Oil Price Shocks and Monetary Policy Responses in China: A Financial CGE Model Analysis

Jing-Yu Liu,[1] Shih-Mo Lin,[2] Ying Fan,[3] and Yan Xia[4]

Abstract

Sharp increases in the price of oil pose a dilemma for monetary policymakers. It is difficult for them to know the exact magnitude of the oil shock's effects on the economy or implement correct monetary policies. In addition, they have to face a trade-off between inflation and reduced economic growth. This study builds a financial CGE model and simulates the interaction between real and financial side of the Chinese economy. We measure the effects of both interest rate and reserve ratio policy of the central bank in response to an oil price shock, and then identify the optimal monetary policies aiming at each inflation target. We found that when tolerance for inflation is high, it is best to implement interest rate policy alone. On the other hand, when tolerance for inflation is low and the government is more focused on social stability and household welfare, reserve ratio policy should also be implemented in addition to interest rate policy. In a scenario where world oil price increases by 100% and the inflation rate is to be targeted at below 2%, the monetary authority should raise the interest rate and reserve ratio by 2% and 2.4%, respectively.

Keywords: Oil shocks, monetary policy, financial CGE, China

1 Introduction

The consumption of crude oil is essential to most economic activities. Both the production of goods and the provision of services involve a substantial use of oil in their day-to-day operations. Consequently, shocks resulting from a sudden rise in oil prices or an unexpected shortage of oil supply will bring significant negative effects to the economy. In fact, a large number of studies have reported that sudden and lasting oil price increases have been generally accompanied by economic contractions and high inflation (e.g., Brown and Yücel, 2002).

The most recent oil price shock occurred in 2007-2008, where it reached a record high of over $140 per barrel. Countries all over the world suffered from such

[1] Center for Energy and Environmental Policy Research, Institute of Policy Management, Chinese Academy of Sciences.

[2] Department of International Business and Center for Applied Economic Modeling, Chung Yuan Christian University, Taiwan. Corresponding author. Address: 200 Chung-Pei Road, Chung-Li 32023, Taiwan. Email: shihmolin@gmail.com.

[3] Center for Energy and Environmental Policy Research, Institute of Policy Management, Chinese Academy of Sciences.

[4] Center for Energy and Environmental Policy Research, Institute of Policy Management, Chinese Academy of Sciences.

a sharp price increase. Despite being a fast-growing economy, China is not immune to this shock. During this period, its economic growth rate declined and inflation increased. This drew the attention of the Chinese government. A sequence of policy actions followed, including its immediate monetary actions and follow-up fiscal stimulations.

Oil price hikes will almost always transmit to the prices of downstream industry and final consumption goods. Inflationary forces result to an increased transactions demand for money. Monetary authorities would have to infuse money to the economy to meet this sudden increase in demand. However, monetary authorities can not deviate from their overarching mission, which is to cope with interfering factors of economic activities and to offset price fluctuations. As a result, they will inevitably face a dilemma of implementing policy measures that might have differential effects on inflation and economic growth.

During a period of sharp rise in oil price, commodity prices tend to increase across the board. Household real income decreases and household welfare suffers. The effects of unequal wealth distribution are magnified. If inflation goes up and wages are adjusted accordingly, spiraling inflation occurs and the economic condition exacerbates. Price volatility adds to the uncertainty and raises the risks. If borrowing is easy or if borrowing cost is low, it might further encourage blind expansions of production, making the operation of economic activities even more risky.

On the other hand, if inflation caused by oil shocks is addressed with tightened monetary policies, it is likely that consumption, investment and exports will slow down simultaneously. Tightened domestic liquidity might stimulate foreign capital inflows and affect the equilibrium of balance of payments. In the case of China, as the managed floating exchange rate system has been adopted for Renminbi (RMB), foreign capital inflows might not help the tightening of liquidity, but to offset some anti-inflation effects of monetary policies. Therefore, we can conclude that in the short to medium term, contractionary monetary policies aimed at fighting inflation might actually contradict the three other goals of monetary authority: economic growth, high employment and equilibrium of balance of payments. Thus, in the face of oil shocks, it is urgent for policymakers to be prepared in making optimal choices to balance these different goals.

The possible causal relations between oil shocks and monetary policies have been researched for decades. Recently, Krichene (2006) found a two-way relationship between oil prices and interest rates. During a supply shock, rising oil prices may cause interest rates to increase; whereas during a demand shock, falling interest rates can cause oil prices to rise. Aastveit (2009), on the other hand, found that the monetary authority usually reacts differently to demand and supply shocks. Ahmed and Wadud (2011) studied the relation among volatility of oil prices, monetary policies and the macro economy for Malaysia. They found that the

Malaysian central bank has been adopting an expansionary monetary policy in response to oil price shocks.

The cause of economic recessions after oil shocks is another interesting topic that has attracted a great deal of research. These studies normally distinguish between the effects of the oil shock itself and that of the monetary policies in response to the oil shock. For instance, Lee et al. (1999) found that between 30 and 50 percent of the negative impact of oil shocks on Japanese output is attributable to the money tightening induced by oil shocks. Leduc and Sill (2003) found that monetary policy contributes about 40 percent to the drop in output following a rise in oil prices. Medina and Soto (2005) showed that the contractionary effect of the oil shock is mainly due to the endogenous tightening of the monetary policy. Leduc and Sill's (2006) principal findings were that monetary policy has played a substantial role in reducing inflation volatility, and a small role in reducing real output volatility. Lee and Song (2009) studied how monetary responses to oil price shocks can affect economic stability and found that an accommodative policy usually yields more stable outcomes. Rahman and Serletis (2010) further found that monetary policy is not only reinforcing the effects of oil price shocks on output, but also contributing to the asymmetric response of output to oil price shocks.

With regard to the target of monetary policy, Kamps and Pierdzioch (2002) claimed that it is important to distinguish between alternative price indices (i.e., CPI, core CPI, and GDP deflator). They demonstrated that targeting the change in the GDP deflator is an inferior monetary policy strategy in the presence of oil price shocks. Carlstrom and Fuerst (2005) compared several monetary policies in trading-off output and inflation. Montoro (2010) thought partially stabilizing the effects of oil shocks on inflation is desirable. Kormilitsina (2009) asserted that the optimal response to the oil price shock would be to raise inflation and interest rates above what had been seen in the past.

The above-mentioned studies have largely relied on two major research tools: VAR (Vector Autoregressive) and extended VAR models (Lee et al., 1999; Aastveit, 2009; Rahman and Serletis, 2010; Ahmed and Wadud, 2011), and general equilibrium models, especially DSGE (Dynamic Stochastic General Equilibrium) models which take New Keynes as the core. Moreover, most of these studies used interest rates to depict the relative tightness of monetary policy. The authors left little room for discussing the reserve ratio policies. They also failed to provide clear and quantitative recommendations for policy makers. Very few studies have looked into monetary policies in responding to oil shocks with a financial CGE (Computable General Equilibrium) model. Financial CGE models could be used to discuss impacts of oil shocks in more detail, together with monetary policies, at the industry level. Also, financial CGE models can describe the transmission channels of macro policies into industry productivity at length. This cannot be easily done with a VAR model or DSGE model.

Among the attempts to add the financial sector into CGE models since the 1980s, some focused on currency devaluation and international balance of funds (Easterly, 1990; Rosensweig and Taylor, 1990; Thissen, 2001), some used Financial CGE models to investigate the income distribution effects (Bourguignon, 1989, 1991; Mansury, 2002) or structure adjustment effects (Naastepad, 2002; Khan, 2007) of financial shocks or policies, while some measured the impact of a series of financial liberalization reforms (Lewis, 1992; Yeldan, 1997). However, none of the above has examined the role that monetary policy plays in responding to oil shocks. This study attempts to fill this void. We build a financial CGE model to investigate the trade-off choices that the central bank faces during sharp rises in oil price. This study also provides quantitative monetary policy recommendations aiming at different inflation targets.

This paper uses the data for China in 2007 and measures the effect of 'neutral' monetary policy on the Chinese economy when the world oil price doubles. We perform counterfactual simulations of tightened monetary policies after an oil shock, and examine their effects on the macro economy and industrial production. We examine the effect on economic activities of packages of tightening interest and reserve ratio policy. For each anti-inflation initiative, we aim to find out the monetary policy package that yields the optimum macroeconomic indicators.

2 The Financial CGE Model of China

2.1 The data

The basic data sets of a financial CGE model are financial social accounting matrix (FSAM) with extended financial sectors. Accounts in our FSAM are: 42 production sectors, current accounts of institutions (household, enterprises, government, ROW), financial accounts of the same institutions, banking system (commercial bank and central bank), financial asset accounts (deposit, loan, enterprise bond, government bond, foreign asset, FDI, foreign lending, etc.) The benchmark data of our current financial CGE model are obtained from a Chinese social accounting matrix of 2007 for the real side, and the flow of fund table and balance sheet of 2007 from the Central Bank of China for the financial side, along with a balance of payments table.

The schematic FSAM is shown as Table 1. The accounts from 11 to 17 are filled with data split from the 'savings' data in the Chinese SAM of 2007. They represent new debts or new assets of institutions, where the consistency between real and financial accounts is maintained.

Table 1 A Schematic FSAM

		Production		Factors		Current Account of Institutions				Fixed Investment	Inventory	Capital Account of Institutions						Financial Flows	Total
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Production	1		IMI			HHE		GOE	EXP	FCF	III								Total Demand
	2	DOS																	
Labor	3		LAI																Factor Income
Capital	4		CAI																
Households	5			LI	CI		TR	TR	TR										Income of Institutions
Enterprises	6				CI														
Government	7	TRF	PRT			IT	IT												
Rest of World	8	IMP						TR											
Fixed Investment	9											INV	INV	INV					Investment
Inventory	10									III									
Households	11					SAV												FL	Changes in Liabilities of Institutions
Enterprises	12						SAV											FL	
Government	13							SAV										FL	
Commercial Bank	14								SAV									FL	
Central Bank	15																	FL	
Rest of World	16																	FL	
Financial Flows	17											FA	FA	FA	FA	FA	FA		Financial Flows
Total	18	Total Supply		Factor Income		Expenditure of Institutions				Investment		Changes in Assets of Institutions						Financial Flows	

Notes: The description of the notations in the table is as follows. IMI: intermediate inputs. HHE: household expenditures. GOE: government expenditures. EXP: exports. FCF: fixed capital formulation. III: increase in inventory. LAI: total labor income. CAI: capital income. LI: labor income to institutions. CI: capital income to institutions. TR: Transfer payments. TRF: tariff. PRT: production tax. IT: income tax. Imp: imports. Inv: investment. SAV: savings of institutions. FL: changes in financial liabilities. FA: changes in financial assets.

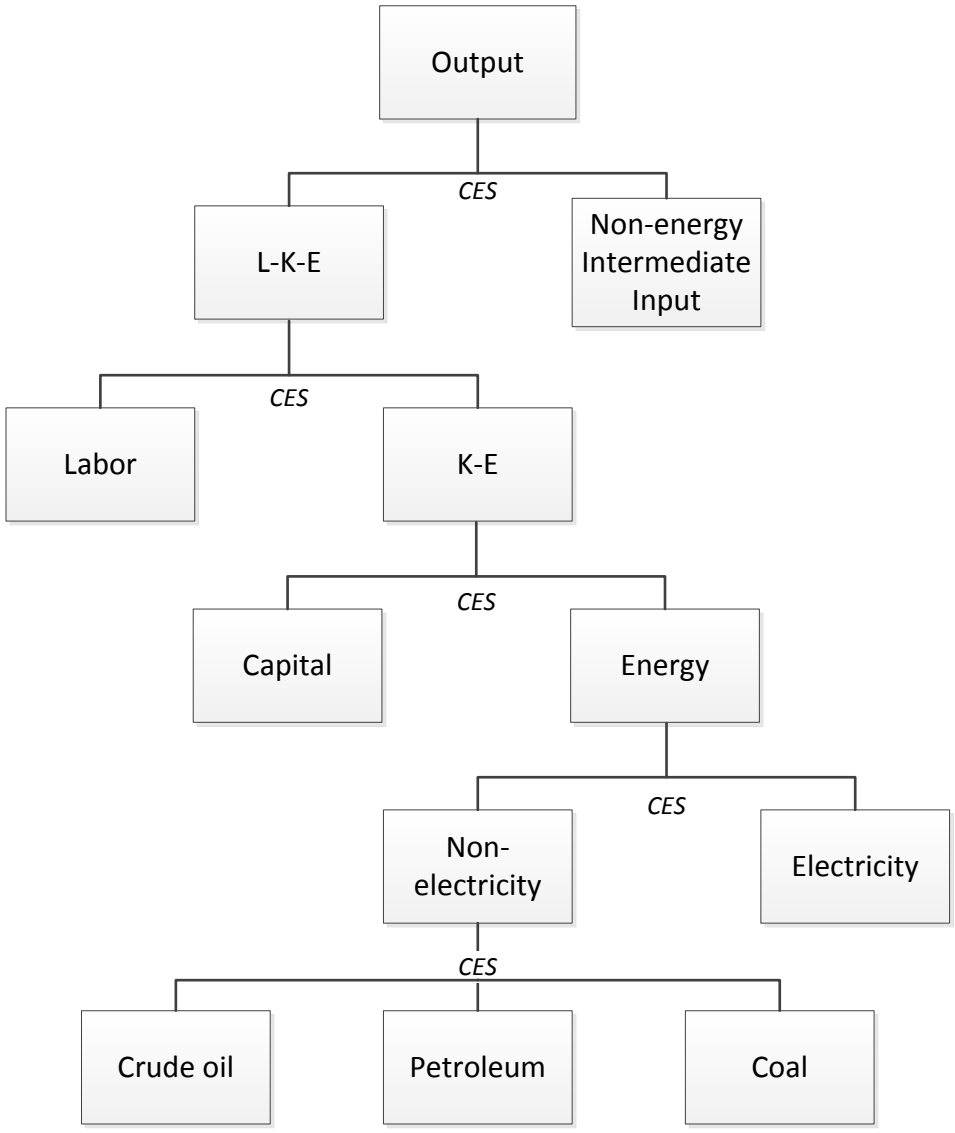

Figure 1 Structure of Production Function of the FCGE Model

2.2 Key features of the model

The specification of the real side of the model follows that of the standard CGE model developed by IFPRI in 2002. Readers can refer to Löfgren et al. (2002) for a detailed description of the model specification. However, our model differs from the standard CGE model in two important aspects. One is in the modeling of energy use. As Figure 1 shows, we consider four kinds of energy (crude oil, petroleum, coal and electricity) as input factors, together with labor and capital. Thus we can pinpoint the role of energy in economic activities and take account of the finite substitutions among different kinds of energy, and among energy and other input factors. The other is the financial module. We extend the saving-investment closure in standard

CGE models by making use of financial intermediation to achieve the transformation of savings to investment. Figure 2 demonstrates the financial intermediate channels with dotted lines.

The modeling of financial sectors in our model is described briefly as follows. We will focus on the major functioning of institutions, including income and expenditure functions of institutions where financial investment and financing are considered, while the list of equations and variable definitions are provided in Appendix A and B, respectively.

Financial decisions of institutions (i.e., household, enterprises, government, ROW) include real investment, financial investment, financing decisions, and so on. Household's rate of saving is positively correlated to real interest rate. The higher the real interest rate, the lower the household consumption saving ratio will be. Household saving plus household loan equals household total investment. Household loan is assumed to be directly proportional to household saving. Household investment includes real investment and financial investment on money, deposit, and bond. The ratio of real investment and financial investment in the household sector is set to be a function of average yield rate of financial investment. The higher the yields, the less the household invests in real economy. The amount of currency household is holding is decided in a money demand function, where money demand is directly proportional to nominal GDP, but inversely proportional to real interest rate. Deposit share to the sum of deposit and bond depends on the relative interest rates between deposit and bond. Raising the deposit rate of commercial bank, household will invest more in deposit instead of in bonds.

Enterprise uses its retained earnings to invest in real economy, apart from a certain amount of working capital in the form of deposit in commercial banks. Investment demand of each industry is decided by capital cost and profit rate of investment. Investment is comprised of public investment from government and private investment from household and enterprise. If public investment increases, private investment would be crowded out.Disposable capital of enterprise is not always enough to meet the demand for real investment. So enterprise explores every means to borrow money. We have four ways of financing in the model: loan from commercial banks, issuing bonds, borrowing from foreign countries or seeking FDI. FDI is a fixed share of enterprise investment. The share variable of enterprise loan to the total three means of financing (loan, foreign borrowing and bond) depends on the relative interest rate of loan and the other two means. Foreign borrowing share to the sum of foreign borrowing and enterprise bond depends on the relative interest rate of these two assets. In our model specifications, due to the equilibrium of balance sheet of commercial bank, a correlation exists between loan and deposit. It means that the amount of loan from commercial bank depends on the deposit it gathered. So enterprise turns first to commercial banks for loans, and then fills its funding gap from bonds and foreign borrowing. Interest rate of commercial bank is exogenous, so is foreign borrowing rate. Rate of enterprise bonds is endogenous, which equilibrates demand and supply in enterprise bond market.

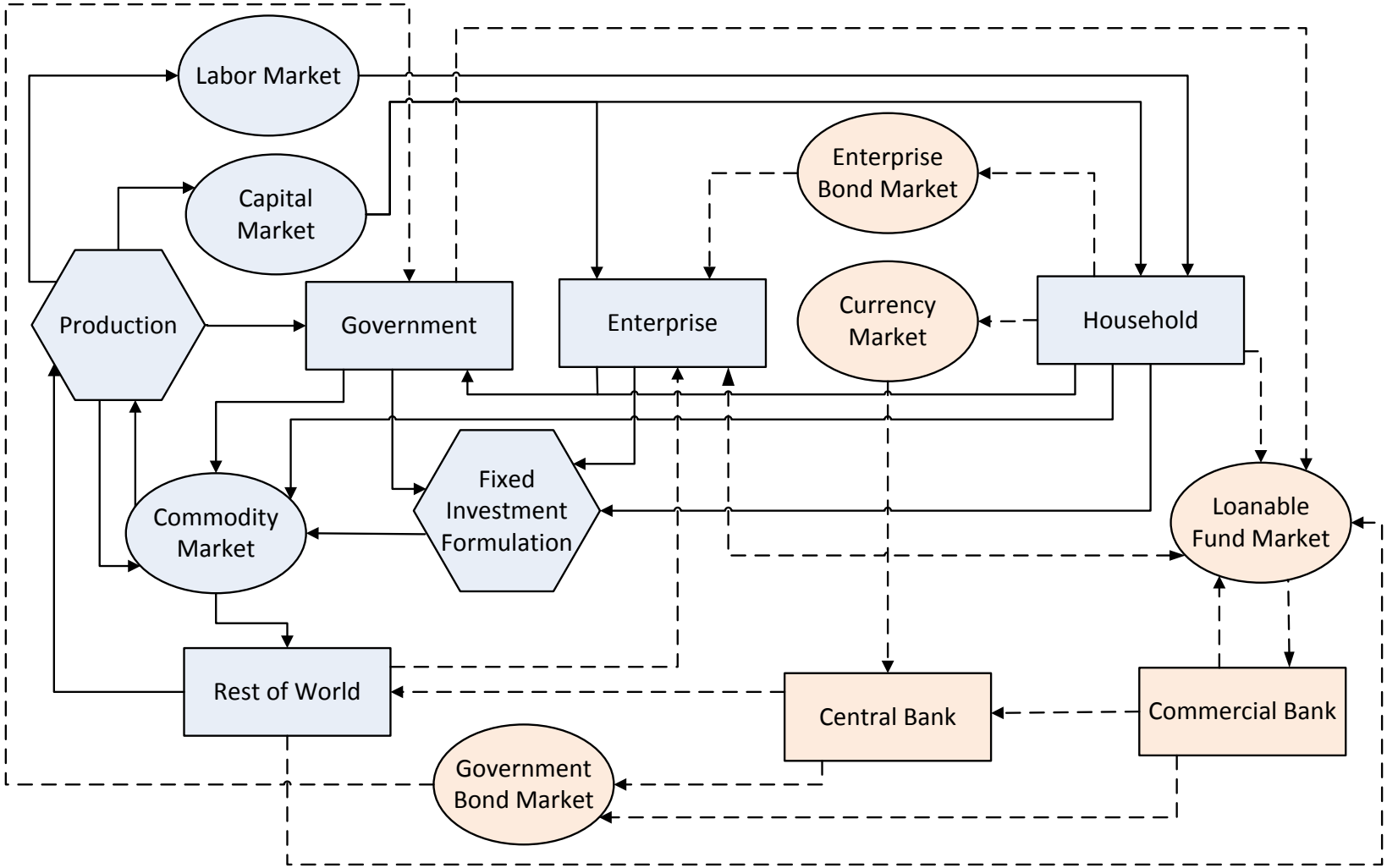

Figure 2 Schematic Diagram of the FCGE Model

Public revenues are used for government consumption and public investment, apart from those kept in commercial banks as government deposit. Government issues bonds to finance the gap. ROW saving plus foreign asset held by domestic bank system is equal to the sum of foreign borrowing to enterprises, ROW deposit and FDI. The difference between current account transactions and financial account transactions is foreign reserve held by commercial bank and central bank, mostly by the latter.

Liabilities of commercial bank are deposits. And assets are loan, reserve, government bond and foreign assets. Foreign asset held by commercial bank is a fixed share of the value of the deposits. Commercial bank reserve is a fixed share of the value of the deposits. Liabilities of central bank are money and reserve. Assets are government bond and foreign asset held by central bank. That means buying government bonds in an open market would increase money supply. And increasing foreign reserve will do the same.

2.3 Other features

Endogenous price level: standard CGE models need a numeraire to decide other relative prices, usually some weighted price index like CPI or labor wage. But it has limitations when explaining macro issues like inflation. This model takes the price of currency as a numeraire, so other prices of commodities or wages can be seen as absolute prices. Thus the price level is endogenous.

Non-neutrality of money: the structure features of the model, such as the fixed labor wage or price control in certain industries, together with the setting that savings and investment are decided by real interest rate, determine the non-neutrality of money in this model. That is, the change of price level would affect real variables (real output of each industry, real import, real export and so on).

Since money is non-neutral, the price level is endogenous, and there are structure adjustments in real economy and financial economy, it is possible to model the process of interaction and mutual influence of real side and financial side of the economy.

3. Scenarios and Results

We first simulate three basic scenarios. In the first scenario, we measured the impact of ‘neutral’ monetary policy on the Chinese economy when world oil price doubles. Then, for the next two scenarios, we performed counterfactual simulations of tightened monetary policies and study their effect on the macro economy and industrial behaviors. We examined the impact on economic activities of packages of tightening interest policy and tightening reserve policy. Under each anti-inflation initiative, we would find out the monetary policy package that yields the optimum macroeconomic indicators.

3.1 Basic scenario analysis

The three basic scenario simulations can be summarized as Table 2 shows.

Table 2 Descriptions of Basic Scenarios

Scenarios	Description of basic scenarios
S0	Oil price increases by 100%; Interest rate and reserve ratio remain intake
S1	Oil price increases by 100%; Deposit rate is raised by 1 percent; Reserve rate remains intake
S2	Oil price increases by 100%; Interest rate remains intake; Reserve ratio is raised by 1 percent

A. Macro impacts of basic scenarios

Table 3 Macro Impacts of Basic Scenarios

Unit: %

	S0	S1	S2
Nominal GDP	3.52	2.73	2.56
Real GDP	-2.30	-2.54	-2.63
GDP Deflator	6.13	5.56	5.49
CPI	4.51	4.06	3.98
PPI	8.56	8.11	8.04
Real Investment	5.49	3.45	4.37
Labor Employment	-1.01	-1.48	-1.68
Capital Rent	0.58	-0.48	-0.66
Household welfare	-5.01	-4.92	-4.98
M0 (100 billion)	1.07	0.68	0.78
M2 (100 billion)	4.89	5.30	3.16
Foreign reserve (100 billion)	-0.71	-0.29	0.72

In scenario S0, oil price goes up by 100% while nominal interest rate and reserve ratio remain unchanged. We learn from Table 3 that overall price level goes up. CPI rises 4.51%. The GDP deflator rises 6.13%. And PPI increases the most, 8.56%. Nominal GDP increased by 3.52% due to the increasing price level. But real GDP decreased by 2.3%. Oil shock has a negative impact on fixed investment. But when prices are raised rapidly while nominal interest rate remains the same, real interest rate becomes negative. It would be a stimulus to investment. The final real investment rises by 5.49%. Household welfare measured by household real income is diminished by 5.01%. On the financial side, M0 increases 10.7 billion since the transactions demand for money increases as the price level goes up. And M2

increases 48.8 billion. Foreign exchange reserves are diminished 7.1 billion mainly due to the growing import cost of oil.

In scenario S1, oil price goes up by 100% while nominal interest rate is raised 1 percent and reserve ratio remains unchanged. Compared with scenario S0, the price level is constrained, and CPI falls by 0.45% in scenario S1. Both nominal and real GDP decrease by 0.79% and 0.24%, respectively. While the cost of funds increases, investment demand diminishes by 2.04% and real interest rate rises. Thus M0 decreases 3.9 billion and M2 4.2 billion. Since the raised interest rate attracts foreign inflows, foreign exchange reserve increases 4.3 billion.

In scenario S2, oil price goes up by 100% while nominal interest rate remains unchanged and reserve ratio is raised 1 percent. Compared with scenario S0, the price level is constrained and CPI falls by 0.53% in scenario S2. Similar to S1, both nominal and real GDP decrease, with a reduction rate of 0.96% and 0.33% respectively. Investment demand diminishes by 1.12% because of the shortage of loanable funds. Thus M0 decreases 3.0 billion and M2 17.2 billion. Since the need for funds attracts foreign inflows, foreign exchange reserve increases 14.3 billion.

B. Sectoral output impacts

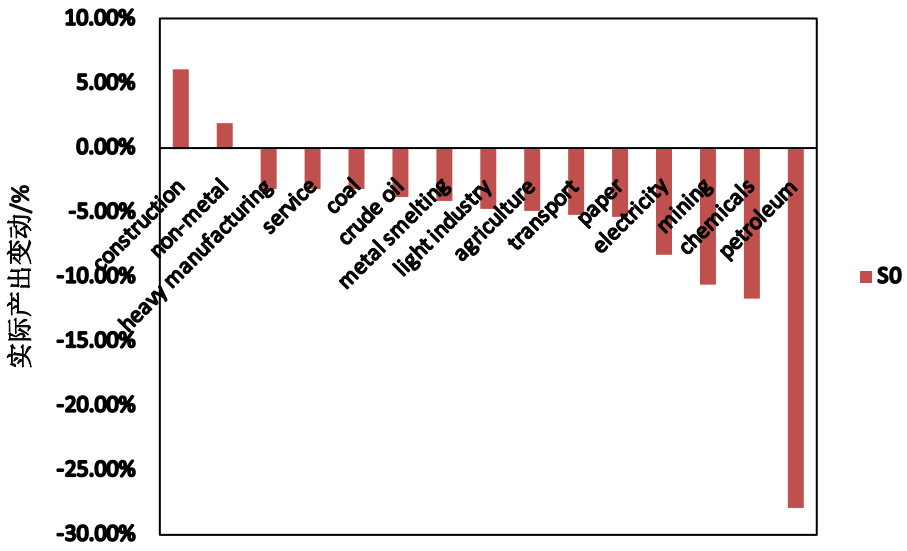

Figure 3 Real Output Changes of Industries in Scenario S0

Crude oil is the major input of petroleum industry. It makes up 68% of the total intermediate input. When crude oil price rises sharply, so does the production cost of petroleum industry. Production price has to be raised. Final demands suffer. In all, real output diminishes 28.05% of petroleum industry.

Domestic crude oil replaces some of the imports. Thus, real output of domestic crude oil industry does not decrease too much, which is 3.83%. Most of the energy-intensive industries, such as chemicals, mining, papers and transport, are

downstream industries of crude oil and petroleum. They suffer most of the impacts and their output diminish the most.

Electricity and coal are alternative energy input resources and substitute for oil product. However, due to the recession of the whole economy, output of electriciy decreases by 8.36% and that of coal decreases by 3.27%.

As for heavy manufacturing, service, light industry, agriculture and other industries which are not energy-intensive, they are far from energy industries in the supply chain. They are affected less with output. Moreover, when fixed investments increase, construction and the main input of construction (non-mental ores and metal smelting) benefit.

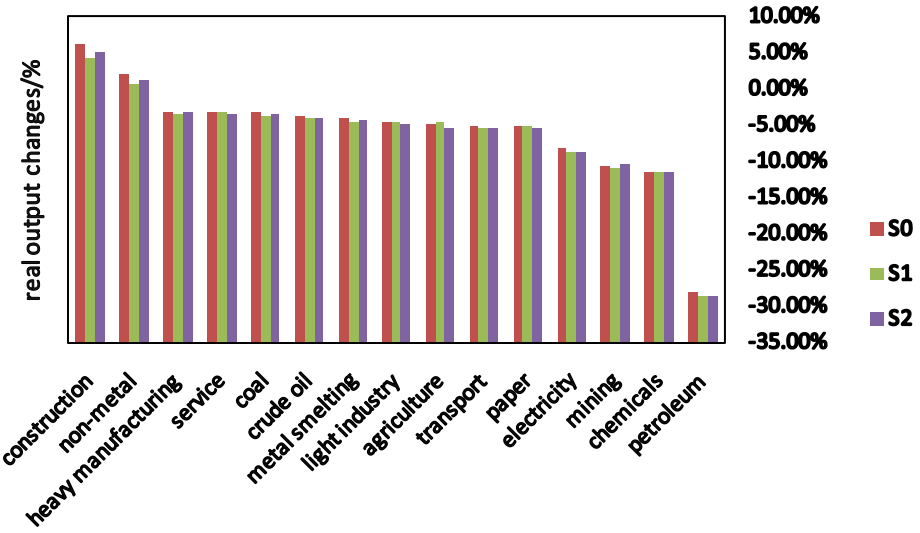

Figure 4 Real Output Changes of Industries in Basic Scenarios

Most industries further reduce their real output in scenarios S1 and S2. Compared with scenario S0, they reduce 1.6% to 3.3% of real output in scenario S1, and 0.75% to 1.75% in scenario S2. Fixed investment is the first to feel the effect of tightened monetary policies. Construction, non-metal, and metal smelting are most affected.

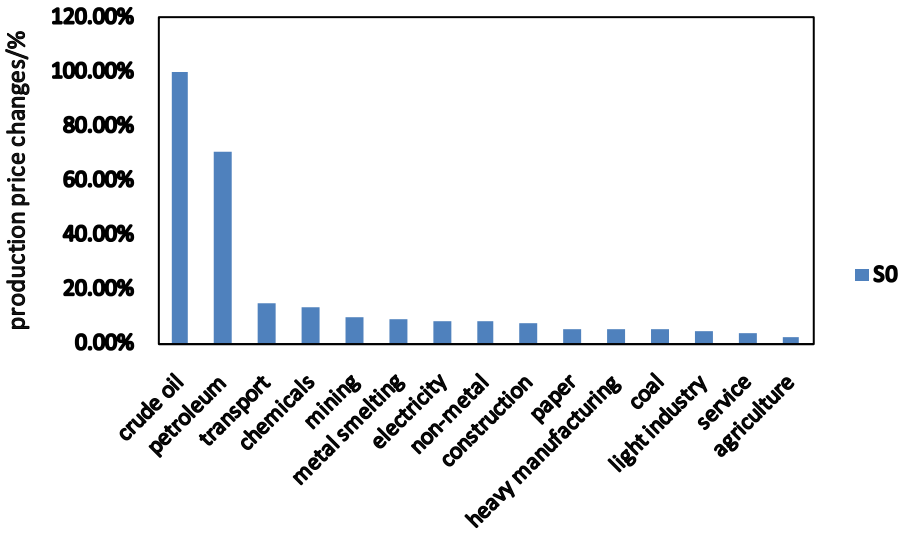

Figure 5 Price Changes of Industries in Scenario S0

With rising oil prices inflating the cost of almost everything, all industries increase their production prices. Petroleum product increases by 70.47%. Prices of energy-intensive industries are the most driven up. They are up by 8% to 15%. Less energy-intensive industries are less driven up, like agriculture, service and light industry. Their prices are raised by 2% to 5%. Heavy manufacturing and papers are export-oriented industries whose production prices would be relatively stable to keep exports competitive.

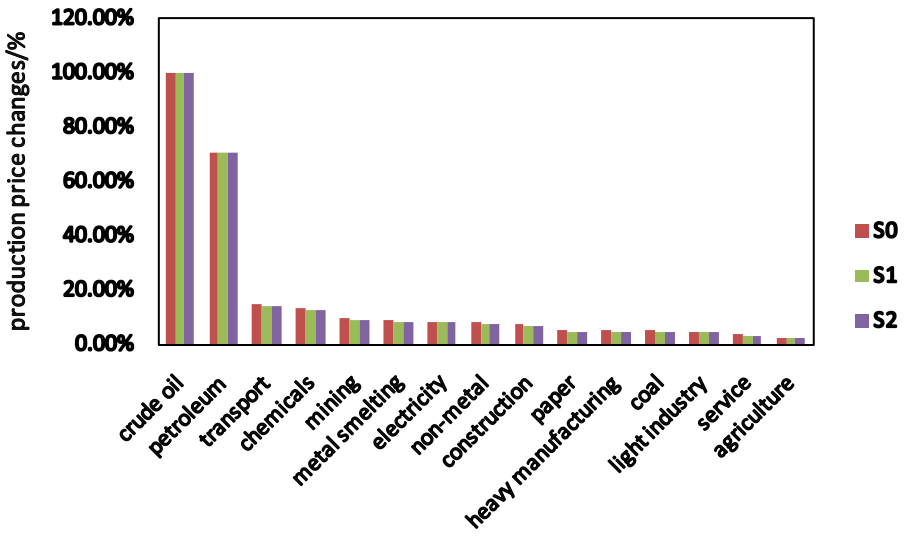

Figure 6 Price Changes of Industries in Basic Scenarios

Most industries' price decrease in scenarios S1 and S2. Prices are 0.1% to 0.6% lower in scenario S1 and 0.1% to 0.7% lower in scenario S2. Agriculture, light industry,

chemicals and manufacturing are less impacted of monetary policies and have less price change.

3.2 Optimal monetary policy package

In this section, we will simulate 121 monetary policy packages that raise interest rate by 0, 0.2, 0.4, 0.6, 0.8, 1.0, 1.2, 1.4, 1.6, 1.8 and 2 percent, while raising reserve ratio by 0, 0.4, 0.8, 1.2, 1.6, 2.0, 2.4, 2.8, 3.2, 3.6 and 4 percent at the same time.

Under each policy scenario, price indices go down at different degrees. Real GDP, household welfare and international balance of payments differ too. There is no absolute optimal monetary policy. If policymakers try to offset the inflation effects of higher oil prices, output suffers. If policymakers try to offset the output effects, inflation rises. We have to make trade-off choices according to current economic performances and consider the most urgent goals of the economy. We in fact treat that this scenario is similar to China's economy around 2007 when world oil price surged which put them at risk of excessive inflation. The top priority of monetary authority would be to counter inflation. Thus we consider first how to achieve the best results of real GDP, or household welfare, or balances of payments. After that we can make sure the inflation is under control.

We have to first screen the monetary policy packages which make the inflation rate below requirements. Then, according to the different results of each indicator (real GDP, household welfare, balance of payments), we select the optimal package.

Table 4 Changes of CPI under Policy Packages

Unit: %

Interest \ Reserve	0%	0.4%	0.8%	1.2%	1.6%	2.0%	2.4%	2.8%	3.2%	3.6%	4.0%
0%	4.510	4.248	3.981	3.709	3.432	3.150	2.861	2.568	2.269	1.965	1.657
0.2%	4.398	4.140	3.877	3.608	3.335	3.055	2.770	2.479	2.183	1.881	1.575
0.4%	4.286	4.032	3.772	3.508	3.238	2.962	2.679	2.391	2.097	1.798	1.494
0.6%	4.175	3.924	3.669	3.408	3.141	2.868	2.589	2.304	2.012	1.715	1.414
0.8%	4.063	3.817	3.565	3.308	3.045	2.775	2.499	2.217	1.928	1.633	1.334
1.0%	3.953	3.710	3.462	3.209	2.949	2.683	2.410	2.130	1.844	1.552	1.254
1.2%	3.842	3.603	3.360	3.110	2.853	2.591	2.321	2.044	1.761	1.471	1.175
1.4%	3.731	3.497	3.257	3.011	2.758	2.499	2.232	1.958	1.678	1.390	1.097
1.6%	3.621	3.391	3.155	2.913	2.664	2.407	2.144	1.873	1.595	1.310	1.019
1.8%	3.511	3.285	3.053	2.814	2.569	2.316	2.056	1.788	1.513	1.231	0.942
2.0%	3.401	3.179	2.951	2.717	2.475	2.225	1.969	1.704	1.431	1.152	0.865

Table 5 Changes of Real GDP under Policy Packages

Unit: %

Interest \ Reserve	0%	0.4%	0.8%	1.2%	1.6%	2.0%	2.4%	2.8%	3.2%	3.6%	4.0%
0%	97.70	97.54	97.37	97.20	97.02	96.84	96.65	96.46	96.27	96.07	95.87
0.2%	97.64	97.48	97.31	97.14	96.97	96.79	96.60	96.42	96.22	96.02	95.82
0.4%	97.58	97.42	97.25	97.09	96.91	96.74	96.55	96.37	96.17	95.98	95.78
0.6%	97.52	97.36	97.20	97.03	96.86	96.69	96.50	96.32	96.13	95.93	95.73
0.8%	97.46	97.30	97.14	96.98	96.81	96.63	96.45	96.27	96.08	95.89	95.69
1.0%	97.40	97.24	97.08	96.92	96.75	96.58	96.40	96.22	96.03	95.84	95.64
1.2%	97.33	97.18	97.03	96.87	96.70	96.53	96.36	96.17	95.99	95.79	95.60
1.4%	97.27	97.12	96.97	96.81	96.65	96.48	96.31	96.13	95.94	95.75	95.55
1.6%	97.21	97.06	96.91	96.76	96.60	96.43	96.26	96.08	95.89	95.70	95.51
1.8%	97.15	97.01	96.86	96.70	96.54	96.38	96.21	96.03	95.85	95.66	95.46
2.0%	97.09	96.95	96.80	96.65	96.49	96.33	**96.16**	95.98	95.80	95.61	95.42

Table 6 Changes of Foreign Reserve under Policy Packages

Unit: %

Interest \ Reserve	0%	0.4%	0.8%	1.2%	1.6%	2.0%	2.4%	2.8%	3.2%	3.6%	4.0%
0%	98.2	100.0	101.8	103.7	105.7	107.6	109.6	111.7	113.8	116.0	118.2
0.2%	98.4	100.2	102.1	103.9	105.8	107.8	109.8	111.8	113.9	116.1	118.3
0.4%	98.7	100.5	102.3	104.1	106.0	108.0	109.9	112.0	114.0	116.2	118.3
0.6%	99.0	100.7	102.5	104.3	106.2	108.1	110.1	112.1	114.2	116.3	118.4
0.8%	99.3	101.0	102.8	104.6	106.4	108.3	110.2	112.2	114.3	116.4	118.5
1.0%	99.5	101.2	103.0	104.8	106.6	108.5	110.4	112.4	114.4	116.5	118.6
1.2%	99.8	101.5	103.2	105.0	106.8	108.6	110.5	112.5	114.5	116.6	118.7
1.4%	100.1	101.8	103.5	105.2	107.0	108.8	110.7	112.7	114.6	116.7	118.8
1.6%	100.4	102.0	103.7	105.4	107.2	109.0	110.9	112.8	114.8	116.8	118.9
1.8%	100.7	102.3	104.0	105.7	107.4	109.2	111.0	112.9	114.9	116.9	119.0
2.0%	101.0	102.6	104.2	105.9	107.6	109.4	**111.2**	113.1	115.0	117.0	119.1

Table 7 Changes of Household Real Income under Policy Packages

Unit: %

Interest \ Reserve	0%	0.4%	0.8%	1.2%	1.6%	2.0%	2.4%	2.8%	3.2%	3.6%	4.0%
0%	94.99	95.01	95.02	95.03	95.05	95.06	95.08	95.09	95.11	95.13	95.14
0.2%	95.01	95.03	95.04	95.05	95.07	95.08	95.10	95.11	95.13	95.15	95.16
0.4%	95.04	95.05	95.06	95.08	95.09	95.10	95.12	95.13	95.15	95.17	95.18
0.6%	95.06	95.07	95.08	95.10	95.11	95.13	95.14	95.16	95.17	95.19	95.20
0.8%	95.08	95.09	95.11	95.12	95.13	95.15	95.16	95.18	95.19	95.21	95.22
1.0%	95.10	95.11	95.13	95.14	95.15	95.17	95.18	95.20	95.21	95.23	95.24
1.2%	95.12	95.14	95.15	95.16	95.17	95.19	95.20	95.22	95.23	95.25	95.26
1.4%	95.14	95.16	95.17	95.18	95.19	95.21	95.22	95.24	95.25	95.27	95.28
1.6%	95.17	95.18	95.19	95.20	95.21	95.23	95.24	95.25	95.27	95.28	95.30
1.8%	95.19	95.20	95.21	95.22	95.23	95.25	95.26	95.27	95.29	95.30	95.32
2.0%	95.21	95.22	95.23	95.24	95.25	95.27	95.28	95.29	95.31	95.32	**95.34**

Table 4 to Table 7 show the simulation results of 121 monetary policy packages. An example may make the point clear. If we set an upper limit to the CPI, say 2%, the shaded parts of these tables are policy packages that do not hit the target that keeps CPI lower than 2%. Thus we exclude the shaded parts and keep the rest. From Table 4 we can see that the optimal choice would be to raise interest rate to 2 percent and to raise reserve ratio to 2.4 percent so that real GDP reaches the maximum. In the same way, we find that the optimal policy package for balance of payments would be the same as real GDP. And we have to raise interest rate to 2 percent and reserve ratio to 5 percent to maximize household welfare.

Table 8 Optimal Policy Package with 2% Inflation Target

Policy package		Real GDP	Foreign Reserve	Household Real Income
Interest rate	Reserve rate			
2%	2.4%	**	**	
2%	5%			**

Using the method above, we plot a relationship diagram between upper limit of CPI and optimal monetary policies for real GDP, as Figure 7 shows.

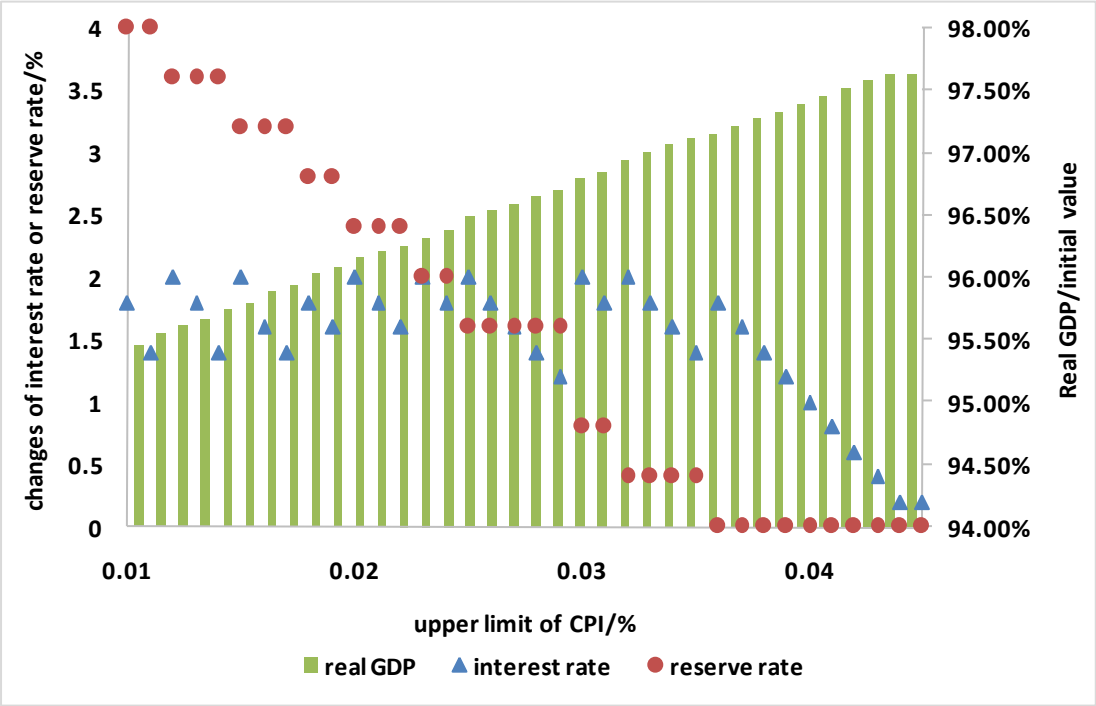

Figure 7 Relationship Diagram among Monetary Policies, Inflation and Output

A drastic change in interest rates would bring the financial institutions great uncertainty. Increasing the interest rate would cause great loss to mortgage assets holders, and will lead to instability of financial markets. Thus we limit interest rates to 2% at most in these scenarios.

Interest policies are more market-based than reserve policies. They would cause less damage to output when they lower the price level. So when monetary authority does not control inflation strictly and set the inflation target between 3.5% and 4.5% when the oil shock occurs, we could rely on interest rate polices alone. When authority is more concerned about stabilizing life of residents and inflation rate has to be tightly controlled, the upper limit of CPI is below 3.5%. Then the interest rate is raised about 2 percent and there is limited room for interest rate to adjust. We have to add reserve ratio policies to further reduce inflation.

When considering upper limits of CPI, we sometimes leave out packages which produce more output, nearly reaching the inflation target, but still fail to meet the inflation requirement. In those cases, we might select policy packages with interest rates fluctuating below 2%.

4 Conclusions and Policy Implications

A sharp oil shock has enormous impacts on macro economy and industries. Industries receive impacts at different degrees. When world oil price rises by 100%, real GDP declines by 2.30%.CPI and PPI rise by 4.51% and 8.56%, respectively. Petroleum, transport, chemicals, mining, metal smelting and other energy-intensive

industries have to raise prices and suffer from output loss. While service，heavy manufacturing, and other industries have less effect on prices and output. Construction and non-metal industries benefit since the real interest rate will be negative.

If the monetary authority tightens monetary policies, most industries' prices are constrained, and majority of their output decrease as well. But losses also differ among industries. Since the investment level is the first to be impacted by monetary policies, construction and non-metal suffers the most negative effects. We can tell that there are not absolute optimal monetary policies to save all. What we have is an option that to trade-off between inflation and output according to different ugency of goals for presents macro economic activities.

Macro-surroundings are varied. The government focuses on different target during different period. When tolerance of inflation varies, we use different degrees of tightening monetary policies. When oil price doubles, if government has to control the inflation rate to be within 2%, it is best to raise the interest rate to 2%, and reserve ratio to 2.4% to maximize real output and minimize the imbalance of payments. When the monetary authority controls price inflation less strictly and sets the inflation target between 3.5% and 4.5% in the face of an oil shock, we can rely on interest rate polices alone. However, if the government is more concerned about stabilizing household welfare and inflation rate has to be tightly controlled, the upper limit of CPI should be below 3.5%. We have to add reserve rate policies to further reduce inflation, since interest rate increases about 2% already and there is little room for further interest rate policies.

When prices of oil or other commodities rise， and potential inflation is increasingly apparent，we would carefully control the amount of domestic monetary aggregates and the speed of credit expansion to avoid further stimulating aggregate demand. Sometimes it is necessary to use tightening monetary policies and sacrifice some economic growth for preventing obvious inflation. But if we do not get the balance right, it might do no good for the economy. And that explains exactly the significance of this article.

Acknowledgment

Financial support from the Chinese Academy of Sciences (No. XDA05150700) and the National Natural Science Foundation of China (No. 71133005 and No. 71203213) is acknowledged. Special thanks from Jing-Yu Liu go to Center for Applied Economic Modeling, Chung Yuan Christian University Taiwan, for all the help and support received during her visit.

References

Aastveit, K. A. (2013). Oil price shocks and monetary policy in a data-rich environment, Norges Bank working paper.

Ali Ahmed, H. J. and I. Wadud (2011). "Role of oil price shocks on macroeconomic activities: An SVAR approach to the Malaysian economy and monetary responses." Energy Policy **39**(12): 8062-8069.

Bourguignon, F., W. H. Branson, et al. (1989)."Macroeconomic adjustment and income distribution: a macro micro simulation model." OECD Development Centre Paris working paper no.1.

Bourguignon, F., J. De Melo, et al. (1991). "Modeling the effects of adjustment programs on income distribution." World Development **19**(11): 1527-1544.

Brown, S. P. A. and M. K. Yücel (2002). "Energy prices and aggregate economic activity: an interpretative survey." Quarterly Review of Economics and Finance 42: 193-208.

Carlstrom, C. T. and T. S. Fuerst (2005). Oil prices, monetary policy, and the macroeconomy, Federal Reserve Bank of Cleveland Cleveland, working paper 05-10.

Carlstrom, C. T. and T. S. Fuerst (2006). "Oil prices, monetary policy, and counterfactual experiments." Journal of Money, Credit, and Banking **38**(7): 1945-1958.

Kamps, C. and C. Pierdzioch (2002). "Monetary policy rules and oil price shocks." Kiel Working Paper No. 1090.

Khan, H. A. (2007). "Social accounting matrices (SAMs) and CGE modeling: using macroeconomic computable general equilibrium models for assessing poverty impact of structural adjustment policies." CIRJE discussion papers series **463**.

Kormilitsina, A. (2011). "Oil price shocks and the optimality of monetary policy." Review of Economic Dynamics **14**(1): 199-223.

Krichene, N. (2006). "World crude oil markets: monetary policy and the recent oil shock." IMF working paper: WP/06/62.

Löfgren, H., R. L. Harris, et al. (2002). A standard computable general equilibrium (CGE) model in GAMS, Intl Food Policy Res Inst (IFPRI).

Leduc, S. and K. Sill (2004). "A quantitative analysis of oil-price shocks, systematic monetary policy, and economic downturns." Journal of Monetary Economics **51**(4): 781-808.

Leduc, S. and K. Sill (2007). "Monetary policy, oil shocks, and TFP: accounting for the decline in US volatility." Review of Economic Dynamics **10**(4): 595-614.

Lee, B. R., K. Lee, et al. (2001). "Monetary policy, oil price shocks, and the Japanese economy." Japan and the World Economy **13**(3): 321-349.

Lee, J. and J. Song (2009). "Nature of oil price shocks and monetary policy." National Bureau of Economic Research working paper 15306.

Lewis, J. D. (1992). "Financial repression and liberalization in a general equilibrium model with financial markets." Journal of Policy Modeling **14**(2): 135-166.

Mansury, Y. S. (2002). Nonlinear impacts of the Asian financial crisis on income distribution in Indonesia: A financial computable general equilibrium approach. United States -- New York, Cornell University. **Ph.D.:** 334.

Medina, J. P. and C. Soto (2005). "Oil shocks and monetary policy in an estimated DSGE model for a small open economy." Documento de Trabajo **353**.

Montoro, C. (2010). Oil shocks and optimal monetary policy, Cambridge Univ Press.

Naastepad, C. (2002). "Trade-offs in stabilisation: a real-financial CGE analysis with reference to India." Economic Modelling **19**(2): 221-244.

Rahman, S. and A. Serletis (2010). "The asymmetric effects of oil price and monetary policy shocks: A nonlinear VAR approach." Energy Economics **32**(6): 1460-1466.

Taylor, L. (1990). Socially relevant policy analysis: Structuralist computable general equilibrium models for the developing world, MIT Press, 1990: 270-332.

Thissen, M. and R. Lensink (2001). "Macroeconomic effects of a currency devaluation in Egypt:: An analysis with a computable general equilibrium model with financial markets and forward-looking expectations." Journal of Policy Modeling **23**(4): 411-419.

Yeldan, A. E. (1997). "Financial liberalization and fiscal repression in Turkey: policy analysis in a CGE model with financial markets." Journal of Policy Modeling **19**(1): 79-117.

Appendix A. List of Equations of the FCGE Model

$$MPS_h / (1 - MPS_h) = \psi_h / (1 + INTRSTHavg_h - PINF)^{\varepsilon mps_h} \tag{1}$$

$$Save_h + FFLOWC_h = \sum_a ZH_{a,h} + FFLOWM_h + FFLOWD_h + FFLOWBH_h \tag{2}$$

$$\sum_a ZH_{a,h} = z1_h \cdot (\sum_a ZH_{a,h} + FFLOWD_h + FFLOWBH_h) \tag{3}$$

$$z1_h / (1 - z1_h) = \psi z1_h / (1 + INTRSTHavg_h)^{\varepsilon z1_h} \tag{4}$$

$$FFLOWC_h = shflowc_h \cdot Save_h \tag{5}$$

$$FFLOWD_h = g1_h (FFLOWD_h + FFLOWBH_h) \tag{6}$$

$$g1_h / (1 - g1_h) = \psi 1_h [(1 + intrstD_h) / (1 + intrstBH)]^{\varepsilon 1_h} \tag{7}$$

$$FSTOCKM = \frac{YGDP}{V_\gamma + V_R \cdot [intrstD_h + (\Delta PLEV_t / PLEV_{t-1})]} \tag{8}$$

$$KSTAR_a = [\frac{QVA_a \cdot PVA_a \cdot \delta_{cap,a}^{va} \cdot (\sum_{f \in F} \delta_{f,a}^{va} \cdot QF_{f,a}^{-\rho_a^{va}})^{-1}}{PK_a \cdot (\sum_{e \in E} INTRST_e^c \cdot \varpi_{e,a} - pinf + dep_a)}]^{\frac{1}{\rho_a^{va}+1}}, \quad a \in A \tag{9}$$

$$ZD_a = \lambda_a \cdot (KSTAR_a - QF_{cap,a}), \quad a \in A \tag{10}$$

$$PK_a \cdot ZD_a = ZG_a + ZH_a + \sum_{e \in E} ZE_e \cdot \varpi_{e,a}, \quad a \in A \tag{11}$$

$$Save_e + FFLOWC_e + FFLOWFB_e + FFLOWB_e + FFLOWFDI_e = FFLOWD_e + ZE_e \tag{12}$$

$$FFLOWD_e = shflowdE_e \cdot YE_e \tag{13}$$

$$FFLOWFDI_e = shflowfdi_e \cdot ZE_e \tag{14}$$

$$FFLOWC_e = g2_e \cdot (FFLOWC_e + FFLOWFB_e + FFLOWB_e) \tag{15}$$

$$g2_e / (1 - g2_e) = \psi 2_e [(1 + intrstC_e) / (1 + intrstBavg)]^{\varepsilon 2_e} \quad (16)$$

$$FFLOWFB_e = g3_e \cdot (FFLOWFB_e + FFLOWB_e) \quad (17)$$

$$g3_e / (1 - g3_e) = \psi 3_e [(1 + intrstFB) / (1 + intrstB_e)]^{\varepsilon 3_e} \quad (18)$$

$$Save_g + FFLOWG = FFLOWD_g + \sum_a ZG_a \quad (19)$$

$$Save_{row} + \sum_{bs} FFLOWFA_{bs} = \sum_e FFLOWFB_e + FFLOWD_{row} + \sum_e FFLOWFDI_e \quad (20)$$

$$FFLOWD_{row} = \psi 4 \cdot ((1 + INTRSTDstd - PINF) / (1 + INTRSTFB))^{\varepsilon 4} \quad (21)$$

$$\sum FFLOWD_h + \sum FFLOWD_e + FFLOWD_g + FFLOWD_{row} =$$
$$\sum FFLOWC_h + \sum FFLOWC_e + FFLOWRE + FFLOWG_b + FFLOWFA_b \quad (22)$$

$$FFLOWFA_b = shflowfab \cdot (\sum FFLOWD_h + \sum FFLOWD_e + FFLOWD_g + FFLOWD_{row})$$

$$FFLOWRE = shflowre \cdot (\sum FFLOWD_h + \sum FFLOWD_e + FFLOWD_g + FFLOWD_{row}) \quad (24)$$

$$\sum_h FFLOWM_h + FFLOWRE = FFLOWG_{cb} + FFLOWFA_{cb} \quad (25)$$

Appendix B. Explanations of Notations

Notations	Explanations
Variables	
MPS_h	marginal propensity to save for household *h*
$SAVE_{ins}$	savings for institution *ins*
$FFLOWC_{insp}$	financial flow of credit for private institution *insp*
$ZH_{a,h}$	real investment to activity *a* by sector of origin for household *h*
$FFLOWM_h$	financial flow of money for household *h*
$FFLOWD_{ins}$	financial flow of deposit for institution *ins*
$FFLOWBH_h$	financial flow of bonds for household *h*
$INTRSTD_{ins}$	interest rate of deposit for institution *ins*
$INTRSTBH_h$	interest rate of bonds for household *h*
$FSTOCKB_e$	financial stock of enterprise bond for enterprise *e*
YE_e	after tax and transfer income of enterprise *e*
$FFLOWFB_e$	financial flow of foreign borrowing for enterprise *e*
$FFLOWB_e$	financial flow of enterprise bond for enterprise *e*
$FFLOWFDI_e$	financial flow of FDI for enterprise *e*
ZE_e	real investment for enterprise *e*
$INTRSTC_e$	interest rate of credit for enterprise *e*
$INTRSTBavg$	average interest rate of enterprise bond and foreign borrowing
$INTRSTB_e$	interest rate of enterprise bond for enterprise *e*
$FSTOCKB_e$	financial stock of enterprise bond for enterprise *e*
$INTRSTFB$	interest rate of foreign borrowing
$FSTOCKFB_e$	financial stock of foreign borrowing for enterprise *e*

YG	after transfer payment government revenue
EG_c	government expenditure on commodity *c*
$FFLOWG_{bs}$	financial flow of government bond held by bank *bs*
ZG_a	government real investment on activity *a* by sector of origin
$FFLOWFA_{bs}$	financial flow of foreign asset held by bank *bs*
$KSTAR_a$	proper capital stock
ZD_a	real investment demand by sector of origin
$QINV_c$	real investment by sector of destination
$FSTOCKM$	financial stock of money of present year
$FSTOCKMpre$	financial stock of money of last year
$YGDP$	nominal GDP
$FFLOWRE$	financial flow of reserve
$INTRSTBstd$	standard interest rate of enterprise bonds
$INTRSTCstd$	standard interest rate of credit
$INTRSTDstd$	standard interest rate of deposit
$INTRSTAstd$	
$OMEGA1_{e,a}$	sector *a*'s share of enterprise real investment for enterprise *e*
$PINF$	inflation rate
$Z1_h$	real investment share of household *h* to disposable income
$g1_h$	deposit share of household *h* to financial assets flow
$g2_e$	credit share of enterprise *e* to total borrowing
$g3_e$	foreign borrowing of enterprise *e* to (foreign borrowing + enterprise bond)
$INTRSTHavg_h$	average interest rate of household's lending
$INTRSTA_a$	interest rate of borrowing for sector *a*
$FSTOCKD_{ins}$	financial stock of deposit for institution *ins*
$FSTOCKBH_h$	financial stock of bonds held by household *h*

$FSTOCKC_{insp}$	financial stock of credit for private institution *insp*
$RGDP$	real GDP
$FFLOWMS$	financial flow of money supply
Parameters	
$shzh_{a,h}$	activity *a* real investment share for household *h* to total real investment
$shflowc_h$	credit share for household *h* to saving
$shflowm_h$	money flow share for household *h* to money flow held by total household
εmps_h	shift parameter of marginal propensity to save function for household *h*
ψmps_h	exponent of marginal propensity to save function for household *h*
$\psi z1_h$	shift parameter of real investment demand function for household *h*
$\varepsilon z1_h$	exponent of real investment demand function for household *h*
$\psi 1_h$	shift parameter of deposit demand function for household *h*
$\varepsilon 1_h$	exponent of deposit demand function for household *h*
$shflowde_e$	deposit share for enterprise *e* to working cost
$shflowfdi_e$	FDI share for enterprise *e* to real investment
$\varepsilon 2_e$	exponent of credit demand function for enterprise *e*
$\psi 3_e$	shift parameter of foreign borrowing demand function for enterprise *e*
$\varepsilon 3_e$	exponent of foreign borrowing demand function for enterprise *e*
dep_a	depreciation rate for activity *a*
λ_a	speed parameter from present capital stock towards proper capital stock
$\omega_{e,a}$	identification of activity *a* to enterprise *e*
$qivty_c$	quantity of inventory commodity *c*
$shflowfab$	foreign asset share for commercial bank to total deposit flow received