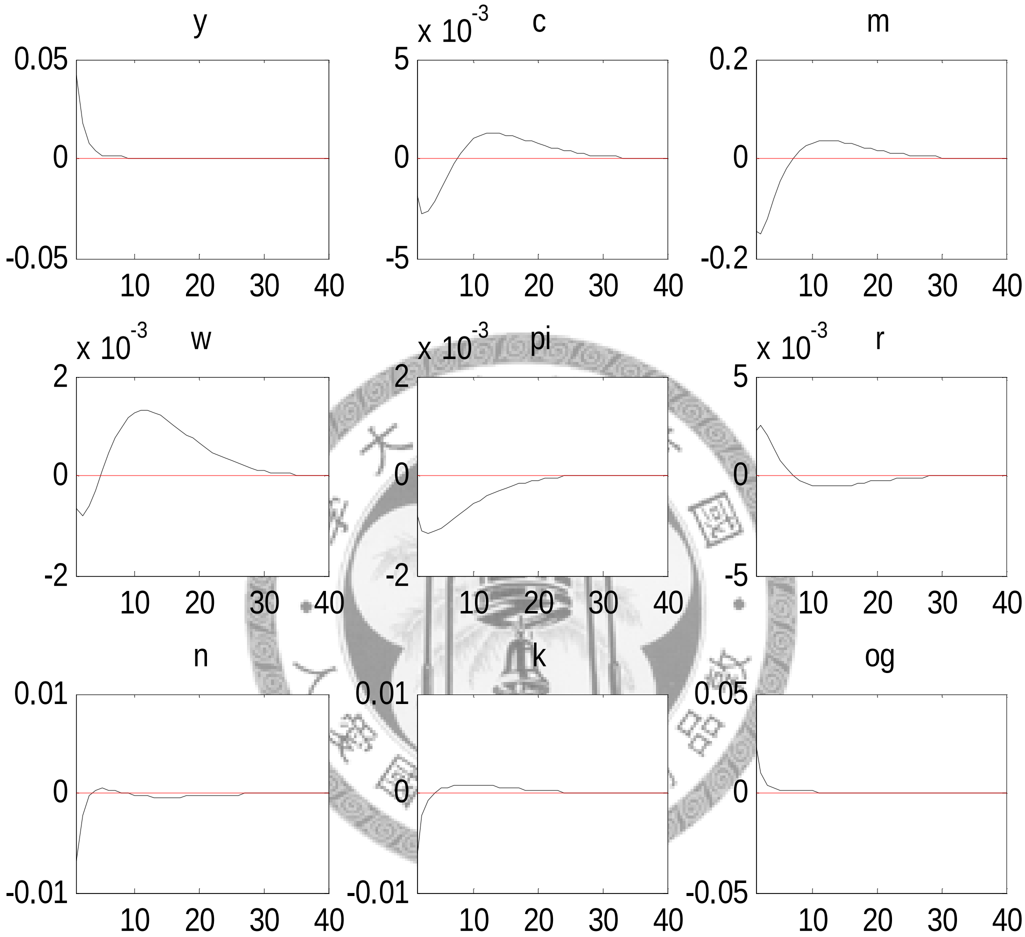

Fig 5.1Impulse response to a 1% production factor shock (oil tax is considered)

(y: Output; c: Consumption; m: Monetary; w:Wage; pi: Inflation; r: Interest rate; n: Labor; K: Investment; og: oil consumption)

5.2.3 The price adjustment cost shock

Figure 5.3 presents the estimated response of output, aggregate consumption, money supply, the nomial wage, inflation, interest rate, number of labor, investment, and oil consumption to an preference exogenous shock is to raise price adjustment cost by 1 percent in the DSGE model including oil tax. With comparison to the DSGE model without oil tax, the upraised amptitudes of output is smaller and the unemployment rate is rising. The aforesaid fact shows the oil tax let the positive effects of price adjustment are obvious.

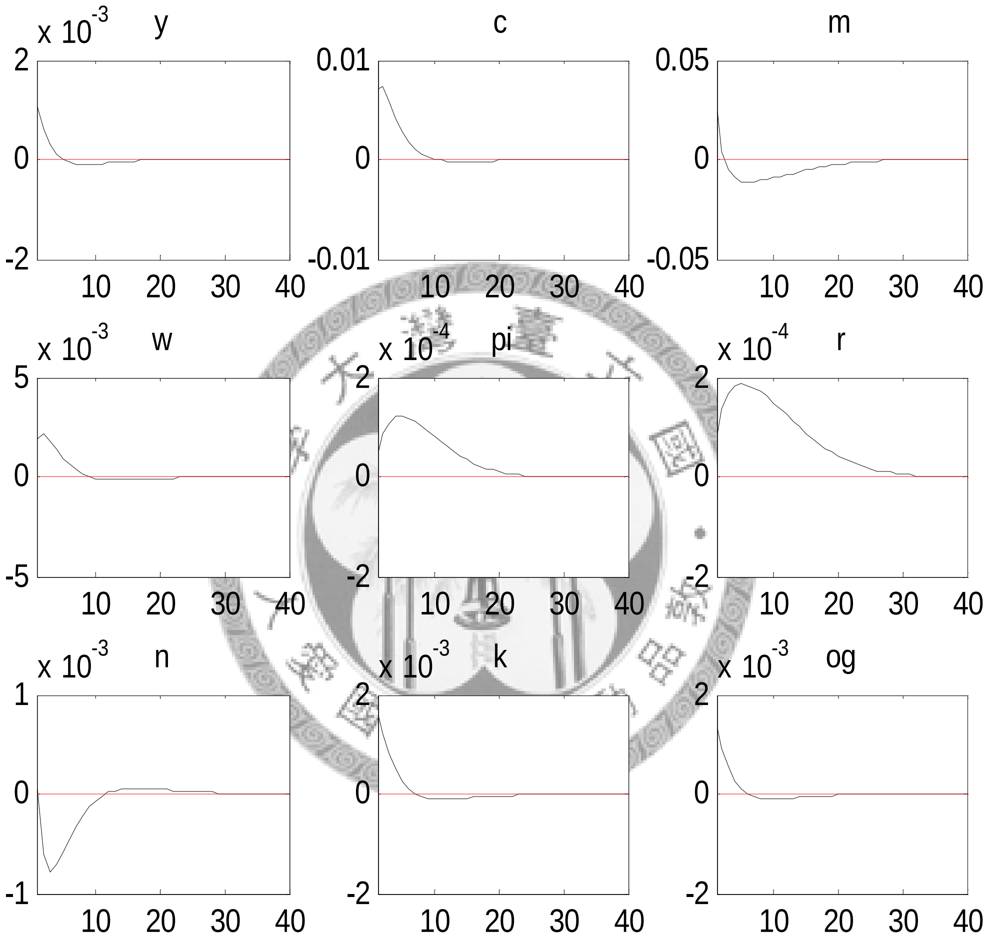

Fig 5.2Impulse response to a 1% consumer preferences shock(oil tax is considered)

(y: Output; c: Consumption; m: Monetary; w:Wage; pi: Inflation; r: Interest rate; n: Labor; K: Investment; og: oil consumption)

5.2.4 The wage adjustment cost shock

Figure 5.4 presents the estimated response of output, aggregate consumption, money supply, the nomial wage, inflation, interest rate, number of labor, investment, and oil consumption to an preference exogenous shock is to raise wage adjustment cost by 1 percent in the DSGE model including oil tax. With comparison to the DSGE model without oil tax, the upraised amptitudes of consumption and wage are smaller and the inflation is rising. The aforesaid fact shows the oil tax reduces the effects of wage adjustment .

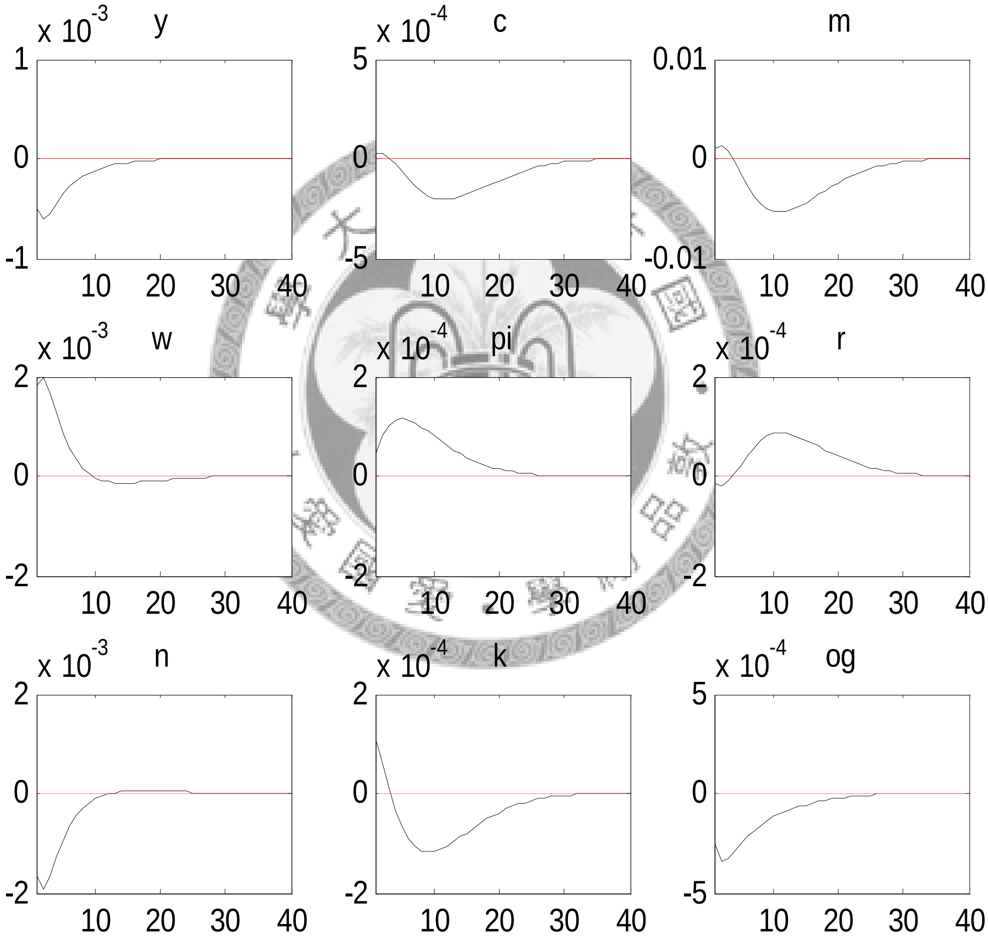

Fig 5.3Impulse response to a 1%price adjustment cost shock (oil tax is considered)

(y: Output; c: Consumption; m: Monetary; w:Wage; pi: Inflation; r: Interest rate; n: Labor; K: Investment; og: oil consumption)

5.2.5 The oil price shock

Figure 5.5 presents the estimated response of output, aggregate consumption, money supply, the nomial wage, inflation, interest rate, number of labor, investment, and oil consumption to an preference exogenous shock is to raise oil price by 5 percent in the DSGE model including oil tax. With comparison to the DSGE model without oil tax, the upraised amptitudes of consumption and output are smaller. The aforesaid fact shows the oil tax will reduce the consumption and production.

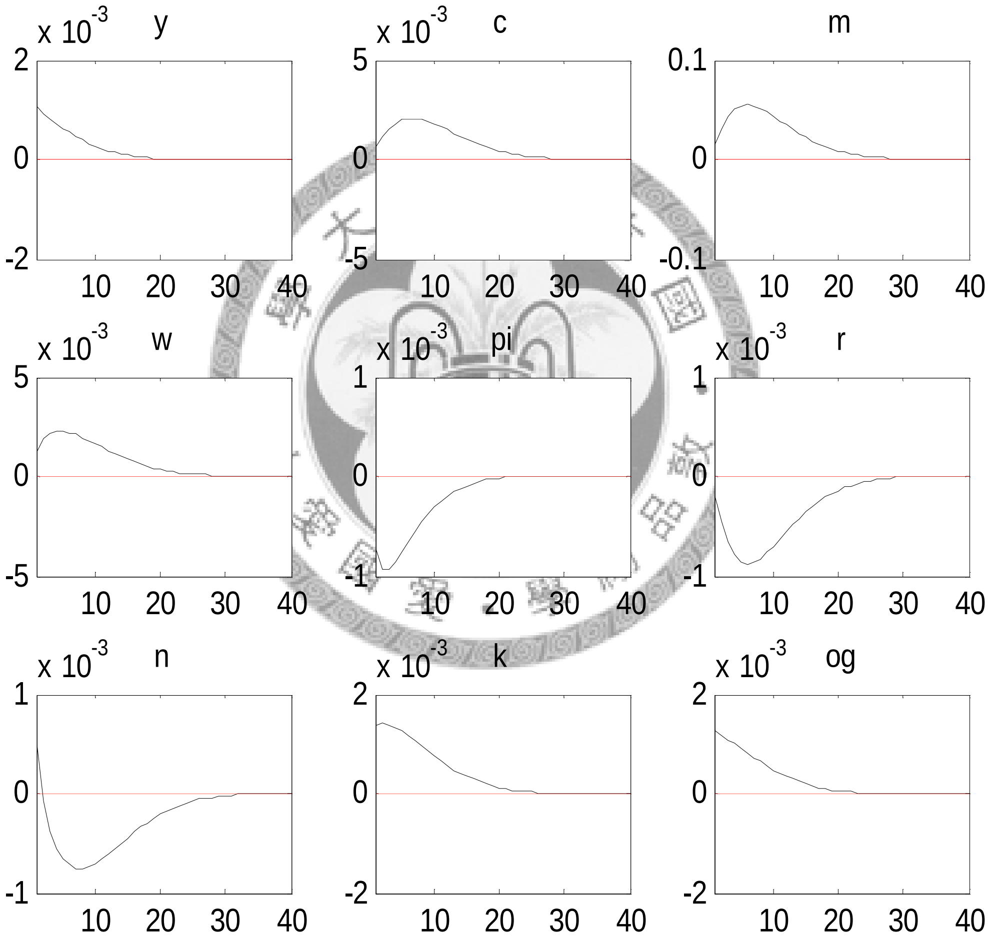

Fig 5.4Impulse response to a 1%wage adjustment cost shock (oil tax is considered)

(y: Output; c: Consumption; m: Monetary; w:Wage; pi: Inflation; r: Interest rate; n: Labor; K: Investment; og: oil consumption)

5.2.6 The capital utillzation shock

Figure 5.6 presents the estimated response of output, aggregate consumption, money supply, the nomial wage, inflation, interest rate, number of labor, investment, and oil consumption to an exogenous shock is to raise oil price by 5 percent in the DSGE model including oil tax. With comparison to the DSGE model without oil tax, the upraised amptitude of wage is smaller . The aforesaid fact shows the oil tax will affect the impcat of capital utilization.

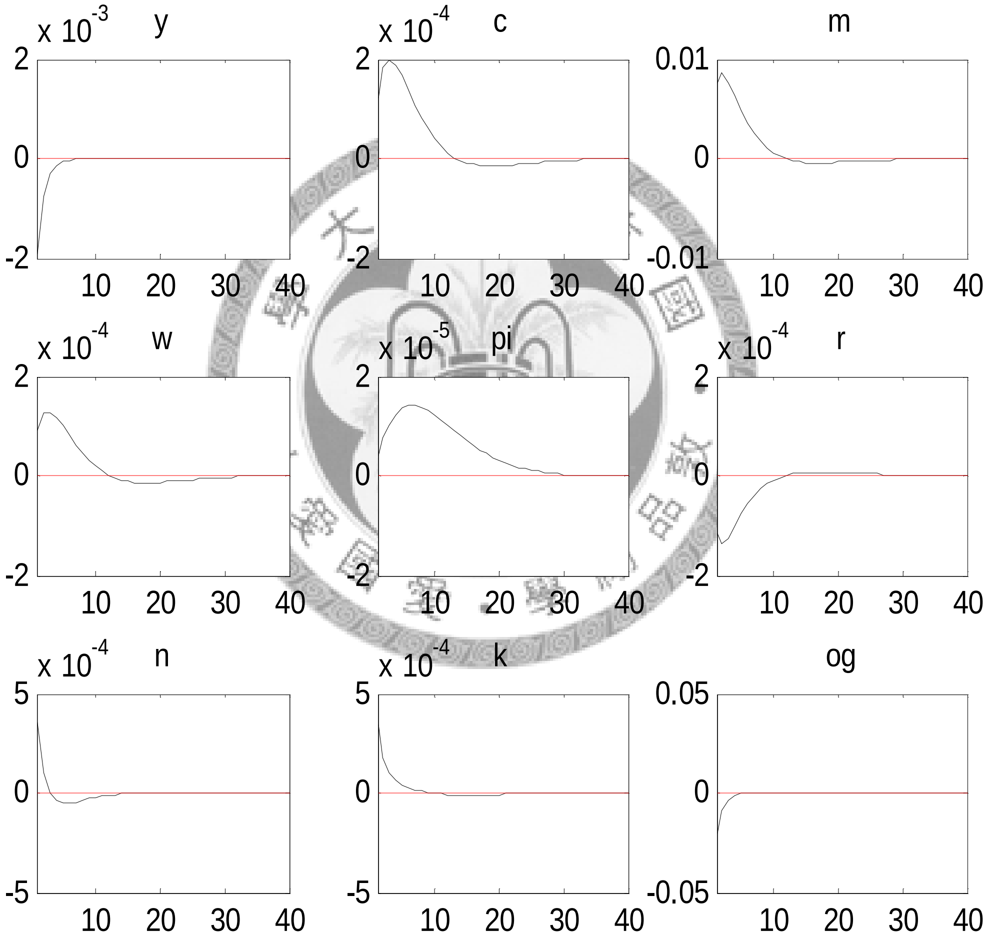

Fig 5.5Impulse response to a 5%oil price shock (oil tax is considered)

(y: Output; c: Consumption; m: Monetary; w:Wage; pi: Inflation; r: Interest rate; n: Labor; K: Investment; og: oil consumption)

5.2.7 The interest rate adjustment cost shock

Figure 5.6 presents the estimated response of output, aggregate consumption, money supply, the nomial wage, inflation, interest rate, number of labor, investment, and oil consumption to an preference exogenous shock is to raise capital utilization by 1 percent in the DSGE model including oil tax. With comparison to the DSGE model without oil tax, the upraised amptitude of output and the decreasing amptitudes of consumption are smaller. The aforesaid fact shows the oil tax will affect the impcat of interest rate adjustment cost.

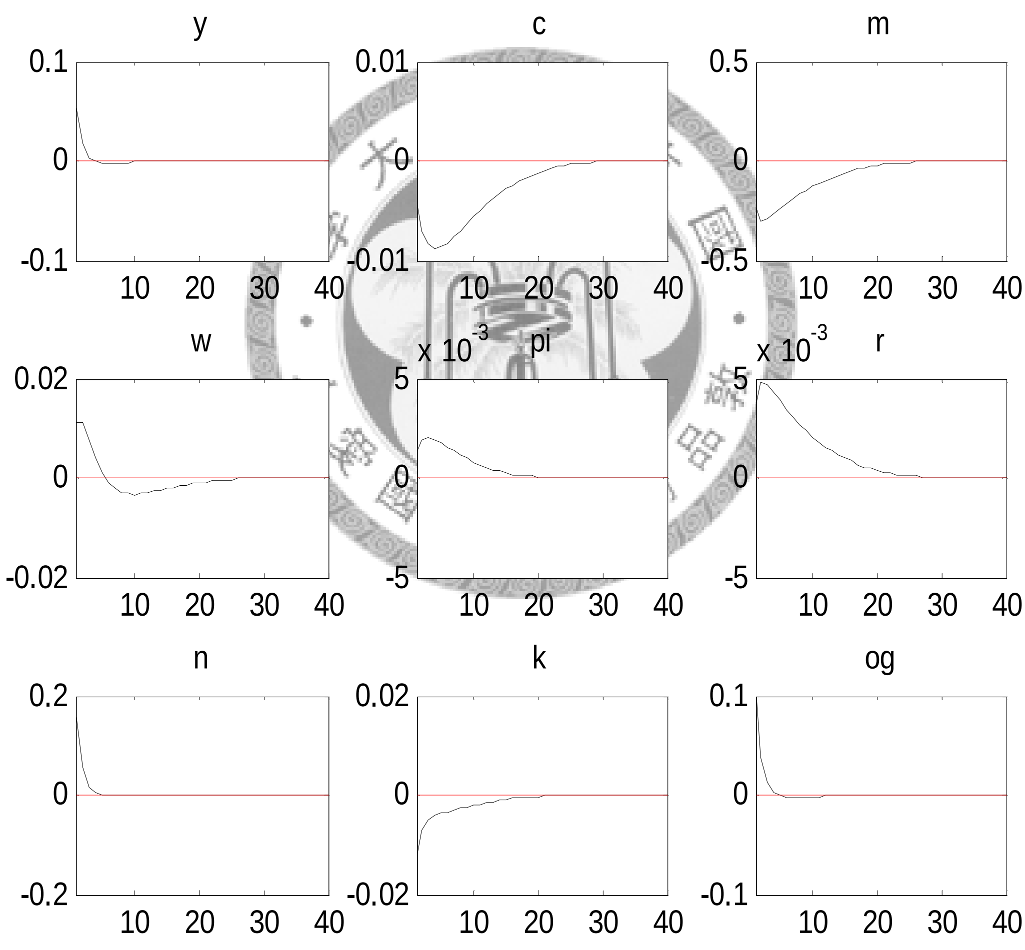

Fig 5.6Impulse response to a 1% capital utilization shock (oil tax is considered)

(y: Output; c: Consumption; m: Monetary; w:Wage; pi: Inflation; r: Interest rate; n: Labor; K: Investment; og: oil consumption)

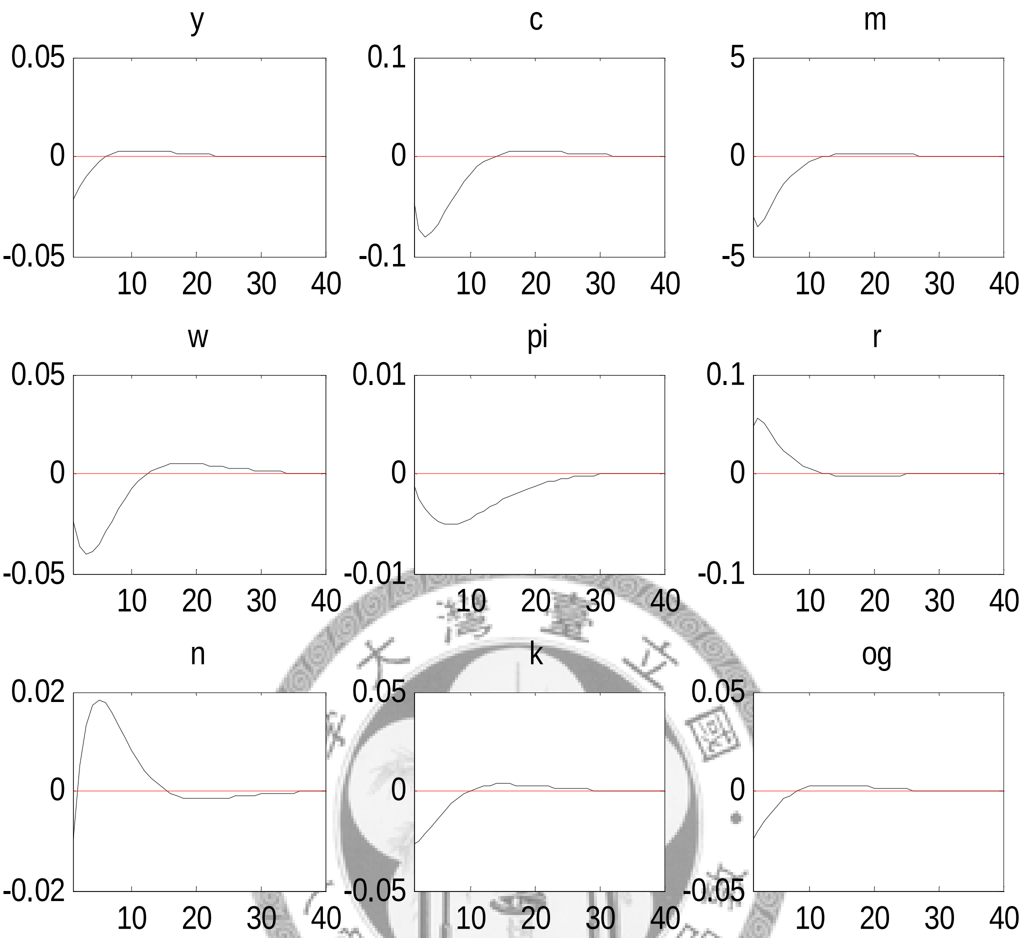

Fig 5.7Impulse response to a 1% interest rate adjustment costs hock (oil tax is considered)

(y: Output; c: Consumption; m: Monetary; w:Wage; pi: Inflation; r: Interest rate; n: Labor; K: Investment; og: oil consumption)

5.3 Impulse responses of structural shocks -the amount of oil tax is proportion to the amount of oil consumption

In this section, the amount of oil tax of the DSGE model is proportion to to the amount of oil consumption, With comparison to the the cases in section 5.2, the estimatined impulses are not obviously different. Figure 5.8 presents the estimated response of output, aggregate consumption, money supply, the nomial wage, inflation, interest rate, number of labor, investment, and oil consumption to an preference exogenous shock is to raise oil consumption by 5 percent. production factor shock is to fall monery supply by 0.15 percent, wage by 0.01percent , number of labor by 0.1 percent, investnent by by 0.1 percent and inflation 0.02 percent. But monery supply, consumption,wage will reverse to rise after 1 or 2

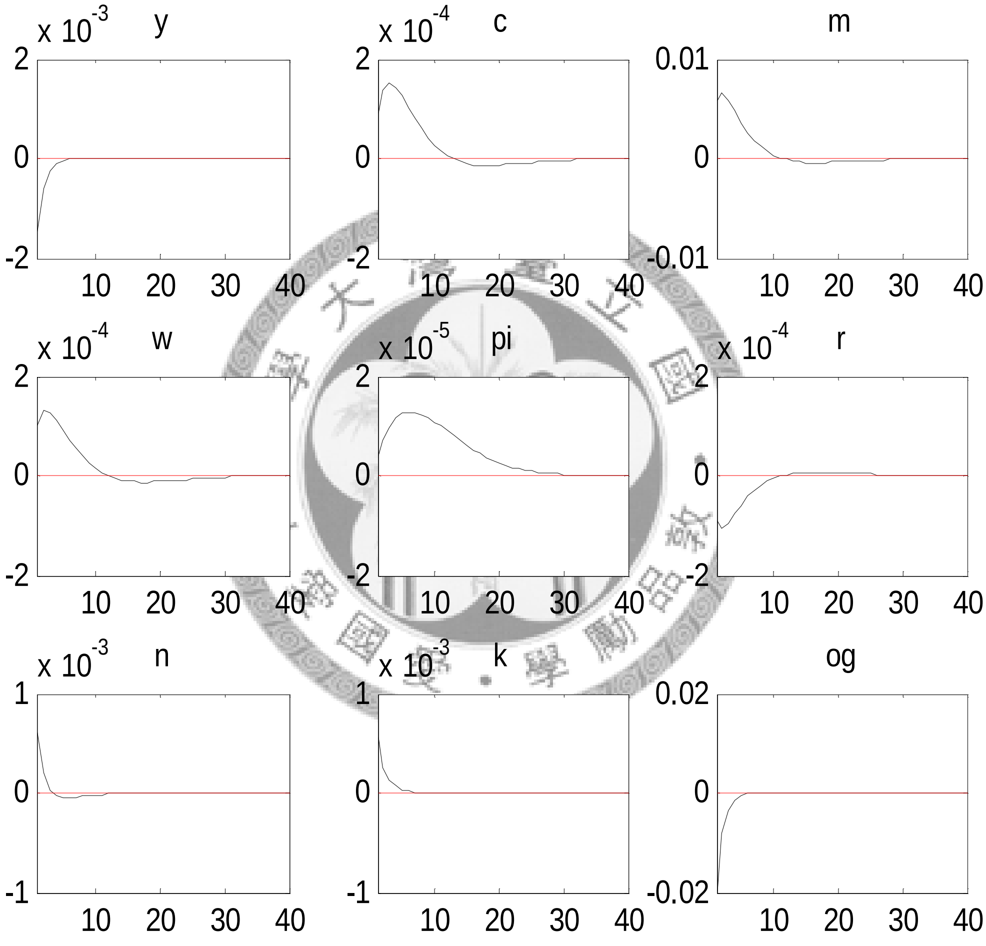

Fig 5.8Impulse response to a 5%oil price shock (oil tax is considered)

(y: Output; c: Consumption; m: Monetary; w:Wage; pi: Inflation; r: Interest rate; n: Labor; K: Investment; og: oil consumption)

Chapter 6 Conclusion

In this paper, we present an estimated a New Keynesian DSGE model for the Taiwanese economy. This paper has estimated a DSGE model of Taiwan developed originally by Christiano *et al* (2005), Ireland (1997) and Peersman *et al* (2012).The basic building blocks of the model are standard in the literature. There are three consumption goods: non-energy output, petrol and utilities; consumers choose how much of each of these goods to consume in order to maximize their utility in their overall wealth. Oil is used as an input to production and a part of households' consumption in this paper. There is a flexible elasticity of substitution between oil and other types of consumption goods in the consumption bundle. We also simulate the oil tax shock on macroeconomic. The results of the present paper are based on a Bayesian estimated model and support the view that inflation and interest rate move in opposite directions after an oil price shock. The simulated results also support the view that the oil tax will make the data worsen.

The main results of this paper are followings. First, the production factor shock, consumer preference shock, wage adjustment cost shock will immediately raise output, the value-add production consumption. The capital utilization shock will raise output due to the raise of number of labor. The price adjustment cost shock, oil price shock will raise inflation and fall consumption. The interest rate adjustment cost shock will fall output and added-value goods. A 1% increase in production factor leads to raise in output of about 1% and a 1% increase in consumer preference leads to raise in output of about 0.025%. A 1% increase in consumer preference leads to raise in consumption of about 1% and a 1% increase in wage adjustment leads to raise in consumption of about 0.025%. A 1% increase in price adjustment leads to fall in output of about 0.02% . And a5% increase in the real price of oil leads to fall in output of about 0.2% and an increase in inflation of about 0.001%.

Second, the contractionary effect of the oil shock is due mainly to the endogenous tightening of the production conductions. By the forecasting of the DSGE model, the oil tax will affect the consumer preference, and weaken the effects of production factor, wage adjustment and capital utilization. Production, consumption and the amount of oil consumptionwill also be reduced and CPI inflation will be raised. There are two types of oil tax rules discussed in this paper:one is that the amount of oil tax is proportion tooil price and another is that the amount of oil tax is proportion tothe amount of oil consumption. However, the effects of two types are not obviously different.

Third, the numerical results show that interest rate and output raise at the same time. But a 1% increase in interest rate adjustment cost leads to fall in output of about 0.25% .

The main contribution of this paper is that we simulate how the exogenous shocks would affect macroeconomic by using the estimated DSGE model. And the numerical results show that the variables are not substantially affected by the presence of nominal rigidities. This paper also aims to explore the complications of the effects between these exogenous shocks. The suggestions of this paper are followings. First, the oil tax would reduce oil consumption and impact economic growth. Second, the effects of different types of oil tax are not obviously different.

In the future work, we must provide a more accurate DSGE macroeconomic model to explain the relations of this economic variables and the mechanisms of changes of this economic variables. The model must include the domestic and foreign economic facts. We can also use the DSGE model to find the optimal oil tax to reduce oil consumptions, but the impacts of oil taxi to economic growth is minimal.

Reference

Beidas-Storm S.,Poghosyan T. (2009), "An Estimated Dynamic Stochastic General equilibrium Model of the Jordanian Economy", International Monetary Fund, *IMF Working Pape*r No. 11/28, 2011, 251pp.

Calvo, G.(1983), "Staggered Prices in a Utility-Maximizing Framework", *Journal of Monetary Economics*, 12, 3, pp. 383-398.

Christiano L.J., Eichenbaum M. and Evans C.(2005),"Nominal Rigidities and theDynamic Effects of a Shock to Monetary Policy", *Journal of Political Economy*, 113,1, pp. 1-45.

De Fiore,F., Lombardo, G., and Stebunovs, V.(2006), "Oil Price Shocks, Monetary Policy Rules and Welfare", *Computing in Economics and Finance*, Society for Computational Economics 402

DeJonga,D. N.,Ingram,B. F., and Whiteman, C. H.(2000), "A Bayesian Approach to DynamicMacroeconomics",*Journal of Econometrics*, Volume, 98, Issue 2, October 2000, Pages 203–223

Funke M., Paetz M., and Ernest Pytlarczyk,E.(2011),"Stock Market Wealth Effects in an Estimated DSGE Model for Hong Kong", *Economic Modeling* , vol. 28, no. 1, 2011, pp. 316-334

Griffoli, T.M. (2007),"DYNARE User Guide: An Introduction to the Solution and Estimation of DSGE models.",*http://www.dynare.org/documentation-and-support/user-guide*

Golosov, M., Hassler, J., Krusell, P. and Tsyvinski, A.(2011),"Optimal Taxes on Fossil Fuel In General Equilibrium", *NBER Working Pape*r 17348.

Hamilton, J.D.(1983), "Oil and the Macroeconomic since World War II", *Journal of Political Economy*, 91, 2, pp. 228-248.

Hamilton, J.D. and Herrera, A.M.(2004),"Oil Shocks and Aggregate Macroeconomic Behavior: The Role of Monetary Policy", *Journal of Money, Credit, and Banking*, 36, 2, pp. 265-286.

Hongzhi,T.(2010),"Effects of Oil Price Shocks on Japan's Economy: A DSGE Approach", *International Research Journal of Finance and Economics*, Issue 42, pp63-73

Ireland, P. N.(1997),"A Small, Structural, Quarterly Model for Monetary Policy Evaluation", *Carnegie-Rochester Conference Series on Public Policy*, 47, pp 83-118

Liu, guangling and Gupta,R.(2007),"A small-scale DSGE Model for Forecasting the South African economy ",*South African Journal of Economics*, Volume 75, issue 2 (June 2007), pp. 179-193.

Liao, E.A.Teng, C.H.(2008),"The Effects of Monetary Policy: a DSGE Model analysis of Taiwan", *Applied Economics*, 40, pp.1043-1051

Lucas, Robert(1976), "Econometric Policy Evaluation: A Critique", *Carnegie-Rochester Conference Series on Public Policy* 1 (1): pp19-46

Medina, J. P. and Soto, C.(2006), "Model for Analysis and Simulations: A Small Open Economy DSGE for Chile", *Conference Paper*, Central Bank of Chile

Millard,S.(2011), "An Estimated DSGE Model of Energy, Costs and Inflation in the United Kingdom", *Bank of England Working Paper* No. 432, July 26

Peersman, G. and Stevens, A.(2012), "Analyzing Oil Demand and Supply Shocks in an Estimated DSGE-Model", *Ghent University, manuscript*

Rabanal, P.(2007), "Does Inflation Increase after a Monetary Policy Tightening? Answers Based on aEstimatedDSGE Model", *Journal of Economic Dynamics & Control*, 31, pp.906–937

Smets, F. and Wouters, R.(2007),"Shocks and Frictions in US Business Cycles: A Bayesian DSGE Approach", *American Economic Review*, 97, 3, pp. 586-606

Smets, F. and Wouters R.(2003),"An Estimated Dynamic Stochastic General Equilibrium Model of the Euro Area," *Journal of European Economic Association*, 1(5), 1123–1175

Teo, W.L.(2009), "An Estimated Dynamic Stochastic General Equilibrium Model of the Taiwanese Economy", *Pacific Economic Review*, 14(2), 194-231

Unalmis,D.,Unalmis,I. and Unsa F. D.(2009),"On the Sources of Oil Price Fluctuations", International Monetary Fund, *IMF Working Paper* No. 09/285

Uhlig, H.(2007)," Explaining Asset Prices with External Habits and Wage Rigidity in a DSGEModel", *American Economic Review*, 97, pp.239–243

Appendix A－Log-linear Model of DSGE model

Household

Momentary equation：

$$-\frac{1}{\gamma}\hat{m}_t + \frac{1}{\sigma(1-h)}(\hat{c}_t - h\hat{c}_{t-1}) = \frac{\beta}{1-\beta}\hat{r}_t$$

$$\hat{c}_t = \frac{1}{1+h}E_t\{\hat{c}_{t+1}\} + \frac{h}{1+h}\hat{c}_{t-1} + \frac{\sigma(1-h)}{1+h}(-\hat{r}_t + E_t\{\hat{\pi}_{t+1}\} - E_t\{\hat{b}_{t+1} - \hat{b}_t\})$$

Investment equation：

$$\hat{i}_t = \frac{\beta}{1+\beta}E_t\{\hat{i}_{t+1}\} + \frac{1}{1+\beta}\hat{i}_{t-1} + \frac{\psi}{1+\beta}\hat{q}_t + \frac{1}{1+\beta}E_t\{\beta\hat{z}_{t+1} - \hat{z}_t\})$$

$$\hat{r}_t^k = \hat{u}_t \big/ \psi_u \;:$$

$$\psi_u = f^{'}(1) \big/ f''(1)$$

$$\hat{k}_{t+1} = (1-\delta_K)\hat{k}_t + \delta_K\hat{i}_t$$

Firm

Technology of the intermediate firm：

$$\hat{y}_t = \eta_t(V\hat{A}_t) + (1-\eta_t)\hat{o}_{gt}$$

$$V\hat{A}_t = \hat{\varepsilon}_t^{TEP} + \theta\hat{n}_t + (1-\theta)\hat{k}_t$$

the demand curves for labor and oil by minimizing cost

$$\hat{n}_t = -(\hat{w}_t - \hat{r}_t^k) + (1+\hat{r}_t^k)\hat{k}_t \; \hat{O}_{gt} = -\alpha(\hat{p}_{O,t} - \hat{s}_t) + V\hat{A}_t$$

$$\hat{s}_t = (1-\theta)\hat{r}_t^k + \theta\hat{w}_t - \hat{\varepsilon}_t^{TEP}$$

Wage equation：

$$\hat{w}_t = \frac{1}{1+\beta}(\hat{\pi}_{t-1} + \hat{w}_{t-1}) - \hat{\pi}_t + \frac{\beta}{1+\beta}E_t\{\hat{w}_{t+1} + \hat{\pi}_{t+1}\} - \frac{(1-\beta\xi_w)(1-\xi_w)}{(1+\beta)\xi_w}(\hat{w}_t - \hat{\mu}_t^* - \frac{1}{\phi}\hat{n}_t - \frac{1}{\sigma(1-h)}(\hat{c}_t - h\hat{c}_{t-1}))$$

Inflation equation :

$$\hat{\pi}_t = \frac{1}{1+\beta}\hat{\pi}_{t-1} + \frac{\beta}{1+\beta}E_t\{\hat{\pi}_{t+1}\} - \frac{(1-\beta\xi_w)(1-\xi_w)}{(1+\beta)\xi_w}(-\hat{a}_t + \alpha\hat{r}_t^k + (1-\alpha)\hat{w}_t - \hat{\mu}_t^p)$$

$$\hat{y}_t = \frac{\mu^p(1-\beta(1-\delta)) - \alpha\beta\delta}{\mu^p(1-\beta(1-\delta))}\hat{c}_t + \frac{\alpha\beta\delta}{\mu^p(1-\beta(1-\delta))}\hat{i}_t$$

Taylor's rule of Central Bank's monetary policy :

$$\hat{r}_t = (1-\gamma_r)(\gamma_w\hat{\pi}_t + \gamma_y\hat{y}_t) + \gamma_r\hat{r}_{t-1} + \hat{v}_t$$

Shock

investment adjustment cost shock : $\hat{z}_t = \rho_z\hat{z}_{t-1} + \eta_t^z$

production facto shock r : $\hat{\varepsilon}_t^{TEP} = \rho_\varepsilon\hat{\varepsilon}_{t-1}^{TEP} + \eta_t^\varepsilon$

consumer preferences shock : $\hat{b}_t = \rho_b\hat{b}_{t-1} + \eta_t^b$

price adjustment cost shock : $\hat{\mu}_t^p = \rho_{\mu p}\hat{\mu}_{t-1}^p + \eta_t^{\mu p}$

wage adjustment cost shock : $\hat{\mu}_t^w = \rho_{\mu w}\hat{\mu}_{t-1}^w + \eta_t^{\mu w}$

wageoil price shock : $\hat{p}_t^o = \rho_{po}\hat{p}_{t-1}^o + \eta_t^{po}$

interest rate adjustment cost shock : $\hat{v}_t = \rho_v\hat{v}_{t-1} + \eta_t^v$

capital utillzation shock : $\hat{u}_t = \rho_u\hat{u}_{t-1} + \eta_t^u$

where $\rho_x \in (-1,1)$ and x are the values of the exogenous shocks in steady state.

η_t^x isdistributed (iid) series with mean 0 and standard deviation is variance σ_z.

Appendix B－Dynare Code

```
var m c r pi b q i z k po n va y w epsilontepmuptmuwut v;
varexoetazetaeetabetamupetamuwetapoetauetav;
parameters gamma sigma h beta psodeltak delta nu eta etat theta alpha pso1
xiwxipgammargammawgammayrhozrhoerhobrhomuwrhomuprhoporhourhov phi psi mup;
gamma=0.5992;
sigma=0.42;
h=0.65;
beta=0.99;
pso=0.148;
deltak=0.025;
delta=0.1;
phi=0.4;
psi=0.5;
nu=1;
eta=0.2;
etat=0.9;
theta=0.35;
alpha=0.41;
pso1=0.42;
xiw=0.8284;
xip=0.9053;
mup=1.2;
gammar=0.7822;
gammaw=1.7;
gammay=0.289;
rhoz=0.41;
rhoe=0.41;
rhob=0.41;
rhomuw=0.41;
rhomup=0.41;
rhopo=0.41;
rhou=0.41;
rhov=0.41;
model(linear);
```

```
(-1/gamma)*m+(1/(sigma*(1-h)))*(c-h*c(-1))=(beta/(1-beta))*r;
c=(1/(1+h))*c(+1)+(h/(1+h))*c(-1)+(sigma*(1-h)/(1+h))*(-r+pi(+1)-(b(+1)-b)) ;
i=(beta/(1+beta))*i(+1)+(1/(1+beta))*pso*q+(1/(1+beta))*(beta*z(+1)-z) +(1/(1+beta))*i(-1);
k(+1)=(1-deltak)*k+deltak*i;
w=(1/(1+beta))*(pi(-1)+w(-1))-pi+(beta/(1+beta))*(w(+1)+pi(+1))-((1-beta*xiw)*(1-xiw)/((1+beta)
*xiw))*(w-muw-((-(w-(ut/0.27))+(1+0.27)*k)/pso1)-(1/(sigma*(1-h))*(c-h*c(-1))));
pi=(1/(1+beta))*pi(-1)+(beta/(1+beta))*pi(+1)+((1-beta*xip)*(1-xip)/((1+beta)*xip))*(-epsilontep+
alpha*(ut/0.27)+(1-alpha)*w-mupt);
n=-(w-(ut/0.27))+(1+0.27)*k;
va=epsilontep+theta*n+(1-theta)*k;
y=etat*va+(1-etat)*(-alpha*(po-((1-theta)*(ut/0.27)+theta*w-epsilontep))+va);
y=(mup*(1-beta*(1-delta))-alpha*beta*delta)/(mup*(1-beta*(1-delta)))*c+(alpha*beta*delta)/(mup
*(1-beta*(1-delta)))*i;
r=(1-gammar)*(gammaw*pi+gammay*y)+gammar*r(-1)+v;
z=rhoz*z(-1)+etaz;
epsilontep=rhoe*epsilontep(-1)+etae;
b=rhob*b(-1)+etab;
mupt=rhomup*mupt(-1)+etamup;
muw=rhomuw*muw(-1)+etamuw;
po=rhopo*po(-1)+etapo;
ut=rhou*ut(-1)+etau;
v=rhov*v(-1)+etav;
end;
initval;
m=0;
c=0;
r=0;
pi=0;
b=0;
q=0;
i=0;
z=0;
k=0;
po=0;
va=0;
n=0;
y=0;
```

```
w=0;
v=0;
epsilontep=0;
mupt=0;
muw=0;
end;
shocks;
varetaz; stderr 0.05;
varetae; stderr 0.05;
varetab; stderr 0.05;
varetamup; stderr 0.05;
varetamuw; stderr 0.05;
varetapo; stderr 0.05;
varetau; stderr 0.05;
varetav; stderr 0.05;
end;
steady;
check;
stoch_simul(hp_filter = 1600, order = 1, irf = 40);

varobs y c m w pi r n k;
estimated_params;
gamma, beta_pdf, 0.5992, 0.002;
sigma, beta_pdf, 0.42, 0.002;
h, beta_pdf, 0.65, 0.002;
beta, beta_pdf, 0.99, 0.002;
pso, beta_pdf, 0.148 , 0.002;
deltak, beta_pdf, 0.025, 0.002;
delta, beta_pdf, 0.1, 0.002;
nu, gamma_pdf, 1, 0.002;
eta, beta_pdf, 0.2 , 0.002;
etat, beta_pdf, 0.9, 0.002;
theta, beta_pdf, 0.35, 0.002;
alpha, beta_pdf, 0.41, 0.002;
pso1, beta_pdf, 0.42, 0.002;
xiw, beta_pdf, 0.8284, 0.002;
xip, beta_pdf, 0.9053, 0.002;
```

```
gammar, beta_pdf, 0.7822, 0.002;
gammaw, gamma_pdf, 1.7, 0.002;
gammay, beta_pdf, 0.289, 0.002;
rhoz, beta_pdf, 0.41, 0.002;
rhoe, beta_pdf, 0.41, 0.002;
rhob, beta_pdf, 0.41, 0.002;
rhomuw, beta_pdf, 0.41, 0.002;
rhomup, beta_pdf, 0.41, 0.002;
rhopo, beta_pdf, 0.41, 0.002;
rhou, beta_pdf, 0.41, 0.002;
rhov, beta_pdf, 0.41, 0.002;
phi, beta_pdf, 0.4, 0.002;
psi, beta_pdf, 0.5, 0.002;
mup, gamma_pdf, 1.2, 0.002;
end;
estimation(datafile=test5,mode_compute=6)
```